WINDSOR’S ENERGY FUTURE

The Final Report of the Citizen Advisory Task Force on Clean and Sustainable Energy

October 18, 2021

Who We Are

Eric Weiner

Liz Yetman

Barbara Peyton

George Slate

Jeff Dyreson

Neil Chaudhary

Our Charge

Identify and study

- Identify and study viable and feasible sustainability projects and programs to reduce energy consumption and/or expenses in town and school facilities.

Increase Public Awareness

- Increase public awareness, education, and municipal participation in sustainability efforts including energy conservation, renewable resources, and other environmentally friendly practices.

Provide Reports

- Provide an annual report to the Town Council and provide any reports as necessary and upon request.

Advise

- Serve in an advisory capacity. Recommendations shall not bind the Town to take any specific action or require that it appropriate funds.

WINDSOR'S MISSION

"To create an environment where dreams can come true for individuals, families, and businesses."

OUR TASK FORCE **MISSION**

"To create **a sustainable and equitable** environment where dreams can come true for individuals, families, and businesses."

OUR TASK FORCE VISION

That the Town of Windsor shall treat energy efficiency, sustainability, and equity as key criteria for decision-making.


WHY CLEAN AND SUSTAINABLE
ENERGY?

Preserve

Clean Air

&

Clean Water

Increase
Local Energy
Autonomy
and
Resilience

Act Locally
to Reduce
Emissions
and Mitigate
Climate
Change

Save Money

A Timeline for Progress

2022

- Creation and Implementation of a new Energy Plan by Town Council

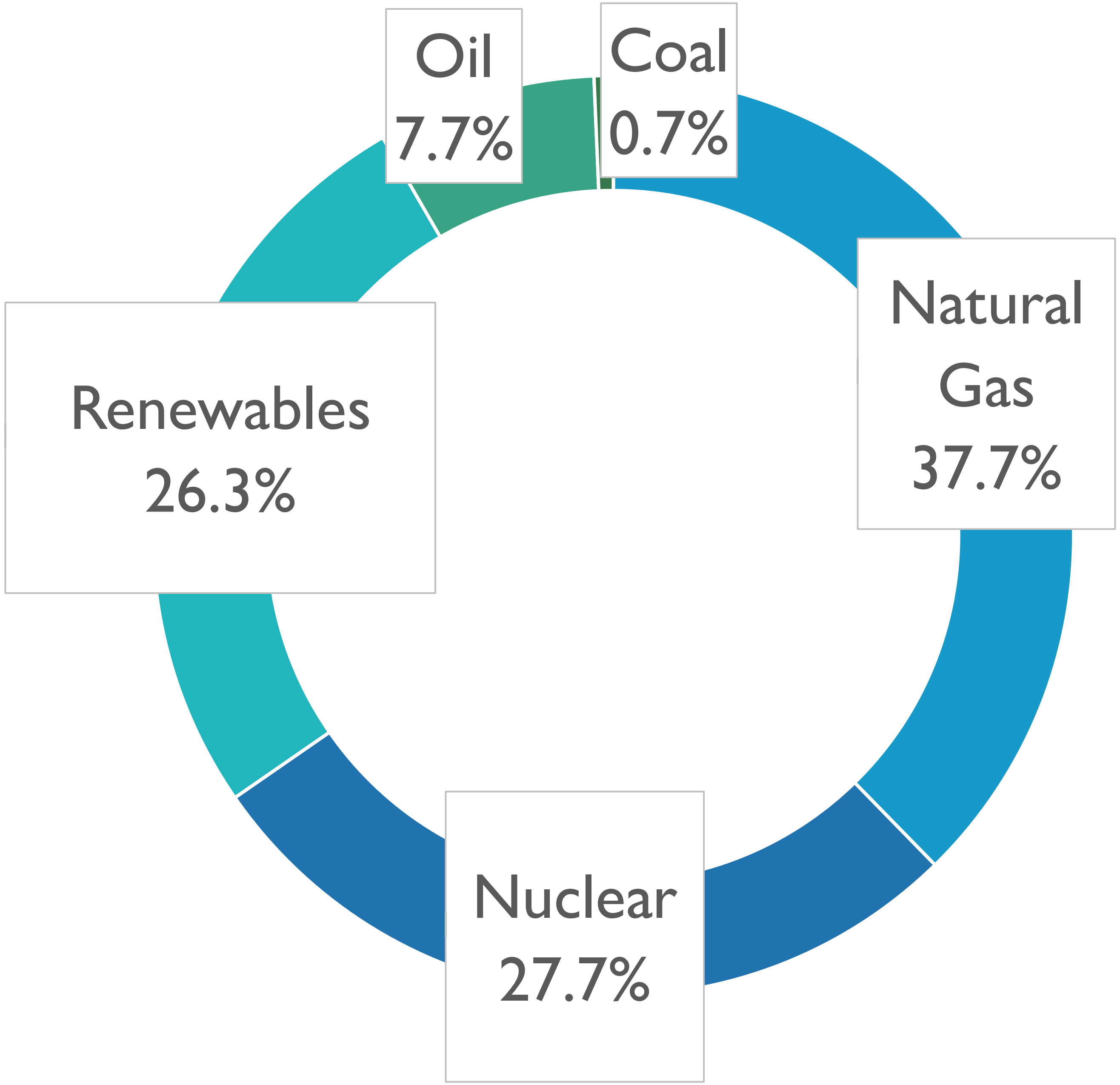
2022–2033

- Annual Progress and Benchmarking

2033

- 100% of municipal power from non-fossil sources
- 100% of municipal vehicles are electric
- 85% of residential and commercial electricity from non-fossil sources
- 50% of residential and commercial heating and cooling from non-fossil sources

Significant Progress Already: ToW uses 54% non-fossil electricity



Completed Municipal Projects

LED Lights

Solar Panels – 800 kW

High Efficiency Heating and Cooling

GETTING THERE FROM HERE

RECOMMENDED ACTIONS

Recommended Actions

Focus on Equity	• Ensure programs benefit all Windsor residents. • Address historic environmental injustices.
Benchmark and Track Progress	• Establish baseline measurements of municipal, residential, and commercial energy use. • Track changes to monitor progress toward goals.
Upgrade Efficiency	• Identify and install cost-effective improvements to insulation and building envelopes. • Replace end-of-life equipment with more efficient and lower emission models.
Deploy New Generation and Storage	• Identify and install cost effective power generation such as solar panels. • Explore and implement energy storage options.
Educate and Empower	• Encourage and empower residents and businesses to make use of available incentives and financing for efficiency, generation, and storage.
Cultivate Partnerships	• Partner with local energy businesses to educate the population and deploy upgrades. • Take advantage of state and regional organizations that support energy improvements. • Connect with regional projects like virtual net-metered solar arrays.


HOW WILL
WE ACHIEVE
THESE
GOALS?

THE KEY TO SUCCESS

THE **ENERGY COORDINATOR**

THE KEY TO SUCCESS

THE **ENERGY COORDINATOR**

RESPONSIBILITIES

- **Establish benchmarks and track town progress** toward energy and equity goals.
- **Identify, develop, and oversee proposals** for efficiency upgrades and renewables deployments.
- **Coordinate outreach, education, and energy work** within the town government.
- **Mediate collaboration with neighboring towns** when advantageous.

ADDITIONAL RESOURCES

Additional resources, including a glossary of terms, more details on the town's past and future projects, the energy plans, projects, and progress of neighboring towns, Connecticut state energy goals and standards, the most recent report of the Intergovernmental Panel on Climate Change, and lists of specific actions we can take to achieve our energy goals, may be found in the appendices.

Appendices Table of Contents

Glossary of terms

Autonomy: increased independence allows distributed energy projects to continue to provide energy at the local level when the larger regional grid is stressed or incapacitated.

Clean Energy: methods of generating energy that have the least impact on the environment and in particular produce little to no greenhouse gases while generating energy.

Energy Efficiency: reduction of the amount of energy needed to perform a certain task.

Equitable: projects, programs and development that meet the needs of, and bring the benefits of clean and renewable energy to, all members of a community regardless of wealth, class, race or ability. They also redress the heavy environmental impact of carbon intensive energy production on particular communities.

Fossil Fuels: energy sources that come from the fossilized remains of living organisms and have been created on a geological time scale (over millions of years.) They cannot be renewed and their combustion increases the concentration of the greenhouse gas carbon dioxide in the atmosphere. Fossil fuels include coal, oil and natural gas (methane extracted from the ground.)

Mitigation: the action of reducing the effects of something; mitigation of climate change can refer to reducing greenhouse gas emissions in an effort to reduce global warming or it can refer to changes in infrastructure that will reduce the impacts caused by climate change.

Renewable Energy: energy sources that are naturally replenishable on a regular and relatively quick or human time scale. Renewable energy sources include sunlight, wind, hydro (dams, tides, waves, etc.), geothermal, biogas (methane from decomposing biomass), biomass (combustion of plant material such as corn, sugar cane, wood, etc.)

Resilience: ability to better prepare for and adapt to changing conditions and to recover from disruptions in energy production and/or delivery

Sustainable Energy: energy generation that meets the needs of the present without compromising the needs of future generations and does not degrade the natural environment.

There are many resources available that define general energy terms as well as clean, renewable and sustainable energy terms. Here are some suggestions:

https://www.cleanenergyresourceteams.org/glossary
https://www.eia.gov/tools/glossary/index.php?id=W
https://www.alliantenergykids.com/AllAboutEnergy/EnergyGlossary

TOWN OF WINDSOR, CONNECTICUT
Special Meeting Notice

Zoom instructions
Dialing in by Phone Only:
Please call: **646 558 8656 or 312 626 6799**
1. When prompted for participant or meeting ID enter: **853 4087 8241** then press #
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2. Only if your computer has a microphone for two way communication, then during Public Comment if you wish to speak press **Raise Hand** in the webinar control. If you do not have a microphone, you will need to call in on a phone in order to speak.
3. During Public Comments if you do not wish to speak you may type your comments into the Q&A feature.

AGENCY: **Citizen Advisory Task Force on Clean and Sustainable Energy**

DATE: **October 7, 2020**

TIME: **6:30 PM**

PLACE: **VIRTUAL MEETING**

AGENDA

1. Call to Order
2. Public Comment
3. *Town Efforts Overview
4. Windsor Climate Action Group Overview
5. *Discussion on sample Municipalities Energy/Sustainability Plans
6. Discussion on Committee Member Resources
7. Discuss Possible Future Agenda Topics
8. Selection of Chairperson, Vice-Chairperson, & Secretary
9. Approval of Minutes
   a) September 16, 2020
10. Adjournment

*Backup materials

Public Act 75-312 requires notice of Special Meetings to be posted in the Town Clerk's Office not less than 24 hours prior to the time of such meeting. No other business shall be considered at this meeting than that listed on this Agenda.

Agenda Item Summary

Date: October 7, 2020

To: Members of the Citizen Advisory Task Force on Clean and Sustainable Energy

Prepared By: Scott W. Colby Jr., Assistant Town Manager Scott W. Colby Jr.

Subject: Town Energy Efforts

Background

Since FY 2010 the Town of Windsor has looked to reduce energy usage by utilizing more efficient technologies and also helping to reduce the overall cost. From FY 2010- FY 2020, the Town has reduced its energy use by approximately 28%. The PowerPoint presentation that has been provided as backup material discusses various items regarding past, current, and future efforts:

- Including energy efficient projects within the Adopted Capital Improvement Program FY 2021- FY 2026
- Installing Solar Photovoltaic Systems at numerous Town and BOE facilities
  - Total system size is 800.8KW
- Installing Geothermal Systems in two facilities
- Participating in C-PACE (Commercial Property Assessed Clean Energy) Program
- Participated in two light bulb exchange programs

Zoning Regulations

The Zoning Regulations that were adopted in December of 2008 and revised in July of 2019 include sections pertaining to the following:

- Provisions for Bicycles
- Provisions for Mass Transit
- Electric Vehicle Charging Stations
- Renewable Energy Facilities
  - On-Site Solar Energy Facilities
  - On Site Wind Facilities
  - On-Site Geothermal Facilities
- Alternative Energy Considerations for Facilities within the Industrial Zone

Plan of Conservation and Development

The Plan of Conservation and Development that was adopted in September of 2015 addressed the need to reduce greenhouse gas emissions through key strategies.

Some of the key strategies that came out of this plan were:

- Continue to replace vehicles with low-emission and alternative fuel vehicles.
- Continue to promote energy conservation programs, alternative energy incentive programs, and simple steps that residents and businesses can take to reduce greenhouse gas emissions.
- Continue to upgrade town facilities to be more energy efficient and to install alternative energy sources.
- Commit to designing new town facilities to meet or emulate green building standards, such as LEED.
- Educate the public on long-term cost savings of energy efficient buildings.

Example Energy Plans

We have also provided sample municipalities' energy plans to use as reference.

Energy Efficiency Efforts

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Energy Overview from FY 2010 thru FY 2020

(All Town & BOE Buildings, Streetlights, & Traffic Control Lights)

Energy=electricity, heating oil, natural gas, & propane

FY 2010

Costs - $2,700,000

Energy Used – 11,500,000 kWh

FY 2020

Costs - $1,995,818

Energy Used – 8,297,396 kWh

This equates:

26% reduction in energy costs or $704,182

28% reduction in energy used or 3,202,604 kWh

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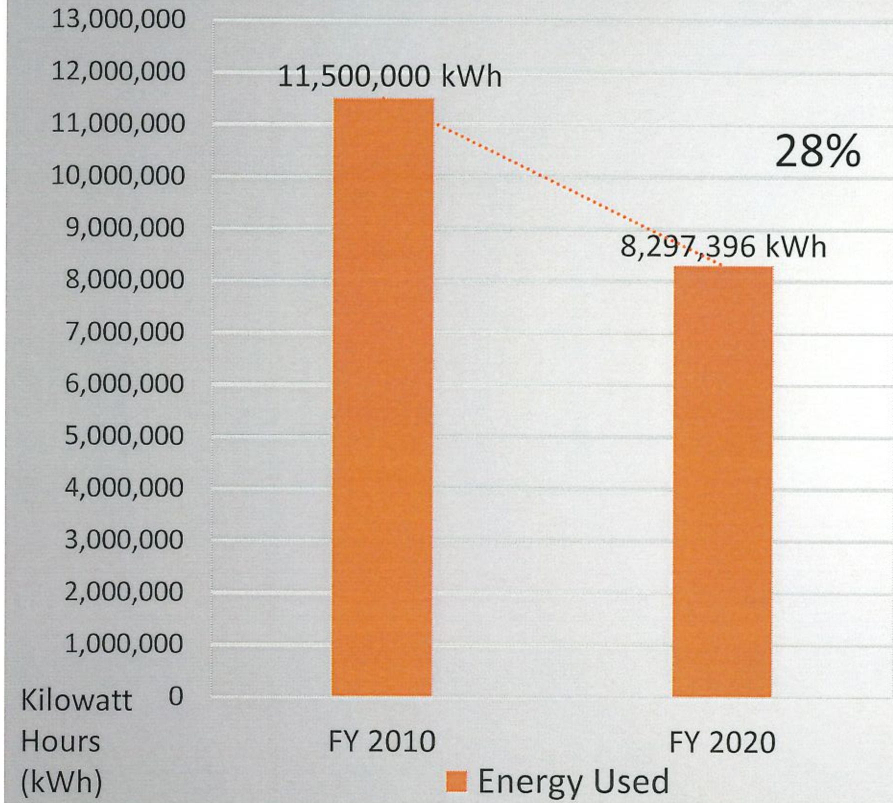
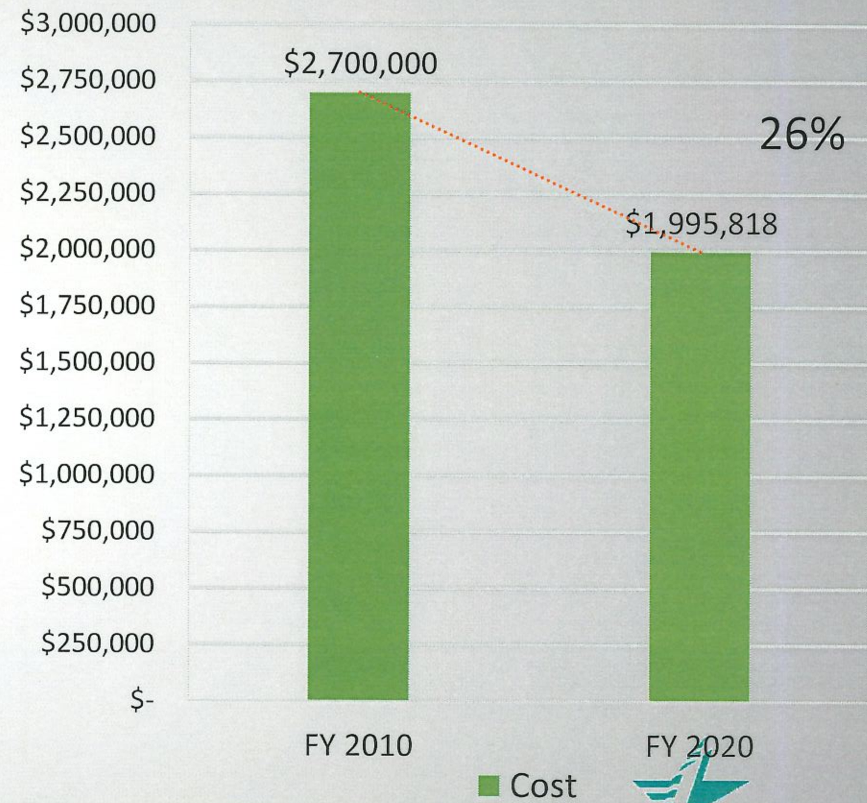
Energy Overview from FY 2010 thru FY 2020





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Reduction in use of energy from FY 2010 – FY 2020 for Windsor, CT

3,202,604 kWh

Carbon Equivalent to

288,780,027
Phones
(smartphones) charged

254,796
Gallons
of Gasoline Consumed

5,242
Barrels
of Oil Consumed

2,957
Acres
of U.S. Forests Saved in 1 Year

383
Homes
Electricity Usage in 1 Year

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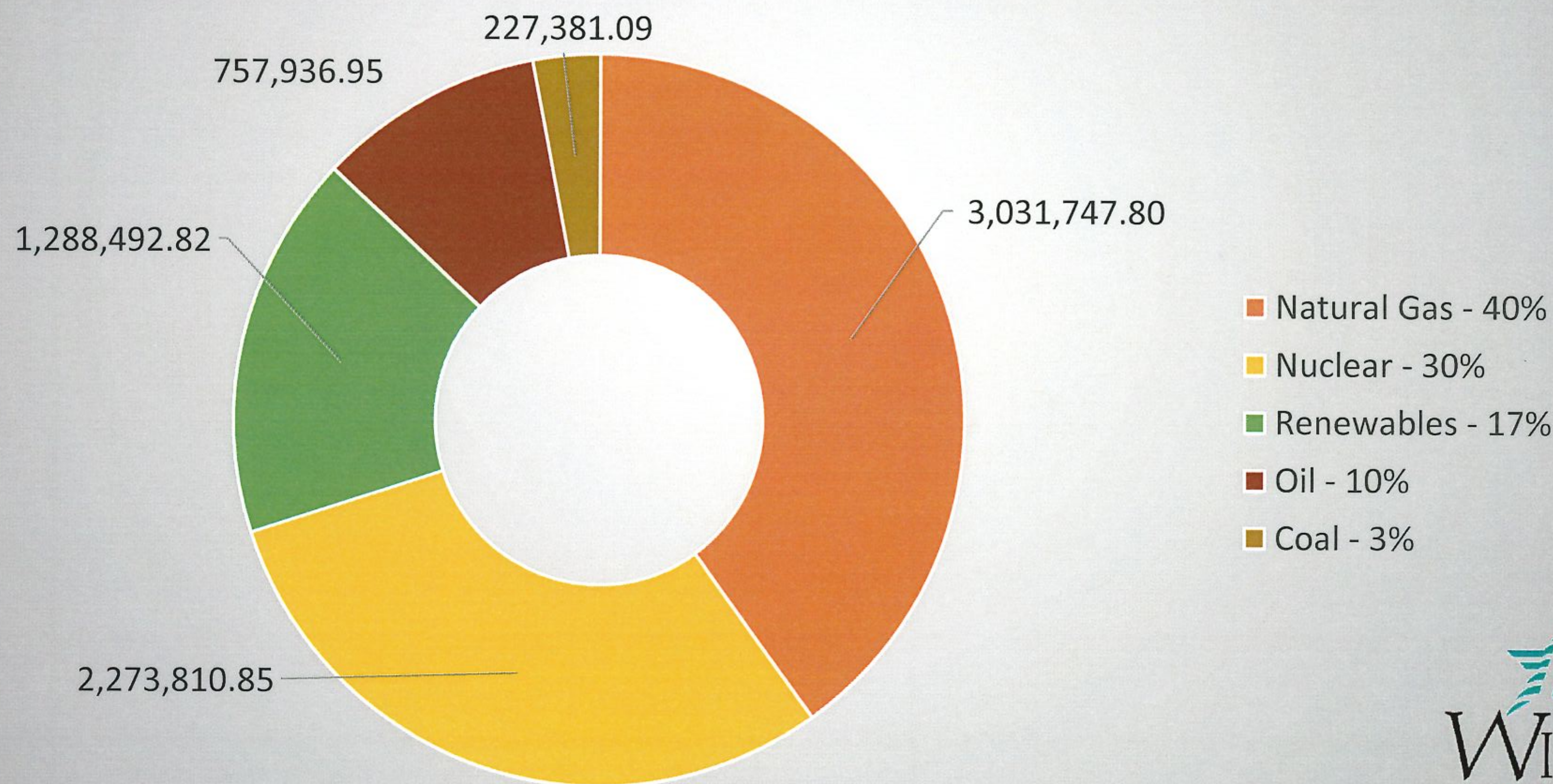
Electricity *(Electricity that is generated and supplied by Eversource)*

The make-up of our electricity that we use is a blend;



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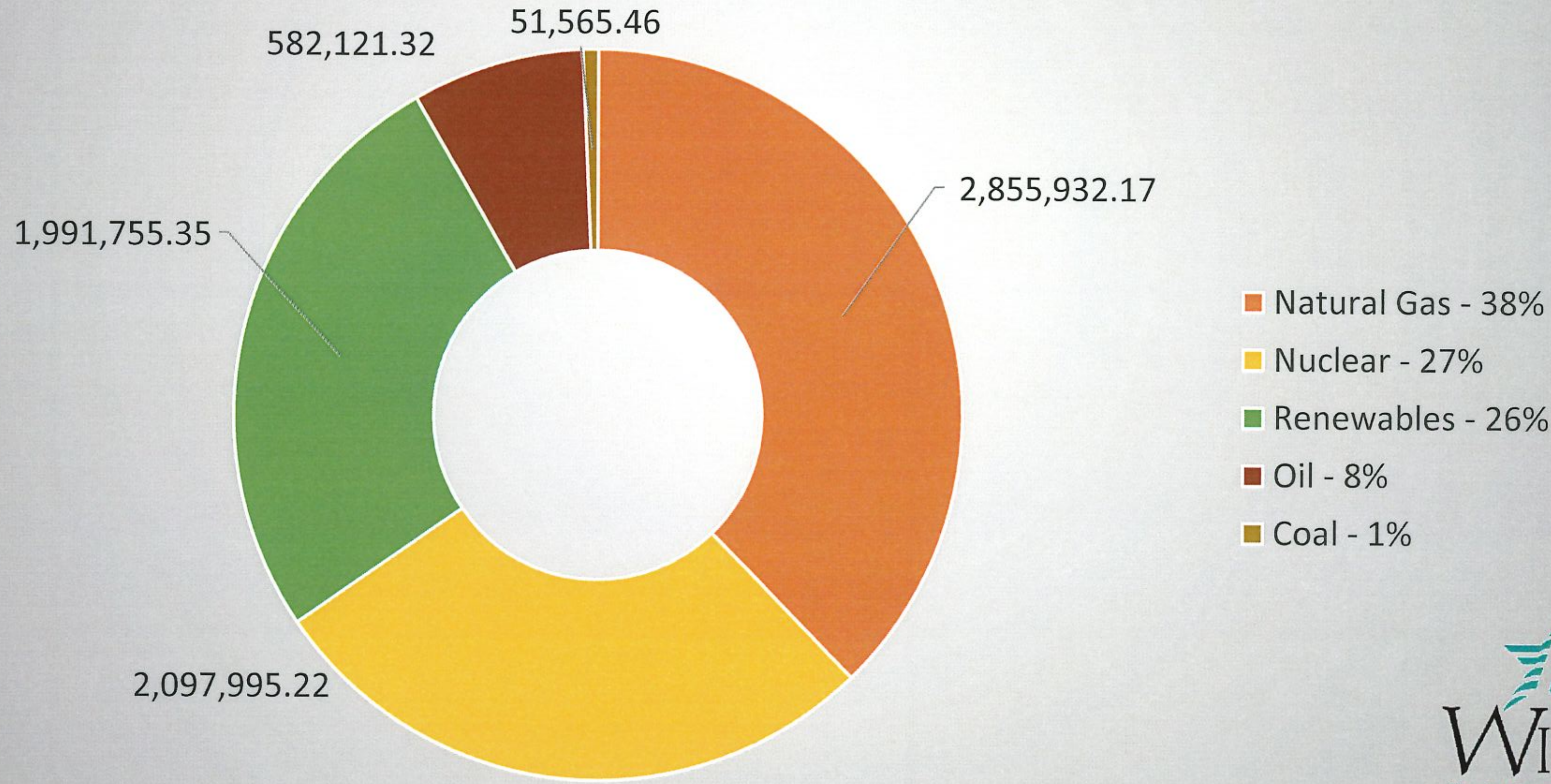
Electricity *(Electricity that is generated and supplied by Eversource with Town Solar included)*

The make-up of our electricity that we use is a blend;



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FY 2012

- Installed Low Condensing Boiler at Pequonock School
- Replaced HVAC at Town Hall with digital controls
- Replaced HVAC + installed digital controls
- LP Wilson Community Center LED conversion
- Converted LP Wilson Community Center & JFK School to Natural Gas

FY 2014

- Solar Panels installed at Oliver Ellsworth School – 150 KW
- Solar Panels installed at LP Wilson Community Center- 250KW
- Solar Panels installed at JFK School- 242KW
- Converted Sage Park & High School Exterior lighting to LED's
- Converted Windsor Volunteer Ambulance Ext./Int. to LED lighting

FY 2015

- Solar Panels installed at WVA - 20KW
- Solar Panels installed at 330 Windsor Community Center – 150KW
- Converted High School, Sage Park, Oliver Ellsworth School, & Clover School to Natural Gas

FY 2016

- Replaced Boiler at the Town Hall
- Replaced & Installed HVAC at Clover Street School
- Solar at Northwest Park Lang House

FY 2017

- Converted Town Hall to LED lighting

FY 2019

- Replaced & Installed HVAC at JFK School
- Converted High School to LED lighting
- Replaced furnace at the Stony Hill School & converted to Natural Gas

- Geothermal units were installed at the Northwest Park in 2010 and at the Wilson Library in 2011.

Energy Efficiency Projects Completed from FY 12 thru FY 19

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Energy Efficiency Projects in FY 2021 – FY 2026 CIP

FY 2021

Town Facility Improvements – Milo Peck HVAC, Electrical and Energy Improvements
Luddy House Windows
Wilson Firehouse HVAC Replacement
BOE – Sage Park Middle School – Alternative Energy and Efficiencies Upgrades
LP Wilson Boilers Replacement Project (Moved up from FY2023)

FY 2024

330 Windsor Avenue Community Center – HVAC & DDC Controls
Windsor High School HVAC Systems Replacement Project

Unscheduled Projects

LP Wilson - Window Replacement
Train Station - Boiler Replacement
LP Wilson - LED Lighting Conversion (Potentially in FY 2021)
LP Wilson - Gym Air Conditioning Project
Town Facilities Improvements – Poquonock Fire Station HVAC Replacement
Streetlight Replacement, Energy, and Maint. Cost Reduction Program

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Solar Photovoltaic Systems for the Town of Windsor

Solar photovoltaic systems convert sunlight into direct current electricity. Solar photovoltaic systems have been installed at the following locations in 2014 and 2015;

- Windsor High School *(small demonstration system installed in 2011)*
- LP Wilson Community Center
- JFK Elementary School
- Oliver Ellsworth Elementary School
- 330 Windsor Community Center
- Windsor Volunteer Ambulance
- Northwest Park – Lang House

Total System Size 800.8KW

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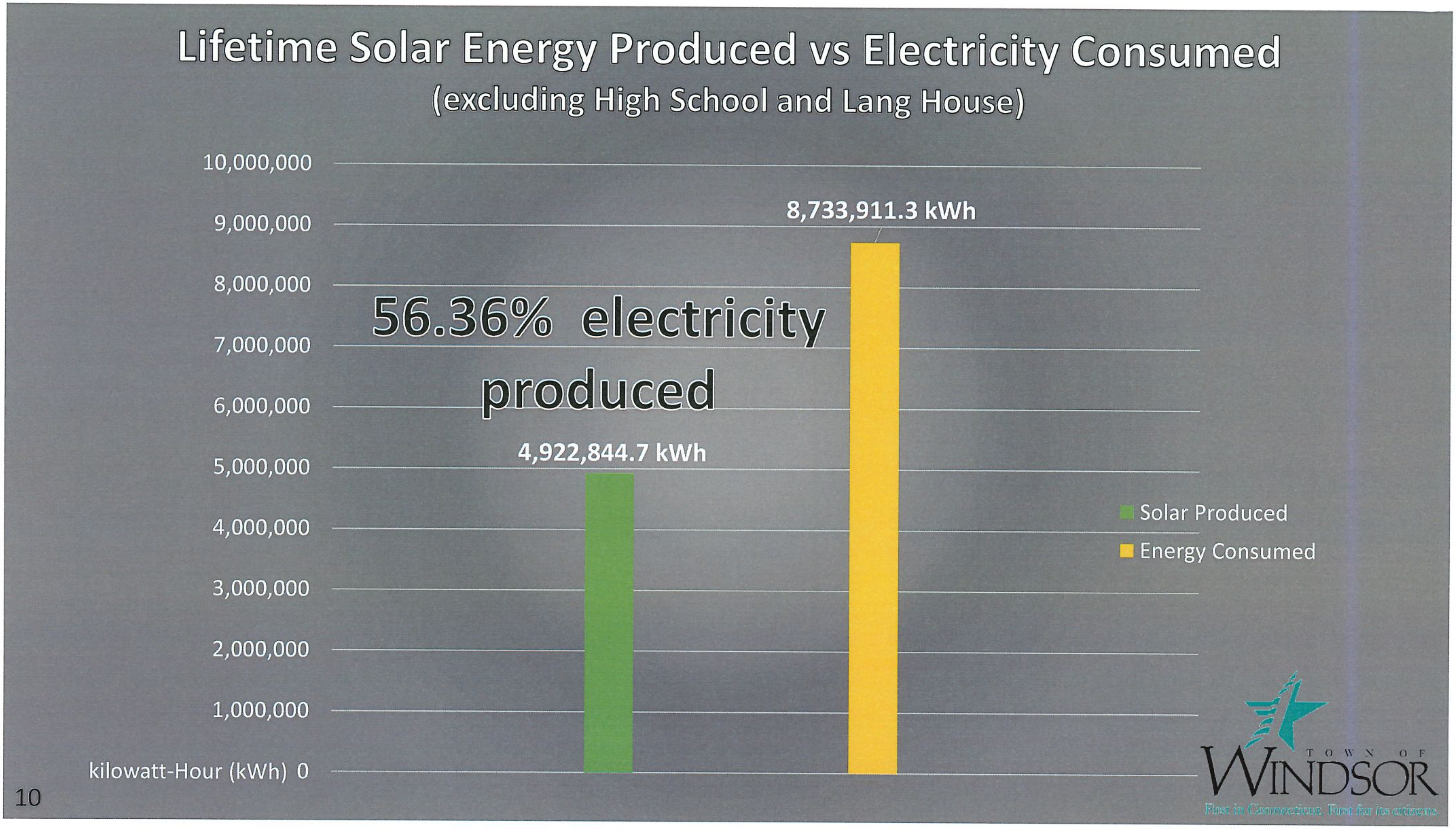

Lifetime Solar Energy Produced vs Electricity Consumed
(excluding High School and Lang House)
10,000,000
9,000,000
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
kilowatt-Hour (kWh) 0
8,733,911.3 kWh
56.36% electricity produced
4,922,844.7 kWh
Solar Produced
Energy Consumed
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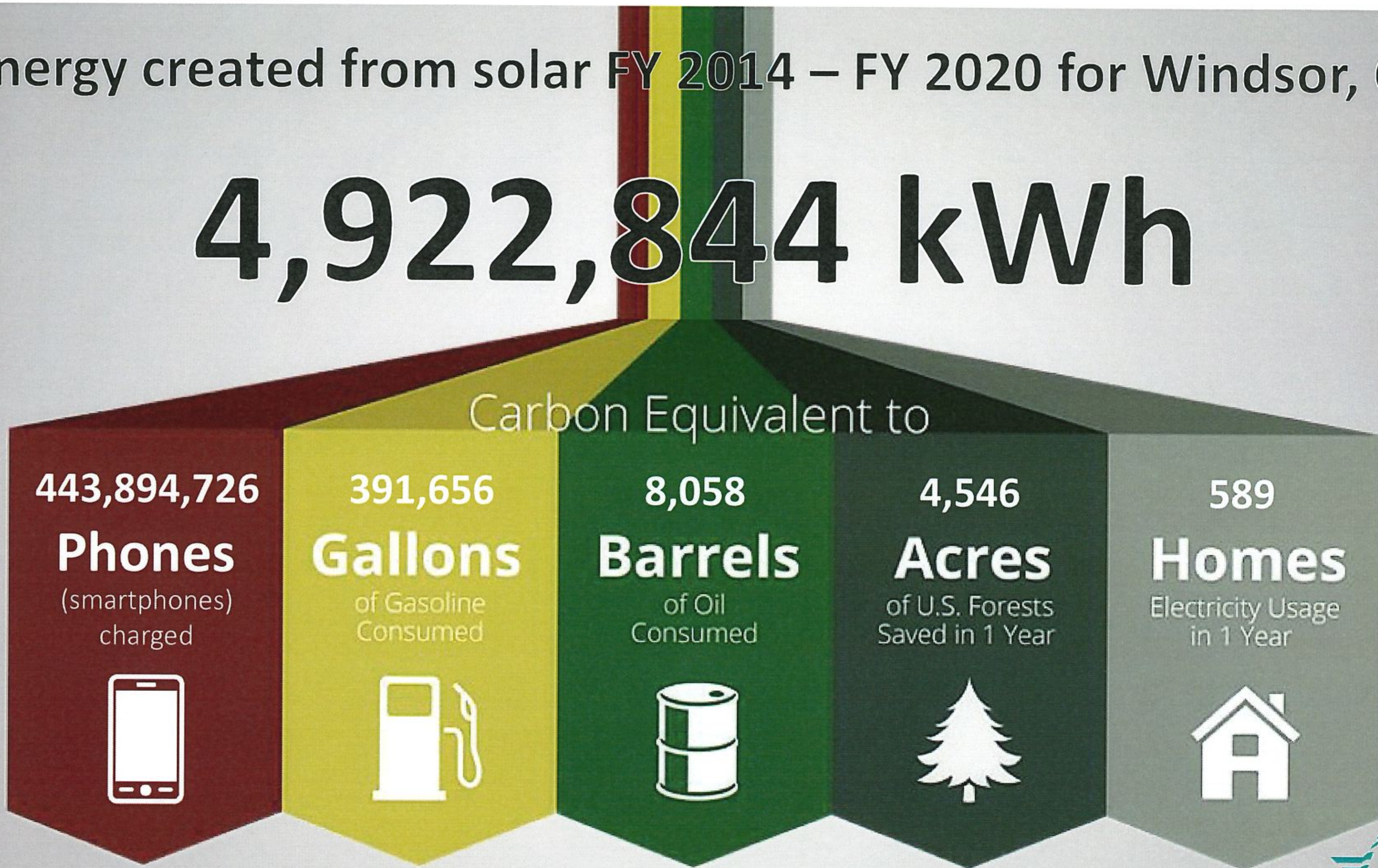
10

Energy created from solar FY 2014 – FY 2020 for Windsor, CT



FUN FACT: How many new housing units built in town over the same period of time?

397 housing units built between 2014 – June 2020 our energy reduction offset one year of electricity to 397 of those units

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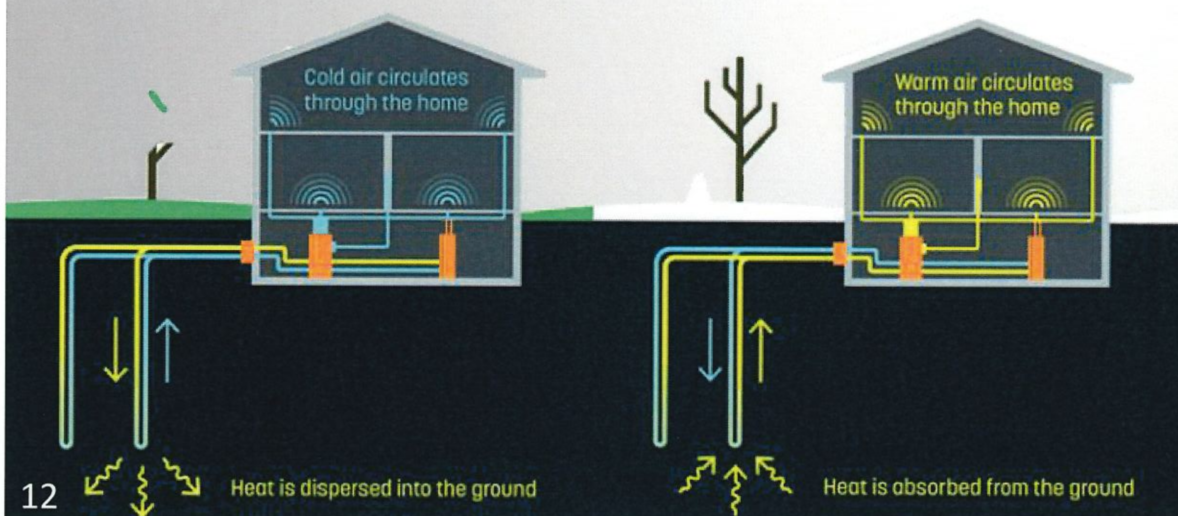
Geothermal Systems in Windsor

Geothermal energy is heat derived underground. Water and/or steam carry the geothermal energy to the surface. Geothermal energy can be used for heating and cooling purposes or be harnessed to generate clean electricity.

- Installed in 2010 at the Wilson Public Library
- Installed in 2011 at the Nature Center at Northwest Park



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Solar Photovoltaic Systems for Residential & Commercial

Solar photovoltaic systems have been installed throughout the town on both residential and commercial properties between FY 2005 and FY 2020;

- There are currently (715) residential properties that have solar installed
  - This is the equivalent to 9,738.30 kWh

- There are currently (17) commercial properties that have solar installed
  - This is the equivalent to 1,266,182 kWh

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EV Charging Station

- In August of 2020 the Town Council approved funding for an Electric Vehicle (EV) Charging Station that will be located at the corner of Broad Street and Maple Street in the Town-owned parking lot.

- Installation is expected to begin once the Farmers Market ends in mid-October.

- This is a duel-port charging station.

- The Town Council voted that there be no user fee trough July 1, 2021 as a trial period.

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Light Bulb Exchange Program

There have been (2) Light Bulb Exchange Programs for residents free of charge.

All costs were supported by Bright Ideas Grants that the Town of Windsor received as a result in its participation in the Clean Energy Communities program.

- December 2015
  - 4,000 bulbs exchanged for LED's
- November 2016
  - 5,988 bulbs exchanged for LED's
- These two programs allowed for 1,997 residents to participate

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C-PACE

C-PACE (Commercial Property Assessed Clean Energy) is an innovative financing solution that makes green energy upgrades accessible and affordable for building owners across Connecticut.

C-PACE, administered by Connecticut Green Bank, offers 100% financing for a wide range of energy improvements, so building owners can modernize their buildings and lower their energy costs.

- Currently there are (2) C-PACE accounts on file with the Town of Windsor with a third account that has not yet been finalized.
- Owners repay CT Green Bank through annual assessment on tax bill

cpace

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Town Of
Enfield
Connecticut

COMPREHENSIVE ENERGY STRATEGY

Endorsed by the Town Council on December 1, 2014

Prepared by the Enfield Clean Energy Committee

Supported by Peregrine Energy Group, Inc.
with funds received from the State of Connecticut

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Endorsement Resolution by Enfield Town Council

WHEREAS, the Town Council of the Town of Enfield is dedicated to reducing energy use and increasing operational efficiency in its activities; and

WHEREAS, the Town Council encourages residents and businesses to become smarter energy users and incorporate use-reduction strategies into their operational activities; and

WHEREAS, the Town Council is dedicated to a structured energy use and reduction strategy advocated by the Enfield Clean Energy Committee;

NOW, THEREFORE BE IT RESOLVED, the Town Council of the Town of Enfield hereby formally endorses the Comprehensive Energy Strategy prepared by the Clean Energy Committee with support from Peregrine Energy Group, Inc., dated November 17, 2014.

Unanimously approved on December 1, 2014

Acknowledgements

The following groups and people worked to produce this energy strategy for the Town of Enfield and deserve recognition for their efforts:

Enfield Clean Energy Committee

http://www.enfieldcleanenergy.net

- Valerie Bak
- Ann Marie Dooley
- Melissa Everett, Ph.D., Chair
- Suzanne Giwoyna
- Dan Glogowski
- Doug Lombardi
- Greg Mark

Town of Enfield

http://www.enfield-ct.gov

- Tom Arnone, Town Council Liaison
- Donna Szewczak, Town Council Liaison
- Joel Cox, Staff Liaison
- Derrik M. Kennedy, Assistant Town Manager

Peregrine Energy Group, inc.

2 Oliver St, Boston, MA 02109
(617) 367-0777
http://www.peregrinegroup.com
Steven Weisman, Vice President, Energy Management Services

Overview

Today, energy costs are a significant budget item for many households and businesses, as they are for the Town of Enfield. This Comprehensive Energy Strategy has been developed by the Enfield Clean Energy Committee (ECEC) to encourage and assist the Town of Enfield to formally adopt policies and practices that reduce energy consumption and increase the use of clean renewable energy sources in municipal operations to the extent practical; and, further, to take action that facilitates increased energy efficiency and the use of renewable energy by Town residents and local businesses. The Strategy is divided into three separate sections, Municipal, Residential, and Commercial/Institutional. The Municipal Strategy is the most detailed of the three for a number of reasons: First, the ECEC has access to more detailed information about energy consumption for municipal operations than it would have for all residences and all businesses. Second, there is consensus that reducing energy expense is a shared objective for municipal operations. And third, there is more information available about opportunities and needs in Town facilities.

The Strategy targets the five-year period from 2015 – 2019, providing the most detail for the first two years. As we describe below, ECEC believes that focused action by Town government in this arena is critical to broad Town-wide success. We hope a commitment to this path by Town government can motivate near-term action in all sectors, while encouraging long-term planning and adoption of emerging opportunities. This will help ensure that Enfield thrives as an efficient, secure and sustainable community.

About the Enfield Clean Energy Committee

The Enfield Clean Energy Committee is composed of citizen volunteers appointed by the Town and supported by Town staff and representatives of Town Council. The Committee's mission is to support and encourage decisions that increase energy efficiency and use of renewables Town-wide, by Town residents and businesses, as well as in Town and school operations. In 2014, the ECEC began this initiative to encourage and assist municipal government to achieve immediate and long-term energy savings and increase its use of alternative and ideally renewable, sources of energy. It also wants Town government to be a resource to Town residents, businesses, and other organizations to help them adopt clean energy strategies, such as increased efficiency and use of energy resources to minimize greenhouse gas emissions. The Committee has been assisted by Peregrine Energy Group, Inc., a consulting firm specializing in municipal energy management solutions, that was competitively selected by the Town in Spring 2014 and engaged using a $15,000 Bright Ideas grant from the State of Connecticut, earned by the volunteer activities of the Enfield Clean Energy Committee. Peregrine attended ECEC meetings, did background research and walk-through analysis of Town buildings, prepared reports for Committee review, and facilitated discussion and decision making by the Committee.

A Sustainable Energy Vision for Enfield

The Enfield Energy Strategy is built on a four-point vision for our community:

- We can achieve town-wide cost savings and greenhouse-gas emissions reduction through an integrated strategy of conservation, energy-efficiency and the use of renewable energy.

- The Town and schools must lead by example in day-to-day operations, demonstrating best practices to the public and business community while generating savings for taxpayers every day.
- Plans need to be developed and put in play to ensure the continued provision of vital services in the event of energy supply disruptions, through the combination of renewable energy supply, high-efficiency backup power and energy storage, including micro-grids, and adoption of best practices in managing energy demand and grid interconnection.
- The Town, supported by the Clean Energy Committee, will provide ongoing, high-quality education about energy issues and options in the schools and to the public, building an energy-smart community with educated consumers and voters who understand the tools and tactics that contribute to a clean, efficient energy future.

This Energy Strategy provides a broad frame work to allow flexibility in rapidly changing circumstances. We developed our vision and approaches to achieving it, to guide the Town's management of energy resources through policy, infrastructure planning, government operations, Town services and public educational programming. The Energy Strategy provides the back bone for more detailed planning and ongoing action by town staff and the Committee, guided by Town Council. It provides a concrete path to advance a Town commitment to a clean, secure, affordable energy future.

Municipal Energy Strategy

Introduction

The Clean Energy Committee recommends that Town Council adopt and embrace the following goals and strategies to reduce greenhouse gas emissions associated with energy use by Town operations, including buildings and other facilities, street lighting, and transportation.

Overall, we suggest that Town Council mandate policies and practices that:

- Reduce energy consumption whenever practical without interfering with satisfying the Town's responsibilities and providing a comfortable work environment for employees
- Invest in more energy-efficient systems, equipment, and technology whenever it is cost-effective or if end-of-life equipment must be replaced
- Favor life cycle cost, including lifetime energy and maintenance expense, as a criteria in purchasing, rather than first cost
- Consider options for municipal operations to increase the use of energy sources that do not require combustion of conventional carbon based fuels nor result in greenhouse gas emissions.

The result of these policies and practices will not only be a cleaner environment, but also cost savings for taxpayers and better working condition for employees and students.

Further, we believe that the Town and Board of Education, by pursuing this course of action and publicizing its goals, strategies, and accomplishments, can lead by example and influence the actions of local residents and businesses.

Baseline for the Municipal Energy Strategy: Current Energy Use

Any plan of action involves establishing goals and strategies to achieve the objectives we have established for ourselves. In this case, with reduction of greenhouse gas emissions in addition to cost savings as the goals, we have selected two primary approaches: 1) reducing our use of energy overall and 2) make greater use of energy sources that do not create additional greenhouse gas emissions.

The best goals are quantitative. They allow us to measure our success over time by comparing where we are now to where we started when we set our goal. This point where we began our efforts is generally called the "baseline." We can select either of two metrics for our baseline: energy use or energy expense. We consider both of these in this analysis and both are important. While there are things we can and should do to influence the price we pay for energy, such as purchase in bulk, shop around and change suppliers, or use alternative fuel sources, prices are generally set outside of our community. On the other hand, Town government policies and practices can have a significant immediate and long-term effect on the amount of energy consumed to accomplish a specified amount of work (e.g. keep us comfortable in buildings, ensure that we have fresh air in classrooms, illuminate our streets at night).Therefore, the focus of our energy strategy is primarily on energy use.

The Town presently uses electricity, natural gas, fuel oil, gasoline, and diesel fuel as its energy sources, all of which are primarily carbon-based and contribute to greenhouse gas emissions. Non-carbon based energy sources used in Enfield's energy supply, generally in the mix of electricity received from Connecticut Light and Power, are nuclear power, solar-generated electricity (known as photovoltaic or PV power), hydropower generated by turning an electric turbine with moving water such as a river, and wind power which is generated by turbines that turn in the wind to generate electricity.

Other non-carbon energy sources are solar generated hot water (known as solar thermal);geothermal energy which is extracted from the ground or from groundwater using water or some other medium as a heat exchanger; air source heat pumps; and sustainably sourced biofuels including combustible pellets and natural gas produced by anaerobic digestion of biomass. Of all of these non-carbon sources, solar energy is the most generally available for use in Enfield: PV and thermal systems can be placed on structurally suitable, south facing roofs; PV systems can also be ground-mounted as renewable energy farms. To date, there has been little or no solar energy use in municipal operations.

Enfield's municipal energy use baseline is the amount of energy in native units (i.e. therms of natural gas; gallons of fuel oil, propane, diesel fuel, or unleaded gasoline; and kilowatt hours of electricity) the Town used for buildings, street lighting, and transportation in a baseline year. For this plan, the Clean Energy Committee has selected Fiscal year 2013, which began July 1, 2012 and ended June 30, 2013, as the Town's baseline year. This is the most recent year for which the Town had complete information for all energy sources when the ECEC began this initiative.

To make it easier to compare the use of energy for different purposes by the Town, Peregrine converted energy use from native units (i.e. kWh of electricity, CCF or therms of natural gas, gallons of fuel oil, and gallons of unleaded gasoline and diesel fuel) that energy is sold in to an equivalent scale based on heat value of the source (i.e. British thermal units) that allows the energy value of different energy types to be combined.[1]

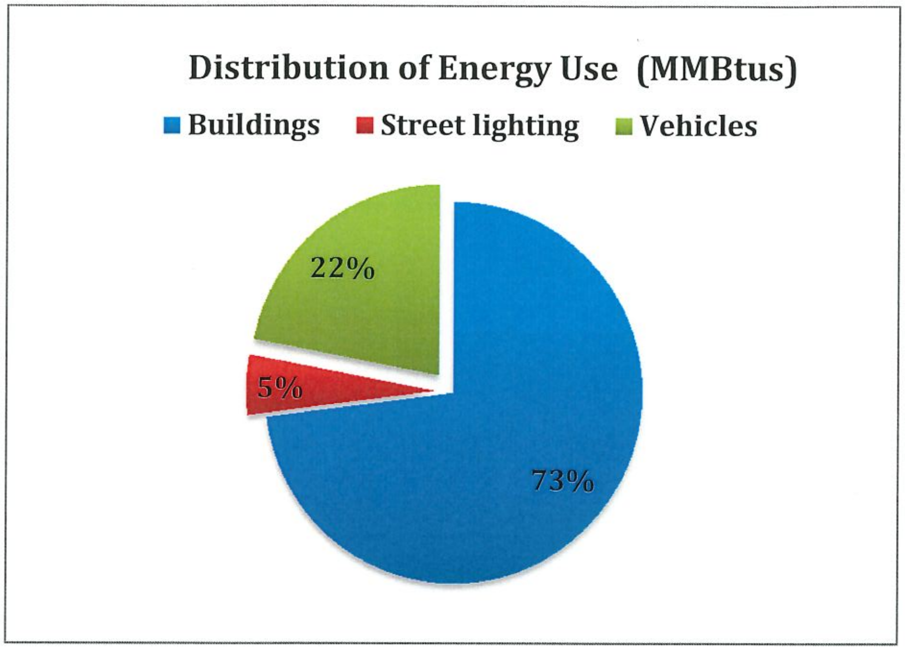
- Energy use in buildings, based on information provided to Peregrine, was13,532,951 kWhof electricity (42,521 MMBtus), 608,130 CCF or therms of natural gas (62,455 MMBtus), and 9,651 gallons of fuel oil (1,338 MMBtus). Building energy use, including wastewater treatment, totals 106,314 MMBtus.

- Streetlights accounted for 2,228,627 kWh of electricity (7,604 MMBtus).

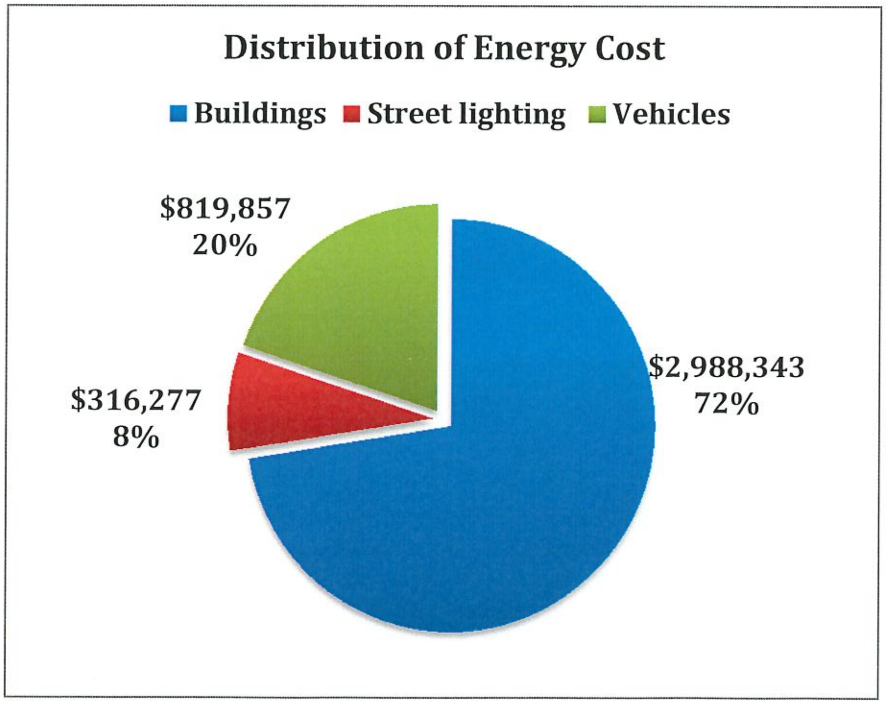
- Vehicles consumed126,536gallons of unleaded gasoline (15,721MMButus) and 119,182 gallons of diesel fuel (16,291MMBtus), for a total of 32,012MMBtus. [Note that vehicle information is for calendar year 2013.]

[1]Conversion factors from native units to British thermal units (Btus):
  - A kWh or kilowatt hour of electricity equals 3412 Btus;
  - A CCF or therm of natural gas equals 102,700 Btus, while a gallon of #2 fuel oil equals 138,690 Btus. This means that there is more heat value in a gallon of fuel oil than a therm of natural gas
  - A gallon of unleaded gasoline equals 124,238 Btus, while a gallon of diesel fuel equals 138,690 Btus. This means that there is more heat value in diesel fuel per gallon than unleaded gasoline.

The percentage distribution of Town energy use, on a BTU basis, for buildings, vehicles, and street lighting is summarized in the following chart:



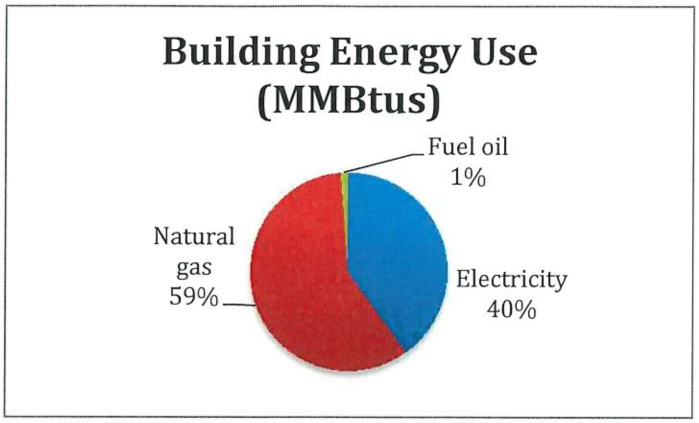
Compare this with the distribution of energy cost for the same end uses:

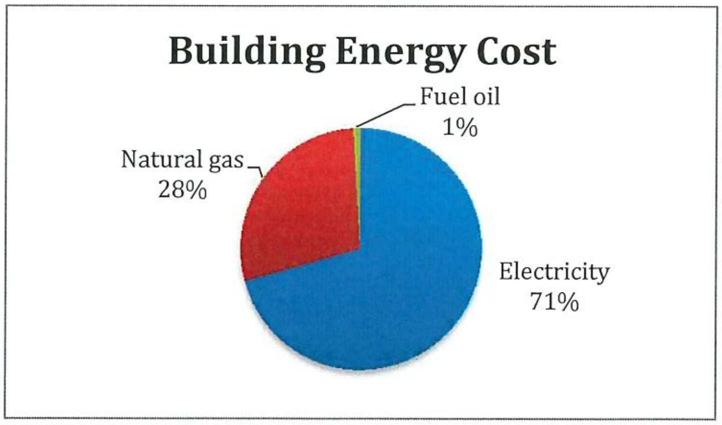


Achieving Energy Objectives in Town and School Buildings

Facility Energy Use and Cost

While natural gas delivers the majority of energy consumed in buildings on an MMBtu basis, electricity is the major expense. Electricity efficiency improvements will yield the greatest economic benefit.





Benchmarking the performance of Enfield facilities

Most of Enfield's public buildings were constructed in the middle of the 20th century, at a time of limited concern about energy efficient construction. In general, Town and school buildings have older equipment for lighting, cooling, heating, and other needs, resulting in higher energy use and expense.

The Town engaged Peregrine Energy Group in Spring 2014 to support the planning effort and conduct a "walk-through" analysis of buildings owned by the Town of Enfield and Enfield Schools and broadly assess them for energy-efficiency and renewable energy opportunities. Peregrine considered the natural energy-intensiveness of the activities in each building. They also considered building use patterns, hours of operation, and temperature settings. Peregrine benchmarked the relative performance of Enfield buildings compared to each other and to similarly purposed buildings in other communities with energy efficient equipment, building envelope, and usage patterns. For the buildings comparison, Peregrine looked at energy use in kBtus (thousands of Btus) per square foot of building area. This shows the relative energy intensiveness of different buildings. Energy engineers call this the Energy Use Index or EUI. Electricity and heating fuel use are presented separately and then combined to look at the total building energy use. The following table, produced by Peregrine, includes provides a color key that shows where the greatest potentials for energy use reduction are likely to be.

TABLE: ENERGY USE BY ENFIELD BUILDINGS

			Electricity		Gas		Oil		EUI
	Building	SF	kWh	kBtu/SF	Therm	kBtu/SF	Gallons	kBtu/SF	kBtu/SF
Town Buildings	Emergency Medical Services	2,371	71,000	102	200	8	-	-	111
	Enfield Waste Water Control Facility	12,000	3,049,000	867	-	-	-	-	867
	Enfield Senior Center		320,000	NA	9,500	NA	-	NA	NA
	Pearl Street Library	4,982	39,000	27	2,300	46	-	-	73
	Central Library	18,244	284,000	53	-	-	4,380	34	87
	Angelo Lamagna Activity Center	15,000	242,000	55	12,100	81	-	-	136
	Enfield Town Hall	22,850	680,000	102	14,300	63	-	-	164
	Department of Public Works	29,850	326,000	37	16,700	56	-	-	93
	Enfield Police Department	22,358	657,000	100	11,000	49	-	-	149
	Adult Day Care	4,200	69,000	56	-	-	5,030	170	226
	Family Resource Center	4,865	328,000	230	1,800	37	-	-	267
	Village Center of Thompsonville	20,223	129,000	22	11,000	54	-	-	76
	Buildings and Grounds	10,800	59,000	19	5,500	51	600	8	77
School Buildings	Enfield High School	186,026	1,697,000	31	97,100	52	-	-	83
	Enrico Fermi High School	202,400	1,897,000	32	90,700	45	-	-	77
	JFK Middle School	157,152	1,097,000	24	102,900	65	-	-	89
	Eli Whitney School	58,633	266,000	15	27,100	46	-	-	62
	Hazardville Memorial School	54,316	298,000	19	49,200	91	-	-	109
	Nathan Hale School	46,295	285,000	21	30,300	65	-	-	86
	Henry Barnard School	70,182	503,000	24	38,500	55	-	-	79
	Edgar Parkman School	60,327	324,000	18	23,000	38	-	-	56
	Prudence Crandall School	60,417	362,000	20	34,500	57	-	-	78
	Enfield Street School	48,439	167,000	12	5,400	11	-	-	23
	Thomas Alcorn School	53,950	378,000	24	25,100	47	-	-	70
	Harriet Beecher Stowe School	49,234	6,000	0	-	-	-	-	0

Opportunity for Reduction
High Potential
Good Potential
Moderate Potential
Less Potential
Unclear: missing or suspect data

The table shows that there are many buildings that have significant savings potential, determined based o on Peregrine's direct observation of equipment being used and from discussions with building staff about operations and maintenance practices, and based on the relative energy performance of Enfield buildings compared to what Peregrine has see in other communities,

The EUI scores for buildings in the table shows that different buildings in Enfield have different levels of energy intensiveness. Sometimes these relative differences are due to the purpose for which the building is used. For example, the Wastewater Control Facility is the largest energy user and, by far, the most energy intensive. This is because wastewater treatment is an industrial process that is, by its nature, a big energy user. The Town is embarking on a Wastewater Facility renovation that should result in significant energy use reductions.

But other times, these different scores for levels of energy intensiveness reflect differences in building efficiency that can be adjusted by a range of strategies. Among the causes of these differences and where changes can be made are hours of operation, temperatures maintained for heating and cooling, and efficiency of equipment and infrastructure. Town Hall is particularly energy intensive, perhaps in part due to the IT server being hosted there and the cooling requirements this creates or perhaps due to extensive evening use. Also, different schools vary significantly in their intensiveness of energy use. Peregrine believes that most schools use more energy than they could, with some schools appearing to be particularly inefficient.

Peregrine has advised the ECEC that a goal of 20% reduction[2] in building energy use is realistic and achievable with commitment and high-quality technical guidance. Benefits created for the Town would include saving money, improving occupant health and comfort, increasing building control, and reducing repairs. Three investment strategies were recommended to achieve these benefits:

- Immediately and continuously pursue low-cost and no-cost energy conservation measures that can be easily implemented, such as controlling lights, managing building schedules and temperatures, and installing weatherization improvements;
- Over the next two years, plan for, fund, and complete efficiency upgrades to many pieces of energy equipment, as well as buildings themselves, resulting in a large combined reduction in consumption and other related benefits; and
- Going forward, whenever replacing major energy consuming equipment at the end of its design life, invest in the most energy-efficient alternative possible.

Goals and Strategies

To translate this vision into measurable results, a series of goals were set for Town operations, and strategies for achieving them were identified.

Goal #1: Reduce energy use in Town and school buildings by 20% within five years.

Using the energy baseline for FY 2013 as a starting point, the Town can reduce the total energy requirement for Town and school buildings using a variety of strategies. In doing so, the Town will not compromise the quality of service it provides and will, in fact, achieve energy and cost savings while:

- Upgrading and replacing older building energy infrastructure and equipment
- Increasing the reliability of building systems and reducing the threat of system failures
- Lowering repair and maintenance costs
- Improving occupant comfort

Strategy 1.1: Confirm the potential for energy use reduction in current operations and pursue approaches to achieve that potential

Confirming the potential for energy use reduction involves both determining what the technical potential is (i.e. is there technology available for this purpose) and evaluate that potential in light of future plans for buildings (staying open indefinitely/closed soon/use changing/unknown) and financial capabilities (availability of capital funds, utility incentives, alternative financing strategies, etc.).

[2] Compared to baseline year of July 1, 2012 through June 30, 2013.

Actions required:

1. Evaluate performance of all buildings
2. Confirm the 10 year plans for each building to ensure investments are aligned with future use
3. Identify opportunities for energy reduction and analyze the economics of changes in terms of costs and savings achieved
   - improvements to operations and scheduling
   - replacement of equipment with more energy efficient alternatives
   - improved maintenance practices
4. Evaluate alternative approaches to financing the energy reduction initiatives and weigh the merits of each in terms of cost, savings, and other benefits over time
   - Use of incentives and services from Connecticut Light and Power and Energize-CT
   - Replacing failing equipment with the most efficient possible upgrades
   - Financing projects proactively through operating budgets and CIP process
   - Performance contracting
5. Establish a detailed plan for proceeding with each project
   - Assign responsibilities
   - Confirm budget
   - Establish a timeline
   - Agree on performance indicators
   - Implement
   - Commission new equipment installations as appropriate
6. Measure and report regularly on progress and adjust approach as needed to optimize results

Current status:

As noted earlier, the Town secured Peregrine Energy Group's services in Spring 2014 to develop an Opportunities Assessment for Energy Reduction in Town and School Buildings. Peregrine completed a high-level performance evaluation of all buildings, which is included above in the baseline discussion.

With respect to the Town's current ten year plans, near term plans for buildings include:

- The combination of Enfield High School and Enrico Fermi High School into a single modernized and expanded facility at Enfield High School. Peregrine recommends that no improvements be made at Fermi until the future use of the school is determined. While there are certainly opportunities for energy reduction long term, given the building's age and construction, any changes to energy systems should be driven by the ultimate needs of the Town. In the meantime, planning should begin for how that building will be maintained and operated, in terms of energy use, until a decision about its final disposition is finalized. Empty buildings need some space conditioning to avoid their deterioration and the emergence of a mold problem. On the other hand, the Town may not want to run an empty building at the same cost it had when it was occupied.

- A planned Wastewater Facility renovation. State-of-the-art energy improvements should be integrated into the Wastewater Facility renovation project, removing the need for a separate energy reduction program for that building.

Peregrine found that there are significant opportunities for energy savings across Enfield's building portfolio. Excluding, for the most part, the energy use at Enfield High School, Fermi High School, and the wastewater facility, they identified opportunities to reduce energy consumption in buildings by over20%.Closure of Fermi High School after the high school consolidation would result in over 5% in additional reductions.

Peregrine proposed a three-pronged strategy for energy use reduction:

- Pursuing relatively low cost and no cost improvements to buildings and operations ("Priority 1"),
- Investing in energy efficient technology that would pay for themselves relatively quickly ("Priority 2"), and
- Replacing old and end-of-life building equipment and systems with state of the art systems that would also create some energy savings ("Priority 3").

The following table summarizes the impact of energy reductions suggested by Peregrine by building. A Report summarizing Peregrine's findings is attached to this plan.

SAVINGS OPPORTUNITIES BY BUILDING – PRIORITIES 1, 2, AND 3

Priority 1 - Building Summary

Building	Approximate Implementation Cost	Utility Incentive Available	Potential Utility Savings: Demand kW	Electric kWh/yr	Gas Therm/yr	Oil Gal/yr	Annual Cost Avoidance	Baseline EUI kBtu/sf	Projected EUI kBtu/sf	Overall Savings	Simple Payback Yr
Enfield High School	$0	TBD	(1,100)	180,000	31,100	-	$61,200	83	63	24.0%	-
Enrico Fermi High School	$0	TBD	-	-	-	-	$0	77	77	0.0%	NA
JFK Middle School	$289,500	TBD	400	192,400	12,100	-	$42,300	89	77	13.3%	6.8
Henry Barnard School	$23,000	TBD	-	77,000	8,000	-	$20,300	79	64	19.1%	1.1
Prudence Crandall School	$78,250	TBD	100	48,600	3,900	-	$11,600	78	68	11.9%	6.7
Enfield Street School	$54,500	TBD	50	24,100	1,100	-	$4,800	62	58	6.4%	11.4
Nathan Hale School	$89,000	TBD	110	55,000	5,700	-	$14,500	86	70	18.9%	6.1
Hazardville Memorial School	$95,000	TBD	110	56,000	6,700	-	$15,700	109	93	14.5%	6.1
Adult Day Care	$7,500	TBD	32	10,500	-	230	$2,500	226	210	7.2%	3.0
Family Resource Center	$5,000	TBD	3	9,000	480	-	$1,800	94	78	17.1%	2.8
Angelo Lamagna Activity Center	$25,250	TBD	21	9,600	200	-	$1,690	136	132	2.6%	14.9
Department of Public Works	$85,000	TBD	214	80,400	(500)	-	$11,500	93	86	8.1%	7.4
Enfield Police Department	$28,250	TBD	-	15,400	800	-	$3,300	149	143	4.0%	8.6
Enfield Senior Center	$20,500	TBD	27	18,500	-	-	$2,800	102	118	-15.5%	7.3
Enfield Town Hall	$26,000	TBD	515	357,000	-	-	$53,500	164	111	32.5%	0.5
Total	*$826,750*	*$0*	*482*	*1,133,500*	*69,580*	*230*	*$247,490*	*88*	*77*	*13.0%*	*3.3*

Priority 2 - Building Summary

Building	Approximate Implementation Cost	Utility Incentive Available	Potential Utility Savings: Demand kW	Electric kWh/yr	Gas Therm/yr	Oil Gal/yr	Annual Cost Avoidance	Baseline EUI kBtu/sf	Projected EUI kBtu/sf	Overall Savings	Simple Payback Yr
Enfield High School	$0	TBD	-	-	-	-	$0	63	63	0.0%	NA
Enrico Fermi High School	$0	TBD	-	-	-	-	$0	77	77	0.0%	NA
JFK Middle School	$181,000	TBD	10	90,000	900	-	$14,500	77	75	3.3%	12.5
Henry Barnard School	$25,000	TBD	-	15,000	800	-	$3,100	64	62	2.9%	8.1
Prudence Crandall School	$0	TBD	-	-	-	-	$0	68	68	0.0%	NA
Enfield Street School	$10,000	TBD	54	3,400	(100)	-	$400	58	58	0.1%	25.0
Nathan Hale School	$5,000	TBD	-	4,000	(100)	-	$500	70	70	0.1%	10.0
Hazardville Memorial School	$50,000	TBD	100	7,000	-	-	$1,000	93	93	0.5%	50.0
Adult Day Care	$56,000	TBD	-	-	(6,200)	4,900	$10,300	210	192	8.6%	5.4
Family Resource Center	$0	TBD	-	-	-	-	$0	78	78	0.0%	NA
Angelo Lamagna Activity Center	$70,800	TBD	-	13,000	2,400	-	$4,600	132	113	14.3%	15.4
Department of Public Works	$107,500	TBD	-	29,000	1,100	-	$5,550	86	79	8.2%	19.4
Enfield Police Department	$0	TBD	-	-	-	-	$0	143	143	0.0%	NA
Enfield Senior Center	$207,000	TBD	33	47,000	1,300	-	$8,500	118	110	6.8%	24.4
Enfield Town Hall	$535,000	TBD	10	72,000	2,800	-	$13,800	111	88	20.8%	38.8
Total	*$1,247,300*	*$0*	*207*	*280,400*	*2,900*	*4,900*	*$62,250*	*77*	*76*	*1.7%*	*20.0*

Priority 3 - Building Summary

Building	Approximate Implementation Cost	Utility Incentive Available	Potential Utility Savings: Demand kW	Electric kWh/yr	Gas Therm/yr	Oil Gal/yr	Annual Cost Avoidance	Baseline EUI kBtu/sf	Projected EUI kBtu/sf	Overall Savings	Simple Payback Yr
Enfield High School	$0	TBD	-	-	-	-	$0	63	63	0.0%	NA
Enrico Fermi High School	$15,500,000	TBD	30	109,000	23,800	-	$42,500	77	63	17.7%	364.7
JFK Middle School	$1,400,000	TBD	-	11,000	8,000	-	$10,500	75	70	7.1%	133.3
Henry Barnard School	$800,000	TBD	3	2,000	3,300	-	$3,900	62	57	7.7%	205.1
Prudence Crandall School	$455,000	TBD	-	3,000	4,600	-	$5,600	68	61	11.4%	81.3
Enfield Street School	$750,000	TBD	(10)	(2,600)	4,300	-	$4,300	58	50	14.9%	174.4
Nathan Hale School	$640,000	TBD	-	-	5,500	-	$6,100	70	58	17.0%	104.9
Hazardville Memorial School	$1,400,000	TBD	-	(6,000)	14,000	-	$14,500	93	68	27.3%	96.6
Adult Day Care	$0	TBD	-	-	-	-	$0	192	193	-0.5%	NA
Family Resource Center	$0	TBD	-	-	-	-	$0	78	78	0.0%	NA
Angelo Lamagna Activity Center	$300,000	TBD	-	-	1,900	-	$2,100	113	101	11.2%	142.9
Department of Public Works	$20,000	TBD	-	-	800	-	$900	79	76	3.4%	22.2
Enfield Police Department	$75,000	TBD	-	-	1,600	-	$1,800	143	136	5.0%	41.7
Enfield Senior Center	$0	TBD	-	-	-	-	$0	110	110	0.0%	NA
Enfield Town Hall	$0	TBD	-	-	-	-	$0	88	88	0.0%	NA
Total	*$21,340,000*	*$0*	*23*	*116,400*	*67,800*	*-*	*$92,200*	*76*	*68*	*10.1%*	*231.5*

Priority 1, 2 and 3 - Building Summary

Building	Approximate Implementation Cost	Utility Incentive Available	Potential Utility Savings: Demand kW	Electric kWh/yr	Gas Therm/yr	Oil Gal/yr	Annual Cost Avoidance	Baseline EUI kBtu/sf	Projected EUI kBtu/sf	Overall Savings	Simple Payback Yr
Enfield High School	$0	TBD	(1,100)	180,000	31,100	-	$61,200	83	63	24.0%	-
Enrico Fermi High School	$15,500,000	TBD	30	109,000	23,800	-	$42,500	77	63	17.7%	364.7
JFK Middle School	$1,870,500	TBD	410	293,400	21,000	-	$67,300	89	70	22.1%	27.8
Henry Barnard School	$848,000	TBD	3	94,000	12,100	-	$27,300	79	57	27.5%	31.1
Prudence Crandall School	$533,250	TBD	100	51,600	8,500	-	$17,200	78	61	21.9%	31.0
Enfield Street School	$814,500	TBD	94	24,900	5,300	-	$9,500	62	50	20.4%	85.7
Nathan Hale School	$734,000	TBD	110	59,000	11,100	-	$21,100	86	58	32.8%	34.8
Hazardville Memorial School	$1,545,000	TBD	210	57,000	20,700	-	$31,200	109	68	38.1%	49.5
Adult Day Care	$63,500	TBD	32	10,500	(6,200)	5,130	$12,800	226	192	15.2%	5.0
Family Resource Center	$5,000	TBD	3	9,000	480	-	$1,800	94	78	17.1%	2.8
Angelo Lamagna Activity Center	$96,050	TBD	21	22,600	4,500	-	$8,390	136	101	25.9%	11.4
Department of Public Works	$492,500	TBD	214	109,400	1,400	-	$17,950	93	76	18.4%	27.4
Enfield Police Department	$48,250	TBD	-	15,400	2,400	-	$5,100	149	136	8.8%	9.5
Enfield Senior Center	$302,500	TBD	60	65,500	1,300	-	$11,300	102	84	17.3%	26.8
Enfield Town Hall	$561,000	TBD	525	429,000	2,800	-	$67,300	164	88	46.5%	8.3
Total	*$23,414,050*	*$0*	*712*	*1,530,300*	*140,280*	*5,130*	*$401,940*	*88*	*68*	*23.1%*	*58.3*

<u>Strategy 1.2</u>: Establish performance standards for new equipment purchases and for new building construction and major renovations

Reducing energy consumption by 20% over the next five years and sustaining and increasing those reductions beyond that will require that Town government and the Board of Education commit to a set of policies that ensure that future energy use is a criteria in purchasing and design decisions for buildings.

<u>Actions</u>:

1. Identify and implement policies to guide future purchases of equipment
   - Make life cycle energy use a criterion in product selection
   - Require that all new equipment meet a minimum energy standard (e.g. Energy Star)
   - Identify who is making buying decisions now and what their criteria are
   - Determine who will have authority to make future buying decisions and educate them as to the policies that have been adopted
   - Establish a mechanism for reporting and measuring adherence
2. Establish policies that govern energy performance of all new construction and major rehabilitation of buildings
   - Require that all new construction meets a documented and measurable performance standard (e.g. Energy Star, LEED, etc.)
   - Incorporate the performance standard in requirements documents for new construction
   - Engage an independent engineer to complete design reviews of all projects prior to construction
   - Engage a clerk of the works to oversee construction to ensure it is consistent with designs
   - Engage a commissioning agent to oversee building commissioning prior to acceptance and final signoff and payments

<u>Current status</u>:

The Town has not adopted formal policies regarding energy and new construction.

That being said, the design for the High School renovation is an example of savings that can be achieved by a forward-looking strategy and how building upgrades must be managed to preserve those savings. As a result of changes to state building codes and the advocacy of the Building Committee, the renovated High School incorporates technology that potentially will make it significantly more energy efficient than either of the two current high schools. On the other hand, the decision to include building-wide air conditioning capacity in the building creates the potential for the erosion of the energy reductions achieved. Effective energy management requires a combination of attention to equipment selection <u>and</u> operation. Putting appropriate schedules and controls in place to avoid unnecessary energy use will be critical to achieving the building's design potential.

<u>Goal #2</u>: Maximize the Town's cost-effective use of available renewable and non-greenhouse gas producing energy sources in Town and school buildings

As buildings are becoming more efficient, the Clean Energy Committee recommends that the Town investigate where and how renewable energy sources and particularly those sources that do not contribute to greenhouse gas emissions can be incorporated into energy supply strategies.

<u>Strategy 2.1</u>: Identify and pursue opportunities to incorporate renewable energy generation into the design of existing and future buildings

The Clean Energy Committee believes that the primary opportunities for using renewable energy sources in buildings are with solar electric and solar thermal technologies, ground-source heating and cooling, and recovery and use of methane generated by wastewater treatment.

<u>Actions</u>:

1. Inventory the availability of renewable energy sources to help supply the energy needs of individual buildings
2. Determine the feasibility of using the sources, including identifying any site constraints that might impact the appropriateness of using available sources and whether those constraints can be resolved (e.g. structural limitations to adding the weight of a solar system to a roof)
3. Where the project is feasible and constraints have a solution (e.g. increasing the structural capacity of a roof), evaluate the economics of adding the technology required to tap the renewable energy source
4. Identify funding sources for the project (e.g. grants, bond issues, developer financing and ownership with a power purchase agreement)
5. If the project is feasible and there is an acceptable financial path forward, develop a plan to proceed, as with any other construction project
6. For new construction, even if there are no funds available for including solar as part of the original construction, all buildings should as a minimum be designed as "solar ready."

<u>Current status</u>:

The Town has yet to complete a comprehensive inventory of renewable potential and opportunity. However, the design for the High School renovation project now in process did include elements that make that building "solar ready" in terms of having sufficient structural strength to carry solar panels and having considered where solar can be placed and including pathways for necessary electrical interconnections. Adding solar photovoltaic to the High School can be straightforwardly done using either ZREC financing from Connecticut Light and Power, or the Municipal Solar Lease program of Energize-CT. This should be done as soon as possible.

<u>Strategy 2.2</u>: Identify and pursue opportunities to develop renewable energy generation on Town land (but not associated with buildings or facilities) and then use the energy produced in Town buildings

It is possible to move electricity generated from renewable energy sources from a location where it can be produced to a location where it can be consumed. Transmission of this electricity uses the electric distribution lines owned by CL&P, and interconnection procedures are regulated by the State. Many communities are capitalizing on the availability of municipally-owned brownfield sites within their boundaries (primarily capped former landfills) for repurposing as solar energy "farms." Most often, these farms are developed, owned, and operated by a private developer who sells the power produced to the community at an advantageous rate. Some communities have identified other excess property that is suitable for this purpose.

Actions:

1. Inventory potential locations for renewable energy generation to be sited and developed within the Town's boundaries
2. Consider other possible uses of the property under consideration to determine if there are other potential uses that are more attractive or create more value for the Town
3. Consider the technical feasibility of siting renewable energy generation at specific locations
4. Where renewable energy generation seems feasible and is potentially the best use for the site, engage in a public dialogue to gauge public opinion and particularly the perspectives of abutters and other nearby residents
5. If the project appears to be feasible and the site is acceptable to the community, proceed with identifying potential developers who would be interested in entering into a long-term ground lease and power purchase agreement with the Town

Current status:

To date, Enfield has taken no actions to pursue this strategy.

Financing Building Improvements

State and Utility Programs

Fortunately, in many cases where savings can be documented, there will be utility incentives available from CL&P. Connecticut's electric ratepayers have contributed surcharges into a fund that now provides financial assistance for municipalities (as well as homes and businesses) to improve their energy-efficiency and lock in long-term savings. Connecticut's Green Bank (the first in the nation) also provides well-designed financing programs with favorable terms for municipal and business energy upgrades. State and utility incentives can offset costs of most of the energy improvement priorities recommended by Peregrine, such as:

- High Efficiency Lighting
- HVAC Upgrades
- New automated building and HVAC controls
- Variable speed drives (VSDs) on motors fans and pumps
- High efficiency chillers, boilers, and furnaces
- High efficiency hot water heating systems
- Combustion and burner upgrades
- Water conservation
- Renewable energy systems

Also, with respect to renewables, Connecticut provides a leasing program for solar power systems on public buildings and schools, and an annual auction of financing known as ZRECs (Zero Emissions Renewable Energy Credits). A special funding program also supports micro-grid development, which might be able to support investment in energy upgrades for a cluster of buildings close together. As no-cost financing resources, these should be given priority to defray energy investments.

Local Capital Improvement Program

Unfortunately, these programs will not cover all of the costs for energy efficiency, renewable energy development, and replacement of major energy conversion equipment like boilers and chillers. Achieving the full, long-term savings potential by upgrading the Town's buildings will require significant investment. Building repairs and equipment replacement is inevitable over time, and funding these major improvements may require tapping the Town's CIP over a number of years. These improvements will need to compete with all other requests for capital, which could mean that savings from energy upgrades will come slowly. Pursuing these options in a piecemeal fashion means the Town will remain vulnerable to catastrophic equipment failures and rising repair costs.

Performance Contracting

An alternative, which the Town is exploring in detail, is to enter into an Energy Savings Performance Contract or "ESPC." The ESPC bundles together multiple projects into a single package and uses savings from efficiency improvements to pay for capital improvements. In such contracts, savings are guaranteed by the energy services company (or "ESCO") that does the work. By reinvesting guaranteed annual savings to pay for the project, the Town can reduce energy use and replace old and out-of-date equipment without raising taxes.

Enfield's Clean Energy Committee believes that the performance contract mechanism could be an excellent fit for the Town. This proven strategy has been and is currently being used by many Connecticut cities and towns, by the State of Connecticut, by the Federal government, and by others elsewhere in New York, New England, and across the country. Nationally, energy saving performance contracting is a decades-old, $4.1 billion industry. Since 1990, performance contracts have led to $40 billion in completed projects and $50 billion in savings for the building owners. They have provided 330,000 person-years of direct employment for engineers, technicians, finance and administrative professionals and others, while cutting CO^2emissions by 420 million tons.

Connecticut has recently kicked off its own statewide Energy Savings Performance Contracting program, developed by an inter-agency workgroup and run by CEFIA and DEEP. Performance contracting is available to school systems as well as municipal governments. The program's resources include a pre-qualified vendor list, technical support, financing, and standardized contracts to provide a repeatable, transparent process for towns and vendors alike. A well-managed performance contract will allow Enfield to capture energy savings, increase building comfort, and protect against maintenance crises, while making the best use of resources by bundling building upgrades together for focused professional attention.

The following Connecticut communities have or are currently using performance contracts: Bethel, Bolton, Bridgeport, Bristol, East Hartford, Fairfield, Farmington, Middletown, Milford, Naugatuck, New Britain, Norwalk, South Windsor, Stamford, Stratford, Waterbury, West Hartford, Windham.

Energy Savings Case Study[3]

The Town of Fairfield received the 2014 Power of Change Award (a public-private partnership between the state and three foundations) for Overall Excellence for its leadership in municipal building upgrades. The highest efficiency HVAC equipment was installed through a $7 million performance contract with Johnson Controls. Large buildings were equipped with dual fuel capability, lighting upgrades, and a fully automated computerized system for energy maintenance. Town employees were trained to operate the new equipment. Two new energy generation facilities were constructed - one producing 590kW and the other 50kw, through multiple means of alternative energy production. Adding to the town's carbon emissions reduction was a purchase of 20% green power through Renewable Energy Credits, and an improvement in recycling to achieve a 50% rate.

Through these measures, Fairfield was able to reduce electricity use by 22% and fuel oil consumption by 86% while cutting building maintenance costs 20%. As a result, the town's total heating bill (paid for by taxpayers) is now less than it was in 1996.

[3] Source: www.sustainablect.com, used with permission.

Achieving Energy Objectives for Town and School Vehicles

Baseline

During calendar year 2013, Town of Enfield vehicles used 126,536 gallons of unleaded gasoline and 119,182 gallons of diesel fuel. Vehicles accounted for 22% of Town energy use on an MMBtu basis and 20% of Town energy expense during this period. The distribution of this fuel use by department, with cost, is as follows:

Department/Division	Gas/Gallons	Total Cost/Gas	Dsl/Gallons	Total Cost/Dsl	Total Fuel Cost
B & G	12,843	$ 40,150	12,440	$ 38,489.44	$ 78,639
Building Code Enforcement	750	$ 2,345	0		$ 2,345
Community Dev. Block Grant	446	$ 1,404	0		$ 1,404
Custodial	899	$ 2,816	53	$ 164.73	$ 2,981
Dial-A-Ride	21,935	$ 68,540	0		$ 68,540
Emergency Management	252	$ 776	0		$ 776
Emergency Medical Services	1,677	$ 5,243	18,640	$ 57,654.82	$ 62,898
Engineering	0		0		
Equipment Maint. & Repair	805	$ 2,515	251	$ 776.88	$ 3,292
Highway Maintenance	2,866	$ 8,943	14,555	$ 45,043.34	$ 53,987
Information Technology	438	$ 1,369	0		$ 1,369
Magic Bus	11,426	$ 35,822	0		$ 35,822
Planning	28	$ 89	0		$ 89
Enfield PD	68,251	$ 213,277	55	$ 168.44	$ 213,446
Public Works Admin	756	$ 2,369	0		$ 2,369
Recreation Administration	121	$ 374	0		$ 374
Refuse Collection & Disposal	1,023	$ 3,191	63,231	$ 195,590.15	$ 198,781
WPC (DIESEL)	0		9,957	$ 30,796.71	$ 30,797
WPC (GAS)	2,020	$ 6,297	0		$ 6,297
TOTAL	126,536	$ 451,172	119,182	$ 368,684	$ 819,856

Opportunity Assessment

The Town of Enfield has both special purpose vehicles with limited opportunity for replacement with more efficient models, as well as a number of more-or-less general-purpose vehicles. Special purpose vehicles include Public Safety pursuit vehicles, snowplows, construction equipment, heavy trucks, street cleaning vehicles, etc. Many of these vehicles use diesel fuel.

While fuel-efficient alternatives are not available for some of these vehicles, their operating efficiency can generally increase through the adoption of energy efficient operating and maintenance practices.

Goals and Strategies

Goal #1: Reduce energy use by Town vehicles by at least 20% in five years

The Clean Energy Committee recommends that the Town make every effort to continuously improve the overall fuel efficiency of its vehicle fleet. We suggest three strategies to consider in pursuing this goal: adherence to proven energy efficient operations and maintenance practices and replacement of vehicles with more fuel-efficient models.

Strategy 1.1: Adopt operations and maintenance policies and practices that reduce fuel use

Driving habits, route selection, maintenance practices, and motor oil and tire choices all affect fuel efficiency.

Actions:

1. Acquire a fuel management system that tracks fuel use by vehicle and driver and review reports for patterns that indicate opportunities for improvements
2. Adopt maintenance procedures, in terms of when vehicles are serviced, what service they receive, and what supplies are used, that improve fuel efficiency and extend vehicle life
3. Provide training as appropriate for employees that drive Town-owned vehicles in energy-conscious driving habits
4. Develop policies to reduce vehicle idling and conserve fuel
5. Review vehicle routes for plowing, pick-up and drop-off of bus and van passengers, refuse pick-up etc. to determine if there are more efficient alternatives
6. Encourage contractors who provide transportation or other vehicular services to the Town to adopt practices and procedures that will reduce fuel use
7. Continue to monitor the fuel efficiency performance of all vehicles to identify further opportunities for improvements.

Current status:

Town-owned vehicles are managed and maintained by the Public Works department under the direction of the Town's Fleet Manager. Public Works provides centralized maintenance services for vehicles and maintains a central fuel depot where all Town vehicles get their unleaded gasoline or diesel fuel.

The Town has had a fuel management system for a number of years that was recently upgraded to FuelMaster, one of the leading products available, which has the capability for detailed reporting by department, fuel, vehicle, and by driver, if needed. The Town also employs a vehicle maintenance software package to track mileage and service of individual vehicles.

To date, there is no idling policy in place, though it has been the subject of discussion. So far, the Town has not included fuel efficiency as a criterion for selecting replacement vehicles, but should start using these considerations going forward.

Strategy 1.2: Replace vehicles with the most energy efficient models available to accomplish the purpose for which the vehicle is to be used.

Given tight municipal budgets, low first cost is often a criterion for vehicle purchase, and finding the most expeditious solution is a typical operating procedure for providing vehicles and transportation. When energy-inefficient police department pursuit vehicles are retired after some number of years, those that still run may be passed on at no cost to another department even though that department's driving needs may be very different. Similarly, large, less energy-efficient multi-task vehicles may be purchased when a sedan may do as well, just in case the occasion comes up when more space is needed.

Action:

1. Inventory vehicle needs and performance for all departments
2. Establish a plan for vehicle replacement based on vehicle age, performance, and number of annual vehicle miles

3. When the need arises to replace an existing vehicle or add a new one, evaluate what the vehicle requirements are and match those needs to the specifications of available vehicles
4. Purchase a replacement vehicle that meets that need that is as fuel efficient as possible

Current status:

To date, the Town has not taken a comprehensive approach to vehicle purchasing with an eye toward reducing fuel use.

Achieving Energy Objectives for Street Lighting

Streetlights

The Town of Enfield owns its streetlights, having purchased them from CL&P more than five years ago. There are 3,691 high-pressure sodium (HPS) cobra head style streetlights with wattages of 70W, 100W, 250W, and 400W. The majority of the lights are 70W. In addition, there are a total of 9270W decorative streetlights, two with double heads, in Hazardville and Thompsonville. These are HPS technology.

Streetlight use is typically not metered; consumption is calculated using an average number of hours of operation assumed for each month from sunset to sunrise that is multiplied by the wattage of individual lights. Total annual energy use for streetlights billed to Enfield in FY2014 was $316,277.

Streetlight maintenance is supervised by the Public Works department and contracted out to Siemens. The current contract has just been awarded and is for a single year with the option of two one-year extensions. The contract value is $61,500 annually plus additional charges for emergency costs.

Traffic signals

Traffic signals are owned and maintained by the Town. Each of these signals is metered. They are mostly incandescent technology. Eight local intersections are signaled with Town equipment, with a total of 31 sets of lights, all with multiple signals. There are additional blinking yellow signals, which are state-owned.

Goals and Strategies

Goal #1: Reduce energy use by streetlights by 50% over the next five years

The Town should apply its policy of replacing older equipment with more energy efficiency state-of-the-art technology to streetlights as well. CL&P has, in the last couple of years, adopted new rate structures that will apply to the latest light emitting diode (LED) streetlights. Like the current streetlight rates, these new rates are based on calculated consumption by streetlights of various wattages.

Strategy 1.1: Review the current streetlight inventory to identify lights that could be eliminated and locations where reduced lighting levels might be appropriate and desirable

Streetlight placement typically occurs in a gradual, organic way without an overall plan. Intersections at lit as are long stretches of roadway. Streetlights are included in new subdivisions and other developments and then ownership passes to the Town. Lighting levels are established with particular objectives in mind which may or may not still be appropriate. Changes in technology over time may not have been reflected in lighting designs. Technology available today may create opportunities for reassessment of what the requirements are for "effective" lighting.

***Strategy 1.2*: Convert all street and parking lot lighting owned by the Town to LED**

Conversion of streetlights to state-of-the-art light emitting diode technology will reduce energy use by 50% on average. LED streetlights last more than twice as long as older high-pressure sodium technology, reducing maintenance expense. LED technology provides much more natural color rendition (which is an aid to law enforcement), and LED lighting can be configured to eliminate the shadowing effect that is common to HPS streetlights.

Goal #2: Convert all traffic signals to best available technology to achieve reductions

If the Town has any traffic signals that have not yet been converted to LED from incandescent, these conversions should be implemented as soon as possible. Savings from conversions from incandescent to LED are around 90% of energy use.

Residential Energy Strategy

Enfield's residential energy strategy supports improvements to existing homes and new construction with all forms of ownership and residents with all income levels. Enfield's housing stock includes owner-occupied detached homes and multi-unit condominiums, as well as a range of rental housing types. Households have a broad spectrum of incomes, with the majority middle income. The Enfield population is stable, but there is ongoing new home construction.

Benchmarking Residential Properties

Primary energy end-uses include heating, cooling, hot water, lighting, and various plug loads, including appliances. Energy use in Enfield residences is assumed to be typical of other Connecticut housing stock of comparable age and construction. Newer residential property is assumed to be more efficient by design than older properties due to evolution in building practices and codes to include more insulation and better windows and doors and due to the fact that heating and cooling equipment and appliances are newer and subject to increased government standards.

Opportunity Assessment

Energy-efficiency and renewable energy are equally important priorities. Opportunities for energy efficiency improvement include weatherization (wall and ceiling insulation and whole building air sealing), adding mechanical ventilation, replacing older heating systems with more energy efficient technology, replacing older cooling equipment with more energy efficient technology, temperature setbacks and scheduling through automated controls, improving hot water heaters and better managing hot water use, making lighting upgrades to more efficient technologies, and replacing older inefficient appliances with Energy Star products. Additional benefits of these actions, beyond energy cost reduction, are improved household comfort and health. Energize-CT, a state program supported by electric rate surcharges and operated in partnership with the local investor-owned utility, offers a range of economically priced energy efficiency programs and services to assist residential customers to use energy supplied as efficiently as possible. Special government-subsidized programs are also available from Community Action Agencies to assist income-eligible residents.

Renewable energy opportunities in residential properties are primarily the installation of solar photovoltaic (electricity generating) systems and solar thermal (hot water generating) systems on south facing roofs. Some biomass options also exist, such as self-feeding pellet stoves. Air-source heat pumps, also known as "ductless mini-splits," can greatly reduce fossil fuel use; ground-coupled heat pumps can also be cost effective in some situations. The economics of renewable energy systems for households are different from utility-generated power in that the entire system is purchased upfront and owned by the user; even when the systems are highly cost-effective over the long term, financing is an issue. Group purchasing programs and state-sponsored loans are beginning to make these purchases more economical.

Goals and Strategies

Existing homes

Goal #1: Assist at least 20% of households to achieve 20% energy reductions over five years

The Town and ECEC will develop an effective methodology for expanding household participation in energy upgrades, targeting residents of existing housing stock and assisting them to use programs, services, and methods, as appropriate to their ownership status to reduce energy consumption and expense.

Strategy 1: ***Make energy information and inspiration available to all residents on a regular basis.***

Create a formal public outreach initiative that is organized as appropriate by market segments, such as owner-occupied single-family homes, tenants and landlords, condominiums, and low-income households.

Specific actions can include:

- Incorporate creative educational and social marketing strategies to help people understand energy-saving opportunities and inspire them to act. Use Challenge campaigns, Energy Expos, Town website, Town-sponsored events, newsletters, etc., and address resident groups such as homeowner and neighborhood associations.
- Promote websites such as Energizect.com, EPA.gov, Department of Energy's Energy Saver section
- Engage local vendors of energy products and services in events to make presentations.
- Engage community volunteers who already have installed energy-efficiency measures, solar or geothermal systems, heat pumps and other new technologies as "ambassadors" to answer questions and address concerns of prospective buyers.
- Collaborate with local non-governmental organizations engaged in energy outreach.

Strategy 2: ***Encourage residents to use existing resources for energy efficiency and track participation***

1. Partner with utilities and agencies to bring certified auditors and technicians from established efficiency programs to Enfield's homes, and target groups with specific needs and opportunities.

   - **Owner-occupied homes:** Supplement direct outreach by service providers with locally initiated neighborhood, block-based, market channel outreach strategies, partnering with Home Energy Solutions contractors, civic associations and other membership organizations to engage households at a significant scale. Consider organizing a neighborhoods competition to spark interest in home energy audits throughout the neighborhoods in town.
   - **Tenants:** Develop specialized service packages for tenants based on steps they can take on their own with landlords on energy initiatives. Reach out to and educate larger landlords.
   - **Condominiums:** Approach condominium associations to identify opportunities and mitigate constraints for energy efficiency upgrades that benefit entire buildings as well as individual units. Bring educational presentations to condominium residents in a coordinated manner.
   - **Low-income residents:** Help publicize the Home Energy Solutions-Income Eligible (HES-IE) program of Energize-CT that provide free home assessments and energy-

saving services; collaborate with Neighborhood Services to bundle and integrate energy outreach with healthy home services such as asbestos and mold removal.

2. Supporting energy-efficiency upgrades in renovations by providing information through the building department when permits are issued. If possible, fast track those permits and inspections involving energy efficient upgrades.

3. Track and publicize how much and what has been done by Enfield residents by market segment to reduce their energy use.

Goal #2: Increase the number of solar installations in town by at least 50% per year

The ECEC had a successful Solarize Enfield campaign in 2013 and 2014, tripling the penetration of photovoltaic systems in the Town. As solar systems become more widespread, familiar with their appearance and public acceptance should grow, with early adopters being joined by "just plain folks".

Strategy 1: Evaluate success and challenges of Solarize Enfield 2013-14 and develop an annual outreach campaign incorporating lessons learned and new incentives.

Strategy 2: Integrate outreach for solar PV with complementary technologies that reduce fossil fuel consumption such as air source heat pumps.

There are electric-based heating and cooling technologies that can be cost effective alternatives to conventional fuels if the electricity required is generated from a renewable source. Integrating PV with such technologies can be attractive.

Strategy 3: Investigate and market cost-effective solar thermal technologies for dedicated outreach campaigns.

Solar thermal is widely in use in many countries and even other areas of the U.S. It was a growing technology here in the 1980's and 1990's until market changes caused vendors and suppliers to disappear. New technologies and vendors are bringing solar thermal back, but outreach is needed to bring consumers back to it.

Strategy 4: Address any zoning or regulatory barriers to PV installation

Examples include: working with the Planning and Zoning Commission to establish guidelines for virtual net metered solar installations on farms and the Historic District Commission to establish guidelines for renewable energy installation in the historic district.

New Construction

Goal #1: Have all new residences constructed in Enfield going forward qualify for ENERGY STAR status

In Connecticut, there have been **9,750** ENERGY STAR certified homes built to date. **432** ENERGY STAR certified homes have been built in 2014 thus far, and **361** ENERGY STAR certified homes were built in 2013. To earn the ENERGY STAR, a home must meet strict guidelines for energy efficiency set by the U.S. Environmental Protection Agency (EPA). Homes achieve this level of performance through a complete package of building science measures including:

- A Complete Thermal Enclosure System – Comprehensive air sealing, properly installed insulation, and high-performance windows work together to enhance comfort, improve durability, reduce maintenance costs, and lower monthly utility bills.
- A Complete Heating and Cooling System – High-efficiency systems are engineered and installed to deliver more comfort, better moisture control, improved indoor air quality, quieter operation.
- A Complete Water Management System – A comprehensive package of best building practices and materials protects roofs, walls and foundations from water damage, provides added protection, and reduces the risk of indoor air quality problems.
- Energy-Efficient Lighting and Appliances – ENERGY STAR certified lighting, appliances, and fans are commonly installed throughout ENERGY STAR certified homes, helping to reduce monthly utility bills, while providing high-quality performance.

To ensure that a home meets ENERGY STAR guidelines, third–party verification by a certified Home Energy Rater (or equivalent) is required. This Rater works closely with the builder throughout the construction process to help determine the needed energy-saving equipment and construction techniques and conduct required on-site diagnostic testing and inspections to document that the home is eligible to earn the ENERGY STAR label.

***Strategy 1*: Identify who is building residential properties in Enfield, educate them about ENERGY STARhomes, and encourage them to join the program and follow Energy Star guidelines in new projects.**

***Strategy 2:* Provide incentives such as accelerated and/or streamlined permitting, discounted or delayed permit fees, priority field inspections, priority with code processing, increased density allowance, and reduced grid hookup fees for ENERGY STAR certified homes.**

Goal #2: Make all new construction "solar-ready"

Solar-ready homes have been built with roofs facing south, roof structures strong enough to accommodate the weight of solar equipment, and plans for wiring requirements of systems. Enfield can facilitate solar adoption in new construction by establishing solar-friendly zoning and design guidelines that are in line with community aesthetics and that require solar-readiness in new construction.

Resources for Financing Residential Energy Improvements

Small loan pilot: CL&P customers can borrow$1000-$3000, 0% interest for insulation, certain water heaters. Repayment is on electric bill. No credit check is required if electric bill has been paid on time.

Insulation and Appliances: (CL&P offers low-interest (2.99% to 6.99%) loans for measures recommended by Home Energy Solutions. $3000 to $25,000 loans for insulation, heating/ cooling systems, water heaters. Up to 20% for necessary non-energy improvements.

CT Housing Investment Fund Energy Conservation Loans: Low interest, income guidelines apply. Info: http://www.chif.org/page/energy-conservation-loan-program.

Smart-E: http://www.energizect.com/smartefinances many energy efficiency or renewable energy measures. Up to 20% of the borrowed amount can be used for health and safety upgrades (i.e. asbestos or lead remediation), roof repair, EnergyStar small appliances, or other related measures.

Cozy Home: This program has same rules as Smart-E, but designed for residents earning below 80% of Area Median Income. Details at http://hdf-ct.org/lending-products/cozyhome or call (888) 232-3477.

Commercial & Institutional Energy Strategy

Enfield's commercial and institutional energy strategy targets commercial buildings occupied by businesses and by institutional users such as private schools, health-care, and other non-profit organizations. Occupants may be owners of properties or tenants within those properties. This market sector includes older existing properties, as well as recent or future new construction. For nonprofit institutions, the benefits of energy improvements are compelling because energy cost savings are available to be invested in service offerings and in other areas of business operations.

Benchmarking Commercial and Institutional Properties in Enfield

Primary energy end-uses in this market sector include heating, cooling, hot water, lighting, and various plug loads, and may also include business-specific process energy use. Energy use by Enfield's commercial and institutional buildings is assumed to be typical of other Connecticut properties of comparable age and construction.

Opportunity Assessment

Opportunities for energy efficiency improvement include weatherization (wall and ceiling insulation and whole building air sealing), adding mechanical ventilation, replacing older heating systems with more energy efficient technology, replacing older cooling equipment with more energy efficient technology, temperature setbacks and scheduling through automated controls, improving hot water heaters and better managing hot water use, making lighting upgrades to more efficient technologies, and replacing older inefficient equipment with Energy Star products. Energize-CT offers a range of economically priced energy efficiency programs and services to assist commercial customers to use energy as efficiently as possible.

Goals and Strategies

Goal: Reduce energy use by as many businesses as possible by 20% over the next five years

Strategy 1: Outreach and education

The Town, through its committee structure and in cooperation with the Clean Energy Committee, should develop and implement an outreach program for energy-efficiency and renewable energy upgrades, including business-oriented outreach through the Chamber of Commerce, Rotary and other service organizations, and town-sponsored events such as business breakfasts.

Strategy 2: Publicize local success stories

Engage local businesses and institutions that have implemented energy improvements as "energy ambassadors" who can inspire others to do the same. Focus on high-impact businesses such as restaurants, health clubs and other gathering places; hardware stores and other points where the building trades come together; high-profile commercial centers such as the malls; and well established institutions such as houses of worship. Develop case studies, gather testimonials, and wherever possible, involve business leaders as peer mentors with their colleagues.

***Strategy 3*: Encourage participation in utility programs and services and available financing programs**

Advise businesses to take advantage of utility services and targeted financing options such as the Connecticut Green Bank's loan program, C-PACE, and integrate education about these options with the overall package of business services provided by the Town of Enfield.

***Strategy 4*: Encourage use of renewables**

Recognizing that public policies can affect the ability of building operators to use renewable energy, the Enfield Clean Energy Committee will work with relevant agencies, boards and commissions to prepare for the Town Council specific policy recommendations to overcome barriers, and specifically to:

- Identify and remove any zoning barriers to the utilization of renewable energy for business sectors, such as agriculture
- To support local joint ventures in renewable energy and expand access for commercial and institutional building owners regardless of their orientation and shading conditions, advocate for expanded virtual net metering without restriction among Connecticut electric customers.

Resources for Financing Commercial and Institutional Energy Improvements

C-PACE: Commercial and Industrial Property Assessed Clean Energy: C-PACE is a financing program of Connecticut's Green Bank, designed to reduce energy costs and greenhouse gas emissions. It offers affordable financing to property owners to undertake energy efficiency and clean energy improvements on their buildings. Businesses who are approved for the program repay investments through a benefit assessment on their property tax. C-PACE requires no money down, providing 100% upfront financing to the owner for various energy efficient upgrades.

C-PACE payback schedules are specifically structured so that projects will be cash flow positive. The dollars saved through energy upgrades are sufficient to cover the loan payments. C-PACE repayment obligations are attached to the property, not the owner. If the facility changes ownership, the new owner takes on both the payback responsibility and the energy-saving benefits including permanent savings after the loan is repaid.

SBEA: Small Business Energy Advantage Program: Businesses interested in reducing energy usage and upgrading to energy efficient equipment can also take advantage of SBEA. The program offers no-cost, no obligation audits of business facilities and makes recommendations to save energy and money through energy efficient upgrades. The program offers incentives from Connecticut Light and Power, and low interest on-bill payment plans to make energy efficiency an achievable goal.

Next Steps

Guiding Principles

The ECEC recommends that the Council follow these guiding principles as it manages the Town's resources and addresses the needs and interests of Town residents and businesses.

Plan for our Energy Future

We suggest that energy considerations can be formally integrated into future planning, decision-making, and operations. This will ensure that energy impacts of decisions made are naturally and proactively addressed, rather than treated as a separate topic.

Specifically, we recommend:

1. Increasing energy efficiency and using clean energy sources is a formally addressed and considered in all Town planning and development efforts, focusing on life cycle cost benefits and other advantages that can be gained by this approach, and that all public sector building or renovation projects include renewable backup power and energy storage, to the extent that this is cost-effective.
2. Requiring an opportunity assessment for micro-grids in all neighborhood and district development plans, preparing to make full use of Connecticut's micro-grid funding program and attract private investment. The Town should make it a priority to develop a community-based energy security plan using renewable energy in combination with backup generators and energy storage, to ensure reliable access to electricity in any extended power outage.

Avoid lost opportunities for increasing energy efficiency and renewables in operations

The Town should make every effort to maximize energy efficiency and renewable energy deployment in new construction and renovation of schools and public buildings, and make results and benefits visible through performance monitoring, exhibits, and signage. To that end:

- Reduce lighting ,heating, cooling, and other electricity consumption wherever possible through improvements to operations and maintenance, the use best available energy technology, and the replacement of aging energy infrastructure with equipment with the lowest life cycle cost
- Embrace the use of natural lighting and green infrastructure (green, light or reflective roofs, living walls, rain gardens near usable outdoor spaces for natural cooling), and passive solar design in buildings
- Set a standard of solar-readiness for new buildings, and secure increasing percentages of energy from renewables from any workable combination of onsite generation, virtual net metering and purchase of Renewable Energy Credits.

Commit to Making Enfield an Energy-Smart Community

Energy improvements should not be made only once. There are continuous opportunities for improvement as technologies and project economics change. Enfield can distinguish itself by, not only promoting widespread participation in current state and utility-sponsored energy programs, but also helping citizens become wiser users of energy and discriminating customers in the energy marketplace.

Partner with the schools for energy education at every learning level

The Town's investment in its schools is great and growing. We suggest that the Town create an energy curriculum that encourages and highlights energy topics in STEM education for K-12 and adult education, as well as providing community-based programs through the Enfield Clean Energy Committee.

Help Educate Consumers

Consumer education and fact-based advocacy should be a priority in the Enfield Energy Strategy. The marketplace is filled with energy products and services of inconsistent quality and claims. The Town should broadly distribute the useful educational resources available through Energize-CT, for "101 level" introduction to energy concepts and resources and build on these with advanced materials collected and developed by the Enfield Clean Energy Committee that address community needs and opportunities.

Implementation

The Clean Energy Committee recommends that Town Council formally endorse the vision and goals presented in this document.

Implementing Enfield's Energy Strategy will be a shared responsibility.

- Political leadership at the highest levels of town government will be required to encourage the use of sound energy criteria in government operations. Town Council approval is needed for policies and major investments.
- Town staff will make decisions that concretely integrate energy criteria into purchasing and operations, as well as developing recommendations for our future energy infrastructure, in consultation with the Council and Clean Energy Committee.

Enfield's Energy Strategy addresses not only government operations, but also making energy savings and cleaner choices easily available to the entire Enfield community. The Enfield Clean Energy Committee, tasked with promoting energy efficiency and renewable energy town-wide, envisions having an ongoing role in implementation.

Full implementation will include:

- Town Council by resolution applying the strategy to government operations, planning and development, and programming, and directing town staff accordingly;
- The Enfield Clean Energy Committee establishing implementation plans for the aspects of the strategy that involve residents, businesses and institutions;
- Committee, Council, and staff creating a timeline for actions, metrics for outcomes, and a mechanism for periodic evaluation of successes and refinement of strategies.

The research and conversations carried out to create the Enfield Energy Strategy have established a clear, realistic set of opportunities to pursue. The walk-through assessment conducted by Peregrine made it clear that more detailed, investment-grade building assessment is worthwhile, and the recommended savings goal of 20% should be pursued without delay. Fleet energy use is significant, and controllable, through the simple recommendations made by Peregrine. The same is true for street lights. Purchasing policy and facility use behavior are choices within the control of the Town that can build momentum for serious implementation of the Energy Strategy. In the residential and commercial/ institutional sectors, the Committee will continue developing and implementing outreach programming with a special focus on helping to stabilize energy costs for Enfield's low and moderate income residents, and establishing the foundation for "energy smart community" initiatives.

Energy planning is a powerful exercise in building consensus about local priorities and taking responsibility for the economic use of resources as a community. The Enfield Clean Energy Committee is pleased to endorse this Strategy and eager to support its implementation.

City of Middletown 2019

Energy Plan

City of Middletown Energy Coordinator
Middletown Clean Energy Task Force
August 2019

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MIDDLETOWN ENERGY PLAN

The following people were instrumental in creating, editing, and finalizing this energy plan:

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This plan would only be a boring word document without the incredible graphic design work of Addision Kenney.

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MIDDLETOWN ENERGY PLAN

In 2018, the State of Connecticut set a goal of producing 40% of its electric power through renewables by 2030. This energy plan recommends this goal for Middletown as well. Our ultimate goal should be to get to 100% renewable energy for by 2050, consistent with State goals.

Energy is one of the most important dynamic forces in Middletown. We use it to illuminate, heat and cool our city buildings, schools, homes and businesses; to run appliances and to travel to work and play. It is also one of the largest expenditures for our citizens.

Sources of energy and the use of energy are at the crux of concerns regarding sustainability and environmental impacts. Middletown has the opportunity to optimize its use and procurement of the energy needed to sustain a robust, healthy community with equitable access for all. This can be accomplished by achieving energy efficiency and implementing renewable energy in both town buildings and also among residents and businesses.

INTRODUCTION AND OVERVIEW

BENEFITS

The Middletown Clean Energy Task Force has prepared this energy plan to help guide the city toward greater energy efficiency and sustainability. Carrying out this plan will yield many benefits to city residents and businesses, including:

SAVINGS

We estimate that the city can reduce its energy expenditures by more than half. And we can keep more of the money we spend right here.

HEALTH

By reducing our reliance on fossil fuels, we will improve air quality, leading to a range of health benefits, including notably lower asthma rates.

COMFORT

By making our homes and businesses more energy efficient, they also become more comfortable.

RESILIENCY

Through greater reliance on local energy generation and a more modern electric grid, the city can safely weather outages and natural catastrophes.

KEY ELEMENTS

The key elements of this energy plan are:

1. Reduce energy usage by improving the efficiency of our buildings, both public and private.

2. Strategically electrify by transitioning transportation to electric vehicles and heating and cooling to high-efficiency heat pumps.

3. Develop an optimal mix of locally supplied renewable energy by promoting the responsible development of solar energy, including residential rooftop solar, community shared solar, commercial solar and solar carports.

INTRODUCTION AND OVERVIEW

A FRESH NEW LOOK

The City of Middletown Energy Plan is referenced in the current Plan of Conservation and Development. By being incorporated by reference into the POCD, the plan may remain dynamic and evolving within the 10-year POCD cycles while offering a foundation of vision and process. The Middletown Energy Plan has also been formally recognized as an important guiding document through a resolution passed by the Middletown Common Council in June of 2019. Both its positioning within the POCD and the Common Council's resolution support the plan's capacity to help create the City of Middletown's optimal energy future.

The 2019 City of Middletown Energy Plan incorporates wisdom and content from previous energy plans. Moreover, the current plan provides the framework of an overarching vision and discussion of process to move toward the ideal expressed by the vision statement.

The plan offers the following organization:

Section I Discussion of a framework of vision and process

Section II Approach to municipal energy use, reduction and conversion to renewable energy

Section III Approach to residential and business sector energy use, reduction and conversion to renewable energy

Appendices 1. 2018 Letter to Clean Energy Task Force, 2. 2017 Energy Action Plan, 3. 2010 Middletown Energy Plan

SECTION I

Middletown Energy Vision and Process Overview

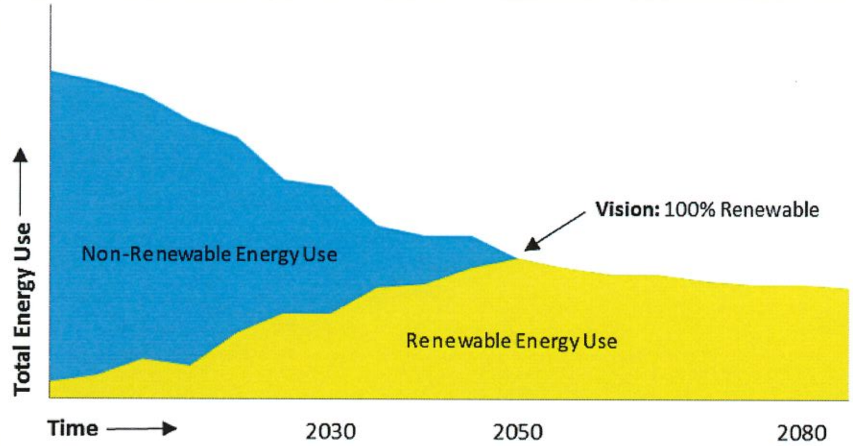
SECTION I:

MIDDLETOWN ENERGY VISION AND PROCESS OVERVIEW

The City of Middletown aspires to transition our entire community to 100% renewable energy by 2050

SECTION 1

MIDDLETOWN ENERGY VISION AND PROCESS OVERVIEW



This section describes an energy vision for the City of Middletown Energy Plan and strategic framework for achieving it, including key process elements and supporting policy recommendations. The vision for Middletown's is based on the ideal of providing all of the needed energy within city boundaries through renewable sources.

The graph illustrates the principle of energy reductions through efficiency gains prior to sourcing energy from renewable sources.nThe key to the vision of 100% renewable energy is recognizing the inherent efficiency gains achieved through strategic electrification. Broadly, these gains include the superior coefficients of performance (COPs) of heat pumps, as well as the more efficient translation of electrical energy into transportation energy.

PEAK RESOURCES

A realistic vision acknowledges the energy and environmental realities currently unfolding, as well as changes expected. This reality includes the finite nature of fossil fuels including the concept of peak fossil fuels in which continued reliance and the resulting depletion is characterized by a decreasing Energy Return on Investment (EROI), and ever-increasing economic and environmental costs.

While the concept of peak fossil fuels is complicated and extremely difficult to predict with regard to timing, the analysis is simplified by the fact that climate disruption will likely overtake depletion concerns due to the emergence of reinforcing, climate feedback loops.

The feedback loops are raising the concerns over carbon concentrations in the atmosphere such that the elimination of fossil fuel use is increasingly seen as an unavoidable necessity. These loops include ocean temperature rise and acidification, methane releases due to melting permafrost and exposure of undersea methane hydroxides (clathrates).

It is, however, key to remember that the longer we expect to obtain fossil fuels through increasingly unconventional methods, the greater the environmental and economic damage.

100% RENEWABLE VISION

Given the above discussion, holding the ideal vision of 100% renewable energy is not only a worthy endeavor, but perhaps an essential one. A 100% renewable energy plan goes beyond generating, procuring or offsetting energy needs with renewables.

It represents a holistic, comprehensive approach to managing the supply and demand for energy, including:

- deep efficiency and conservation
- generation of renewable energy
- energy storage
- electrification of transportation, heating, and cooling
- active load management (i.e., "demand response")
- a modern community microgrid
- a new utility rate structure and business model

100% RENEWABLE VISION

(continued)

Such a program would seek to answer the following questions pertinent to a comprehensive vision:

- How much energy do we currently use, including electricity, heating, cooling and transportation?
- How much could we reduce energy usage through conservation, efficiency and electrification of all heating, cooling (i.e., heat pumps) and transportation (i.e., electric vehicles)?
- How much renewable energy could we produce in town?
- How do we re-think and redesign the electric grid using community microgrids to accommodate a higher level of distributed energy resources?
- How do we constructively engage with the electric utility to develop new technical, business, and financial models?

Finally, the 100% effort can help develop a citywide picture of deployed, decentralized, renewable infrastructure such as windmills on brownfield sites, solar arrays on roadway medians, coordinated microgrid systems and other examples of the localization of energy generation and delivery. To the extent that these elements are reflected in the Energy Plan, they have a much better chance of being brought to fruition.

POLICY

Through the effort to develop a useful vision as the context for an energy plan, the City will become much more capable of articulating guiding ideals that are broadly supported by City leaders and constituents. In order to better serve these ideals, the City should consider codifying them in the form of policies, resolutions and ordinances. As the environmental and economic challenges of the energy future reveal themselves more fully, it will be increasingly important to install a framework of acceptable and not acceptable responses.

Examples include:

- Requiring minimum efficiency standards for vehicles and buildings
- Prioritizing the use of otherwise unusable land, such as brownfields, for the siting of renewable energy infrastructure
- Requiring all new buildings to meet 'net zero' criteria
- Subsidizing the installation of 'ground-couple' components to improve the efficiency of high-efficiency air-cooled heat pumps
- Banning/limiting plastic bags and other forms of plastic
- Eliminating single use plastic water bottles and prioritizing the availability of clean water for everyone within city boundaries

Well-developed policies can provide important support to the implementation of the energy plan.

ENERGY TRACKING AND MANAGEMENT

Category	2017	2018	Change	% Change
Total Household Electric - kWh	142,578,842	145,066,736	2,487,894	2%
Total Household Natural Gas - CCF	4,715,174	3,758,283	-956,891	-20%
Total Business Electric - kWh*	884,358,396	884,358,396	0	0%
Total Business Natural Gas - CCF	14,894,388	11,329,484	-3,564,904	-24%
Totals (MWh equivalent)	1,601,661	1,471,622	-130,038	-8%

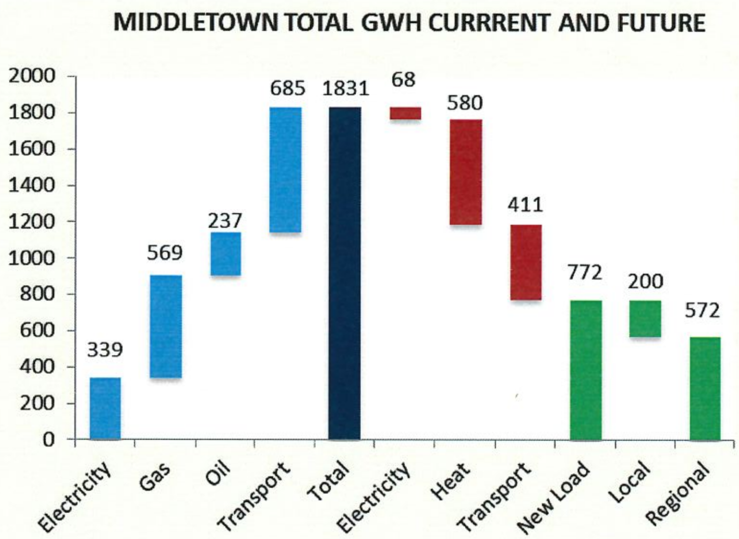
*2017 data was erroneous; this table assumes no change from 2017 to 2018

Table 1. Summary of Electricity and Natural Gas Use

Municipal energy is tracked by Middletown's Energy Coordinator through utility company billing and through the Energy Star benchmarking program. Residential and business usage is tracked through the Clean Communities Dashboard, offering a high level view of all energy consumed within town boundaries.

Table 1. illustrates the high level tracking available through the Clean Communities Dashboard. The data is categorized by household energy and all else. Municipal energy – representing about 2% of the total shown below - is discussed in more detail in the next section.

ENERGY REDUCTION GOALS AND ACTIONS



Total energy use within city boundaries includes oil used for heating and transportation energy. **Figure 1** above summarizes estimated totals for all energy use in the city, and also projects potential efficiency reductions.

The graph Indicates a total of 1,831 Giga-watt hour (GWh) equivalent energy. This total consists of 339 GWh of electricity, 569 GWh or natural gas, 237 GWh of heating oil and 685 GWh of transportation energy.

The right side of the graph indicates potential efficiency reduction resulting from a combination of conservation/efficiency efforts and strategic electrification. The total project future energy needs of the city, disregarding growth for the moment, is 772 GWh. This value represents the ideal for which the city might seek to provide through renewable source. The breakdown of 200 and 572 GWh respectively indicated reasonable estimate of renewable production that might be available within city boundaries, and more regionally.

The assumptions included in the above projects include 20% in efficiency gains for lighting and appliances, current heating efficiency at 85%, 100% conversion of heating to heat pumps that provide 3:1 energy output versus input. Transportation is similarly estimated because the translation of electrical energy to transportation energy is significantly better than fossil fuel energy to transportation.

CLEAN ENERGY GOALS

Basic Principles

Based on the analysis, a long-term goal for the City of Middletown to achieve 100% renewable energy would require clean energy production of about 772 GWh. This would require 88 mega-watts (MW) running 24/7, or roughly a solar installation of about 600 MW. However, this analysis is still quite preliminary for several reasons, the most important of which is probably the sizing and interaction of energy storage with generating capacity. This analysis is currently beyond this Energy Plan.

PEAK DEMAND GOALS AND ACTIONS

Peak demand represents an additional dimension of energy use that significantly impacts energy costs and the need and size of energy infrastructure. Reducing peak demand implies that the use of energy is spread over a longer span of time; therefore the 'peak' requirement is reduced. The ideal relationship between peak demand and use is a flat load in which the energy needed is spread equally over all hours.

Peak demand drives the capacity and sizing of energy infrastructure needed to safely serve an energy load. If the ideal were met in which the energy needed could be provided in equal parts over time, the infrastructure needed would be minimized. However, the ideal is seldom the case. Most energy needs occur during certain times of the day (ie., 'diurnal'), during which more energy is needed at certain times, and less energy at other times. An example of this is a school for which energy needs are minimal at night and maximal during the day.

The extent to which energy need, or 'demand' is concentrated during certain times drives the need for infrastructure and is reflected in the cost to deliver energy. As energy grows, there is a tension among energy users (concurrent demand) and the capacity of the system to serve the concurrent demand. As the infrastructure system ages and energy use continues to grow, the cost of demand is receiving more and more focus.

PEAK DEMAND GOALS AND ACTIONS

(continued)

Clean, renewable energy has the potential to distribute the production of energy and reduce the load that needs to be served by energy infrastructure. To the extent that Middletown energy needs are concentrated during the daylight hours, the application of renewable energy can reduce peak demand.

It is important to recognize that such reductions are subject to the variability of renewable energy due to weather and other operational characteristics.

The City of Middletown continues to work to develop a culture of awareness of peak demand. This awareness is most acute during system demand days in which the current infrastructure is most burdened due to, for example, high outdoor temperatures and wide-spread need for air-conditioning. Middletown participates in demand management programs in which we can respond to request to reduce energy demand. The City also maintains awareness of peak systems days during which 'captag' assignments are made by energy suppliers. Captag is an indication of the amount of infrastructure needed to supply the city accounts and is a component of energy cost that is constant throughout the year. Managing energy to reduce captag during the annual system peak can produce energy cost savings year round.

CONCLUSION

The above discussion applies to both the Municipal sector and the Residential/Business sectors, both of which are discussed below in their respective sections. These sections will address the application of the City's vision of an energy future, and how to achieve it through goal-setting, policy, energy tracking, and a process of actions to impact both energy consumption and peak demand.

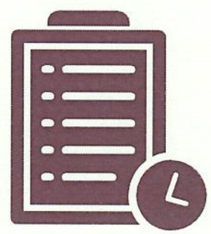
SECTION II

MUNICIPAL APPROACH

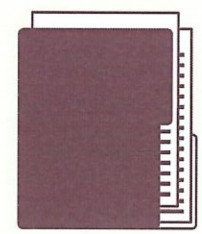
SECTION II:
MUNICIPAL APPROACH

The approach to meeting energy goals for the Middletown municipal and school buildings includes:

Energy Auditing



Screening and Prioritizing Opportunities



Bundling and Implementing Projects

ENERGY AUDITING

In order to take a strategic approach to financing energy-related improvements and pursuing energy efficiency goals, the City has implemented an Energy Efficiency Program to fund comprehensive energy auditing of all energy consuming buildings and systems in the City.

This includes:

- Municipal buildings
- School buildings
- Street lights
- Water and sewer plants and pumping stations
- Telecommunications and security system
- Transportation

Middletown's Energy Coordinator uses energy auditing to identify energy opportunities and provide initial characterizations of the costs and benefits of the individual projects. Benefits include hard savings estimates, but also softer considerations such as the avoidance of repair, maintenance or capital replacement. All of the project information gathered is compiled on a single spreadsheet that then drives the strategic planning across all buildings and systems.

The single spreadsheet can be thought of as the 'universe' of opportunities. While it will describe a gross savings potential, this total or 'goal' will be overstated as not all projects will meet the criteria for implementation.

SCREENING AND PRINTING OPPORTUNITIES

Once all of the needs and opportunities are understood, the City plans on taking a strategic approach to implementing those projects that meet a minimum cost/benefit ratio. This ratio will include the relationship between hard costs and estimated savings, as is often described by a simple payback analysis. However, other benefits may accrue from any given project. The City has the opportunity to include those benefits in the analysis as well.

Other benefits may include improvements to comfort and reliability, or reduced or avoided repair, maintenance or replacement costs. While the above analysis is typical of large integrated energy projects, this evaluation is often performed by a third party in which many assumptions are not made obvious. The City plans to maintain control of the analysis, and the controlling assumptions, in order to gain the most value from the energy efficiency approach. The resulting aggregate screened and prioritized project list will offer a realistic energy reduction goal. Estimates of the magnitude of the energy reduction goal are discussed in the following sections.

BUNDLING AND IMPLEMENTING PROJECTS

Bundling and Implementing Projects
To achieve a balanced approach to implementing the myriad opportunities, the screened and prioritized project list will be sorted into bundles that will represent phases of the larger energy project. Bond funding is envisioned for the phases of the aggregate project. A multi-million dollar project may require several phases and a few years to implement.

The bundles will be assembled based on respective urgency of various projects, as well as the ability to blend stronger and weaker financially performing projects to arrive at a bundle with a weighted average financial performance that meets a pre-determined metric. For example, bundle projects with gross paybacks of about six years can be financed with the savings (ie. neutral cash flow) over a term of 10 years and at the typical – though competitive - bond interest rate available to the City of Middletown. Bond interest rates are affected by the City's financial strength that has been excellent over the last several years with our AAA bond rating.

ENERGY TRACKING AND MANAGEMENT

Energy tracking and management is currently addressed through a variety of systems. In general, the purpose of tracking and management is to facilitate an understanding of energy use year-over-year, to identify unexpected changes in this use, and to use the information to improve energy strategy.

While efficiency and the quantity of energy used – sometimes adjusted for weather – are primary concerns, management activities include monitoring pricing, optimizing procurement and prioritizing investments. Cost savings derived from more competitive procurement strategies can be applied to efficiency efforts.

Energy tracking for municipal buildings is accomplished through:

- utility billing and website
- Eversource customer engagement platform
- Energy Star website and benchmarking

ENERGY REDUCTION GOALS AND ACTIONS

As of 2018, the City consumed about 36,000 MWh of equivalent energy – meaning this value included electrical, process and heating ventilation and air-conditioning (HVAC) energy. The amount of electrical energy used by the City is about half of the 36,000 MWh total.

While the City's total energy requirement has remained flat since 2011, the contribution from renewable energy had declined to 115 MHw equivalent prior to the installation of a 400 kilowatt (kW) fuel cell that the High School.

The High School is the largest energy consumer in the city. With its installation, all of the electrical energy needs to the building are provided by the fuel cell. This occurs as a result of the 24-hour per day operation of the fuel cell in which much of the electricity needed in the building during the day is produced during the night time hours and 'stored' on the electric grid. The stored energy is retrieved each day.

Although the fuel provides a modest financial benefit as a result of its classification as a renewable energy source, the need to retrieve energy during the day results in costly demand charges. However, the total contribution by the fuel cell of some 3,000,000 kWh per year accounts for 19% renewable energy contribution toward the 18,000 total electrical use by the City.

PEAK DEMAND REDUCTION GOALS AND ACTIONS

Demand, and efforts to impact demand, are organized under two general initiatives:

- CAPTAG MANAGEMENT
- DEMAND RESPONSE

CAPTAG MANAGEMENT

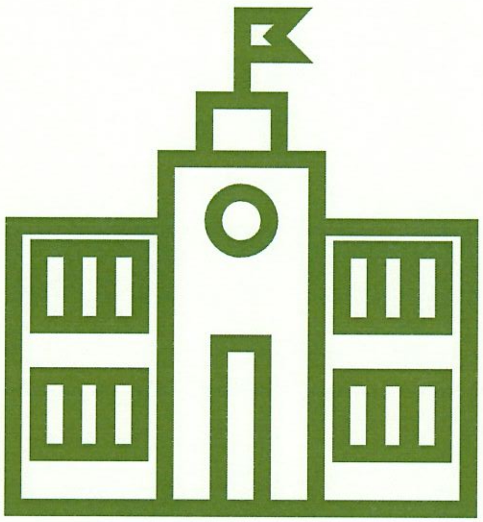
The generation portion of the City's electric costs includes transmission costs – the space on the large transmission system that brings electricity into the local distribution system. The transmission costs are administered through a characteristic unique to each customer called its "captag." The captag is an representation of the aggregate, or combined, demand of all electric accounts for any given customer. It is determined on the peak day for the regional electric system serving the customer.

Captag management involves monitoring the system for its peak day and attempting to reduce demand on that day. Any reductions are reflected as a lower captag with an associated reduced cost for all electricity purchased.

While the process is straightforward if successful reducing electric load, it is not so straightforward predicting the peak day. Peak days that occur early in the summer season may be exceeded later in the summer. So there may be multiple days in which curtailment or load reduction is attempted. In addition to the potential to reduce energy costs, another advantage of managing captag includes raising awareness about electric demand its cost.

DEMAND RESPONSE

Tracking the largest users through interval meters, the City of Middletown Board of Education participates in a demand response program with C-Power Energy Management for some larger schools:



Bielfield Elementary

Lawrence Elementary

Wesley Elementary

Keigwin Middle (to be repurposed within two years)

Woodrow Wilson Middle (to be replaced within two years)

Middletown High

DEMAND RESPONSE

(continued)

Each of the schools listed has an interval meter that can provide detailed demand information. Currently, Eversource is developing the ability to provide this information via its Customer Engagement Platform. Through the C-Power program, the above schools are audited twice per year to develop a measurement of the facilities ability to curtail load if requested. This capacity to curtail generates modes income for the City and Board of Education.

Additional revenue potential exists if ISO New England, the regional electrical system operator, requests an emergency curtailment through C-Power.

The above demand management is reactive in nature, meaning it only responds to requests for curtailment. In the future, as real-time metering becomes more available, the City will responds to measured demand proactively to try to maintain demand below predescribed levels.

CLEAN ENERGY GOALS

Master Plan Study for Schools

Master Plan Study for Municipal Buildings

100% Renewable Energy Program

MIDDLETOWN SCHOOLS' ENERGY AUDITING

As of August 2019, the City of Middletown has completed energy auditing of over 800,000 square feet comprising all of our schools. The energy auditing identified energy efficiency projects as well as deferred maintenance needs. The information will be compiled, screened, prioritized and bundled into projects based on urgency, cost, savings and other benefits under the 2019 Energy Efficiency program. The projects will be implemented in a phased manner.

A similar effort is beginning in late 2019 for all municipal buildings.

While this above described process will identify real energy savings potential, the comprehensive approach should result in reductions across the board of about 20%.

Additionally, in 2019, 150 computers were replaced, reducing demand by about 60 kW, and reducing usage by about 150,000 kWh.

MASTER PLAN STUDY FOR SCHOOLS

In order to evaluate the value and appropriateness of solar on schools, a master plan study is contemplated to evaluate the myriad intersectional considerations when applying solar. First and foremost, it is useful to consider that solar energy fits well with the diurnal operation of schools. This fundamental fit matches the energy production of the solar, increasing during the morning, peaking during the afternoon, and decreasing in the late afternoon – with the building's needs. During the cooling season, these needs tend to mirror the production closely. Heating needs, while less exaggerated, are greatest in the morning, relatively flat during occupied periods, and diminishing post-occupancy – yielding, still, a rather good fit between production and use.

The other considerations that need to be evaluated during the master study include:

- Condition of the roof
- Availability of ground-mount area in addition to roof mount
- Optimal sizing of the solar given the building needs
- Grid interconnection concerns
- Shading, solar production
- Cost versus benefits
- Long-term plan for the facility

Some schools will score better than others with regard to solar. The Master Plan offers the opportunity to strategic evaluate these factors.

MASTER PLAN STUDY FOR MUNICIPAL BUILDINGS

Similar to the school master plan solar study, a study is contemplated for the municipal buildings as well. All of the same criteria apply. Moreover, the combination of the School and Municipal master plan studies offers insight into the aggregate value of solar production that is potentially available to the City of Middletown in the context of the 100% Renewable Energy Program.

Renewable energy was generated by a 200 kW fuel cell in 2011, contributing 1,664 MWh, 9% of total electrical energy use. In 2015, this contribution briefly declined until a new 400 kW fuel cell was brought online in FY2017. FY2015 renewable contribution consisted of energy from a 21 kW photovoltaic (PV) system on the Police Station, and an 88 kW PV system on Moody School. The overall, current renewable energy contribution has increased by 107% over FY2011 levels and represents 19% of total city-wide electrical energy use. The increase is attributable to the systems described above and a recently installed 218 kW PV system installed at the Bacon Water Treatment Plant (Higby).

Renewable Energy System	Capacity (kW)	Annual Production (MWh)
Police Station PV	21	21
Moody School PV	88	113
High School Fuel Cell	400	3,035
Higby PV	218	280
Total	727	3,449

Table 2. Summary of Current Renewable Energy Systems

TRANSPORTATION SECTOR

The transportation sector provides additional opportunity for the City to analyze transportation use and the current means of meeting these needs. From that baseline, alternative, more efficient approaches can be identified. The alternatives would then be subject to cost/benefit analyses that would support a process of screening and prioritizing as discussed in previous sections.

One of the challenges of moving the City fleet and broader transportation sector toward greater efficiency is the need to break down the general consideration that unfettered transportation is a characteristic of an efficient work place. The City's first action with regard to its transportation sector is the willingness and ability to look closely at the miles driven, miles per vehicle, energy per mile and other metrics that can reveal efficiency characteristics of city work process.

Transportation is a large source of greenhouse gases in the United States. According to the EPA the increase in emissions coming from transportation increased move over the last 2 decades than any other greenhouse gas source and now accounts for 27% of total emissions.

Decreasing transportation-generated emissions in a community can have an immediate effect on local air quality in a way that other sustainability activities may not. Encouraging people-powered transportation (bikes, walkways), increasing public transportation access, and supporting non-fossil fuel transportation options (electric cars) are all ways to move toward this goal.

TRANSPORTATION SECTOR

Improved

According to the National Association of Realtors (NAR), walkable/bikeable communities are prefered by homeowners (2017)

Preferred

Improve local air quality and noise levels

Available and Easy

Communities with available and easy to use public transportation access show resilience in property values even in times of volatility (NAR, 2013)

MICROGRIDS

All of us in Middletown rely on the electric grid to provide electricity to our homes, businesses and town facilities. Our current grid performs exceptionally well, but was built and designed before the advent of solar panels, allowing individual houses and businesses to generate their own electricity, and batteries, allowing them to store it. Moreover, it is vulnerable to blackouts during major storms and attacks. While the Middletown history of electric utility availability has been excellent over the recent past, the consideration of microgrid benefits is essential to strategically ensuring a resilient system as disruptive tendencies increase with time.

These tendencies, of course, include the condition of the grid itself, and the threat of. If we want to continue to encourage more renewable energy and greater resilience, we need to re-think the grid. A key building block of the future grid will be microgrids, consisting of smaller subsets of power sources, users, wires and controls. Microgrids are capable of operating while connected to the wider grid, or they can "island" or operate separately in the event of a grid outage. An example of a microgrid could be a collection of key town facilities, a solar array, battery storage and a backup generator. In the future, the grid might consist of a series of interconnected microgrids.

BENEFITS OF MICROGRIDS

- **Enables more renewable energy** through integration of storage and smart controls. Electricity can flow in multiple directions.
- **Greater reliability,** allowing the microgrid or key facilities (e.g., emergency shelter) to operate even when the broader grid is down.
- As prices of solar and batteries decline, microgrids offer **cost savings.**
- **Gives local residents greater flexibility and control** of their energy usage and generation.

PROGRESS TO DATE

- On two occasions, Middletown explored the feasibility of creating microgrids:
  - One downtown
  - One built around the High School
- On both occasions, for different reasons, the projects did not proceed
  - Importantly, we learned about the barrier to participation in the state microgrid program in which significant engineering investment is required to submit an application
  - This information is useful for planning any future applications
  - We have potential future projects in store as we learn more about the cost/benefit relationship for microgrids

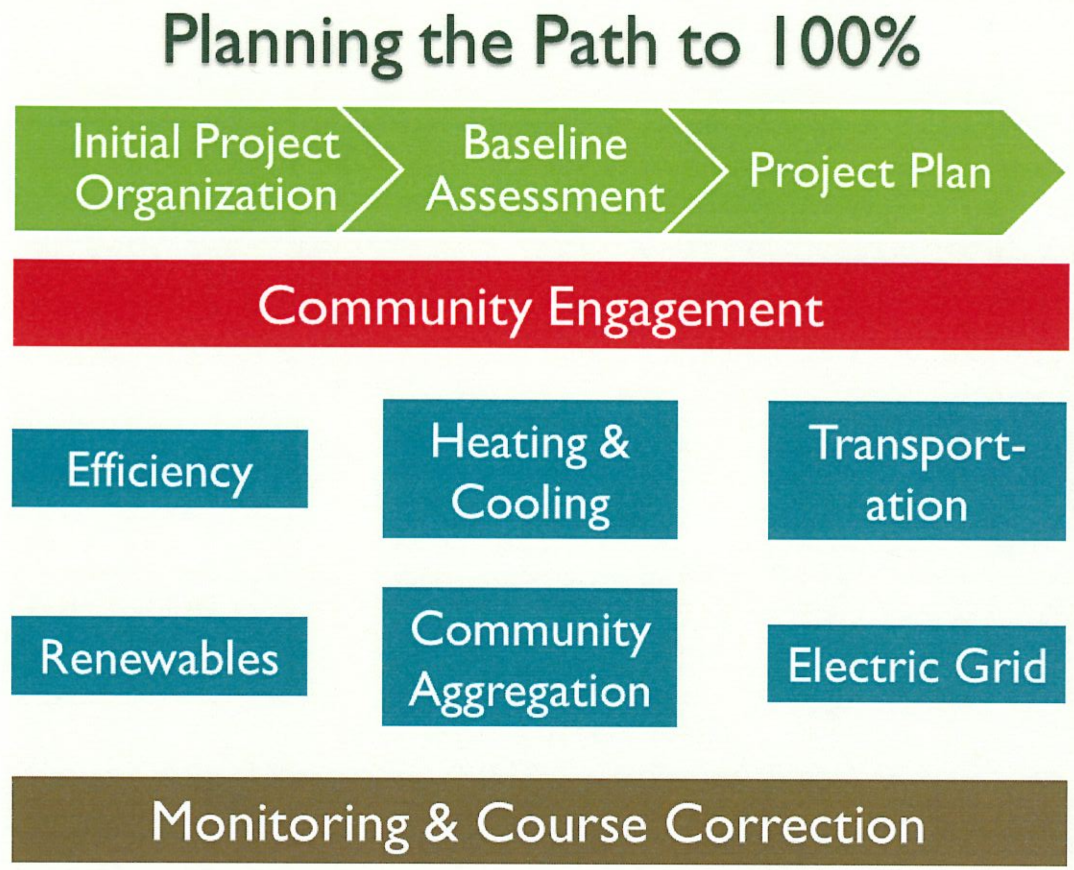
SECTION III:
RESIDENTIAL AND BUSINESS SECTOR APPROACH

Measure and track residential and business sector energy use on an ongoing basis

Evaluate current residential and business sector energy use and renewable energy generation potential

Set target for energy use reduction in the residential and business sectors

SECTION III : RESIDENTIAL AND BUSINESS SECTOR APPROACH



BENCHMARKING

The Middletown Energy Plan addresses the residential and business sectors through the vision of 100% Renewable Energy. The process for moving toward 100% Renewable involves initially estimating the total energy use by all sectors within the city boundaries. This information is largely available on the Eversource/Connecticut Clean Communities website. Below is a screen shot of the current total energy use for the City of Middletown.

This activity is known as benchmarking. It is a process of developing an understanding of energy use for two purposes:

1. To understand total current energy use for estimating and tracking reductions in usage.
2. To develop capacity estimates for serving the expected energy needs of the community.

OUTREACH TO LOW AND MODERATE INCOME RESIDENTS

CHEER Middletown

The CHEER Middletown program (Comfortable, Healthy, Energy Efficient, and Renewable) works with existing state programs, like Home Energy Solutions Income=Eligible energy audits and matches state and utility funding with internal CHEER funds to address health and safety issues alongside energy efficiency and renewable energy for low- and moderate-income Middletown homeowners and renters.

Renewable Energy

The City's Clean Energy Task Force and Energy Coordinator's Office are continually looking for opportunities to make renewable energy accessible to all. In 2019, the City led a Solar for All campaign with no money down and no credit check required solar leases to homeowners. The City continues to investigate options for making renewable energy available to renters, including the future possibility of shared solar.

BENCHMARKING

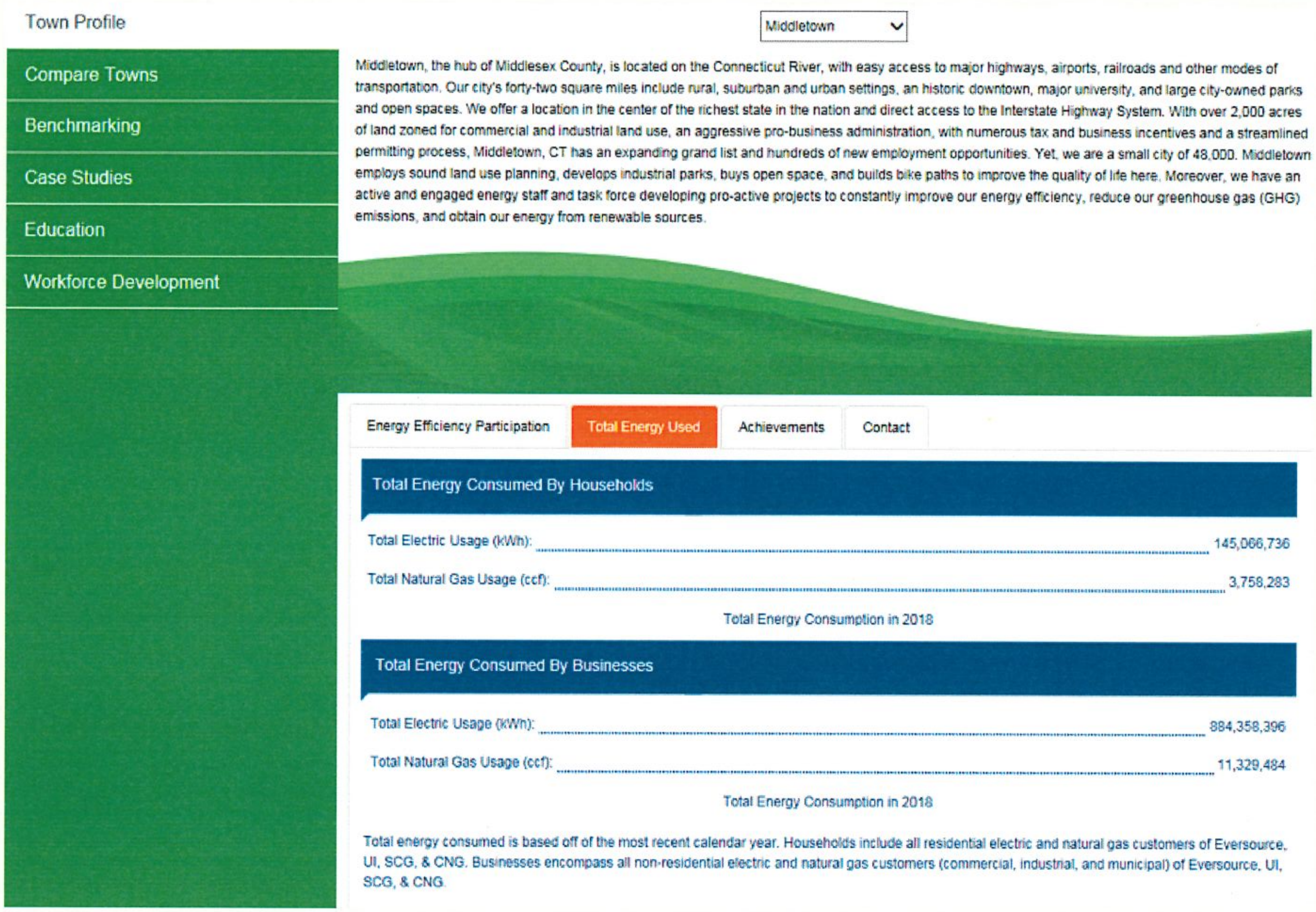


Figure 3.
Clean Communities Screen Shot

TABLE 3. ENERGY VALUES FOR MIDDLETOWN

2018 Residential and Commercial Aggregate Energy Usage by Town

Households include all residential electric and natural gas customers of Eversource, UI, SCG, & CNG. Businesses includes all non-residential electric and natural gas customers (commercial, industrial, and municipal) of Eversource, UI, SCG, & CNG.

Town Name	Residential Electric Usage (kWh)	Residential Natural Gas Usage (ccf)	Commercial Electric Usage (kWh)	Commercial Natural Gas Usage (ccf)
Middletown	145,066,736	3,758,283	884,358,396	11,329,484

As can be seen above, the Middletown commercial electrical usage is extremely high. While we have submitted inquiries to better understand this value, note that this is the largest value of any Connecticut town. The table below is available through the Clean Communities web-site and has been sorted to show the towns with the highest values of commercial electric usage.

TABLE 4: CT TOWNS WITH HIGHEST ELECTRICITY CONSUMPTION

Town Name	Residential Electric Usage (kWh)	Residential Natural Gas Usage (ccf)	Commercial Electric Usage (kWh)	Commercial Natural Gas Usage (ccf)
Middletown	145,066,736	3,758,283	884,358,396	11,329,484
Stamford	473,598,076	21,091,000	789,603,445	24,000,075
New Haven	307,410,861	33,895,699	731,293,767	30,965,794
Hartford	221,095,036	36,335,319	684,929,927	60,957,008
Bridgeport	331,826,021	38,156,266	419,756,709	34,384,329
Milford	176,970,426	12,929,181	412,756,166	8,348,635
Danbury	280,351,173	8,752,741	377,409,551	19,182,421
Waterbury	345,494,588	17,084,158	375,792,231	22,506,056

In correspondence with Eversource, we have identified a usage of 225 million kWh, Middletown's usage for calendar year 2017, as a more representative value for the town. We are in the process of trying to unravel the abnormally high value currently being reported by Eversource.

HEAT AND TRANSPORTATION ENERGY

The process of evaluating the total energy use of the city includes estimating fuel oil and propane use for heating and process, and estimating transportation energy. The process we have used to date involves information from the Tax Assessors office from which we are able to extrapolate the additional energy use. The table on the next page is a summary of the current calculations for total energy use.

TABLE 5: ENERGY, ENERGY EQUIVALENT AND GHG TOTALS

2017 Energy Consumption
Middletown

		Unit	Commercial	Residential	Total
Current Energy Used	Natural Gas	CCF	14,894,388	4,715,174	19,609,562
	Transport	Gallons	4,713,348	15,627,696	20,341,043
	Oil Heat	Gallons	454,569	5,378,868	5,833,437
	Electricity	KWh	196,807,199	142,578,842	339,386,041
Current Energy in Giga Watt Hours	Natural Gas	GWh	432	137	569
	Transport	GWh	159	527	685
	Oil Heat	GWh	19	219	237
	Electricity	GWh	197	143	339
	Total	GWh	806	1,025	1,831
Current Greenhouse Gas Emissions	Natural Gas	GHG - tons	87,207	27,607	114,814
	Transport	GHG - tons	44,541	147,682	192,223
	Oil Heat	GHG - tons	5,091	60,243	65,334
	Electricity	GHG - tons	57,487	41,647	99,135
	Total	GHG - tons	194,326	277,180	471,506

RESIDENTIAL AND BUSINESS SECTOR ENERGY USE TARGET REDUCTION

Over the next several years, the City of Middletown will further analyze non-municipal energy use as we develop our path to 100% renewable energy. To make this 100% renewable goal more accessible, we seek a minimum of 10% reduction in energy use in residential and commercial sectors. This goal will be revisited and revised as further action is taken.

TRANSPORTATION

Transportation is a large source of greenhouse gases in the United States. According to the EPA the increase in emissions coming from transportation increased move over the last 2 decades than any other greenhouse gas source and nowaccounts for 27% of total emissions.

Decreasing transportation-generated emissions in a community can have an immediate effect on local air quality in a way that other sustainability activities may not. Encouraging people-powered transportation (bikes, walkways), increasing public transportation access, and supporting non-fossil fuel transportation options (electric cars) are all ways to move toward this goal

BENEFITS

- **Improve** local air quality and noise levels
- According to the National Association of Realtors (NAR), walkable/bikeable communities are **preferred** by homeowners (2017)
- Communities with available and easy to use public transportation access show **resilience** in property values even in times of volatility (NAR, 2013)

PREPARING FOR 100% RENEWABLES: AFTER THE BENCHMARKING

The following are suggested steps as a process for moving the City toward 100% renewable energy:

STEP 1: ASSESS EFFICIENCY PROSPECTS

Develop plan and adjust benchmarking

STEP 2: ASSESS ELECTRIFICATION PROSPECTS

Identify sites in the community & prioritize (e.g. based on use factors, distribution, grid and user proximity)

STEP 3: IDENTIFY GENERATING SITES NEAR THE COMMUNITY & POTENTIAL FOR COLLABORATIVE PROJECTS WITH SURROUNDING COMMUNITIES

Engage with utility: reality-check local and regional generating capacity

PREPARING FOR 100% RENEWABLES: AFTER THE BENCHMARKING

STEP 4: ITERATIVE REVIEW:

Steps 1 – 3, evaluate, repeat

- **Quantitative contribution of each item to 100%** - How close are we? What are limiting factors and strategies for dealing with these factors?
- **Qualitative assessment** – Which of these have greatest socio-political support? Who are needed partners and how do we invite them on board?
- **Fit with the community's culture, values, awareness** – esp. efficiency and electrification
    - How to go at these for success?
    - How much/how fast?
    - Where to begin to build success and support?

PREPARING FOR 100% RENEWABLES: AFTER THE BENCHMARKING

STEP 5: SCREEN, SORT, PRIORITIZE POTENTIAL PROJECTS

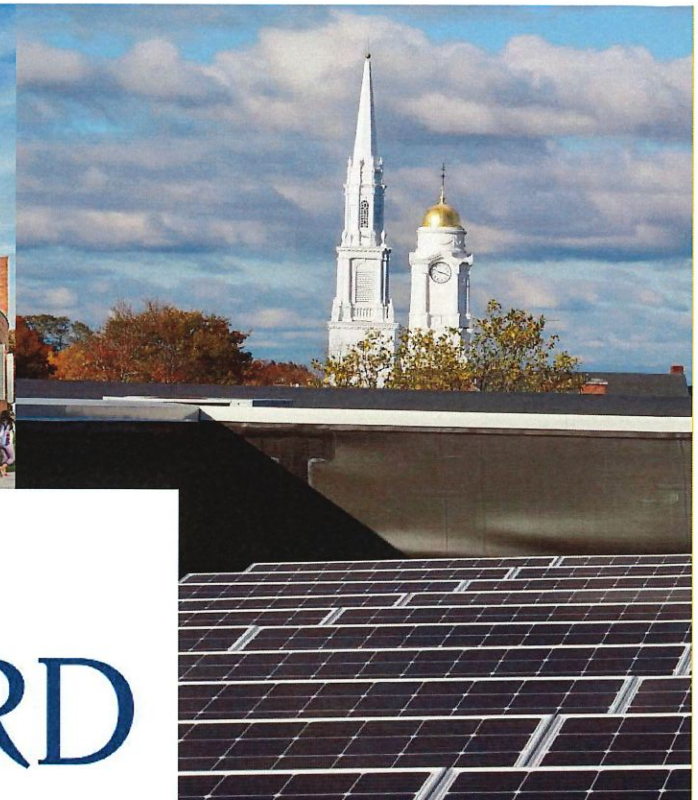
- **Time:** short – medium – long term
- **Investment levels:** easy – moderate – challenging to execute (consider people-power, time investment, levels of uncertainty)
- **Cost:** low – moderate – high
- **Cost-effectiveness:** high – moderate – low (financial, political, social capital, leverage, etc.)
- **Ease of funding/financing:** easy – moderate – difficult
- **Risk:** low – moderate – high
- **Impact on 100% shift:** low – moderate – high impact
- Other criteria that matter to the community

APPENDICES

Appendix 1. 2018 Energy Coordinator Letter to Clean Energy Task Force

Appendix 2. Energy Action Plan

Appendix 3. 2010 Middletown Energy Plan



WEST HARTFORD

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Energy Plan

West Hartford Clean Energy Commission | 2020

DRAFT – June 16, 2020


We aspire for our entire community
to use 100% clean, renewable energy
by 2050.
DRAFT – June 16, 2020

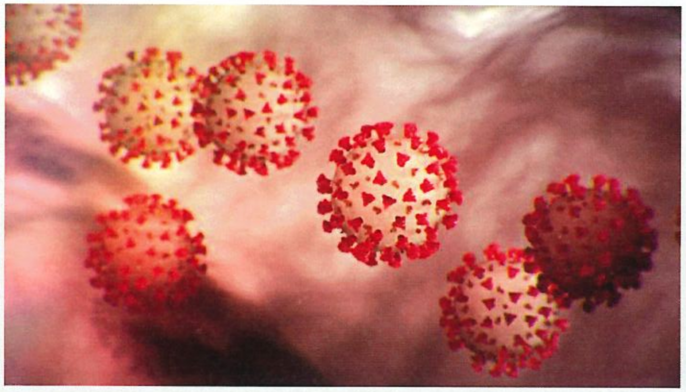
a Note on COVID-19 and Racism

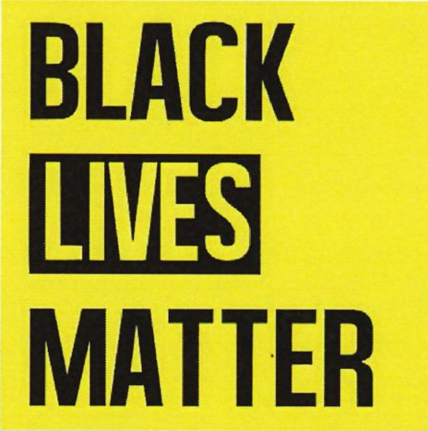
This Energy Plan was largely written before the COVID-19 outbreak and George Floyd's murder. However, we felt it necessary to acknowledge that these events have changed the way we look at the world, even in the context of this plan.

We must forward on energy in a meaningful, inclusive way. This includes seeking out multiple perspectives, acknowledging and calling out both individual and systemic inequity and injustice, and committing to work actively to dismantle barriers and transform our institutions, polices, practices, and actions so that they work for everyone.

Disruption affords us an opportunity: to recover and rebuild, not "back to normal" but "back to better," to choose a different path , a different energy path – a cleaner, greener, sustainable, and just path.

Include something to this effect?





DRAFT – June 16, 2020

Introduction

Energy is essential. It is the lifeblood of West Hartford. It heats and cools our buildings, runs our lights and appliances, and allows us to travel to work and play. Yet, most of our energy still comes from the burning of fossil fuels, which is the biggest contributor to green house gas emissions and climate change.

Our use of energy comes with an intrinsic responsibility to consume and produce it sustainably. Recognizing and acting on this responsibility today is necessary to ensure that West Hartford continues to thrive and prosper. It protects our future and our children's future. It also offers opportunities to shape what that future looks like.

As a local community, we have the power to affect change. The West Hartford Clean Energy Commission has prepared this 2020 Energy Plan to build on the work of its 2009 Energy Plan and to guide the town toward greater energy efficiency and sustainability.

Implementing this plan will yield many benefits to our residents and businesses:

- **Economic and financial**: By saving energy, we will save money: money that can be spent other basic needs, or maybe right here in town to support our local ecomony. It may also create new jobs.
- **Environmental, health, comfort**: By saving energy and reducing fossil fuel use, we will lower emissions, improve air quality, and improve health, especially for vunerable popultations like children and seniors. By making our homes and businesses more energy efficient, they will also be more comfortable.
- **Equity and inlcusion:** By focusing on inclusive solutions to save energy and provide assistance, we will make a difference in the lives of all our residents, including marginalized or at-risk communties and those who currently bear the largest energy burdens.
- **Security and resiliency**: By reducing overall energy needs, modernizing our grid and increasing local generation, we will make our energy supply more secure and be in a better position to weather storms, outages and other natural or man-made disasters..

Mayor Cantor and Council Members Sweeney and Kerrigan activate Town Hall's solar array, October 2019.

The State of Connecticut is committed to reducing its greenhouse gas emissions 45% from 2001 levels by 2030. Governor Lamont's Executive Order No. 3 commits Connecticut to 100% carbon neutral electricity by 2040. This Energy Plan aims to achieve similar goals for West Hartford: **We aspire for our entire community to use 100% clean, renewable energy by 2050.**

While it will be difficult to achieve this vision, it is both achievable – even with today's technology – and realistic – as other cities and states have set similar goals and timelines. There is general consensus that "business as usual" is not an option. Recently, more voices – for youth and climate justice – have joined in demanding action.

By fostering a culture of conservation throughout our community and by making the right choices, West Hartford can address energy and climate change challenges in a meaningful way. Over the last decade, the town has lead by example. With the adoption of this plan, we will move our community forward into a efficient, clean, inclusive, and sustainable future.

West Hartford Clean Energy Commission, June 2020

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West Hartford's Energy by Numbers

With about 64,000 residents, West Hartford is the 9th largest town in Connecticut; we also rank 9th in energy use.

The West Hartford Clean Energy Commission compiled data from local utilities and the town's grand list to estimate total community energy use. This use includes: Residential (homes and apartments), Commercial (businesses, including industry and municipal operations), and Transportation (vehicles registered in West Hartford, including municipal and school buses). Details on these estimates can found in Appendix 1.

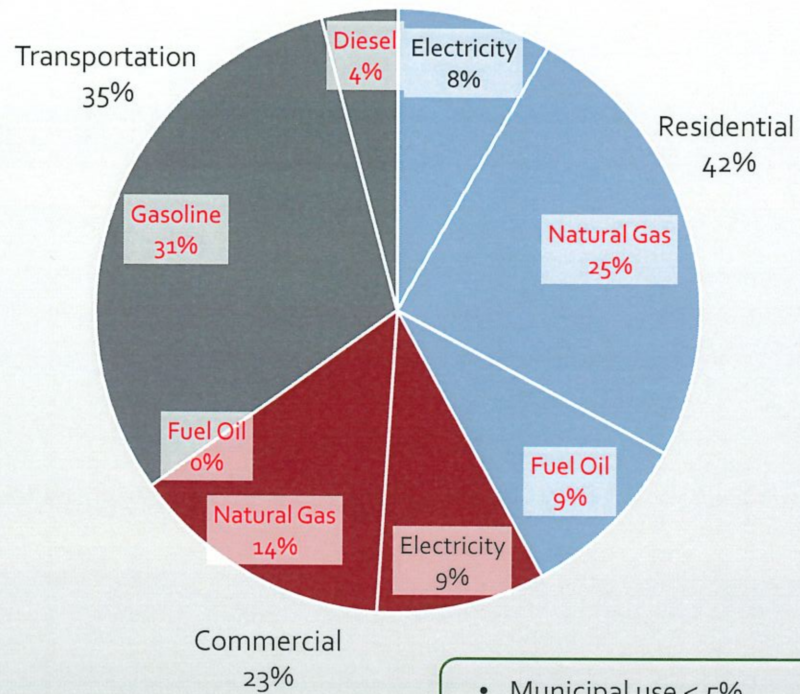
We estimate that in 2019, West Hartford: I still think MMBTU

- Spent $168.5 million on energy, or $2,663 per person.
- Consumed the energy equivalent of 2,181 Gigawatt-hours, or 34,000 Kilowatt hours per person.
- Generated 556,727 tons of greenhouse gases (GHG), or 9 tons per person.

As shown in the pie-chart, two-thirds of West Hartford's energy use is Residential and Commercial, primarily building use, while one-third is Transportation. **Municipal operations account for less than 5% of the total.**

Direct fossil fuel use (red on the pie chart), which is the largest contributor to green house gas emissions and climate change, **accounts for over 80% of West Hartford's total energy use.** Residential and Commercial buildings rely on natural gas and fuel oil for heating. While our Transportation is almost exclusively comprised of vehicles that run on gasoline or diesel. Electricity represents 17% of total energy use.

2019 Total Energy Use = 2,181 GWh



- Municipal use < 5%
- Direct fossil fuel use > 80%

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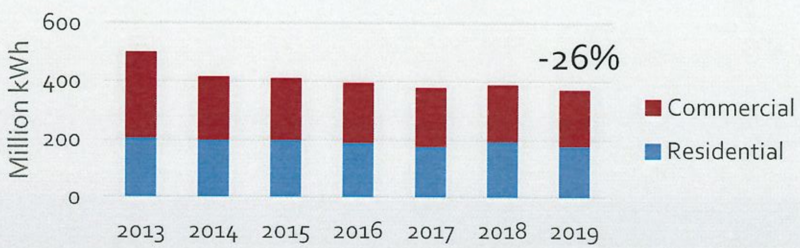
West Hartford's Energy Trends

I feel this section needs to directly address progress on the 2 BIG metrics: 1. Reducing, Produce

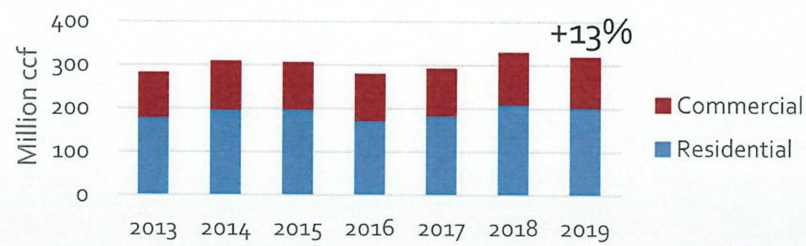
West Hartford has not experienced any major growth or decline recently as a town that would significantly impact energy use. **West Hartford's total energy use is up/down XX% from 2017,** the first time the Clean Energy Commission compiled these numbers

Year	Total Energy Use (GWh	% Change
2013		
2017	2,181 GWh	
2019	2,080 GWh	-4%

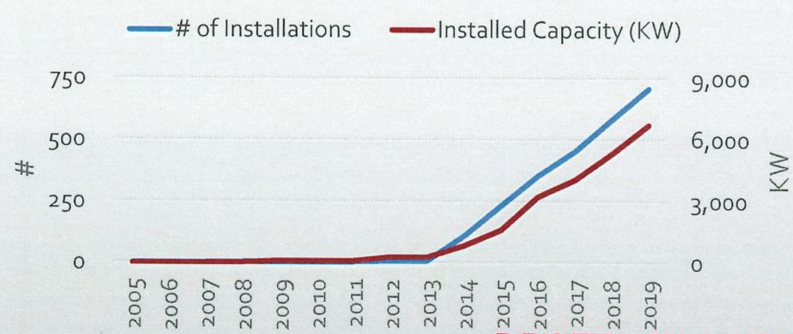
As reported by local utilities, West Hartford's electricity use has declined 26% since 2103 to 369 Million kWh in 2019. Energy efficiency and solar energy, generated and consumed on site, or behind the meter, are likely reasons for this drop. The Commercial sector has seen a bigger drop than Residential.



On the other hand, gas use, has increased 13% since 2013 to 31.7 Million ccf in 2019. Conversions to natural gas are likely one of the drivers behind this increase. Town assessor data indicates an increase of XXX homes heated by natural gas from 2017 (XXXX) to 2019 (xxx). Weather can also impact the annual use of natural gas for heating.



Another notable trend is the rise of solar photovoltaic (PV) installations in the last decade. There are about 700 solar installations in town with total capacity of about 6.7 MW (or 8 Million kWh annually). About 650 West Hartford homes have gone solar. Twelve municipal buildings, including 7 schools, also have solar. Since 2014, West Hartford has been adding just over 100 installations (or 1 MW of capacity) a year. Make just residential



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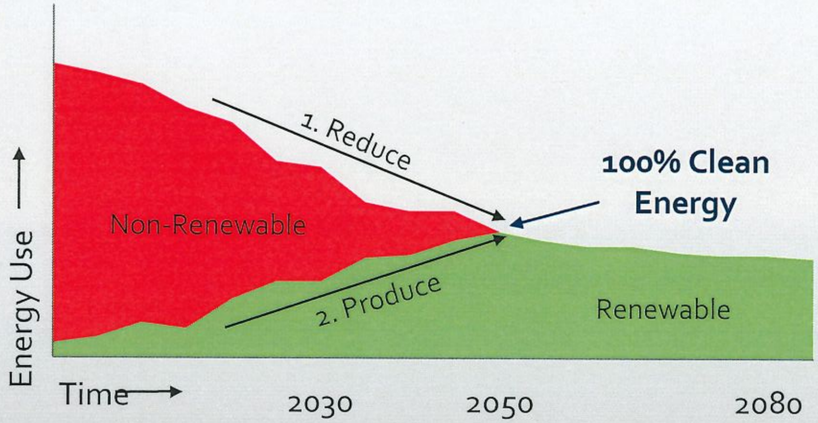
100% Clean Energy by 2050

West Hartford aspires to use 100% clean energy by 2050. The path to 100% clean energy comprises two complementary actions as illustrated in the chart below:

1. Reduce: We must reduce our overall energy consumption dramatically.
2. Produce: We must increase the amount of that energy that is produce by clean, renewable sources.

The goal is to reach a point – 100% Clean Energy – where our new efficient level of consumption is supplied entirely by clean, renewable sources.

Minimizing energy use must be a priority. We estimate that **in order to reach 100% clean energy, West Hartford will need to reduce energy consumption by about 50-60% in roughly 30 years.** This may seem like an impossible task, but, mathematically it represents only a 2.5-3% drop in total energy use per year. Over a five year period, it is a drop of 14%.



Some reductions will be achieved through behavior change or adoption of simple energy efficiency measures like home weatherization or installing LED lights. But, significant reductions will depend on the adoption of new, more transformative technologies to move us away from direct fossil fuel use for building heating and cooling and transportation. For example, electric vehicles have significantly better fuel economy than conventional vehicles and zero tailpipe emissions. Electric heat pumps can deliver efficiency levels of 300% (3 units of heat or every 1 unit of energy) compared to 98% for a condensing natural gas or oil furnace. As we move away from direct fossil fuel use and strategically electrify certain end-uses, we expect the amount of **electricity** we use to increase. It will require policy and planning to ensure reliable infrastructure and capacity is available to support these changes (e.g., EV chargers, a modernized electric grid).

Likewise, our transition to clean energy will not happen overnight. It will involve a range of simpler, short-term solutions, such as the replacement of fossil fuels with greener alternatives, like bio-fuels or fuel-cells, and long-term solutions like the development of storage and a modern "smart" electric grid, powered by distributed local and regional renewable generation like solar, off-shore wind, or other emerging technologies.

The path to 100% clean energy by 2050 will be an evolving journey, but one we must make. Some key elements of this Energy Plan are:

1. Reduce energy use by improving the efficiency of our buildings – public and private.
2. Transition heating and cooling in buildings to more efficient technologies that will enable the use of clean energy
3. Promote alternative mobility (e.g., bike, walk, public transport) and the transition to electric vehicles, including planning for sufficient charging infrastructure.
4. Promote the responsible development of renewable energy in town, including residential rooftop solar, community shared solar, commercial solar and solar carports Geo thermal, solar thermal?
5. Explore and advocate for other clean, renewable energy options both locally and regionally, such as solar, bio-fuels, wind, and a cleaner grid, including collaboration with utilities to modernize our electric grid to enable higher levels of renewables.
6. Ensure that our solutions are inclusive and equitable, serving and protecting the interests of all our residents.

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Approach

Energy efficiency is sometimes referred to as the "first fuel" because it offers the possibility of reducing energy consumption before turning to the more complex, often more expensive question of energy generation.

To drive down energy use in the **Residential, Commercial,** and **Transportation** sectors, our approach centers on three strategies that are within our power to accomplish:

1. Provide **education** and **outreach** to engage and encourage the community to make responsible energy choices
2. Facilitate and support **participation** in energy programs and services and the **adoption** of new technology and capital improvements
3. Develop and support **policy** and **planning** to ensure an sustainable clean energy future and the infrastructure to support it.

These same three strategies will help facilitate the transition to **Clean Energy**.

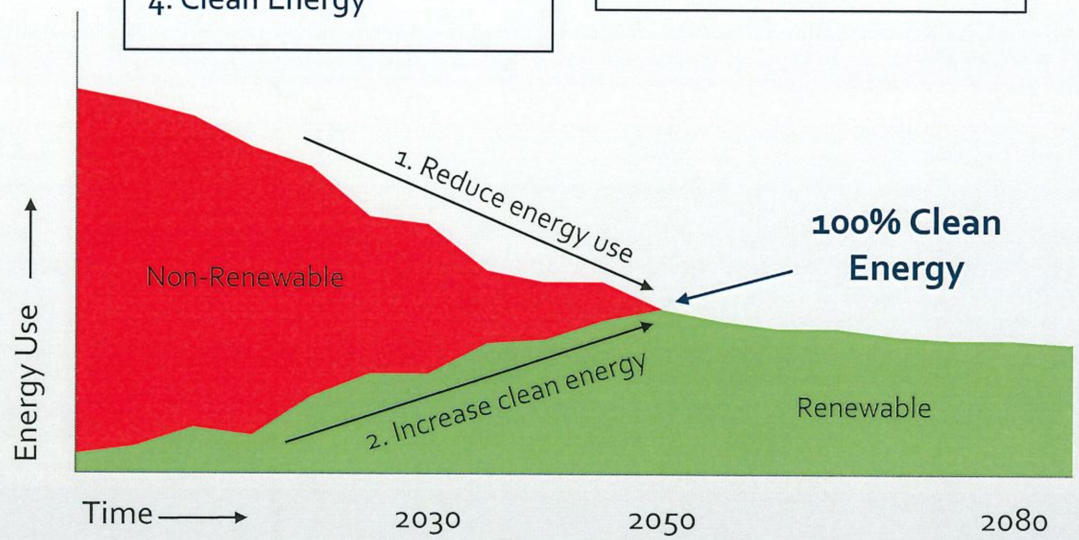
We have also selected a handful of indicators for each sector While not comprehensive by any means, these metrics are readily available and we believe will provide insight into our progress towards 100% clean energy by 2050.

4 Sectors

1. Residential
2. Commercial
3. Transportation
4. Clean Energy

3 Strategies

1. Education & Outreach
2. Participation & Adoption
3. Policy & Planning



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Residential

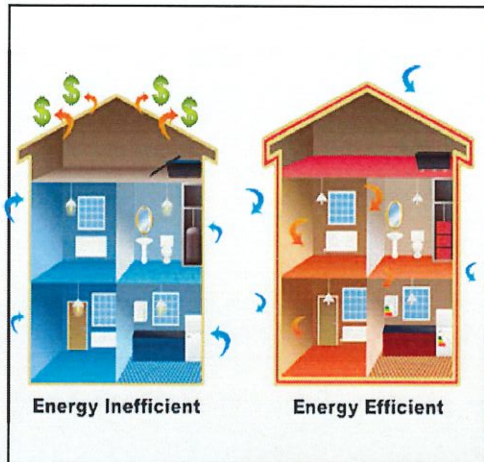
About 1/3 of our community's energy use is Residential. Some members of our community have trouble paying their monthly utility bills. In 2019, the town's Social Services department processed XXX applications for Energy Assistance.

Many West Hartford homes were built in the 1950-60s and have ample opportunities to improve efficiency. Efficiency can have an immediate impact by reducing energy bills and delivering savings year after year to increase household disposable income or pay off an investment. Many improvements have additional benefits of making a home more comfortable or increasing property value.

A wide range of programs and incentives exist for residents – both home-owners and renters – to make their homes more efficient or purchase energy-efficient equipment and appliances. Additional assistance is available for residents who meet certain income eligibility criteria.

Typically 50% of a household's annual energy use is for heating and cooling. In West Hartford, most homes heat with fossil fuel – natural gas (66%) or fuel oil (31%). A typical residential furnace is about 80-85% efficient; new high-performance one can reach 95-98% efficient. However, an electric air-source heat pump can deliver efficiencies of over 300% – by recovering hot/cold air – allowing homeowners to lower their energy costs, and at the same time, reduce direct fossil fuel use and greenhouse gas (GHG) emissions. Long used for cooling in warm climates, heat pumps are now able to provide efficient heating in cold climates, even at outdoor temperatures as low as -15 °F. Heat pumps are capable of both heating and cooling, using the same technology as a refrigerators or air conditioners. Heat pumps can be used alongside existing heating systems to address specific needs and lower cost. They can also be a convenient way to add air conditioning to older homes.

By educating and incentivizing residents to reduce energy needs through common sense efficiency measures, towns can help mitigate the need to increase generation of electricity and expansion of natural gas lines.



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Residential Progress & Goals

Progress-to-Date
- 20% of households participate in EnergizeCT efficiency programs
- LED lightbulb swaps held at libraries and Elmwood CC
- Occasional community presentations and WH-CPTV programming
- Energy Assistance case officer located on-site at town hall

Approach

1. Education & Outreach. Increase energy efficiency awareness via multi-touch, multi-channel messaging. Use website, social media, email, tax inserts, video, events, networking, etc. Consider using multiple languages. Work with partners like Social Services, Housing Authority of WH, WHPS, houses of worship, EnergizeCT, Efficiency for All, utilities, contractors, etc.

2. Participation & Adoption. Promote Home Energy Solutions and other energy programs. Host giveaways or sign-up events. Educate about options/technology like LEDs, EnergyStar appliances or electric heat pumps. Showcase positive examples and stories. Target specific groups such as low-to-income residents, oil-heated homes, new home owners, etc. Identify identify and address barriers (e.g., landlord permission, language, financing)

3. Policy & Planning. Investigate use of municipal building, tax codes to accelerate efficiency. Work towards zero-energy new construction policy. Support and advocate for applicable legislation, including increased funding and wise use of Connecticut Energy Efficiency Funds.

"We are very happy with our decision to install an electric heat pump. We did not have air conditioning before. Our house is more comfortable now, in both the summer and winter. And, while our electric bill has gone up, our natural gas/oil bill is virtually zero. Max?

Benefits
- Lower energy bills
- More comfortable, healthy living environments
- Reduced need for energy generation
- Greater security
- Greater resiliency during extreme weather
- Lower CO_2 and greenhouse gas emissions
- Local job creation

2022 Goals
- 30% of residents participate in EnergizeCT energy efficiency programs
- 10% of residents receive rebates for performing energy retrofits.
- Drop in # of shut-offs/energy assistance applications
- At least 6% drop in residential energy use, including a shift from oil and natural gas to electricity
- X% homes using heat pumps

Long-Term Goals
- 100% of residents participate in programs
- 50% of residents receive rebates
- 0 utility shut-offs
- 50% drop in residential energy use

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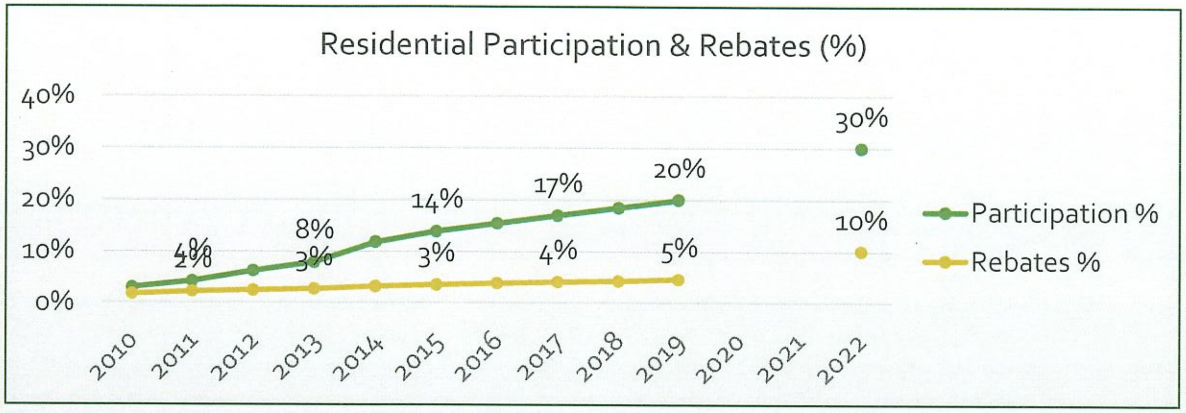
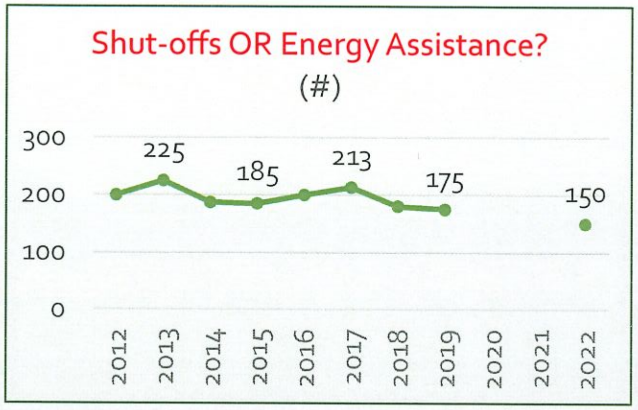
Residential Indicators





1. **Residential Participation** is the % of West Hartford's households that have participated in EnergizeCT energy efficiency programs like Homes Energy Solutions, Home Energy Solutions-Income Eligible and Residential New Construction. Source: EnergizeCT.
2. **Residential Rebates** is the % of West Hartford's households that have received an energy rebate for installing an qualifying project or equipment. This % is lower than Residential Participation, meaning that not all households that participate in an initial home assessment do follow-on energy efficiency projects. Source: EnergizeCT.
3. **Utilty Shut Offs / Energy Assistance** Source: Town of West Hartford, Social Services. Need input #s – made up

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Commercial

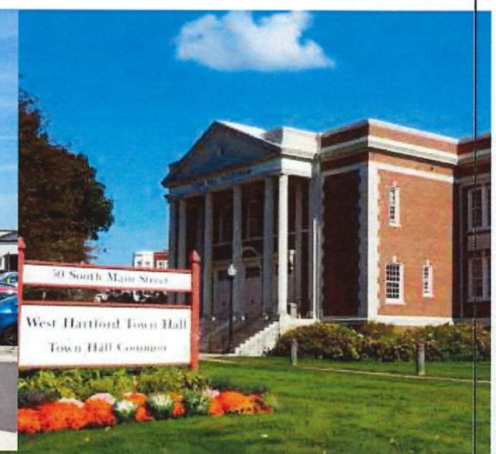
28% of West Hartford's energy use is Commercial This sector includes retail shopping and services, offices, schools, health care, food establishments, lodging , and others. Any industrial or manufacturing is also counted in Commercial.

The Commercial sector differs from Residential. There are fewer – often larger – properties and fewer owners, including corporations, management companies and the town itself. Building energy systems may be centralized and have high, peak demand at certain times of the day. Space heating is typically natural gas, and represents about 25% of building use. Leases or other contractual arrangements can make it complicated to align the energy and capital improvement interests of owners and tenants.

Like Residential, there are a wide range of energy incentive and financing programs available to commercial property owners to make measures such as lighting, building controls and HVAC upgrades more achievable and profitable. Programs are available for existing buildings and new construction, as well as for regular businesses, non-profits, institutional, and municipal customers. Some projects – like LED lighting – can reduce energy use by over 50% - and pay for themselves quickly, yielding a high return on investment. These shorter-payback measures can be "packaged" with more expensive capital items for more comprehensive energy upgrades.

The town has tried to lead by example, using utility programs to implement over $5 Million of energy efficiency projects across the portfolio of municipal properties in the last 4 years. These projects, including LED interior, exterior, and street lights and building control system upgrades have helped reduce municipal electricity use by 25% and total energy use by 16.5% from 2015-2019.

New commercial development and construction is also an area where the town can .... In 2016, Charter Oak International Academy was rebuilt to LEED Gold green building standards with a geo-thermall/ electric heat pump system for heating and colling nd solar. This schools is the district's top energy perforamce with an energy use idex, or energy use per sf in the the low 30's kBtis/sf.



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Commercial Progress & Goals

Progress To Date

- 28% of businesses participate in EnergizeCT efficiency programs
- 2 C-PACE projects
- Over $5 Million of energy efficiency projects implemented in municipal buildings with savings over $1 Million annually.
- 15% reduction in total municipal energy use since 2013
- Direct mail efforts in partnership with vendors and CT Green Bank

Approach

1. Outreach & Engagement. Increase awareness of programs and benefits. Share results. Use word of mouth and B2B network. Work with partners like Chamber of Commerce, Community Development, neighborhood business associations, CT Green Bank, design professionals, contractors, utilities, etc.

2. Participation & Adoption. Promote Small Business Energy Advantage, C-PACE, LEED, Energy Star, and other commercial energy efficiency or certification programs . Encourage the formation of green teams in buildings and tracking of energy use.. Meet with individual property owners and companies. Identify and address barriers (e.g., financing, privacy). Have local businesses and town share their success stories, projects, and experience.

3. Policy & Planning. Investigate use of municipal building, tax codes, procurement, standards and recognition programs to accelerate efficiency. Work towards zero-energy new construction policy. Advocate for increased funding and wise use of Connecticut Energy Efficiency Funds. Support applicable legislation (e.g., High Performance Building Standards).

"Aiken Elementary School's annual electric use (kWh) has dropped X% since installing LEDs. There is also a noticeable drop in demand. (KW). We are savings about $2000 a month. Our classrooms have brighter, more consistent light, and maintenance cost have virtually disappeared. Results are similar in other buildings. It's a win-win. – Catherine Diviney, Energy Specialist, West Hartford.

Benefits

- Lower energy bills
- More comfortable, healthy working, educational environment
- Reduced need for energy generation
- Greater security and resiliency during extreme weather
- Lower CO_2 and greenhouse gas emissions
- Local job creation
- Enhanced public image

2022 Goals

- 40% business participation in EnergizeCT programs
- 25% reduction in municipal energy use
- At least 6% drop in commercial energy use
- 2 new C-PACE projects

Long-Term Goals

- 100% business participation in EnergizeCT programs
- Multiple C-PACE projects
- 50% drop in commercial energy use, including municipal

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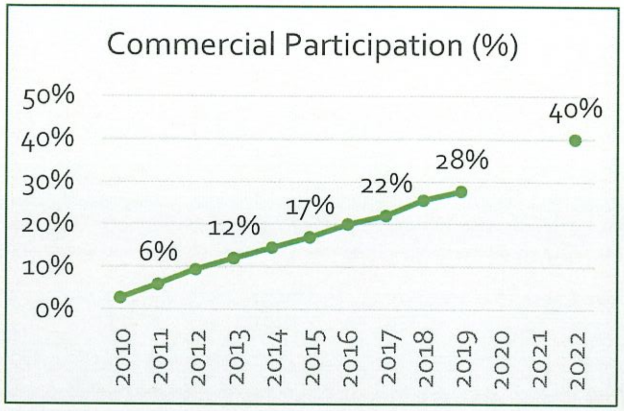
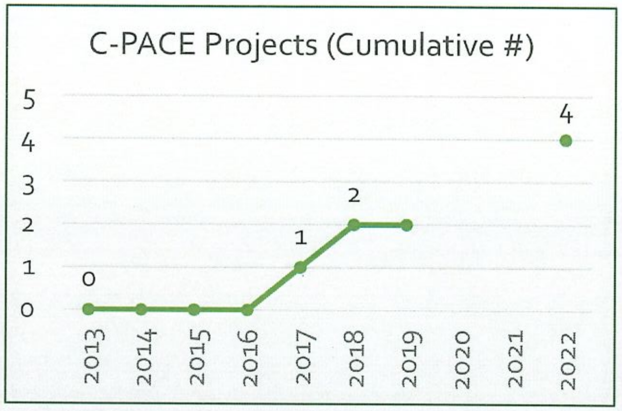
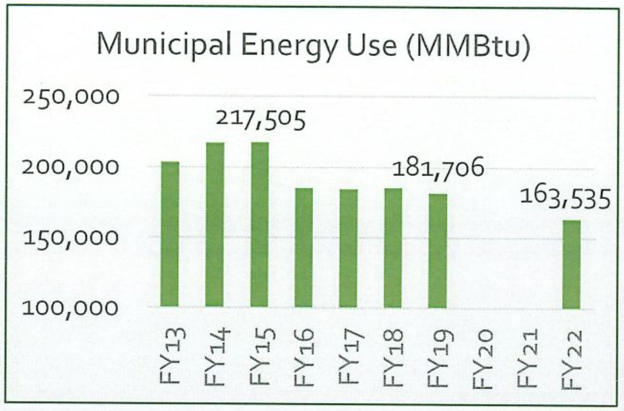
Commercial Indicators







1. **Commercial Participation** is the % of West Hartford's businesses (including municipal) that have participated in any energy efficiency programs. Source: EnergizeCT.

2. **C-PACE Projects** is the cumulative number of C-PACE projects reported by the CT Green Bank. C-PACE (Commercial Property Assessed Clean Energy) is a financing program available to businesses and non-profits to finance energy efficiency and clean energy projects to be repaid through a voluntary benefit assessment placed on their property by the municipality. Source: CT Green Bank

3. **Municipal Energy Use** is the annual energy use of all municipal operations, including town and school buildings, parks & pools, parking lots, and street & traffic lighting. All fuel types (e.g., electricity, natural gas and fuel oil) are converted to a common unit MMBtu. Source: Town of West Hartford, Plant & Facilities Services.

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Transportation

West Hartford's Transportation sector accounts for about 1/3 of our community's energy use. It relies almost entirely on fossil fuels. According to the US EPA, in the last 2 decades, the emissions coming from transportation has grown more than any other greenhouse gas source and is now the largest source of greenhouse gas emissions in the United States.

Decreasing transportation-generated emissions in a community can have an immediate positive effects in ways that other sustainable energy efforts may not.

By designing systems around people, not cars, and encouraging alternative mobility (e.g., walking, biking, public transport), we can improve access, traffic congestion, safety and equity. By supporting non-fossil fuel based transportation (e.g., electric vehicles), we can improve air quality, noise pollution, save money, and transform this sector for the long-term. Policy and planning and infrastructure (e.g., walkways, bike lanes, EV chargers, etc.) are key pieces to support this transformation.

The State of CT's newly released *EV Roadmap* (April 2020) also sites the widespread deployment of electric vehicles in the state as "a key tool in the state's effort to improve air quality for residents while also addressing the climate crisis." Recent satellite data pre and post-COVIDhas shown the massive impact that stay safe stay hmme and the reduction of combustion of fossil fuel / transportation has had on pollution emissions.,.

It is widely believed that by 2022, electric vehicle will cost the same as conventional ones. In addition, studies show that the total cost of ownership, including fuel and maintenance costs is lower.

Currently, the town owns only 2 hybrid cars and no EVs. The town should look to be a leader in cleaning up this sector. The limited range, daily travel patterns of some town vehicles – municipal parking, building inspectors, school buses – ar e ideally suited to EVs. Advocating for electric school buses is a particular issue cornered citizens can get behind to protect the heath and well-being of our children, let alone the planet, from toxic air pollution.

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Transportation Progress & Goals

Progress-to-Date

- Electric Vehicle Day in 2016 and w/ Kingswood Oxford School in 2018
- 8 registered public EV changers; 4 municipal-owned.
- 2% of registered vehicles are EV
- Active Complete Streets program
- Mutli-town RFP for ride-share (scooter) program

Approach

1. Outreach & Engagement. Increase awareness via multi-touch, multi-channel messaging. Use website, social media, email, tax inserts, videos, events, networking, etc. Provide information on benefits (e.g., health, cost of ownership). Consider using multiple languages. Work with partners like Pedestrian Bicycle Commission, Greater Hartford Transport District, WHPS, car dealerships, etc.

2. Participation & Adoption. Promote programs and financial incentives (e.g., CHEAPR, federal tax credits). Leverage grant funds (e.g., VW, DERA) or collective buying opportunities. Host EV demo days and Q&A with owners. Target specific groups like commuters, employers, people looking to replace vehicle, WHPS Board of Ed. Identify and address barriers (e.g., technology, fear, cost of ownership, charging infrastructure)

3. Policy & Planning. Investigate use of work place policies or municipal code to support sustainable mobility options and accelerate adoption of EVs (e.g., bus pass, work-from-home). Support Ped Bike Commission and alternative mobility strategies. Identify infrastructure needs for EVs and non-vehicle transportation (e.g., EV chargers, bike lanes). Incorporate emissions reductions into municipal RFPs and policy (e.g., anti-idling, bio-diesel, electric school buses).

"I was hesitant to buy an electric car because I was scared I would run out of battery and get stranded somewhere. I am so happy, I did! My Bolt is quieter, cleaner, costs less and is more fun to drive. Given the choice, I don't know why anyone would buy a conventional vehicle again." Bernie or Matt,

Benefits

- Lower CO_2 and greenhouse gas emissions
- Improved air quality and health (e.g., asthma)
- Less noise, traffic congestion
- Better fuel economy and financial savings
- Reduced risk of fuel-related environmental spills, leaks
- Increased energy security, reduced dependence on foreign oil
- Walk/bike friendly communities are preferred and can increase property value.

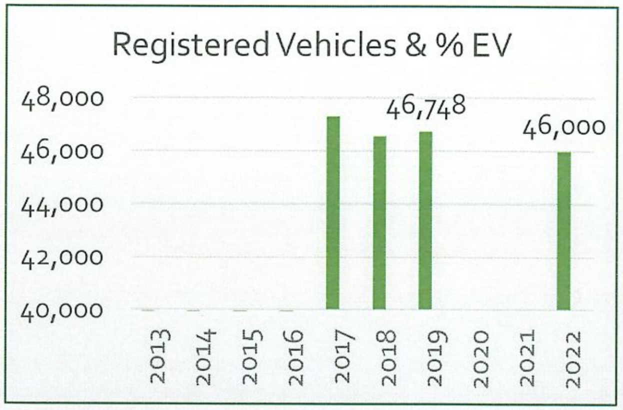
2022 Goals

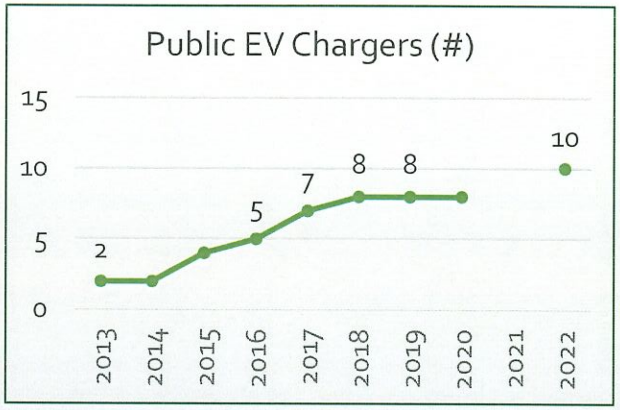
- EV strategy in municipal vehicle fleet plan
- 1 more municipal EV charger
- EV requirements incorporated into school bus RFP (contract expires Aug 2023).
- 10% of registered vehicles are EV; at least 1 municipal EV
- Review/revise municipal policies regarding commuting and work-from-home
- Community ride share program implemented

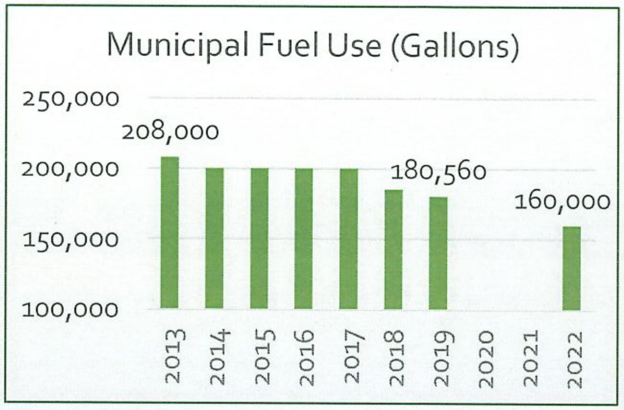
Long-Term Goals

- Fewer vehicles, fewer vehicle miles travelled, less traffic, more people bike/walk
- 100% of vehicles EV or powered by clean renewable energy; including municipal fleet and school busses

Transportation Indicators







1. **Registered Vehicles is the number of vehicles listed on the town's Grand List**, including municipal-owned vehicles. % EV is the portion of those vehicles that are designated with fuel type "electric.".Source: Town of West Hartford, Assessor. (need data)

2. **Public EV Chargers** is the total number of public electric vehicle charging stations that are listed on the US DOE's Alternative Fuel Data Center website, This includes municipal-owned chargers. Details on charger type, fees, and accessibility are available on the website. Source: US DOE, ADFC.

3. **Municipal Fuel Use** is the fuel (gas and diesel) used in municipal fleet, including all municipal and public safety vehicles, that is purchased via gas procurement card. This is the primary method that the town uses to purchase fuel for vehicles. This does not include fuel for school buses, which are under third-party contract. Source: Town of West Hartford, Public Works. (need data), school bus rpt?

1. **# of Registered vehicles**
2. **% of registered vehiles EV**
3. **Gallons of fuel (school buses)**
4. **Municpal gallons - vehicles**

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Clean Energy

People sometimes confuse renewable energy with saving energy. But, renewable or clean energy simply refers to the source of the energy, or how it is generated.

West Hartford has been a US EPA Green Power Partner since 2014. In FY20, 100% of West Hartford's municipal electricity use (about 16 Millions kWh) was renewable. About 650 West Hartford homes have gone solar and 12 municipal or school buildings. In 2016, Charter Oak International Academy was rebuilt to LEED Gold green building standards with geo-thermal and solar. The town also participates in a solar Virtual Net Metering agreement. As the price continues to decline, solar may be an affordable option for many. More households and businesses are looking at solar to stabilize or reduce energy coats and go green. Google's Project Sunroof estimates that West Hartford could support 205 MW of solar, producing 228 Million kWh annually. Other options like shared solar or green power purchases may be available as alternatives to on-site generation.

While the focus is certainly on solar, we cannot forget other technologies and solutions at the local and regional levels: geo-thermal, solar hot water, bio-fuels, and fuel cells, as well as off-shore wind and renewable energy credit (REC) purchases or utility renewable portfolio standards (RPS) to support a cleaner grid.

We also need to re-think the electric grid if we want to encourage more renewables and greater resilience. A key building block of the future will be microgrids, consisting of smaller subsets of distributed power sources and storage, users, wires and controls. Microgrids are capable of operating while connected to the wider grid, or they can "island" to operate separately in the event of an outage. An example of a microgrid could be several key town facilities, a solar array, battery storage and a backup generator. In the future, the grid might consist of a series of interconnected microgrids.

The clean energy industry has evolved and will continue to evolve. Changes in technology, pricing, market conditions, even political and public support will all contribute to where we settle eventually. West Hartford should look for ways to accelerate the use of clean energy in ways that support and enhance local economic, development and equity goals.

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Clean Energy Progress & Goals

Progress To Date

- Solarize West Hartford campaign in 2013; Solar for All campaign in 2018
- 718 West Harford homes have solar
- 12 schools and town buildings have solar
- Renewable Energy Credit (REC) purchase in Fy19 = 20% of municipal electricity use

"*I have had zero problems with my solar panels since they were installed in 2012. I can track how much energy they are producing via a weblink. My electricity bill is now half of what is was. The cost of installing the panels will be paid back in X years. We LOVE that we are able to do something good for the planet." Bernie or Matt,*

Approach

1. **Outreach & Engagement.** Increase awareness via multi-touch, multi-channel messaging. Use website, social media, email, tax inserts, videos, events, networking, etc. Consider using multiple languages. Work with partners like CT Green Bank, Clean Water Action, Posigen, contractors, neighborhood groups.

2. **Participation & Adoption.** Promote residential solar, and C-PACE programs. Educate about financing options and technology. Showcase positive examples and stories, both residents and businesses. Target specific groups such as properties with good exposure, EV-owners, etc. Identify and address barriers (e.g., income perceptions, safety, zoning)

3. **Policy & Planning.** Investigate use of municipal building, tax codes to accelerate adoption of clean energy. Analyze brownfield sites in town and potential for microgrids. Work towards zero-energy new construction policy. Support state renewable policies like off-shore wind and community shared solar and efforts to modernize the local and regional grid.

Benefits

- Improved air quality and public health due to decrease in pollution from burning fossil fuels.
- Lower CO_2 and greenhouse gas emissions
- Savings or stability on energy bills
- Improved energy independence
- Greater resiliency during power outages
- Creates jobs and economic growth
- Positive community image

2022 Goals

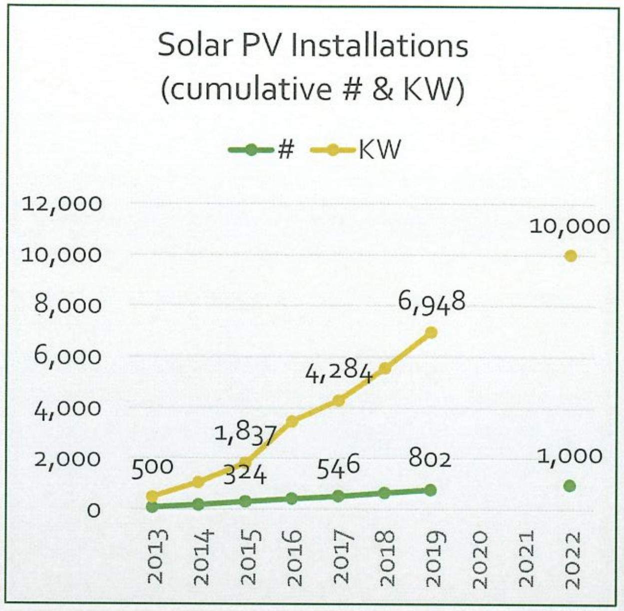
- 1,000 West Harford homes have solar, including low-to-moderate income
- 100% municipal electricity supplied by clean, renewable sources
- Investigate possible microgrid in town
- Asses remaining municipals sites for solar rooftop or carports.

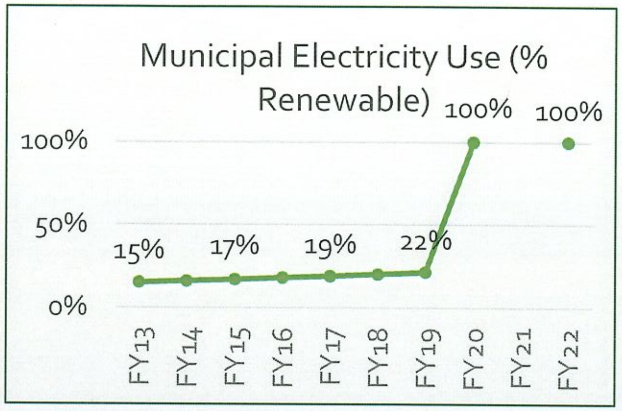
Long-Term Goals

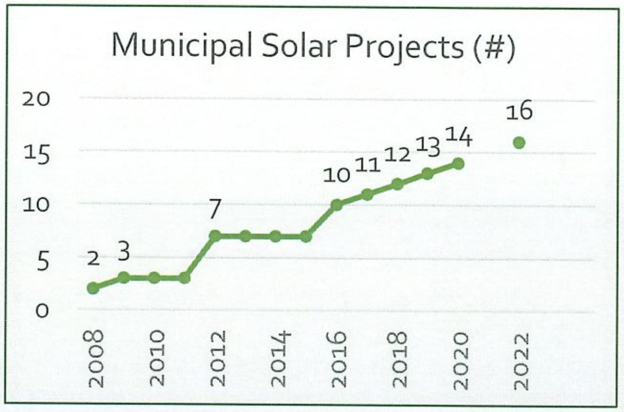
- 100% of West Hartford's energy supplied by clean, renewable sources
- Multiple microgrids in town

, 2020

Clean Energy Indicators







1. **Solar PV Installations** is the cumulative number of solar photovoltaic installations and their production capacity (KW AC or DC?) based on utility interconnection agreements – both residential and commercial – reported since 2014. Source: EnergizeCT. (Data prior to 2014 has been estimated and requested from Eversource.) need to confirm data.

2. **Municipal Electricity Use (% Renewable)** is the % of total municipal electricity use that is supplied by clean, renewable sources. Please note: The town does not own the renewable energy credits (RECs) on many of its solar projects; therefore those projects cannot be claimed in this %. The town makes a separate annual Green-e certified REC purchase, which supports this official claim. Source: Town of West Hartford, Plant & Facilities Services.

3. **Municipal Solar Projects** is the number of total projects on-site (installed on municipal properties and schools) and off-site (virtual net metering). Most of these projects are under Power Purchased Agreements and the town does not own the renewable energy credits. As of 2020, these 15 projects total 4.1 MW and produce about 5 Million kWh annually. A list of projects is included in Appendix 2. Source: Town of West Hartford, Plant & Facilities Services.

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Next Steps – Energy Action Plan

2020-2021

1. Adopt resolution to support 100% clean energy and new Energy Plan
2. Give regular updates to Town Council, Public Works & Facilities subcommittee
3. Develop effective network or means of reaching community on energy issues, re-think connection with Sustainable West Hartford.
4. Invite youth/high school representatives on join Clean Energy Commission.
5. Conduct Heat pump education campaign
6. Work with Social Services, to design and implement an energy outreach campaign focused on equity (e.g., low-to-moderate income (LMI) residents)
7. Conduct outreach for the RF100 campaign – goal of 2021 adoption
8. Explore desire to create broader Sustainability Plan, Climate Action Plan, greenhouse gas inventory, (including Transportation and Waste/Materials Magement) with Town Council, and other appropriateCommissions.
9. Secure request from Town Council for a greenhouse gas inventory or Climate Action Plan?
10. Hold or partner on an electric vehicle event.
11. Support focus on energy efficiency and clean energy industry and jobs as part of economic stimulus and growth
12. Recruit group to implement Electric School Bus Toolkit (WHPS transportation RFP 2022)

Municipal-specific

1. Revamp town's clean energy website.
2. Disseminate quarterly communication on building performance
3. Work with Recycling Coordinator, quarterly meetings with schools
4. Review schedule of upcoming municipal capital improvement projects in conjunction with energy data
5. Analyze interval energy use of town buildings; develop plan to reduce peak demand
6. Update municipal fleet plans to include strategy for electrification and/or emissions reductions (e.g., bio-diesel).
7. Additional municipal solar or virtual net metering projects
8. Achieve Sustainable CT silver certification

Next

1. Join Sierra Club's Ready for 100 campaign.
2. Investigate potential for a microgrid in town
3. Consider implementing Community Choice Aggregation
4. Work with town staff and zoning and planning commissions to promote solar, heat pumps and EV-readiness in new construction.
5. Conduct Energy Star appliance or product campaign.
6. Explore how efficiency and clean energy adoption could be accelerated through municipal policy, building and/or tax codes
7. Pass municipal resolution or adopt policy zero-energy new construction be net zero.
8. Inventory brownfields for alternate use
9. Conduct residential Home Energy Audit (HES) audit campaign.
10. Restart Small Business Energy Advantage (SBEA)
11. Promote C-PACE financing of commercial projects
12. Top-ten sustainable things campaign.
13. Conduct solar campaign, including community discussion of responsible and sustainable solar development in town and options available for all.
14. Promote alternative mobility options to reduce vehicle mile travelled,
15. Collaborate with other commissions to complete a Greenhouse Gas Inventory

Municipal-specific

1. Retrofit a town building – at least in part - with a heat pump and monitor results for future installations. (King Phiilip and COIA are heat pump.)
2. Reinstate WHPS Energy Challenge or explore additional ways to reduce municipal energy use – e.g., treasure hunts, night audits, town vs. town energy competition, project fund
3. Develop a Sustainable Purchasing Policy
4. Expand GIS and anti-addling policies to reduce mile travelled and fuel use in municipal fleet
5. Complete assessment of EV charging infrastructure and needs

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Appendix 1

2017 West Hartford Energy Benchmark

	Unit	Commercial	Residential	Total
Natural Gas	CCF	10,575,622	18,466,160	29,041,782
Transport	Gallons	2,656,947	19,928,564	22,585,511
Oil Heat	Gallons	0	4,955,922	4,955,922
Electricity	KWh	196,807,199	179,238,436	376,045,635
Natural Gas	GWh	307	536	842
Transport	GWh	90	672	761
Oil Heat	GWh	0	202	202
Electricity	GWh	197	179	376
Total	GWh	593	1,588	2,181
Natural Gas	GHG - tons	61,920	108,119	170,040
Transport	GHG - tons	26,038	195,300	221,338
Oil Heat	GHG - tons	-	55,506	55,506
Electricity	GHG - tons	57,487	52,356	109,843
Total	GHG - tons	145,446	411,281	556,727

Notes

Natural gas and electricity data provided by Energize CT. Municipal data is provided by Dept of Plant & Facilties Services. Oil is estimated using data from the West Hartford Grand List and U.S. Census Bureau American Community Survey.

Conversion factors for each fuel type to MWh are:

- 1 CCF Natural Gas = 0.0293 MWh
- 1 Gallon Heating Oil = 0.04059 MWh
- 1 Gallon Propane = 0.02677 MWh
- 1 Gallon Gasoline = 0.03341 MWh

Greenhouse gas emission rates are:

- 1 CCF Natural Gas = 0.005855 tons GHG
- 1 Gallon Heating Oil = 0.01120 tons GHG
- 1 Gallon Propane = 0.006348 tons GHG
- 1 Gallon Gasoline = 0.00980 tons GHG
- 1 MWh Electricity = 0.0000292 tons GHG

Costs per unit of fuel are:

- $1.25 per CCF natural gas
- $2.80 per gallon heating fuel
- $3.00 per gallon propane
- $2.80 per gallon gasoline
- $0.18 per KWh electricity

Prepared by: Bernard Peletier, WH Clean Energy Commission and PACE.

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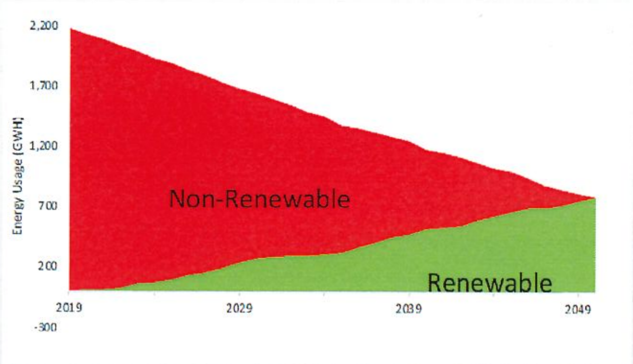
Include Waterfall chart?

The path to 100% renewable energy comprises two complementary actions:

- Overall energy consumption must be decreased dramatically by a combination of energy efficiency and electrification of heating, cooling and transportation.
- Electricity consumed in town must come from clean, renewable sources.

These complementary actions are visible in the declining overall consumption and increasing renewables in the chart below.

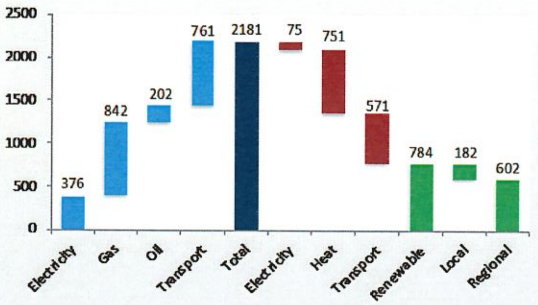


The key elements of this energy plan are:

1. Reduce our energy usage by improving the efficiency of our buildings, both public and private.
2. Transition heating and cooling to high-efficiency heat pumps.
3. Promote the responsible development of renewable energy in town, including residential rooftop solar, community shared solar, commercial solar and solar carports. For remaining energy needs, pursue regional solutions and advocate for a cleaner grid.
4. Promote public transportation and the transition to electric vehicles through various measures, including planning for sufficient charging opportunities.
5. In collaboration with Eversource, modernize the local electric grid to enable higher levels of renewable energy

The chart below is another way of visualizing West Hartford's path to 100% renewable energy. The blue bars on the left side of this graph represent the town's current energy usage, expressed in a common unit: gigawatt-hours. The red bars represent the potential reduction in energy usage through efficiency and electrification, resulting in a vastly reduced energy load. The green bars represent the sources of local and regional renewable energy to meet this need.

Current Load - Future Load - Renewable



Energy Reduction Targets

As seen in these two graphs, West Hartford aims to reduce energy consumption by over half in roughly thirty years. Because these reductions will be accomplished in part through "fuel switching" (e.g., from gasoline to electric vehicles), we do not set reduction targets for each fuel type. In fact, we expect electricity usage to more than double over this period.

West Hartford's 2050 energy target can be achieved through modest annual reductions of 3.4% per year. **Based on our initial analysis, we are selecting a 3.5% annual reduction target for all town sectors: residents, businesses and municipality. Over a five-year period, the targeted reduction is therefore 17.5%.** As our analysis of the town's energy usage develops, we may differentiate this target by sector and year. Together with the Dept. of Public Works, the Clean Energy Task Force will monitor town energy usage using existing online monitoring tools and update this analysis annually.

Appendix 2

Town of West Hartford Solar Projects

Year	Site	Size (KW DC)
2006	Town Hall	3 KW (removed)
2008	Hall HS Conard HS	3 KW 3 KW
2009	Bristow MS	95 KW
2012	Department of Public Works Bishops Corner Library Wolcott ES Conard Green Energy Lab	102 KW 58 KW 11 KW demonstration
2016	Westmoor Park Charter Oak International Academy Conard HS	5 KW 100 KW (also 64 geothermal wells) 357 KW
2017	Aiken ES	238 KW
2018	Off-Site (Thompson, CT) – Virtual Net Metering	2,400 KW
2019	Town Hall	129 KW
2020	King Philip MS	515 KW (under construction)

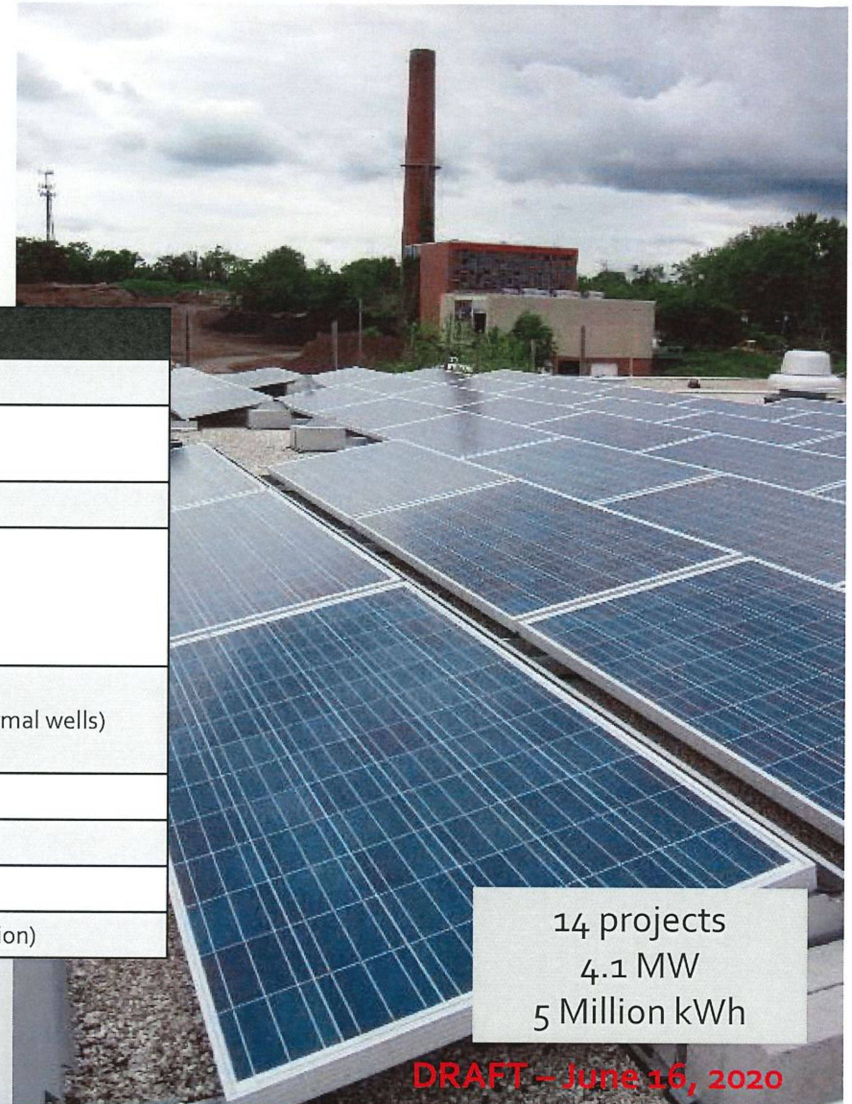


Photo Credits

Page 1 – Kingswood Oxford School; SolarCity; Perkins Eastmann; Ronnie Newton/WeHa.
Page 2 – NOAH.
Page 3 – CDC.
Page 4 – Ronnie Newtown/WeHa.
Page 9 – Energy; Realtor.com
Page 12 –
Page 15 –
Page 18 –

Resources

Residential

- www.EnergizeCT.com (Your Home)
- www.CTGreenBank.com

Commercial

- https://www.energizect.com/your-business (Your Business)
- www.CTGreenBank.com
- www.C-PACE.com
- www.

Transportation

- EVConnecticut (CT DEEP)
- Electric School Bus Toolkit (Live Green)
- https://portal.ct.gov/DEEP/Air/Air

Clean Energy / Renewables

- www.GoSolarCT.com
- www.EnergizeCT.com (Residential Solar Investment Program)
- https://portal.ct.gov/DEEP/Energy/Energy (CT's Energy Agenda)

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TOWN OF WINDSOR
First in Connecticut. First for its citizens.

Citizen Advisory Task Force on Clean and Sustainable Energy
VIRTUAL MEETING
September 16, 2020
Special Meeting

UNAPPROVED MINUTES

1. CALL TO ORDER

Town Manager Souza called the meeting to order at 7:00 p.m. Present were Committee Members; Neil Chaudhary, Jeffrey Dyreson, Barbara Peyton, George Slate, Pamela Stratton, Eric Weiner, and Elizabeth Yetman.

Staff: Peter Souza, Town Manager; Scott Colby, Assistant Town Manager

2. INTRODUCTIONS

The task force was introduced to one another and to staff.

3. PUBLIC COMMENT – None

4. OVERVIEW OF COMMITTEE'S RESPONSIBILITY AND CHARGE

Town Manager Souza reviewed the task forces charges, information pertaining to the Freedom of Information Act (FOIA), and logistics of the meetings.

Task force members asked questions regarding the logistics.

5. SELECTION OF CHAIRPERSON, VICE-CHAIRPERSON, & SECRETARY

Town Manager Souza reviewed the roles and responsibilities for each position.

The task force unanimously decided that they needed more time to decide on this item.

MOVED by Mr. Slate and seconded by Mrs. Stratton to table this item until the next meeting.

Motion Passed 7-0-0

6. DISCUSS POSSIBLE FUTURE AGENDA TOPICS AND SET NEXT MEETING DATE

Town Manager Souza proposed some ideas of possible future agenda items. Each of the task force members also provided input as to what items they would also like to include on the next agendas.

Staff will work on coordinating with the task force members their availability to schedule the next two meetings and preparing the agenda.

7. ADJOURNMENT

MOVED by Mr. Slate and seconded by Mrs. Stratton to adjourn the meeting at 8:33 p.m.

Motion Passed 7-0-0

Respectfully Submitted,

Scott W. Colby Jr.
Assistant Town Manager

The following is a sampling of clean energy and sustainability projects that can be implemented in Windsor that have been completed or approved in other Connecticut towns.

Towns	Virtual solar	Shared solar	Solar canopies	Electric buses	Net Zero Energy Buildings	Residential Heat Pumps	Other Projects
Bloomfield		Community Solar Project					Tree planting project
Branford						HeatSmartCT	
Cheshire			Police station solar carport for 40 cars				
Guilford						HeatSmartCT	
Manchester					Net zero school renovation		
Mansfield					Net zero school new construction		
Middletown				1st electric bus in CT		HeatSmart Program press release HeatSmartCT	PPA from BioGas Generator
South Windsor	28% of town's electricity		Approved for police station				
Southington							PPA from Quantum Biopower
Vernon			3 solar canopy projects				
West Hartford							Solar for All

Prepared in accordance with Section 16a-3a of the Connecticut General Statutes

Integrated Resources Plan

Pathways to achieve a 100% zero carbon electric sector by 2040

OCTOBER 2021

Connecticut Department of Energy and Environmental Protection

Table of Contents

Takeaways for Policymakers

Key Findings

- There are multiple achievable pathways to meeting a 100% Zero Carbon electric sector target.
- It is critical to prioritize affordability and equity in making this significant investment in Connecticut's clean energy future.
- Storage and demand management will play an increasingly significant role in ensuring reliability of the grid, and minimizing wasted generation.
- The existing transmission system needs to be upgraded and expanded to meet the regional clean energy capacity additions needed to achieve Connecticut's and other states' goals.
- The retention of Millstone beyond 2029 is a critical factor in how much more and how quickly Connecticut needs to procure new clean energy additions.
- Developments in clean, dispatchable generation technology could decrease reliance on natural gas resources as reliability resources.

Key Objectives

1. Decarbonize the electricity sector.
2. Secure the benefits of competition & minimize ratepayer risk.
3. Ensure energy affordability and equity for all ratepayers.
4. Optimize siting of generation resources.
5. Upgrade the grid to support and integrate variable and distributed energy resources.
6. Balance decarbonization and other public policy goals.

Key Recommended Actions

- Commit to a 100% Zero Carbon electric sector target by 2040, as over a dozen other states have since 2018.
- Advocate for and pursue wholesale energy market reforms so that clean energy resources are deployed efficiently, cost-effectively, and costs are spread equitably.
- Support and maintain historic deployment levels of distributed generation throughout the state.
- Identify and remove barriers to participation in Connecticut's clean energy programs for overburdened and underserved communities.
- Advance proactive planning policies for regional transmission development

Executive Summary

With overwhelming scientific evidence of global climate change caused by increases in greenhouse gas (GHG) emissions produced through human activities, swift action is critical to decarbonize the state's electric supply and adapt the region's electric system to withstand extreme and unprecedented weather events.[1] In Executive Order 3, issued in September 2019, (EO3) Governor Lamont directed the Department of Energy and Environmental Protection (DEEP, or "the Department") to identify pathways within this Integrated Resources Plan (IRP) to achieve a 100 percent zero carbon electric supply by 2040 ("100% Zero Carbon Target"). The significant investments Connecticut has made over the years in robust clean energy and energy efficiency programs have already put the state on a strong path to achieving the 100% Zero Carbon Target. Today, through direct investment in the form of long-term contracts, Connecticut ratepayers are supporting grid-scale, zero-emission renewables and zero-carbon nuclear resources equivalent to over 66 percent of the electricity consumed by customers of the state's two electric distribution companies: Avangrid, Inc. and Eversource Energy (the "EDCs"). By 2025, that percentage is expected to increase to 92 percent, as new offshore wind and grid-scale solar projects that have been contracted but not yet constructed are scheduled to come online.

Key Objectives

This IRP assesses Connecticut's current and future electricity supply, in accordance with Connecticut General Statutes (C.G.S) Section 16a-3a, with respect to six key objectives focused on reliability, affordability, optimization, and achieving a 100% Zero Carbon electric sector:

1. Decarbonizing the Electricity Sector

The modeling in this IRP tested four different scenarios under two load levels to evaluate potential costs, fossil fuel retirements, and new resources needed to meet the 100% Zero Carbon Target while maintaining system reliability. Each of these scenarios tests different blends and quantities of zero carbon electric generating resources like on- and offshore wind, grid-scale solar, and battery storage, but all enable Connecticut to meet its 100% Zero Carbon Target by 2040. In addition to assessing pathways to achieve the 100% Zero Carbon Target pursuant to EO3, the IRP is required to plan for the state's energy needs consistent with the State's statutory greenhouse gas (GHG) emissions reduction goals to reduce economy wide emissions 45 percent by 2030 and 80 percent by 2050.[2] **This IRP concludes that there are multiple pathways available to achieve the 100% Zero Carbon Target, and doing so will further the state's ability to meet its GHG emissions reduction goals. Thus, this IRP confirms a 100% zero carbon electric supply by 2040 as the goal of Connecticut and sets forth the necessary steps to achieve that goal affordably, reliably, and equitably.**

2. Securing the Benefits of Competition & Minimizing Ratepayer Risk

One of the key aims of the deregulation of electricity supply in Connecticut was to achieve lower-cost electricity by relying on competitive markets to source the State's power supply, thereby insulating ratepayers from the risks of uneconomic investments and stranded costs. This IRP evaluates the extent

[1] Intergovernmental Panel on Climate Change, *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change,* August 7, 2021, *available at:* https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf

[2] Conn. Gen. Stat. § 22a-200a.

to which Connecticut ratepayers are obtaining the benefits of deregulation under the current market paradigm.

Current energy markets are not producing significant investment in clean energy resources, causing Connecticut to have to procure, through state jurisdictional markets and mechanisms, the resources needed to meet the State's Renewable Portfolio Standard (RPS) and other GHG emission reduction goals. The wholesale market's overreliance on natural gas generation has placed Connecticut ratepayers at risk of paying unreasonable and duplicative costs for clean energy supply, and taking on additional costs to preserve fuel security in the region. These issues are difficult to overcome because the ISO-New England (ISO-NE) governance structure lacks accountability and transparency. **Connecticut and the other New England states must drive the ISO-NE to reform the regional wholesale markets to ensure they are meeting the needs of the states and their ratepayers,** including Connecticut's need to meet emissions reduction goals and provide reliability at the lowest cost to ratepayers.

In addition to reforming the wholesale markets, the IRP analysis reveals several urgent, threshold issues that need to be resolved. These include **improving transmission planning, and scaling investment in storage, efficiency and demand response.** Connecticut must prioritize these efforts in the near-term (2021-2022) in order to prepare the state to efficiently deploy new zero carbon resources. Reforms to the wholesale market will allow zero carbon resources needed to meet states' goals to enter the market more efficiently, thereby lowering costs to ratepayers. An upgraded and well-planned transmission system, coordinated with non-wires alternatives like storage and demand management, will help to **optimize interconnection points and minimize renewable curtailment.**

Distributed generation (DG) resources such as solar and fuel cells will also have a significant role to play in Connecticut's Zero Carbon Electric Supply future by providing resilience, portfolio diversification, and economic benefits. They can also be simpler to site than grid scale resources. The tariffs being developed by the Public Utilities Regulatory Authority (PURA) to support these resources, in Docket No. 20-07-01 and pursuant to Section 16-244z(b), will create a transparent, fixed incentive mechanism for both energy and RECs associated with DG. In developing and tracking that incentive over time, it is important to **maintain deployment levels of DG historically achieved through the Residential Solar Incentive Program (RSIP), low-carbon renewable energy credit (LREC), and zero-carbon renewable energy credit (ZREC) programs to continue the pace of diversifying the State's zero carbon resources and sustain the existing in-state economic infrastructure supporting these programs**. Recommended deployment levels could change in future years if additional benefits to distributed generation are unlocked through grid modernization or if the current price gap between grid scale and DG resources decreases.

3. Ensuring Energy Affordability and Equity for all Ratepayers

Due in significant part to the ISO-NE energy market and governance concerns highlighted in Objective 2, Connecticut has some of the highest electric rates in the United States, and an energy affordability gap that has serious impacts on low to moderate-income utility customers and the communities they live in. **The state's electricity supply should be affordable for all customers and maximize residential and business customer value to ensure that Connecticut continues to be economically competitive.** Regional market reform, governance changes, and a proactive approach to transmission planning must be prioritized to address energy affordability.

In addition, **energy equity requires expanding access and removing barriers for underserved and overburdened customers to participate in Connecticut's energy policy programs**, consistent with the direction from Governor Lamont in EO3 that the Governor's Council on Climate Change (GC3) analyze climate mitigation and adaptation progress through that lens. This IRP recommends that incentive levels for the residential rooftop solar successor tariff be structured to ensure at least 40 percent of the installations are deployed at low-income households statewide, and low to moderate-income households in environmental justice communities. To further address energy equity and affordability, this IRP recommends increasing the low-income and low to moderate-income subscribership requirements under the Shared Clean Energy Facilities (SCEF) program structure, working towards a 100 percent low- to moderate-income subscribership goal. Moreover, DEEP's Equitable Energy Efficiency proceeding is identifying barriers to equitable participation in energy efficiency programs and pathways to address those barriers, and developing metrics for defining equity and measuring program outcomes from an equity perspective.

4. Optimal Siting of Generation Resources

Since deregulation, Connecticut's transmission infrastructure and other energy infrastructure have made it a target location for the development of merchant fossil fuel-powered generation facilities. Fossil fuel generating resources are primarily constructed in low income or historically marginalized communities, creating inequitable air quality and environmental justice issues. Adoption of the 100% Zero Carbon Target for the state's electricity supply will ensure that the state can clearly plan for and achieve a decarbonization goal that will, in concert with similarly robust targets being adopted by other states in the New England region, minimize operation of fossil fuel generation in the region. **Pursuing reforms of the wholesale electricity markets is necessary to address ISO-NE market rules that over-procure capacity, prevent state clean energy investments from clearing in the capacity market, and imbed preferences for natural gas and other fossil resources in the capacity market.** Fully reforming the market will ensure that zero carbon resources are selected to meet public policy and reliability needs.

Siting of renewable and zero carbon generation also has its challenges, including potential impacts to natural resources, environmental quality, and agricultural resources. Connecticut must fully align its energy and environmental policies, by identifying and incorporating eligibility criteria in procurements that reflect a consistent and appropriate balance of price, environmental quality and natural resource values, and providing transparent, predictable and efficient permitting and siting processes for renewable energy resources. The draft IRP called for a stakeholder engagement process, led by DEEP, to improve and refine solar siting and permitting practices with respect to grid-scale procurements, and to develop siting practices tailored to ground-mounted solar projects. The Department initiated the Sustainable, Transparent, and Efficient Practices (STEPs) for Solar Development in June 2021 and it is still underway.[3] The Department will rely on the outcomes of this process to inform its next procurement of zero carbon renewable energy resources.

The IRP also recommends leveraging regional approaches to improve our understanding of the best available science, tools, and practices for environmental and commercial fisheries mitigation for offshore wind (OSW) siting through entities such as the Northeast Regional Ocean Council, the Responsible Offshore Development Alliance/Responsible Offshore Science Alliance, and the Regional Wildlife Science

[3] Connecticut DEEP, Sustainable, Transparent and Efficient Practices (STEPs) for Solar Development, https://portal.ct.gov/DEEP/Planning/Steps-for-Solar-Development

Entity for Offshore Wind. As required by Public Act 19-71, DEEP will also utilize input from the Commission on Environmental Standards and will incorporate resulting best siting practices for OSW as requirements in future solicitations.

5. Upgrade the Grid to Support and Integrate Variable and Distributed Energy Resources

Today's wholesale electric power grid, and the electric markets it supports, have been designed around the development of traditional, dispatchable (i.e. controllable) resources such as natural gas and oil generators. While the transmission system has capacity to support some variable energy resources (VERs) like wind and solar in the near term, modeling demonstrates that curtailment of intermittent resources will happen in each of the modeled pathways to a 100% Zero Carbon Target. **Upgrading the transmission system can significantly reduce curtailment and increase the ability of VERs to interconnect to the existing grid over the next two decades.** With reduced curtailment, less clean energy will be wasted, thus reducing any oversupply needed to meet reliability and emissions requirements. The modeling shows that eliminating or reducing transmission constraints can also reduce the overall ratepayer costs of achieving the 100% Zero Carbon Target.

Under the current ISO-NE tariff, proactive planning is a challenge, as the approach has been primarily reactive. In order to address state policies, a scenario-based proactive planning process is needed. **As the region pursues further deployment of both grid-scale and behind the meter (BTM) resources, the New England states must work to upgrade the existing transmission system to unlock constraints and maximize the value of zero carbon generation.** This may require Connecticut to seek to work with other New England states to initiate a procurement of transmission infrastructure. In addition, **Connecticut must invest in energy efficiency, active demand response and storage resources to reduce and manage load to balance VERs.**

The state must also consider the increasing risks the grid faces from both climate-based threats, and cyber threats. **Exploring and implementing security and resiliency measures must be a priority in planning the future grid.** Within its Microgrid and Resilience Program, DEEP will evaluate how to best leverage state and federal funds for resilience planning and to build a project pipeline prior to issuing a request for project proposals, with a focus on vulnerable communities. DEEP will also further explore resilience planning in the upcoming Comprehensive Energy Strategy proceeding.

6. Balancing Decarbonization and Other Public Policy Goals

Connecticut's energy policies currently support technologies that are not zero emissions but provide solutions for other important public policy goals. **In evaluating pathways to reach a 100% Zero Carbon Target for electric supply by 2040, the IRP recognizes the distinct and related policy goals of the RPS and the Global Warming Solutions Act.** Waste-to-energy (WTE) plants, for example, emit GHGs and other air pollutants, but provide vital services to the state in avoiding landfilling and maintaining self-sufficient waste disposal. **The IRP highlights opportunities to align the state's decarbonization efforts with the broad public policy goals of the RPS and other state policy goals.** This includes phasing down reliance on biomass and seeking to diversify the state's waste management infrastructure by scaling up deployment of anaerobic digestion.

Key Recommended Actions

There is significant work to be done to achieve the Objectives set forth above. This IRP establishes several priority actions over the next two years, including:

State-Level Actions
• Adopt the 100% Zero Carbon Electric Sector goal as the planning target for Connecticut's electric supply, with a focus on affordable, reliable and equitable attainment of the goal. • Complete the Sustainable, Transparent and Efficient Practices (STEPS) for Solar Development stakeholder processes to identify best siting practices for renewables in Connecticut to incorporate in future procurements and improve siting and permitting processes. • Incorporate the conclusions of STEPS in the next zero carbon renewable energy procurement to continue progress toward clean energy goals. • Report on variables and contingencies that could influence expedited clean energy procurements prior to 2023 estimated need in the beginning of 2022. • Identify measures that can be taken at the state level to protect ratepayers against the abuse of supplier-side market power in the wholesale markets. • Request that PURA initiate a proceeding to evaluate potential modifications to Connecticut's RPS compliance; including whether retaining RECs purchased through procurements and public policy programs is in the best interest of stakeholders, and how BTM resources affect compliance accounting. • Adopt appliance efficiency standard regulations to lock in cost-effective, enduring energy savings for Connecticut's ratepayers. • Support historic deployment levels for DG resources, with a focus on low-income customers in the residential and shared clean energy successor tariffs. • Engage in coordinated planning for workforce and economic development. • Issue a request for information (RFI) and process to determine energy storage use cases that maximize benefits to Connecticut's electric system in advance of using DEEP's energy storage procurement authority and in furtherance of the state's energy storage goal. • Request and incorporate data from the municipal power cooperatives in the state regarding their progress in deploying clean energy to develop a holistic view of Connecticut's clean energy portfolio. • Solicit public input on proposed changes to electric sector emissions accounting to more accurately reflect emissions reductions realized by Connecticut's investments in clean energy. • Within the Microgrid and Resilience Program, evaluate how to best leverage state and federal funds for resilience planning and to build a project pipeline prior to issuing a request for project proposals, with a focus on vulnerable communities. DEEP will also further explore resilience planning in the upcoming Comprehensive Energy Strategy proceeding. • Assign Class II alternative compliance payment revenues towards sustainable waste management measures to better align Connecticut's coexisting energy and environmental goals.

Regional-Level Actions
• Pursue regional wholesale market reform and improvements to the transparency and governance of ISO-NE. • Continue to push for the elimination of, or substantial reform to, the MOPR to ensure that state-sponsored resources are no longer precluded from the ISO-NE capacity market. • Continue actively engaging with other New England states and ISO-NE to help develop the transmission planning process called for in the Vision Statement and agreed to by ISO-NE. • Initiate a proceeding to determine biomass resources covered by the phasedown as directed by Public Act 13-303.

Recommended Procurement Schedule

This IRP outlines several contingencies in Strategy 5 that could affect a procurement schedule designed to meet the 100% Zero Carbon Target. DEEP therefore concludes it is prudent to monitor contingencies and provide an update to the procurement schedule set forth in Strategy 5 at least every 12 months. This will help guide DEEP in determining whether changes in the frequency and scale of procurements are needed due to new conditions. DEEP will commit to providing the first update in the beginning of 2022.

Given the significant quantities of clean energy currently under contract, and accounting for what conditions are presently “known and knowable” rather than the many contingencies discussed in this IRP, the modeling projects that new grid-scale resources needed to meet the 100% Zero Carbon Target may need to be procured beginning in 2023. Thus, DEEP will plan to conduct its next procurement proceeding at the conclusion of the ongoing Sustainable, Transparent and Efficient Policies for Solar Development (STEPs) process, in advance of the need identified by the IRP to maintain progress towards the greenhouse gas reduction goals. This sequence will allow the next set of procured grid scale zero carbon Class I resources to benefit from improved transparency and efficiency of siting policies in Connecticut, and for the state to account for planned projects that may not achieve commercial operation.

This IRP also considers the creation of a “portfolio standard for thermal energy,” including “biodiesel that is blended into home heating oil,” as required by Public Act 19-35. Widespread use of biodiesel blends beyond 20 percent may be impractical in the next several years. Questions remain about greenhouse gas reduction benefits of biodiesel from various feed stocks, and about the potential for biodiesel subsidies to prolong the use of fossil-based heating fuel. While this IRP does not recommend the creation of a portfolio standard for thermal energy at this time, DEEP will track these open issues and will consider a renewable thermal portfolio standard in the upcoming Comprehensive Energy Strategy, among other options for encouraging investment in renewable thermal technologies.

Stakeholder Engagement for the IRP

On October 15, 2019, DEEP issued a Notice of Revised Scope, Updated Schedule, and Opportunity for Public Comment for the Integrated Resources Plan. This notice revised the scope and approach of the Integrated Resources Plan initiated in 2018 to take into account Governor Lamont's Executive Order 3, new market and policy developments, multiple competitive procurements for zero carbon resources, and new legislation authorizing DEEP to procure offshore wind. DEEP outlined the additions it planned to add to the IRP, including a policy assessment of deregulation, modeling analysis of various pathways to a 100% zero carbon electric sector for Connecticut, recommendations for the establishment of a Thermal Renewable Portfolio Standard, recommendations for an offshore wind procurement schedule, and recommendations for a biomass generation phase-down schedule. DEEP accepted public comment on this proposed revised schedule through October 29, 2019.

In the months following this initial notice, DEEP hosted multiple in-person and virtual technical meetings, and accepted many rounds of public comments. These meetings and requests for comment spanned a range of topics in preparation of the draft IRP, including the proposed modeling scenarios, assumptions, and inputs, approaches to market reforms, and biodiesel as a thermal resource. A record of these meetings and public comments are listed below.

2020 IRP Procedural Record

Date	Action	Topic
10/15/2019	Notice	Revised Scope, Schedule, and Opportunity for Public Comment
10/29/2019	Comments Due	Revised Scope & Schedule
1/8/2020	Notice	Technical Meeting 1- Markets & Deregulation, and Opportunity for Public Comment
1/21/2020	Notice	Supplemental Materials for Technical Meeting
1/22/2020	Tech. Meeting	Markets & Deregulation
2/5/2020	Comments Due	Markets & Deregulation
2/5/2020	Notice	Technical Meeting- Biodiesel as a Thermal Resource, and Opportunity for Public Comment
2/20/2020	Notice	Technical Meeting- Markets & Deregulation
2/24/2020	Notice	Modeling Scenarios, Assumptions, & Inputs and Opportunity for Public Comment
3/4/2020	Tech. Meeting	Markets & Deregulation
3/11/2020	Comments Due	Modeling Scenarios, Assumptions & Inputs
3/16/2020	Tech. Meeting	Biodiesel as a Thermal Resource
3/30/2020	Comments Due	Biodiesel as a Thermal Resource
5/28/2020	Notice	Preliminary Modeling Results, Technical Meeting, Schedule, and Opportunity for Public Comment
6/18/2020	Tech. Meeting	Preliminary Modeling Results
6/24/2020	Notice	Technical Meeting- Biodiesel as a Thermal Resource, and Opportunity for Public Comment
7/2/2020	Comments Due	Preliminary Modeling Results & Remaining Model Runs
7/6/2020	Comments Due	Biodiesel as a Thermal Resource
7/13/2020	Tech. Meeting	Biodiesel as a Thermal Resource
7/15/2020	Notice	Opportunity for Public Comment on Biodiesel as a Thermal Resource
7/22/2020	Comments Due	Biodiesel as a Thermal Resource

12/16/2020	Notice	Release of Draft IRP, Technical Meetings, Public Hearings, and Opportunity for Public Comment
1/14/2021	Public Hearing (day session)	Draft IRP
1/14/2021	Public Hearing (evening session)	Draft IRP
1/21/2021	Tech. Meeting	Draft IRP- Policy Findings and Recommendations
1/28/2021	Tech. Meeting	Draft IRP- Modeling
2/8/2021	"Power Hour"	Informal public engagement session on the Draft IRP
2/17/2021	Comments Due	Draft IRP
10/7/2021	Final Draft	Final draft of IRP released

On December 16, 2020, DEEP published the draft IRP along with a notice of public hearings, technical meetings, and an opportunity for comments on the draft. In addition to the conventional technical meetings and public hearings, DEEP also hosted an informal public engagement session, referred to as a "Power Hour." This meeting was intended to serve as a more accessible and inclusive opportunity for Connecticut's citizens to engage with DEEP staff and ask questions and make comments without the constraints of more formal public meetings. Spanish translation services were made available for both the meeting materials, and the live meeting discussion. DEEP acknowledges that the earlier these kinds of meetings are held, the more effectively stakeholders' concerns and lived experiences can be incorporated into a policy recommendation. DEEP intends to make this meeting style a regular practice in future planning processes.

The Department received written and oral comments on the Draft IRP from over 90 individuals and organizations. The Department highly values feedback from stakeholders and has taken these comments and recommendations under advisement. In accordance with Conn. Gen. Stat. Section 16a-3a, DEEP has summarized and cataloged these comments, with a corresponding record of any relevant changes in the table below in Appendix A8. Though not all of the comments can be addressed in this finalized draft, DEEP notes that energy planning is an iterative and ongoing process and many issues raised by the comments will be taken into account in future proceedings.

Some key revisions made by the Department in response include the following:

- **Content organization and clarity:** Several comments noted that the IRP was very dense and unclear at times. The Department acknowledges that the IRP is a highly technically and expansive document, covering many topics and modeling approaches in great detail. In an effort to improve readability and understanding, DEEP has made clarifying and organizational edits throughout the document. The Department is committed to equity, which includes making documents and reports accessible to a wide audience and is continuously working to improve communication and documentation methods.
- **Further updates on DEEP's work to address energy equity and justice:** DEEP received multiple comments highlighting the urgent need for the state to address equity and justice in energy and climate policy. The Department recognizes that critical, immediate action is needed across programs and policies. Additional discussion on recent steps taken and key issues for consideration going forward have been added to Objectives 3 and 4. This includes additional discussion on the value of distributed energy resources for these communities.

- **Enhanced discussion of opportunities for storage resources:** Several comments recommended including greater focus on storage as a peaking power unit replacement. The Department agrees with this recommendation and has added a discussion of the hourly clean energy balance modeling results from Appendix A3 and the potential for storage and active demand response resources to help meet peak demand needs and periods of clean energy imbalance to Objective 5. Additionally, DEEP has added more specificity to its recommendations regarding integrating and deploying storage.
- **Added discussion on the importance of grid security and resilience:** Several participants commented that more discussion of security, resiliency and microgrids should be included. DEEP agrees and has added a discussion of grid security, cybersecurity, and resiliency to Objective 5, and a relevant strategy to its original list of fifteen. This strategy recommends that the existing Microgrid Pilot Program be expanded to include funding for relevant measures that will make communities' critical infrastructure more resilient.
- **Thermal renewable portfolio standard:** Several comments called for greater attention to evidence that substituting biodiesel for fossil-based heating oil reduces emissions of pollutants that contribute to formation of ozone. DEEP has revised the text to indicate that, in light of new analysis submitted in early 2021, its concern about near-term air-quality impacts has been allayed. Several comments emphasized the benefits of biodiesel for GHG reduction, and DEEP has pointed out that the ability of Connecticut's GHG inventory to account for lifecycle emissions reductions that occur outside the state is quite limited.

Part I: Objectives of the IRP

Introduction

Section 16a-3a of the Connecticut General Statutes (C.G.S.) requires DEEP to prepare an Integrated Resources Plan (IRP) for Connecticut's electricity supply. The IRP is intended to assess the resources available to meet the State's needs for energy and capacity, and develop a plan for procuring energy resources "in a manner that minimizes the cost of all energy resources to customers over time and maximizes consumer benefits consistent with the State's environmental goals and standards, including, but not limited to, the State's greenhouse gas reduction goals."[4]

Before Connecticut deregulated its electricity sector, integrated resources plans were prepared by the predecessor entities of the state's two current electric distribution companies, Eversource Energy and Avangrid, Inc. (EDCs)—who had exclusive ownership of the electric generating facilities at the time— to ensure that they had an acceptable plan to procure the power supply needed to meet expected customer demand over a long-term planning horizon. Public Act 98-28 directed the EDCs to divest their generation assets and caused the State to rely primarily on wholesale markets under the jurisdiction of the Federal Energy Regulatory Commission (FERC or Commission) for Connecticut's energy supply. By the same Public Act, however, the State established a preference for an increasing portion of the State's supply to be met by clean and renewable energy sources and funded the State's utility-administered energy efficiency programs.

Since that time, Connecticut has continued with the practice of integrated resources planning—conducted by State policymakers, in consultation with the EDCs—to ensure that the State's preferences for clean energy, efficiency, and other policy-supported resources are being met, and that the regional electricity system is adequately meeting a variety of objectives. The Connecticut General Statutes spell out many specific resource objectives that must be considered in the IRP's resource assessment. Consistent with those requirements, the objectives examined in Part I of this Integrated Resources Plan are as follows:

1. **Decarbonizing the Electricity Sector.** Pursuant to Governor Lamont's Executive Order No. 3, this IRP assesses pathways to achieve a 100 percent zero carbon electric supply by 2040 (100% Zero Carbon Target). In addition, the IRP is required to plan for the state's energy needs consistent with the State's greenhouse gas emissions reduction goals to reduce economy wide emissions 45 percent by 2030 and 80 percent by 2050.[5] Pursuant to this requirement in C.G.S Section 16a-3a, it is necessary for the state to meet the 100 percent zero carbon electric sector goal by 2040 to meet the broader economy-wide climate goals, and the plan and recommendations put forth by this IRP are the necessary steps to meet those targets.
2. **Securing the Benefits of Competition & Minimizing Ratepayer Risk.** One of the key aims of deregulation was to achieve lower-cost electricity by relying on competitive markets to source the state's power supply, thereby insulating ratepayers from the risks of uneconomic investments and stranded costs. This IRP evaluates the extent to which Connecticut ratepayers are obtaining the benefits of deregulation under the current market paradigm, and the measures that have been taken to advance state policies outside of the markets and will need to be taken in the future absent market reform.

[4] Conn. Gen. Stat. § 16a-3a(a).

[5] Conn. Gen. Stat. § 22a-200a.

3. **Ensuring Energy Affordability and Equity for all Ratepayers.** The state's electricity supply should be affordable for all customers and maximize residential and business customer value to ensure Connecticut has continued economic competitiveness. Moreover, energy equity requires expanding access and removing barriers to participation in Connecticut's energy policy programs by underserved and overburdened communities.
4. **Optimal Siting of Generation Resources.** Is the use of generation sites in Connecticut optimal? How are new and legacy fossil-fired generation facilities in the state impacting local air quality, and environmental justice communities? In addition, as the state invests in new renewable and other zero emission resources to meet our decarbonization goals, this development must be harmonized with environmental quality, natural resource, and other land use protections.
5. **Upgrading the Grid to Support and Integrate Variable and Distributed Energy Resources**. As the New England region pursues deeper decarbonization, through the deployment of both grid-scale and behind-the-meter resources, it becomes increasingly important to upgrade the existing transmission system to prevent curtailments and ensure ratepayers receive the full amount of energy zero carbon resources are able to produce. This will also include non-wire solutions such as accelerating the deployment of energy efficiency to reduce load, and storage and active demand response to balance intermittent resources. Additionally, the security and resiliency of the grid must continue being prioritized.
6. **Balancing Decarbonization and Other Public Policy Goals.** Connecticut's Renewable Portfolio Standard has been a critical policy tool for advancing investment in clean energy as well as supporting other important public policies, such as promoting economic development and maintaining in-state waste disposal infrastructure. Over time, the State's progress towards achieving sustainability goals and economy-wide GHG emissions reductions will provide opportunities to harmonize all the public policy goals underlying the RPS and other electric sector programs.

After assessing each of these objectives, Part II the IRP evaluates and proposes a set of resource and procurement strategies that meet the various objectives. Part III of this IRP considers the creation of a "portfolio standard for thermal energy," including "biodiesel that is blended into home heating oil," as required by Public Act 19-35.[6]

It is important to note that integrated resources planning involves developing a variety of assumptions based upon is the best available information that is known and knowable at the time the modeling for the IRP is conducted. Given the relatively rapid rate of technological advancement and market transformation in the electric sector, near-term modeling results are inherently more reliable than longer-term projections. Moreover, this IRP is not a full cost-benefit analysis of policies supporting different zero carbon resources; rather, it analyzes the price and emissions impacts of pathways to meet the 100% Zero Carbon Target based on current policy and market structures. Changes to market structure, as called for in Objective 2, upgrades to the transmission system, as called for in Objective 5, as well as a variety of other contingencies could have meaningful impacts on the projections made in this IRP. The Department's biennial IRP cycle is designed to allow Connecticut's policy approaches to be adapted and refined over the medium and long term in response to changing conditions.

[6] Conn. Gen. Stat. § 16a-3a.

Objective 1: Decarbonizing the Electricity Sector

Events on the regional, national, and international stage highlight the urgency of decarbonization in Connecticut. The early impacts of global climate destabilization make it clear that our communities and infrastructure are profoundly vulnerable. Month after month, headlines about climate change grow increasingly ominous: a long series of global temperature extremes; hurricanes wreaking ever more destruction; rapid deterioration of the polar ice caps, portending rapid sea level rise; unprecedented wildfires on several continents; troubling changes in major ocean currents. In Connecticut, climate change impacts are particularly a threat in shoreline and other low-lying areas, as well as for forested areas weakened by drought and invasive pests, increasing the likelihood of power outages resulting from storm damage to electric infrastructure.

The extent of these impacts depends on the decisions we make now on our global emissions. The 2018 National Climate Assessment authored by the US Global Change Research Program found that, under the International Panel on Climate Change (IPCC) business-as-usual scenario, annual losses to labor productivity and coastal property could reach hundreds of billions of dollars by 2100.[7] However, these same economic damages can be significantly reduced if instead our global emissions peak by 2040 and continue to decrease thereafter with an 85 percent lower emissions level by 2100. Under this scenario, for example, we can reduce the number of deaths and health risks from climate change by 50 percent.

In Connecticut, climate change has already impacted our state. By 2050, Connecticut will experience up to 20 inches of sea level rise, an increase in coastal flooding from once every few years to multiple times per year, an increase in the average temperature by 5°F, and increased frequency of drought, hot weather, intense storms, and extreme precipitation.[8] These expected changes will affect the reliability and cost of electricity supply. Beyond 2050, the extent of these impacts in the state highly depends on our choices on how to address emissions. The impacts we can expect to see between now and 2050 are serious, but with careful planning, using the best available climate science, we can adapt to them. Impacts in the latter half of the century however become increasingly severe with the potential to cause widespread disruption in the state and making adaptation measures extremely costly. For example, sea level could rise by as much as 80 inches by 2100 without reductions in GHG emissions. With emissions reductions, we increase the likelihood that our temperature could stabilize, but with no reductions, temperatures will continue to rise. Investment in deep, systemic reductions in GHG emissions to prevent climate destabilization from continuing to escalate is crucial to avoid more catastrophic costs in human lives, health risks, and economic damage, and is more cost effective than an adaptation-only strategy.

In 2008, Connecticut enacted the Global Warming Solutions Act (GWSA), C.G.S Section 22a-200a, requiring significant long-term reduction of GHG) emissions across all sectors of the economy: an 80 percent reduction in GHG emissions from 2001 levels by 2050. The GWSA was amended in 2018 to establish a mid-term goal of 45 percent reduction in GHG emissions from 2001 levels by 2030. These emission

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[7] *See* Fourth National Climate Change Assessment, U.S. Global Change Research Program, 2018, p. 1358, Figure 29.2 (interpreting the economic impacts of the International Panel on Climate Change, Representative Concentration Pathway (RCP) 8.5).

[8] *See* O'Donnell, J, *Sea Level Rise in Connecticut*, February 2019, *available at* https://circa.uconn.edu/wp-content/uploads/sites/1618/2019/02/SeaLevelRiseConnecticut-Final-Report-1.pdf

reductions must be achieved across transportation, buildings, and the electricity sector, which are the major contributors to GHG emissions in the state.

In September 2019, Governor Lamont signed Executive Order 3, which directed DEEP to analyze in this IRP pathways to achieve a 100 percent zero carbon electric supply by the year 2040. Connecticut's policies and programs to date have advanced the state's progress towards meeting this 100% zero carbon Target. Over the last two decades, Connecticut has achieved significant decarbonization of the electricity supply through a variety of programs and investments:

- **Retirement and reduced operation of coal- and oil-fired power plants.** In 2000, oil- and coal-fired generation accounted for approximately 22 percent and 18 percent, respectively, of the total electricity consumed (MWh) in New England.[9] As of 2019, oil and coal collectively accounted for less than one percent of the region's electric generation (MWh).[10] Environmental regulations have changed fossil generator economics, and the increased availability of lower-priced natural gas fuel has accelerated the shift of the region's generation fleet away from older and dirtier coal and oil plants. Through Connecticut's participation in the Regional Greenhouse Gas Initiative (RGGI), the State has instituted a regional cap on carbon emissions from the electric power sector, incenting fossil generators in the eleven northeast states participating in RGGI to minimize their carbon footprint. The Regional Greenhouse Gas Initiative is the nation's first mandatory multi-state market-based program to cap and reduce CO_2 emissions from the power sector. Between 2005-2018, RGGI-participating states experienced a reduction of over 90 million short tons of annual power sector carbon pollution, a 50 percent reduction.[11]
- **Increased energy efficiency.** Over the last twenty years, Connecticut's Conservation & Load Management (C&LM) programs have led to the increased installation of energy efficiency measures in residential homes and in commercial and industrial facilities. These successfully installed measures have cumulatively produced 70,900 MWhs in savings, reducing the need for 1,000 MW worth of new power plant construction, while reducing the energy bills of participating customers.[12] Connecticut's energy efficiency programs promote the permanent reduction of energy usage by influencing market transformation. The energy efficient products, green building codes, and efficient appliance and lighting standards facilitated by Connecticut's programs have helped transform the market, resulting in more efficient buildings and products even without program participation. Changes in the residential lighting market, accelerated by the State's energy efficiency program, saw LED saturation (defined as the percentage of all sockets fitted with LEDs) more than double between 2015 and 2018 – equivalent to a tenfold increase from 2012.[13]

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[9] ISO New England, Resource Mix, *available at* https://www.iso-ne.com/about/key-stats/resource-mix/.

[10] *Id.*

[11] Regional Greenhouse Gas Initiative, Inc., The Investment of RGGI Proceeds in 2018, July 2020, p. 4. *available at https://www.rggi.org/sites/default/files/Uploads/Proceeds/RGGI_Proceeds_Report_2018.pdf*

[12] Eversource Energy, United Illuminating, Connecticut Natural Gas Corporation, and Southern Connecticut Gas, *2020 Plan Update to the 2019-2021 C&LM Plan*, March 1, 2020, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/8525797c00471adb8525851a006d6e11/$FILE/Final%202020%20Plan%20Update%20Text%20for%203-1-20%20Filing.pdf.

[13] *See* NMR Group, Inc., *R1706 Residential Appliance Saturation Survey & R1616/R1708 Residential Lighting Impact Saturation Studies* – Final Report, October 1, 2019, p. 8, *available at*

As of 2020, 49 percent of commercial and industrial, and 28 percent of residential annual energy savings reported by the C&LM Plan result from lighting upgrades.[14]

- **Increased grid-scale renewable supply.** In 1998, Connecticut established an RPS to spur investment in renewables by mandating that an increasing portion of the state's electricity needs be supplied by certain types, or classes, of renewable resources. Connecticut's total RPS goal for 2020 now stands at 29 percent of supply, expanding up to 48 percent by 2030.[15] Decreasing GHG emissions was an important—but not the only—goal of the RPS. Some resources with the potential to emit GHGs, waste-to-energy (WTE), biomass, and fuel cells, are included in the RPS, so as to meet other policy objectives, such as avoiding practices that emit higher GHG emissions (such as landfilling), promoting economic development, supporting grid resiliency, and diversifying fuel sources. In 2013, DEEP conducted a study of Connecticut's RPS and determined that about 11 percent of RPS-eligible electricity supply being utilized to meet Connecticut's RPS was coming from zero-carbon sources, while the other 89 percent was coming from biomass and landfill gas projects primarily located out of state.[16] Beginning in 2013, the State began to directly procure grid-scale renewables through competitive Requests for Proposals (RFPs) for long-term power purchase agreements (PPAs).[17] Since that time, The Department has procured 710 MW of grid-scale solar and 1,108 MW of offshore wind over eight separate procurements, harnessing a competitive framework to drive down the price paid by all ratepayers for this clean energy supply.[18]
- **Increased behind-the-meter renewable supply.** In July 1998, Connecticut first authorized net metering for small renewable resources through Public Act 98-28,[19] and expanded the program in 2007 to allow net metering for all customers with Class I facilities with a nameplate capacity of two MW or less.[20] The net metering program currently supports distributed generation (DG) across more than 45,000 customers. To accelerate behind-the-meter (BTM) renewable development, Connecticut added supplemental incentives in 2011 when it authorized programs that purchase renewable energy credits (RECs) associated with these net-metered, BTM systems to support additional deployment, like the low and zero emission renewable energy certificate (LREC/ZREC) program run by the EDCs and Residential Solar Investment Program (RSIP) run by the

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https://www.energizect.com/sites/default/files/R1706%20and%20R1616-R1708%20CT%20RASS%20Lighting_Final%20Report_10.1.19.pdf.

[14] Connecticut Energy Efficiency Board, *2020 Programs and Operations Report*, March 1, 2021, pp. 4, 5, *available at* https://energizect.com/connecticut-energy-efficiency-board/about-energy-efficiency-board/annualreports.

[15] Conn. Gen. Stat. § 16-245a, as amended by Public Act 18-50 (extending the Class I target to 40% in 2030).

[16] The expectation of future RPS and wholesale energy market revenues alone provided insufficient certainty to finance private development of zero-emission renewable resources. The 2013 RPS Study concluded that direct investment by Connecticut ratepayers, in the form of long-term contracts to purchase energy and/or Renewable Energy Certificates (RECs), would be needed to meet the state's RPS targets with zero-emission renewables.

[17] For purposes of this IRP, "grid-scale" means facilities greater than 2 MW.

[18] The state has also procured 10.6 MW of fuel cells from the Section 127 of Public Act 11-80 solicitation and 52 MW of fuel cells from another procurement.

[19] Public Act 98-28, An Act Concerning Electric Restructuring, *available at* https://www.cga.ct.gov/ps98/Act/pa/1998PA-00028-R00HB-05005-PA.htm.

[20] Public Act 07-242, An Act Concerning Electricity and Energy Efficiency, *available at* https://www.cga.ct.gov/2007/act/pa/2007pa-00242-r00hb-07432-pa.htm.

Connecticut Green Bank (Green Bank). Since their inception, these programs have led to the installation of 416 MWs of distributed solar and 45 MWs of distributed fuel cells.

- **Preventing the retirement of baseload (nuclear) zero carbon resources.** In 2017, the Independent System Operator of New England (ISO-NE) issued a report indicating that the retirement of the Millstone nuclear facility would subject the region's grid to the risk of rolling black- and brown-outs.[21] At the same time, Millstone's owner, Dominion Energy, Inc., indicated that the plant was unprofitable and would shut down. Under direction from the Connecticut General Assembly, DEEP and PURA conducted an assessment of the Millstone nuclear generating facility, reviewed the facility's financials, and determined that the facility was at risk of retirement given projected low energy market revenues and plant operating costs.[22] Absent viable regional alternatives to support this critical resource, Connecticut entered into a long-term contract with the Millstone facility for 9 million MWh of energy (approximately 36 percent of Connecticut EDCs' load) and all environmental attributes associated with the plant through 2029. By preventing the Millstone retirement Connecticut saved the region from significant negative impacts on the region's electric grid with respect to fuel diversity, energy security, and grid reliability; avoided an estimated $1.8 billion (2017$) in replacement costs that would have been borne by Connecticut ratepayers, and prevented *regional* carbon emissions from increasing by 20 percent.[23]

In total, these trends, programs and investments have contributed to a 36 percent reduction in Connecticut's electricity sector GHG emissions since 1997 when emissions were at their peak.[24] Thanks in large part to energy efficiency investments and BTM solar energy consumed onsite, Connecticut's total electricity demand has declined by 18 percent since 2005—avoiding the need to construct more than 1,100 MW in new power plants, and helping reduce customer bills.[25] Connecticut's RPS Class I requirement stands at 21 percent as of this year, and as of the most recent RPS compliance data provided by PURA, zero-emissions renewables now account for approximately 6 percent of the electricity (in MWh) utilized for RPS compliance in Connecticut.[26] Meanwhile, through direct investment in the form of long-

Connecticut ratepayers are currently supporting over 600,000 MWh/year of operating grid-scale, zero-emission resources; equivalent to nearly 65 percent of the electricity consumed by customers of the state's two EDCs.

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[21] *See* ISO-NE *Operational Fuel-Security Analysis*, January 17, 2018, p. 50, *available at* https://www.iso-ne.com/static-assets/documents/2018/01/20180117_operational_fuel-security_analysis.pdf.

[22] *See* Connecticut DEEP and PURA, PURA Docket No. 17-07-32, *Resource Assessment of Millstone Pursuant to Executive Order No. 59 and Public Act 17-3*, Draft Report and Determination, January 22, 2018, *available at* https://portal.ct.gov/-/media/DEEP/energy/EO59/2018Jan22DraftReportandDeterminationpdf.pdf.

[23] *Id.*

[24] Connecticut DEEP, 2017 Connecticut Greenhouse Gas Emissions Inventory Supporting Data, 2020, *available at* https://portal.ct.gov/DEEP/Climate-Change/CT-Greenhouse-Gas-Inventory-Reports

[25] ISO-NE, Load Forecast, *available at* https://www.iso-ne.com/system-planning/system-forecasting/load-forecast/?load.more=2.

[26] *See* PURA Docket No. 18-06-28, *Annual Review of Connecticut Electric Suppliers' and Electric Distribution Companies' Compliance with Connecticut's Renewable Energy Portfolio Standards in the Year 2017*, Final Decision, Page 36, July 1, 2020

term contracts, Connecticut ratepayers are currently supporting over 600,000 MWh/year of operating grid-scale, zero-emission renewables and more than 9 million MWh/year of zero-carbon nuclear resources; equivalent to nearly 65 percent of the electricity consumed by customers of the state's two EDCs. By 2025, that percentage is expected to increase to 92 percent, or 25million MWh/year, as new offshore wind and grid-scale solar projects that have been contracted but not constructed will come online.[27]

Looking back over the last decade, Connecticut has made significant strides in reducing carbon emissions from the electricity sector through a variety of programs and investments. These programs have been successful in deploying new technologies at scale. Prices for many GHG-reducing technologies—like LED lighting and solar panels—have dropped dramatically during this time, achieving GHG emissions reductions at lower cost over time. Some programs have cost ratepayers substantially more than others per unit of GHG emissions reduced. In some cases, economic development, job growth, and attractive savings for participating customers have also been important drivers of support for these initiatives. There are over 44,000 clean energy jobs in the state, comprising 2.6 percent of all jobs. Clean energy companies contributed $6.5 billion to the gross state product in 2019.

Modeling conducted in 2017-18 for the GC3 charted various pathways to reach the 2050 GWSA target. One such pathway requires Connecticut's electric sector to achieve at least 66 percent zero carbon generation by 2030 to complement similar emissions reduction achievements in the transportation and buildings sectors needed to achieve the 2050 GWSA target.[28] The modeling in Objective 1 below analyzes various scenarios through which Connecticut can achieve its 100% Zero Carbon Target by 2040 as set out in EO 3, using a simulation model of the New England electric grid. These modeling scenarios are intended to highlight contingencies and inform decision-making; they are *not* intended as policy proposals or preferred outcomes. As the modeling below indicates, achieving a 100 percent zero carbon electric supply by 2040 is feasible, and provides for greater flexibility in meeting long-term economy-wide GWSA goals for sectors, such as buildings and transportation, that have been slower to decarbonize to date. The modeling also highlights key contingencies that can affect compliance with GC3 pathway of a 66% zero carbon electric supply to meet the state's 2030 GWSA economy-wide emissions reduction target.

Key assumptions that DEEP used in running the simulation model are discussed first; then a description of the different scenarios tested in the model; and finally, a discussion of the modeling results. The purpose of the IRP pursuant to Connecticut General Statute Section 16a-3a is to assess the state's supply and demand needs in furtherance of GHG emissions reduction goals in a manner that minimizes costs and maximizes benefits. The modeling in this IRP included quantifiable benefits, with other benefits for resources discussed qualitatively. It is important to note that since the IRP modeling is generally based on what is known and knowable, not every potential benefit of each resource is included in the financial

[27] The projected EDC load uses ISO New England CELT data, net of municipal EDC load, for the year 2025, because that is the year when all current contracted resources are expected to be operational.

[28] In order to track compliance with the GWSA, electric sector emissions attributed to Connecticut are currently accounted for based on the regional New England emissions factor. However, because Connecticut has increased its purchases of zero carbon generation and is using those resources for the purposes of GWSA compliance, DEEP is in the process of aligning its GWSA electric sector accounting to reflect the state's investment in zero-carbon resources as progress towards meeting the GWSA mid-term target, as further discussed in Strategy 7.

modeling results, given that many benefits are dynamic in nature and/or either partially or fully dependent on grid technologies or rate offerings that are not yet available.

Zero Carbon Pathways Modeling Methodology

How much new generation or energy efficiency will be needed to support a 100 percent zero carbon electric supply by 2040, while maintaining a reliable power supply around the clock? How many of the region's existing power plants—especially fossil fuel-fired power plants—can be expected to shut down if Connecticut achieves this decarbonization target? How will these answers change in a "business-as-usual" reference scenario, if Connecticut does not adopt the 100% Zero Carbon Target? Or, if Connecticut meets its GWSA goals for decarbonizing the transportation and buildings sectors by shifting those sectors to electric vehicles, heating, and cooling; a shift that will increase the amount of electric demand? An economic model provides a way to estimate the answers to these questions, using a computer-generated simulation of the New England electric grid.

Setting the Regional Emissions Target

Connecticut shares an electric grid with the five other New England states: Rhode Island, Massachusetts, Maine, New Hampshire, and Vermont. The New England grid is a network of power plants, and transmission and distribution lines, operated by the Independent System Operator of New England (ISO-NE), that can deliver electricity generated at those plants to customers around the region. A small number of high-voltage transmission lines "tie" the New England grid into Canadian and New York power grids, allowing for imports and exports from those neighboring grids. Residential, commercial, and industrial consumers in Connecticut use approximately 28.8 million MWh of electricity each year, which comprises about 25 percent of the electricity consumption in New England.

Because Connecticut's grid is integrated with the rest of New England, meeting the 100% Zero Carbon Target in 2040 is not practically achievable independent of the other states in the region. For the purposes of the modeling in this IRP, DEEP developed a Regional Emissions Target for the region by (1) assuming that Connecticut's share of New England electricity consumption in 2040 would be met 100 percent by zero carbon sources, and (2) consulting with the other New England states and identifying specific assumptions for a zero-carbon or renewable target applicable to the share of electricity consumption for each state.

While the New England states share a regional carbon emissions cap under RGGI, some New England states have climate and clean energy policies that compliment and, in some cases, exceed the stringency of the RGGI cap. In this IRP, the model assumes a zero-carbon electric sector target by 2040 for Rhode Island, and the electric sector emissions reductions required in Massachusetts by regulation.[29] The other New England states were assumed to hold emissions constant from 2016 values, the last year consistently available in state emissions inventories at the time of modeling. Accordingly, the Regional Emissions Target met by the Zero Carbon Scenarios (see Figure 1.1, below) in 2040 is not 100 percent zero carbon.

[29] *See* 310 CMR 7.74. In general, this regulation requires Massachusetts to acquire 80% of its electricity sales from clean energy resources by 2050.

The Department acknowledges that climate policy throughout New England is constantly evolving and expects that the Regional Emissions Target will likely be more stringent in future iterations of the IRP.[30]

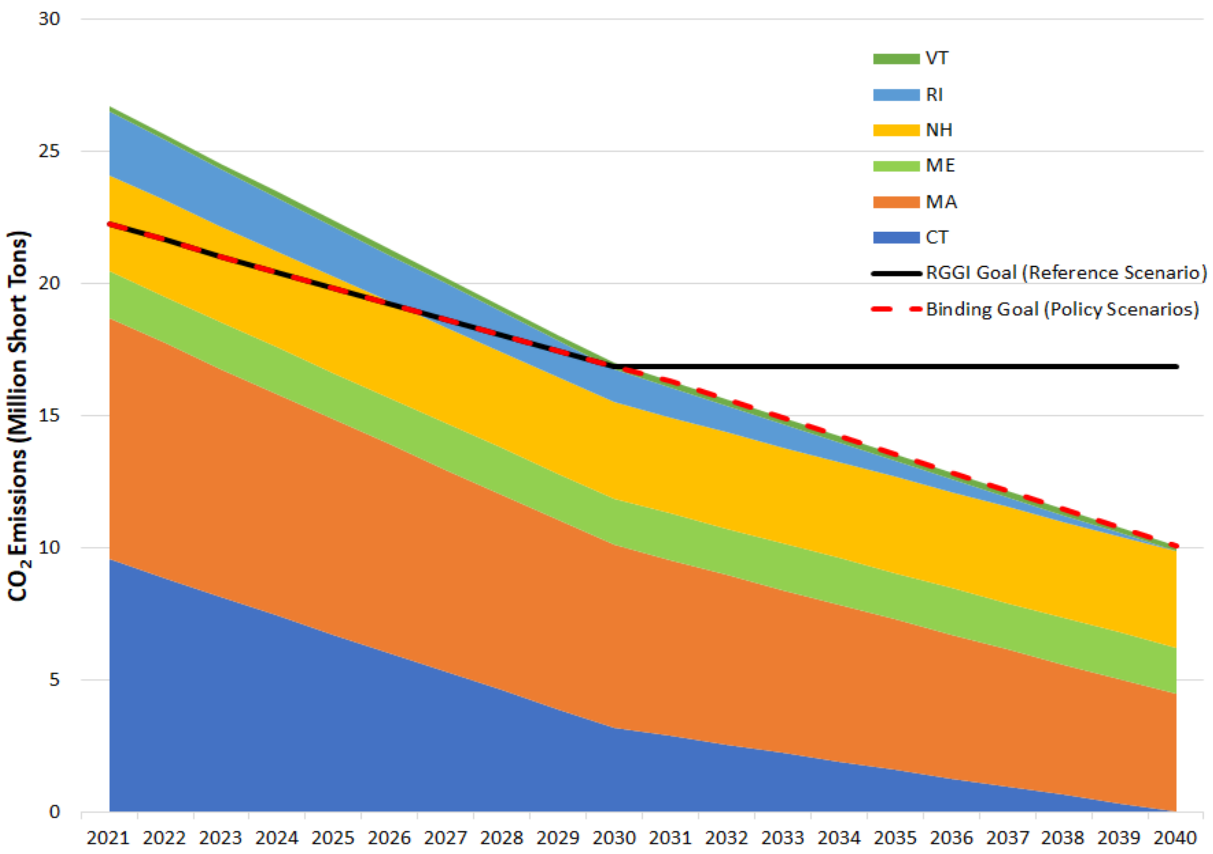
As previously stated, the six New England states have committed to a cap of 18.8 million tons of GHG emissions per year by 2030 (a 30 percent decline) through participation in RGGI, and that number was therefore used as the emissions constraint in the Reference scenario. The Regional Greenhouse Gas Initiative's cap is only set through 2030, and it is not yet clear how the cap level will change after 2030. Thus, for the Reference scenario, the model assumes that emissions in the New England electricity sector will be at the same level as the RGGI cap in 2030 and will stay at that level through 2040.

This IRP utilized economic optimization modeling software to estimate the quantities (MW and MWhs) of electricity supply resources that would likely retire or need to be added to the New England system each year under a variety of different scenarios to meet the Regional Emissions Target while maintaining adequate power supply to meet reliability requirements.[31] The scenarios, described in more detail below, evaluated different combinations of clean energy and efficiency resources that could be utilized to meet the Regional Emissions Target.

[30] DEEP finalized these assumptions in November of 2019, and notes that the policies of other states have likely changed since that time. This IRP does not endeavor to predict which strategies or policies other states might implement to mitigate climate change but rather seeks to model how Connecticut can meet a zero carbon electric sector target as a component of a regional grid. Future IRP iterations will reflect updated state policies as they are implemented.

[31] This IRP used Aurora's Long-Term Capacity Expansion economic optimization modeling software for each scenario. The aggregated GHG emissions targets were translated into MWh of clean energy for inclusion in Aurora's capacity expansion model.

Figure 1.1: Annual ISO-NE CO_2 Emissions Comparison, Base Load Scenarios



Additionally, the model was required to meet long-term resource adequacy (reliability) requirements. This means that, given current technology, the model retained some fossil generation to ensure that there are enough resources that can quickly produce power during periods of extreme peak demand in the region, or if a resource suddenly goes offline.

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The model also calculates the present value of all existing resources and determines which existing generators would be likely to shut down, or retire, based on differential costs and benefits through 2040. The model runs until it produces a balanced solution of new generating resource additions and retirements, taking into account electric system needs, including reliability, and ratepayer cost. Each time the model is run, it refines the set of new resource options and retirements it places into the system and tracks their economic performance based on anticipated market prices resulting from which resources are selected in the model run. Specifics about projected resource costs are included in Appendix A1. At the end of each run, the model decides how to adjust the current set of new builds and retirements until the model selects an optimal solution. Because Connecticut is part of the New England regional electricity market, forcing the model to retire all of Connecticut's in-state fossil generation would ultimately not achieve the outcomes desired by such a policy. The reality is that, under the current market structure, if Connecticut were to force the closure of all in-state fossil plants the result would likely be that more expensive, dirtier fossil plants in other states would fill in the gap, exporting their power to consumers in Connecticut. Thus, while emissions from plants located in Connecticut would go down, regional emissions would increase significantly, which is not a desirable outcome, particularly because climate change is a global problem. The Department has determined that the balance of interests supports allowing the model to retire the most uneconomic and dirtiest plants throughout New England towards meeting the aggregate emissions reductions goals of the New England states, including the 100% Zero Carbon Target assumed for Connecticut. This approach is currently consistent with that of policies developing in other states. As of July 2021, nearly all of the states with 100% zero or net-zero carbon electricity supply statutory goals focus their goals on the GHG emissions of electricity sold to ratepayers, not energy generated in the state.[32]

Elsewhere in this IRP, however, the Department identifies strategies for reducing emissions from in-state fossil generation, which contributes to air quality impacts that disproportionately harm many environmental justice communities. These include market reforms (discussed in Objective 2), placing a carbon tax on in-state generation (discussed in Objective 4), advancing technology in energy storage and hydrogen production (discussed in Objective 5), and continued refinement of modeling assumptions.

Determining What Counts towards Connecticut's 100% Zero Carbon Target

Another important assumption used in the modeling exercise is what types of resources "count" towards compliance with the 100% Zero Carbon Target. For the purpose of this IRP, DEEP took a multi-step approach—which can be described as a simplified consumption-based emissions accounting method—to determine what emissions should be "assigned" (i.e. credited to Connecticut) towards meeting the 100% Zero Carbon Target.[33]

First, the emissions profile from any zero carbon resources that have already been, or would need to be, procured by Connecticut under long-term contracts funded by Connecticut ratepayers to meet the 100% Zero Carbon Target are assigned to the State. This assignment is made even though any RECs associated with those contracts may be either retained or sold by the EDCs under current practice. Using this GHG consumption-based inventory for the electric sector, the IRP identified the percent of Connecticut's electricity consumption that will be carbon-free over the Reference scenario study period.

After the emission profiles from these contracted resources are assigned to Connecticut's load, the emissions from the remaining "unassigned" resources across the region are totaled, and the model assigns each state a share of those emissions proportional to the state's electricity consumption, or load. Connecticut's load share of those emissions from "unassigned" resources in the region is applied to the remaining load needed to be met in Connecticut. To account for the fossil fuel resources needed for reliability purposes in 2040, additional clean energy is brought online and attributed to Connecticut in the IRP modeling to meet the 100% Zero Carbon Target as required by EO3. It is important to note that the modeling selects specific types of resource additions (technologies) needed each year to maintain progress towards the Regional Emissions Goal based on reliability and projected cost optimization, as described above. The resulting assignments of these selected resources to Connecticut in each year should be interpreted as the quantity of zero carbon energy the State would need to procure based on those resource cost projections. Any procurements DEEP conducts for resources based on the findings of

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[32] The states referenced in this statement currently include Arizona, California, Hawaii, Maine, New Mexico, New York, Nevada, Oregon, Virginia, Vermont, and Washington.

[33] As defined in DEEP's *2017 Greenhouse Gas Emissions Inventory*, "a consumption-based approach calculates emissions based on Connecticut's share of electricity consumption in New England, using the emissions profile of the regional electric grid's generation fuel mix." https://portal.ct.gov/-/media/DEEP/climatechange/2017_GHG_Inventory/2017_GHG_Inventory.pdf

this IRP to meet the 100% Zero Carbon Target would open to all zero carbon Class I resources, consistent with past grid-scale procurements conducted by the State.

An overview of the modeling results for each scenario is presented below in this Objective, with more detailed modeling results included in Appendix A3.

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The Scenarios Tested in the Model

For the IRP, DEEP tested five scenarios, including a "business-as-usual" Reference scenario which meets the existing regional emissions reduction target established by RGGI, plus four scenarios which use different resource portfolios to meet the Regional Emissions Target (including the 100% Zero Carbon Target) by 2040. Each of the five scenarios is evaluated against two different forecasts of electricity consumption trends:

- in the "Base" case, electricity consumption continues on the existing trajectory based on current energy policies and primarily relies on the ISO-NE 2019 Capacity, Energy, Loads and Transmission (CELT) Forecast;[34]
- in the other "Electrification" case, the deployment of electric vehicles and building heating technology are assumed to triple by 2040, increasing electricity consumption by 18,800 GWh in 2040 relative to the base case.[35]

Additional information on the assumptions used to develop the load cases can be found in Appendix A1. In each of the scenarios, the model selects different quantities of zero-emission resources to meet the Regional Emissions Target, including the 100% Zero Carbon Target for Connecticut, with the goal of minimizing associated costs. The zero-emission resource types selected include:

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- offshore wind (OSW),
- land-based wind (LBW),
- grid-scale solar photovoltaics (PV),
- nuclear generation,
- hydroelectricity imported from Canada, and
- grid-scale battery storage.

The model also relied on some fossil-fueled generation and imports from New York and Canada over existing transmission tie lines to meet the reliability requirements of the region, without exceeding the applicable Regional Emissions Target for each scenario. The ten resulting scenarios are summarized by Table 1.1 below.

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[34] Each year, ISO New England prepares a projected forecast of the next 10 years' annual capacity, energy demand, loads, and transmission needs. This is used in power systems planning and reliability studies. These studies are all accessible at https://www.iso-ne.com/system-planning/system-plans-studies/celt/

[35] The purpose of the Electrification load case is to begin planning and modeling resource needs under a future with significantly higher forecasted electricity demand. The assumptions used to develop this load case are not policy recommendations but were influenced by policy recommendations from other statutory reports produced by DEEP. the Governor's Council on Climate Change, and regional efforts. Electrification assumptions were based on what was known and knowable at the time of modeling and are subject to change with continued planning, modeling, and research. Detailed discussion on these assumptions is available in Appendix A1.

Table 1.1: Composition of Study Scenarios

Gross Load Case	Resource Portfolio Scenario		Summary
Base	BR	Reference	Business-as-usual; assumes continuation of existing, "known and knowable" energy policies
	BB	Balanced Blend	Deploys least cost resources to meet the 100% Zero Carbon Target assuming Millstone retires
	BS	BTM Solar PV Emphasis	Assumes an increased amount of behind the meter (BTM) solar is deployed, then deploys least cost resources to meet the 100% Zero Carbon Target
	BM	Millstone Extension	Assumes Millstone continues operating beyond 2029 (the end of Connecticut's current contract) and then deploys least cost resources to meet the 100% Zero Carbon Target
	BT	No Transmission Constraint	Eliminates transmission constraints, then deploys least cost resources to meet the 100% Zero Carbon Target
Electrification	ER	Reference	Business-as-usual; assumes continuation of existing, "known and knowable" energy policies
	EB	Balanced Blend	Deploys least cost resources to meet the 100% Zero Carbon Target assuming Millstone retires
	ES	BTM Solar PV Emphasis	Assumes an increased amount of BTM solar is deployed, then deploys least cost resources to meet the 100% Zero Carbon Target
	EM	Millstone Extension	Assumes Millstone continues operating beyond 2029 (the end of Connecticut's current contract) and then deploys least cost resources to meet the 100% Zero Carbon Target
	ET	No Transmission Constraint	Eliminates transmission constraints, then deploys least cost resources to meet the 100% Zero Carbon Target

Modeling Assumptions

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Except where explicitly stated, the assumptions used in this IRP are based on what is currently known and knowable concerning factors such as technological advancements, energy and climate policy, ISO-New England market rules, etc. As the study horizon projects further out into the future, predictability declines, because of how rapidly technologies and policies change. Importantly, modeling assumptions provide a way to test the impact of different contingencies and circumstances on the state's energy supply objectives; the assumptions are not, in and of themselves, expressions of state policy or desired outcomes. All modeling assumptions are documented in detail in Appendix A1.

Millstone Extension Scenario

If an assumption was modified to test the sensitivity of that assumption, it is clearly stated. For example, all of the scenarios assume that the Millstone Nuclear Plant located in Waterford, Connecticut, retires when its current ratepayer-backed contract ends in 2029. A 2018 appraisal of nuclear power-generating facilities' financial circumstances found that Millstone was at risk of early retirement based on the generator's disclosed financial statements and insufficient expected market revenues.[36] In order to retain Millstone's efficient and reliable zero carbon energy, Connecticut has entered into a contract through 2029. For these reasons, the modeling assumes that Millstone will continue to be at-risk at the end of its contract and will retire in all scenarios except the Millstone Extension. In the Millstone Extension scenario, the model assumes that Connecticut's contract with Millstone extends beyond 2029. Again, this assumption does not indicate a policy expectation or intent for the state to continue the contract, but tests a hypothetical circumstance in which the nuclear facility continues to operate beyond 2029 (utilizing the current contractual mechanism in place to provide for that continued operation, and assuming there is no wholesale market reform as called for in Objective 2 below), and the consequences of that continued operation for the quantities of other zero carbon resources needed to reach the 100% Zero Carbon Target. The IRP discusses later, in Part II, the policy implications of these modeling insights.

Behind the Meter Solar PV Emphasis Scenario

Similarly, the BTM Solar PV Emphasis scenarios adjust the assumed level of rooftop solar that is deployed regionally. Eligible rooftops were used as a proxy to determine the increased BTM solar PV potential, leading more populated states, like Connecticut and Massachusetts, to have much higher growth levels relative to the Reference Scenarios.[37] The annual deployments are not linear, but average to be approximately double what is assumed in the Reference scenarios.

No Transmission Constraint Scenario

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Finally, the No Transmission Constraint scenarios begin with the same resource base as the Balanced Blend scenarios. The adjusted assumption is that constraints on energy transfer among New England zones are relaxed in Aurora. The result effectively turns New England into a "copper sheet" which would allow electricity to flow freely, and the modeling to assume that any transmission-based congestion between Regional System Plan (RSP) zones is eliminated over the IRP study horizon. It is important to note that this scenario does not attempt to predict or include the costs of such transmission upgrades but rather focuses on the improved efficiency of energy transmission around the region.[38] Further information on the assumptions used in this IRP for all scenarios is included in Appendix A1.

Reference Scenario

The Reference scenario for each load analyzes the "business-as-usual scenario," which assumes the New England states continue with the existing energy policies that were known and knowable to DEEP as of

[36] Connecticut PURA, PURA Docket No. 18-05-04, *PURA Implementation of June Special Session Public Act 17-3,* Interim Decision, December 5, 2018.

[37] As stated, the Reference scenarios relied on what is known and knowable and in the case of BTM solar PV, assumed deployment was based on ISO-NE's 2019 CELT report.

[38] DEEP notes that transmission technology is rapidly changing and costs are challenging to predict. The Department will be monitoring these developments in the New England Vision proceedings described in [XXX] and in DEEP's other transmission planning steps.

January 1, 2020, and meets the RGGI cap for all years across the region. Figures 1.2 and 1.3 below show regional generation by resource type under this business-as-usual scenario for the base and electrification loads, both of which assume load increases over the modeling horizon.

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Under the Reference scenario, the region continues to rely on existing and currently scheduled dispatchable fossil capacity, primarily natural gas, and imports from neighboring regions over existing transmission ties, like New York, to maintain resource adequacy, as demonstrated by Figure 1.2 below. As described in Appendix A1, energy efficiency and behind the meter (BTM) solar PV are included as load reducers and therefore are not displayed in Figures 1.2 and 1.3. Biomass and WTE resources also (contained in the "Other" category) continue to operate absent alternative waste management policies in the states. New England-based hydroelectricity ("Hydro") continues to provide a steady amount of zero-carbon generation, though siting requirements limit any increases in generation. As the number of annual RGGI emissions allowances decreases in the first half of the modeling period (as shown in Figure 1.1 above), renewable generation from zero-carbon resources like land-based wind, offshore wind, and grid-scale solar increase under both loads. Notably, when Millstone is assumed to retire at the expiration of its current contract in 2029, the region will need to fill the zero carbon electricity demand left behind, which the Reference scenario achieves primarily through an additional high voltage direct current cable (HVDC) line importing more hydroelectricity from Canada.[39] Additional grid-scale solar, LBW, and OSW generation also help fill the gap after 2029 to maintain the RGGI target emissions levels, and are balanced by dispatchable, fossil generation to continue maintaining reliability. It should be noted that the model did not allow for any new dispatchable, fossil generation additions over the modeling period.

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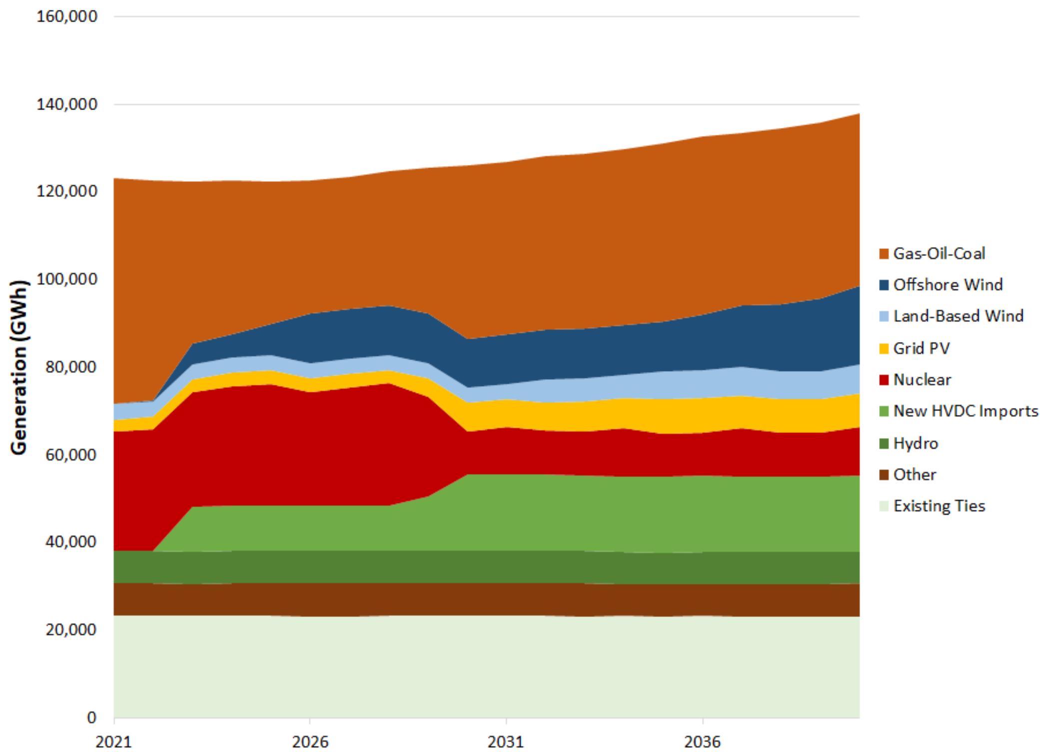
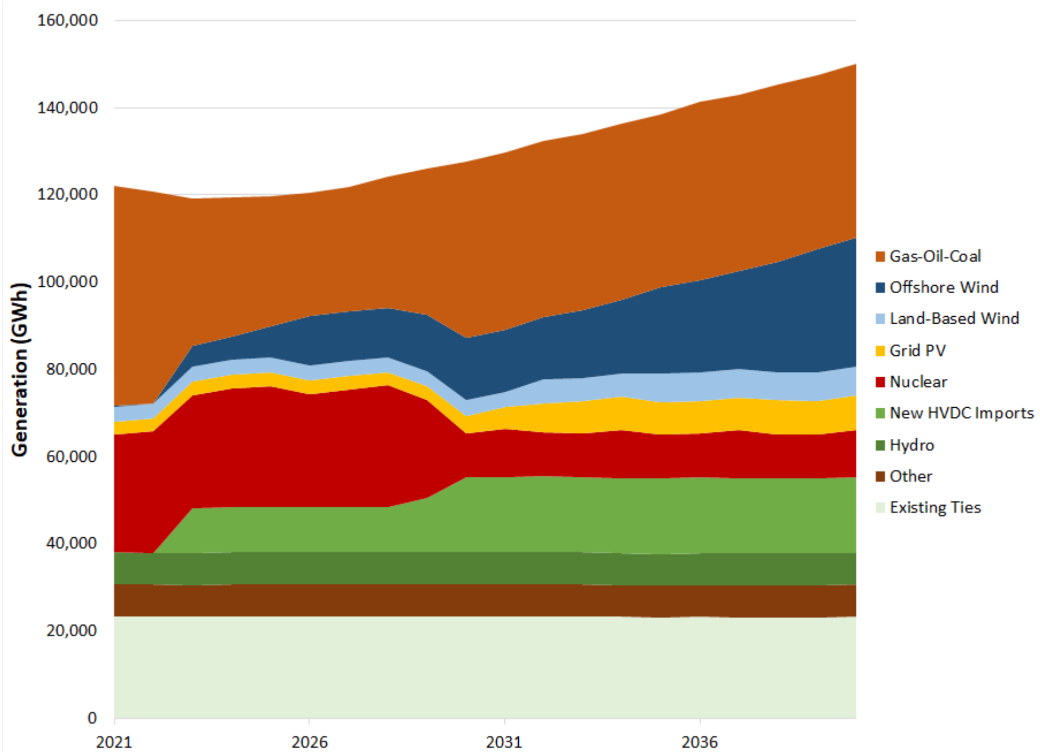
[39] The assumption in this IRP that Millstone would retire in 2029 absent a contract extension is based on the Resource Assessment and Appraisal conducted to satisfy the requirements of Executive Order No. 59 (July 25, 2017) and June Special Session Public Act 17-3, which found that "Millstone Station's profitability is highly correlated with the cost assumptions highlighted in Dominion's and others' comments, and that, when some adjustments are made, the financial viability of Millstone's continued operation could be at risk." *available at* http://www.dpuc.state.ct.us/dockcurr.nsf/8e6fc37a54110e3e852576190052b64d/a2d566dfd5533fed8525822700725e33/$FILE/DEEP-PURA%20FINAL%20Report%20and%20Determination%202-1-18.pdf

Figure 1.2: Annual Regional Generation, Base Load Reference Scenario[40]



[40] The "Other" category aggregates many different technologies. The majority of "other" is wood waste and municipal solid waste units.

Figure 1.3: Annual Regional Generation, Electrification Load Reference Scenario



Under this business-as-usual scenario, in addition to relying upon a new HVDC line to import power from Canada, Connecticut would need to procure new resources to come online in 2029 in order to meet the RGGI goals. Using a least-cost deployment strategy employed by the model, these procurements would begin with grid-scale solar balanced by storage, then land-based wind in 2032 and offshore wind in 2036.[41] See Figures 1.4 and 1.5 below. While all capacity additions are limited to zero carbon resources, it is important to note that even under a business-as-usual future, these resources could face siting challenges in the forms of environmental conservation and land-use restrictions, public opposition (i.e. the recent conflict around the New England Clean Energy Connect (NECEC) transmission line planned to bring approximately 1 GW of hydroelectricity from Canada, through Maine, down to Massachusetts), and industry opposition. Careful planning with lead times sufficient to consider stakeholder input and public education can help hedge against the risk of delays or prevention of buildouts, as discussed in Objective 4.

[41] For a more detailed explanation of Aurora's economic optimization modeling functionality, see Appendix A1.

Figure 1.4: Incremental Resource Capacity Allocation to Connecticut, Base Load Reference Scenario

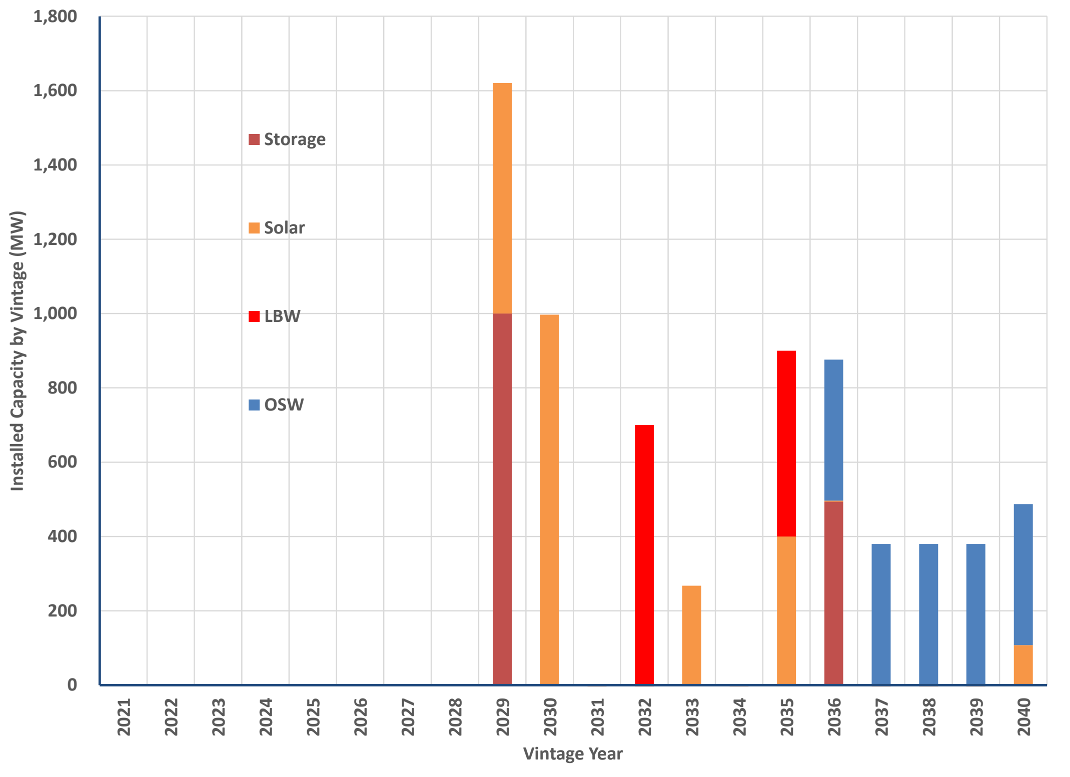
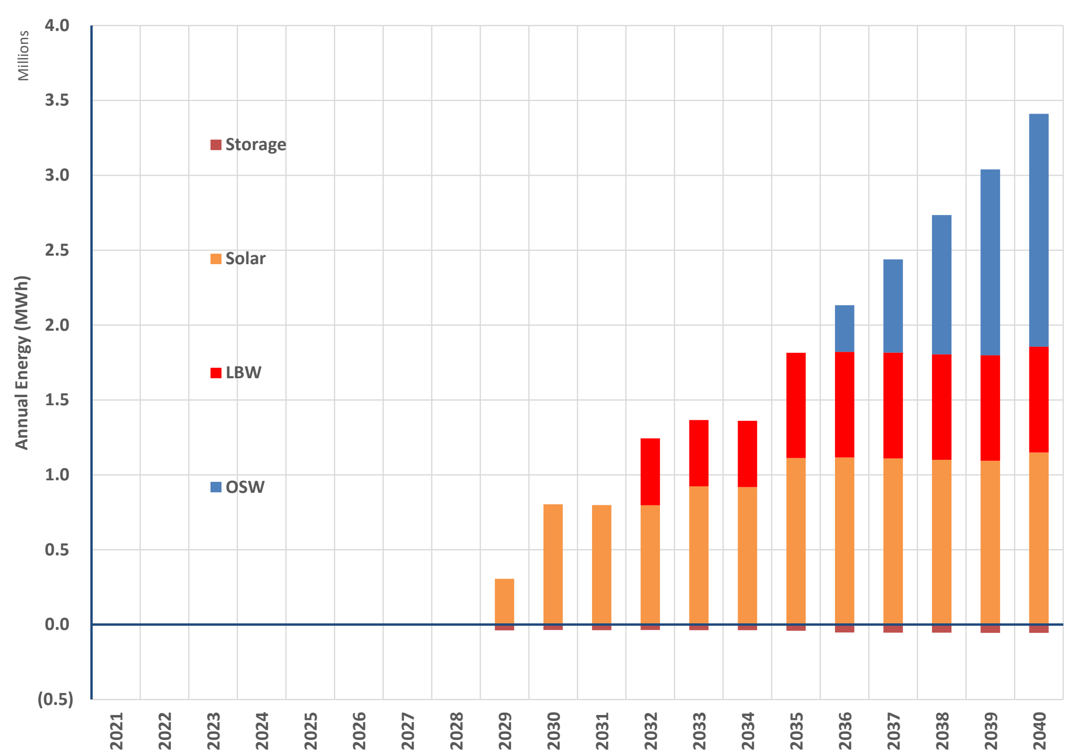


Figure 1.5: Incremental Resource Energy Allocation to Connecticut, Base Load Reference Scenario



Zero Carbon Policy Scenarios Results

Aside from the Reference scenario, all of the scenarios considered in this IRP are considered Zero Carbon Policy scenarios. The Zero Carbon Policy scenarios represent various pathways towards meeting the region's aspirational emissions reduction goal for Connecticut's electric supply. This means that the overall 2040 emissions cap in these scenarios reflects the combined emissions targets from the six New England states. This cap is roughly equal to 10 million short tons in 2040, as previously shown in Figure 1.1. The aggregated GHG emissions targets were translated into MWh of clean energy for inclusion in the model's capacity expansion modeling. Because not all states have zero carbon electric supply goals as Connecticut does, the model allowed some emitting resources to continue to operate over the modeling horizon.

The objective of the Zero Carbon Policy scenarios was to maintain reliability and meet the necessary Regional Emissions Target in each year while minimizing the overall costs of achieving those goals. The allocation of zero carbon resources in each year works backwards from 2040 to ensure that the Regional Emissions Target is met. Because the model selects resources to meet the Regional Emissions Target, allocations of resources specifically to Connecticut were determined after the model selected resources for the scenario.[42] None of these scenarios were selected to represent a preferred policy path to meet the 2040 target—but rather to test the impact of various contingencies and circumstances (such as the retirement of Millstone, or procurement of transmission or larger amounts of behind-the-meter solar) on the quantity of different types resources that could be needed, and associated cost, to meet the goal.

Key Findings

The Zero Carbon Policy scenarios demonstrate that the 100% Zero Carbon Target for Connecticut's electric supply is achievable by 2040 under many different conditions and pathways, and that the State is already well on its way to achieving this goal thanks to existing clean energy procurements and energy efficiency investments. As noted above, through existing investments, approximately 65 percent of Connecticut's electricity supply is currently generated by zero carbon resources such as wind, solar, and nuclear. Broadly speaking, each scenario shows similar trends under the two different load levels, with the exceptions that the Electrification Load scenarios will generally require: (1) larger quantities of new clean energy resources (offshore wind in particular) to meet the higher load and avoid emissions, and (2) fewer retirements of existing fossil facilities (mostly natural gas) that can provide energy immediately during periods of low renewable generation or especially high demand. Importantly, as the economics of batteries and other forms of storage improve, they will be able to take on more of this role.

> *The Zero Carbon Policy scenarios demonstrate that the 100% Zero Carbon Target for Connecticut's electric supply is achievable by 2040 under many different conditions and pathways, and that the State is already well on its way to achieving this goal thanks to existing clean energy procurements and energy efficiency investments.*

Each pathway (i.e. scenario) highlights certain tradeoffs that Connecticut will need to carefully weigh in order to balance achieving the 100% Zero Carbon Target for electric supply with the State's other energy

[42] Further discussion of resource allocation ratios can be found in Appendix A4.

and environmental policies. For example, the Balanced Blend scenarios select the lowest cost portfolio of clean energy resources needed to achieve the 100% Zero Carbon Target, assuming that Millstone retires in 2029. Notably, this scenario provides for a progressive pace of new renewable builds to meet the 2040 target—highlighting the importance to moderate rate impacts for Connecticut ratepayers—but does exhibit a dip in emission reductions in the early- to mid-2030s, below the 66 percent zero carbon electric sector planning target modeled by the GC3 in 2018. Earlier procurements of renewables would be needed to avoid this temporary dip, in the event a Millstone retirement becomes likely.

Comparatively, the Millstone Extension scenarios demonstrate that if Millstone continues to operate through 2040, this will (1) reduce the total cost of meeting the 100% Zero Carbon Target by offsetting the need for new incremental resources, (2) allow Connecticut to meet emissions reductions targets in all of the modeled years through its continued generation of zero carbon electricity, and (3) allow more fossil units to retire throughout the region than under the Balanced Blend. This scenario assumes, however, that Connecticut continues to rely on nuclear energy to meet about half of its zero carbon energy policy targets.[43] Establishing a regional mechanism for valuing the reliability and zero carbon aspects of Millstone's electricity generation is one alternative to provide for the continued operation of this resource beyond 2029; in that event, the share of nuclear energy contributing to the 100% Zero Carbon Target would decrease, and additional investment in renewables would be needed to achieve that target.

This IRP also considers how increased deployment of distributed generation resources throughout the region, specifically behind-the-meter (BTM) solar PV, would affect a least-cost portfolio of resources needed to meet the 100% Zero Carbon Target. These scenarios follow a path similar to the Balanced Blend, meeting the 100% Zero Carbon Target by 2040, but falling short in the interim years due to Millstone's retirement. The key difference is that the overall cost of the resource portfolio is higher because BTM solar PV is a more expensive technology on a cost-per-unit basis than other zero carbon resources. Additional BTM solar PV avoids the need for some OSW development in the later years, but not enough to offset the higher costs of the BTM solar PV technology.

Finally, all scenarios indicate escalating levels of curtailment as the amount of intermittent renewable capacity increases. Variable energy resources (VERs) like offshore wind turbines or solar panels cannot be turned off or on (i.e., dispatched) like traditional capacity. If the sun is shining, and the wind is blowing, they are generating power; otherwise, they are not. The New England grid can only distribute so much capacity at once, so if there is more energy being produced than can be used because the system cannot move the power to the load—absent investment in additional transmission, or energy storage--some energy must be curtailed, or "spilled." Spilled energy reduces the revenue a resource receives from the energy market, and therefore increases the costs that the resource must recover through alternative mechanisms, such as state-jurisdictional procurements.[44] These insights highlight the importance of low- or no-emission strategies to reduce spillage and reliably integrate intermittent renewables, through the use of demand response, energy storage, and transmission investment.

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[43] Note that this scenario assumes that, due to the flawed regional energy markets, Connecticut alone will continue to support a resource that provides critical reliability to the region.

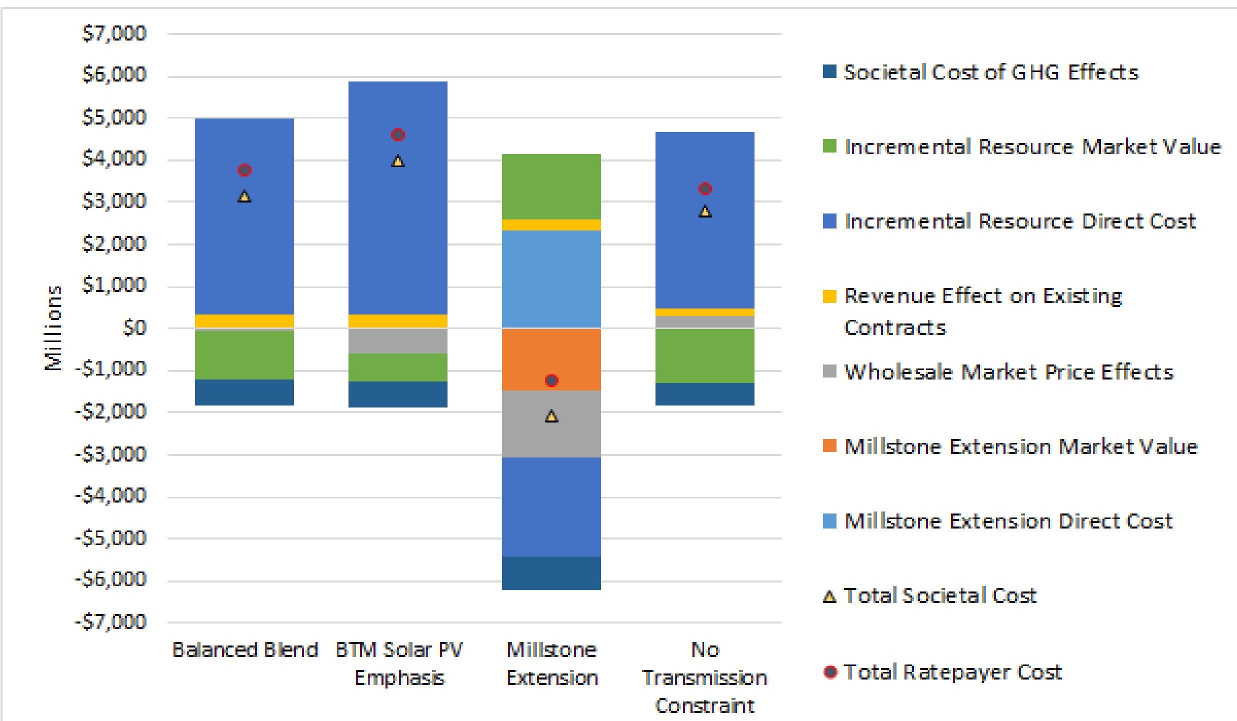
[44] ISO New England, *2019 Economic Study: Offshore Wind Integration*, June 30, 2020.

As an example, the No Transmission Constraint scenarios (Transmission scenarios) test how much renewable "spillage" could be avoided through upgrades to the transmission system to handle the increased power production during certain hours, avoiding wasted energy while still meeting the 2040 Emissions Reduction Target. The scenarios found that while elimination is not fully possible due to weather-based variables, reducing transmission constraints could significantly reduce costs to ratepayers by avoiding the need to build additional clean energy resources.[45]

The specifics of each Zero Carbon Policy scenario are further discussed below. Costs in the "Key Findings'' boxes (provided for each scenario and load pairing) are presented as the net present values over the study period (2021-2040) in each scenario compared to the Reference scenario, calculated using a seven percent nominal discount rate. The composition of each scenario's present value costs is shown in Figures 1.6 and 1.7 below, relative to each load level's Reference scenario (i.e. the Reference scenario is the baseline). "Total Ratepayer Cost", identified by the red and grey circles, are inclusive of all costs and benefits except for "Societal Cost of GHG Effects" (i.e. avoided costs of GHG effects). "Total Societal Cost", identified by the yellow and black triangles, include "Societal Cost of GHG Effects" and therefore demonstrate a lower net present value cost for each scenario. These amounts reflect the total cost above the market cost of a future that does not endeavor to meet the carbon target. Additional information on each cost component can be found in Appendix A4.

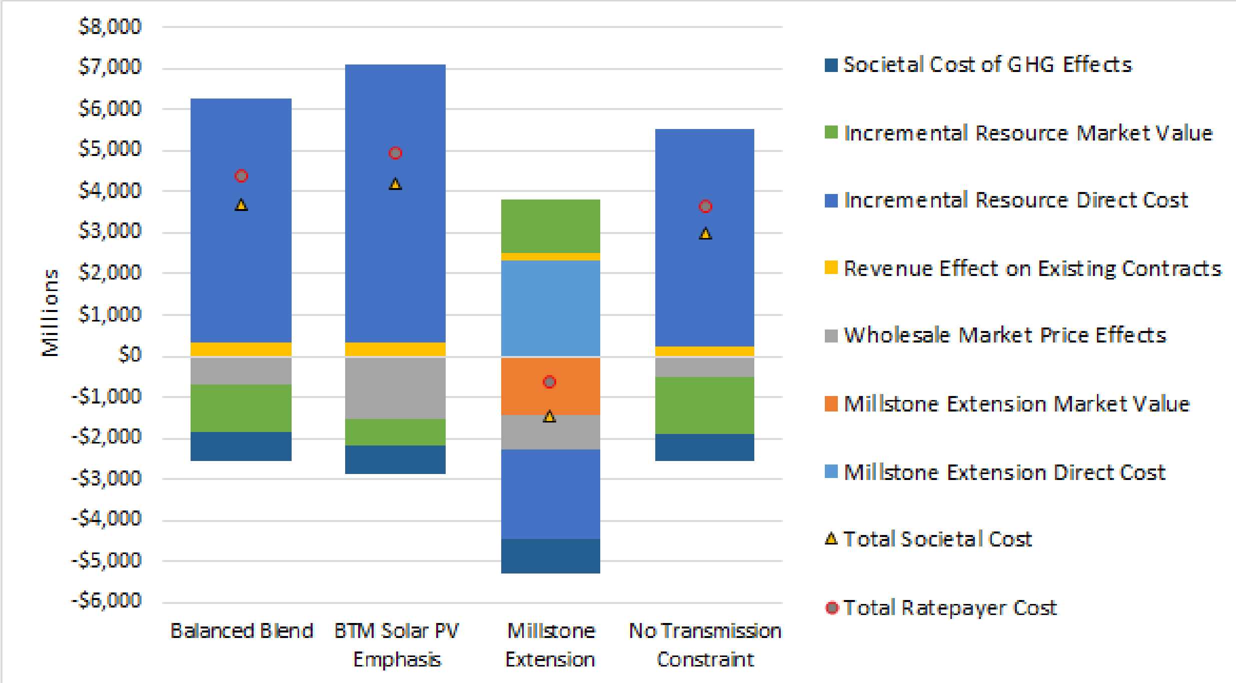
APPENDIX A4

Figure 1.6: Base Load Scenarios Present Value Costs Relative to the Reference Scenario



[45] As noted above in this section, the costs of eliminating transmission constraints were not modeled in this scenario.

Figure 1.7: Electrification Load Scenarios Present Value Costs Relative to the Reference Scenario



Balanced Blend Scenarios

The Balanced Blend scenarios select the lowest cost portfolio of resources needed to meet the Regional Emissions Target, inclusive of a 100% Zero Carbon Target for Connecticut's electric supply, and assumes that Millstone Nuclear Power Station (Millstone) retires in 2029 at the end of the existing Connecticut contract period.

Base Load Balanced Blend (BB) Scenario

When modeled under the Base Load, New England will need to install approximately 30 GW of clean energy resources in order to meet the Regional Emissions Target. Connecticut alone will need to procure approximately 8.5 GW of these additions in order to meet the 100% Zero Carbon Target. The majority of both regional and Connecticut additions under this scenario are offshore wind and grid scale solar.[46]

Key Findings: Base Load Balanced Blend

- Present Value Total Societal Cost: $3.15 B
- Present Value Total Ratepayer Cost: $3.76 B
- 2040 zero carbon goal will be met, though some interim years fall short.
- 8.5 GW Connecticut clean energy procurements by 2040
- 10.2 GW regional fossil fuel retirements by 2040
- CT wholesale energy price decreases ~25% by 2040 due to transition from high variable cost resources to high fixed cost resources
- Weather effects, seasonal demand, and transmission constraints will result in the loss of 6.8% of wind and grid-scale solar generation.

[46] As previously stated, the modeling optimizes resource selections to minimize costs and maintain resource adequacy. Modeled procurement schedules (e.g. Table 1.2) in each scenario present the necessary quantities of clean energy capacity Connecticut would need under the set of assumptions used for that scenario. In reality, procurements conducted by the State would be open to all eligible zero carbon Class I resources.

The Base Load Balanced Blend scenario successfully meets the 100% Zero Carbon Target for electric supply, as shown by Figure 1.8, which displays the metric tons of CO_2-equivalent that must be displaced each year over the study horizon (brown line), and the composition of resources that will meet each year's CO_2-equivalent emission target. The amount of CO_2 that must be displaced each year follows a simple, linear path until the kink in the brown line ("Resources Required for Compliance") at 2030, which represents the interim electric sector emissions reduction target estimated by the GC3.[47] A new linear path continues from that point until the 2040 100% Zero Carbon Target amount of CO_2-equivalent necessary to achieve a zero carbon electric supply. Details on the key to Figure 1.8 include:

1. *Connecticut (CT) Existing Contracts*: fixed amounts of zero carbon energy from existing contracts, including the Millstone contract and existing grid-scale solar and wind procured through DEEP's grid-scale procurements
2. *CT BTM Solar*: Connecticut's portion of BTM Solar PV
3. *HQ Imports*: amount of hydropower assumed to come online through an additional import line
4. *Current Vintage Allocations to CT*: the amount of new resources allocated to Connecticut in that given year to meet the 100% Zero Carbon Target. A breakdown of the cumulative resources needed for each year is included in Table 1.2.
5. *Prior Vintage Allocations to CT*: the cumulative amount of resources brought online to meet the 100% Zero Carbon Target allocated to Connecticut in previous years
6. *Current Vintage Allocations to Rest of Pool*: the amount of new resources allocated to other states in the region

APPENDIX A3

The blue line (Gross CT Load) shows Connecticut's gross energy load, which tightens against the brown line as it approaches the 2040 goal year, demonstrating how the proportion of Connecticut's gross load from clean energy grows each year. Table 1.2 identifies the annual incremental procurement schedule of various zero carbon generation resource types that Connecticut would need to achieve the goal under this scenario. Annual clean energy generation amounts corresponding to Figure 1.8 can be found in Appendix A3.

[47] Governor's Council on Climate Change, *Building a Low Carbon Future for Connecticut: Achieving a 45% Reduction by 2030,* 2018. *available at*: https://portal.ct.gov/-/media/DEEP/climatechange/publications/BuildingaLowCarbonFutureforCTGC3Recommendationspdf.pdf

Figure 1.8: Connecticut Incremental Resource Allocation, Base Load Balanced Blend Scenario

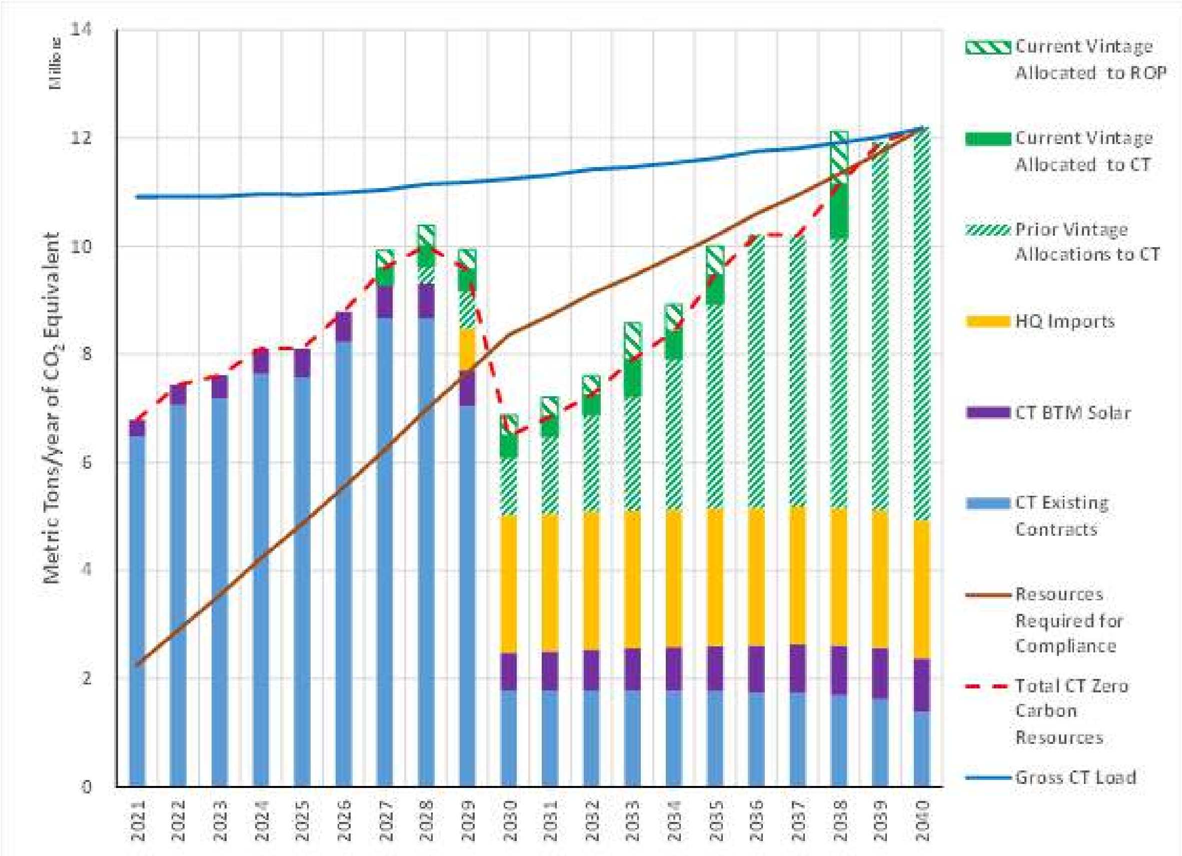


Table 1.2: Cumulative Incremental Resource Capacity, Base Load Balanced Blend Scenario

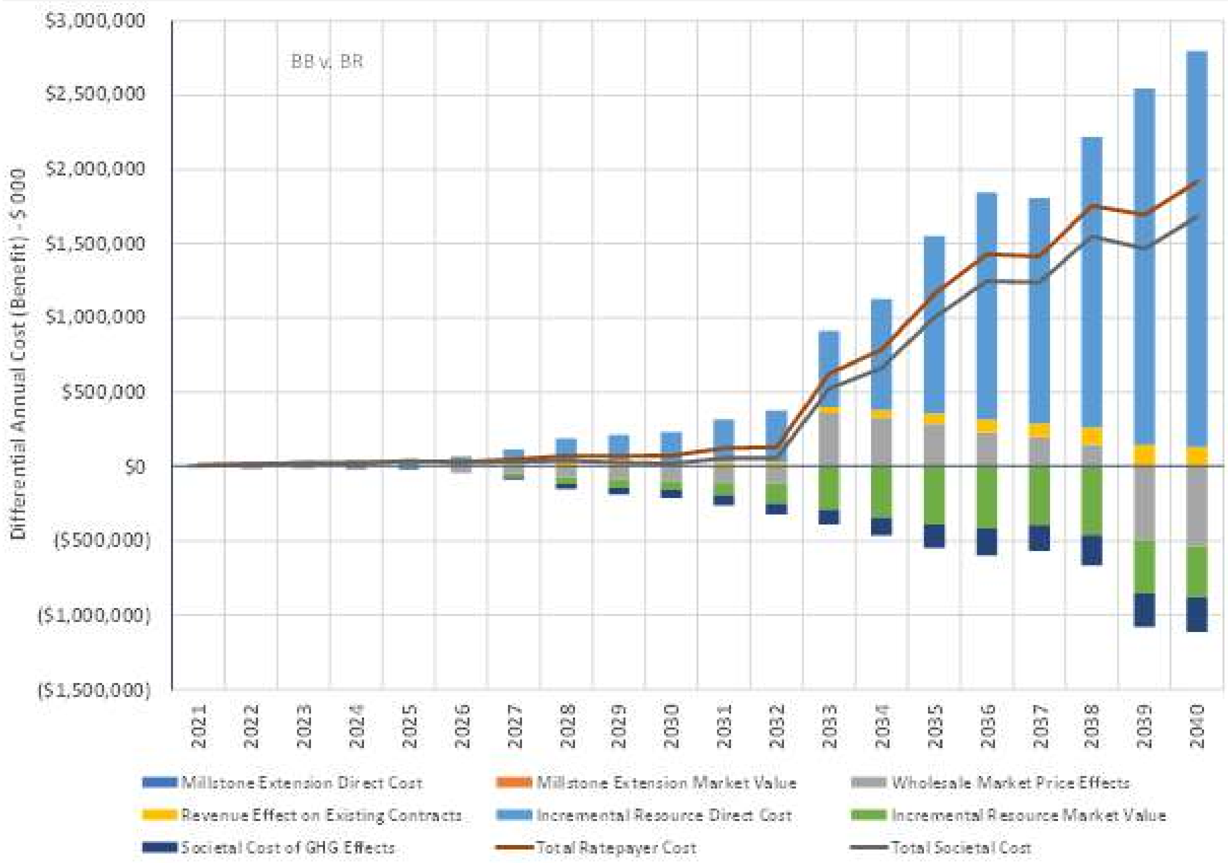
Calendar Year	Cumulative Incremental Resource Allocation CT Storage (MW)	CT Solar (MW)	CT LBW (MW)	CT OSW (MW)
2021	0	0	0	0
2022	0	0	0	0
2023	0	0	0	0
2024	0	0	0	0
2025	0	0	0	0
2026	0	0	0	0
2027	0	432	0	0
2028	0	933	0	0
2029	0	1,432	0	0
2030	0	1,928	0	0
2031	121	2,421	0	0
2032	372	2,912	0	0
2033	372	3,401	352	0
2034	372	3,384	352	388
2035	372	3,399	352	1,165
2036	372	3,382	352	1,745
2037	373	3,365	352	1,745
2038	542	3,348	352	2,545
2039	588	3,332	352	3,344
2040	1,060	3,316	352	3,745

Under the Base Load Balanced Blend scenario, Connecticut exceeds the annual goal in the first half of the study period, satisfied by Connecticut's existing clean energy contracts, including the continued operation of Millstone. New clean energy resources begin to appear in 2027 and scale up through the mid-2030s to replace the Millstone capacity. Connecticut falls short of meeting the 2030 goal for the electric sector identified by the GC3 in 2018. This does not necessarily mean that the state would fall short of meeting the GWSA economy-wide target for 2030, but doing so would require greater emissions reductions to be achieved in the transportation and buildings sectors. The state does meet the 2040 zero carbon electric goal under this scenario.

APPENDIX A4

The annual costs of meeting the Base Load Balanced Blend scenario over business as usual (i.e. the Reference scenario) are outlined in Figure 1.9; in other words, the cost of meeting the Reference case is the baseline in Figure 1.9. If Connecticut procured zero carbon resources at a quicker pace than demonstrated in Table 1.2 to achieve the 2030 GC3 goal, then the costs would be higher than what is presented in Figure 1.9. A full discussion of each cost category can be found in Appendix A4.

Figure 1.9: Differential Annual Costs – Base Load Balanced Blend Scenario v. Base Load Reference Scenario



As illustrated by Table 1.2, under the Base Load Balanced Blend scenario, 2027 is the first year that Connecticut would need to have new zero-carbon resources ready to operate. Figure 1.9 demonstrates how the net cost increases as new resources are brought online. The increases are partially offset by the societal avoided cost (Societal Cost of GHG Effects) associated with a reduction in CO_2 emissions, and the value of energy and capacity revenues associated with zero carbon resources (Incremental Resource Market Value). The projected net cost to Connecticut ratepayers to purchase incremental resources needed to achieve the 100% Zero Carbon Target over the study period under the Base Balanced Blend scenario is $3.8 billion. This amount will be reduced by an estimated $600 million if the societal cost of carbon is included for a net societal cost of $3.2 billion. It is also important to note that this cost does not include the full cost of demand side programs implemented in the Balanced Blend scenarios. The scenarios under the Base load do not include consideration of demand side management (DSM) programs beyond business-as-usual. The net cost to ratepayers could be lowered with additional investment in DSM programs. It is clear that there is significant potential for additional DSM in Connecticut, which is further discussed in Objective 5.

Electrification Load Balanced Blend (EB) Scenario

Under the Electrification Load scenarios, Connecticut will need to procure more clean energy resources in order to meet both increased load and the 100% Zero Carbon Target. Like the Base Load Balanced Blend scenario, the Electrification Load Balanced Blend scenario relies primarily on the large-scale deployment of offshore wind and grid-scale solar resources, though OSW deployment for Connecticut increases by 50 percent over the Base Load Balanced Blend, shown by Table 1.3.

Key Findings: Electrification Load Balanced Blend

- Present Value Total Societal Cost: $3.7 B
- Present Value Total Ratepayer Cost: $4.4 B
- 2040 zero carbon goal will be met, though some interim years fall short.
- 10.9 GW Connecticut clean energy procurements by 2040
- 7 GW regional fossil fuel retirements by 2040
- CT wholesale energy price decreases ~26% by 2040 due to transition from high variable cost resources to high fixed cost resources
- Weather effects, seasonal demand, and transmission constraints, will result in the loss of 11.6% of wind and grid-scale solar generation.

An additional and critical difference between the two load cases is that the Electrification Load Balanced Blend scenario retires fewer fossil resources across the region. The deployment of significantly more VERs to meet both the higher energy demand and carbon targets in the Electrification Load scenarios means that energy production is less stable and reliable than business-as-usual. The modeling used "known-and-knowable", industry-accepted assumptions around wind and solar production over the study horizon, but these assumptions come with some uncertainty, particularly in the mid- and long-term.[48] The Department anticipates advancements with technologies like battery storage and renewable hydrogen could help balance variable zero carbon resources and better achieve the 100% Zero Carbon Target and will continue to assess the advancement of these technologies in future IRPs.

APPENDIX A3

New England's regional independent system operator, ISO-NE, maintains standards for reliability, which require a specific amount of resources, called reserves, that can quickly turn off and on to meet demand during particularly high peaks, or when a generator shuts down unexpectedly.[49] Higher load results in a higher peak, and therefore means a higher reserve requirement. Additionally, in this IRP, meeting the carbon constraints under the Electrification load requires more renewable VERs, as discussed above. These resources have a more variable output, often heavily influenced by weather conditions, and must therefore be balanced with operating reserves. While some of these reserves can be met with demand response (DR), hydropower, and battery storage, the majority will be met with fossil resources because these fuel types can be readily and continuously dispatched to meet demand, unlike VERs such as wind and grid-scale solar. Figures 1.10 and 1.11 show how the modeling meets these reserve needs under the Base and Electrification load cases. Despite having fewer fossil plants retire, the Electrification Load Balanced Blend scenario does meet a slightly larger portion of the reserve requirement with non-fossil resources than the Base Load Balanced Blend,

[48] More information on the assumptions used in modeling resource generation can be found in Appendices A2 & A3.

[49] More information on ISO New England Operating Reserve Requirements can be found in Appendix A1.

particularly driven by increased battery storage additions. Further details on these reserve resources can be found in Appendix A3.

Figure 1.10: Operating Reserve Mix by Scenario in 2040, Base Load Case

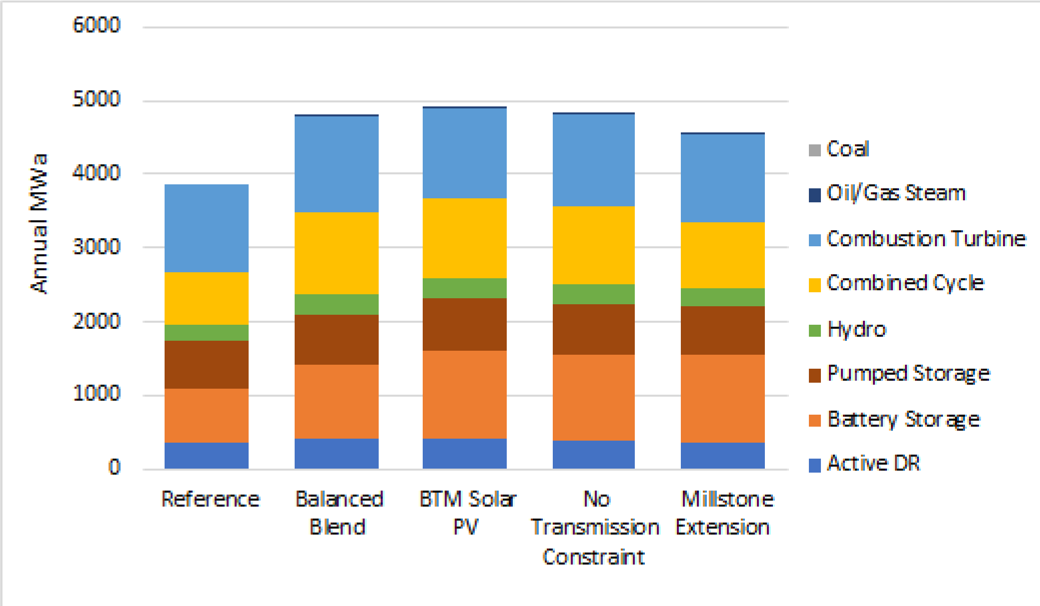


Figure 1.11: Operating Reserve Mix by Scenario in 2040, Electrification Load Case

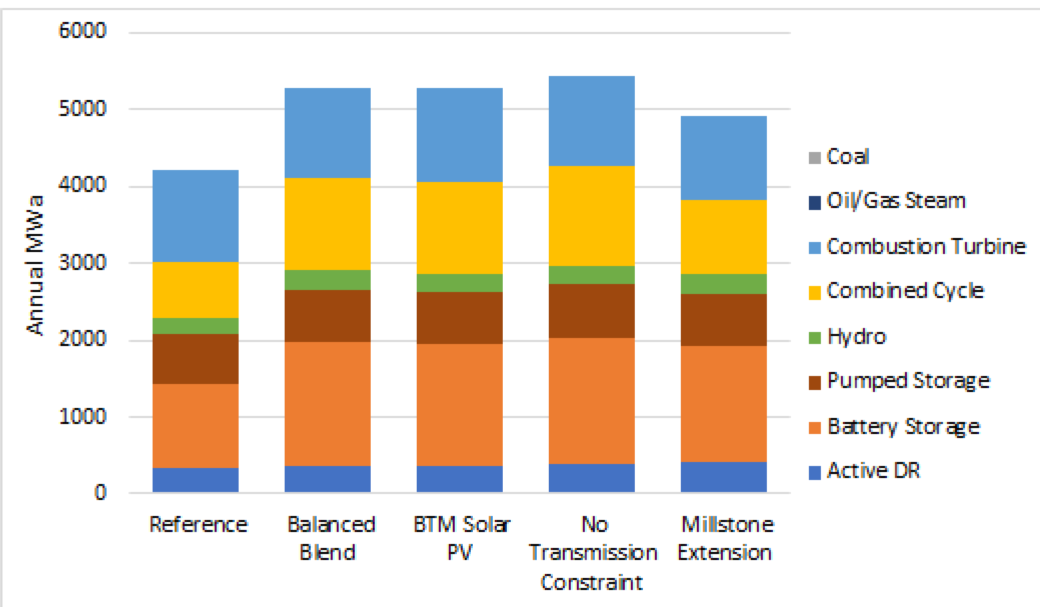


Figure 1.12 shows how the 100% Zero Carbon Target for Connecticut's electric supply will be met under the Electrification Load Balanced Blend scenario. Similar to the Base Load Balanced Blend scenario, Connecticut meets the annual targets through the assumed retirement date of Millstone in 2029, then misses annual targets after 2030 before ultimately meeting the 100% Zero Carbon Target in 2040. As in the Base Load Balanced Blend, Connecticut would need an accelerated procurement schedule in order to

also meet the GC3 2030 66% pathway. Cumulative resources allocated to Connecticut each year are included in Table 1.3.

Figure 1.12: Connecticut Incremental Resource Allocations, Electrification Load Balanced Blend Scenario

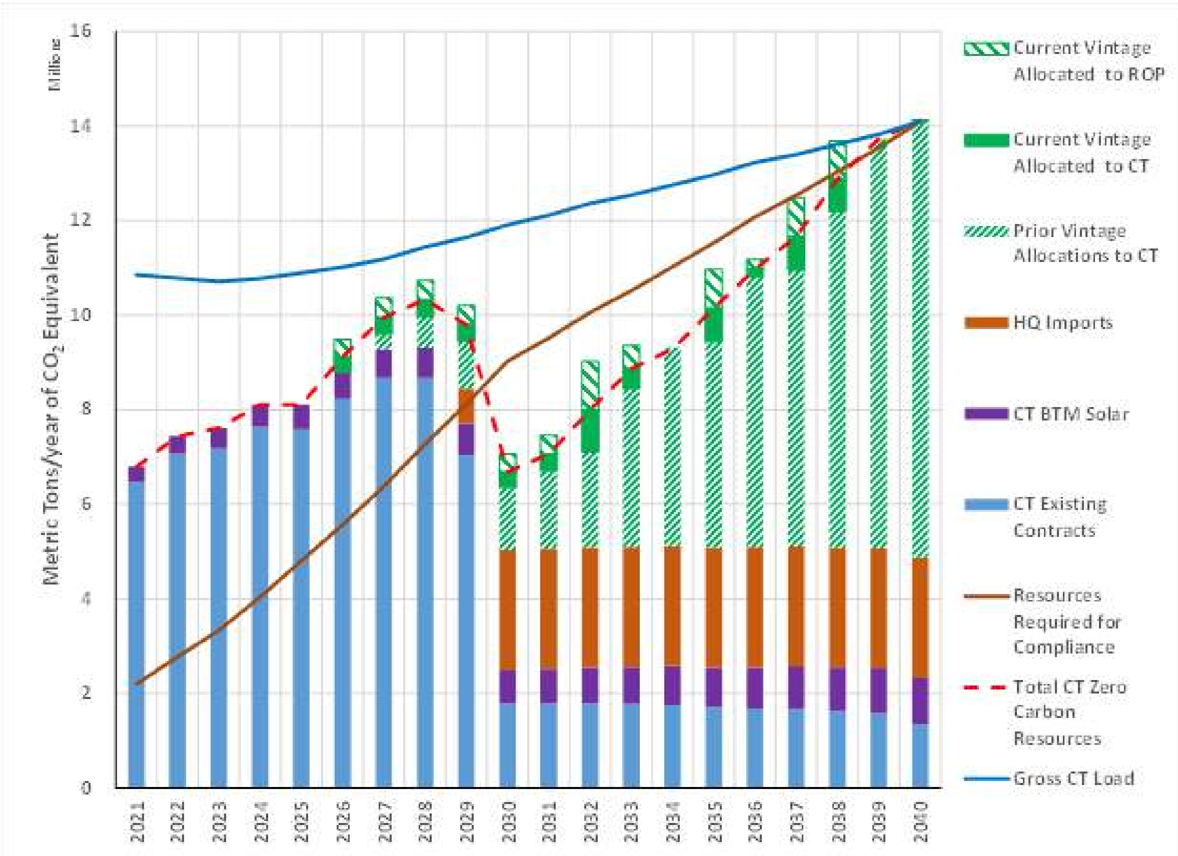
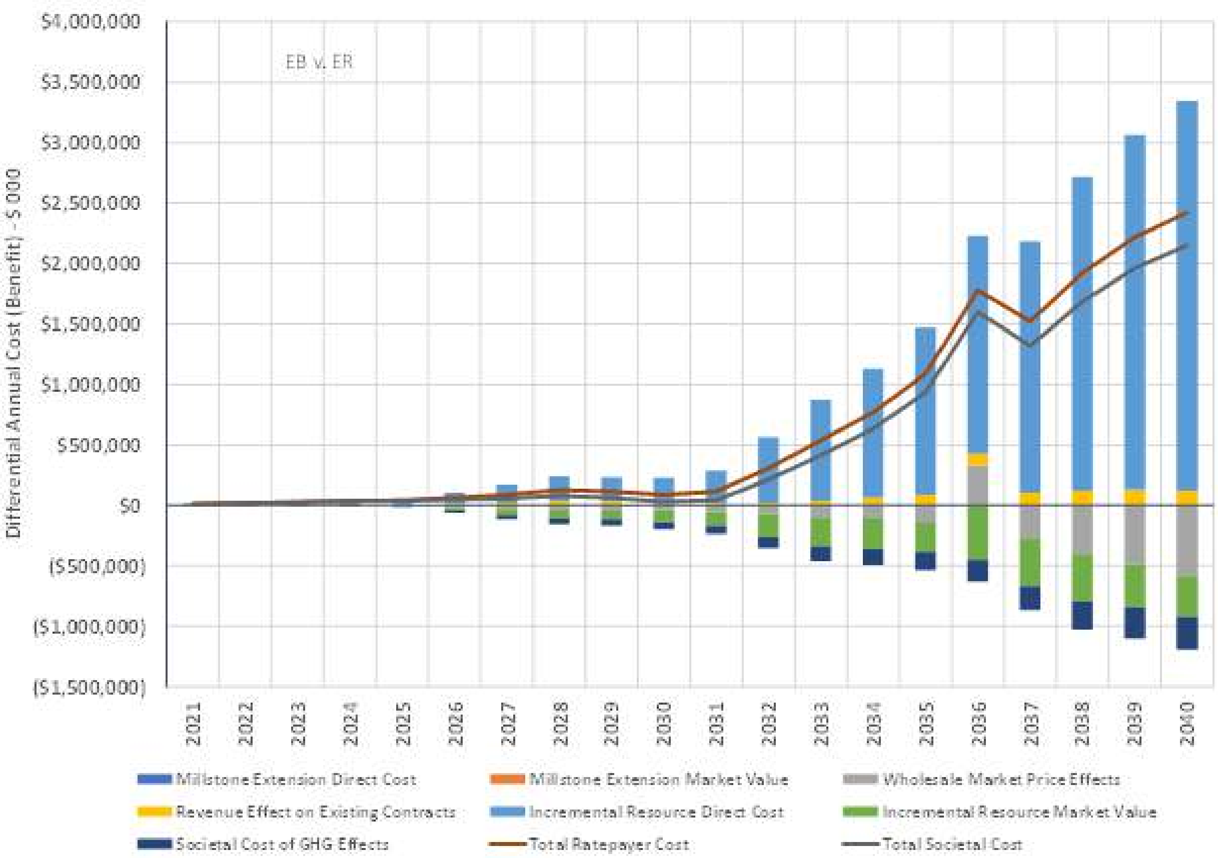


Table 1.3: Cumulative Incremental Resource Capacity, Electrification Load Balanced Blend Scenario

	Cumulative Incremental Resource Allocation			
Calendar Year	CT Storage (MW)	CT Solar (MW)	CT LBW (MW)	CT OSW (MW)
2021	0	0	0	0
2022	0	0	0	0
2023	0	0	0	0
2024	0	0	0	0
2025	0	0	0	0
2026	0	425	0	0
2027	0	887	0	0
2028	0	1,347	0	0
2029	0	1,805	0	0
2030	232	2,260	0	0
2031	232	2,713	0	0
2032	464	2,900	325	358
2033	464	3,146	325	892
2034	929	3,131	325	1,245
2035	929	3,115	325	1,962
2036	929	3,100	557	2,503
2037	1,139	3,084	557	3,077
2038	1,603	3,069	557	4,208
2039	1,603	3,054	557	5,152
2040	1,603	3,045	557	5,710

Annual differential costs for the Electrification Load Balanced Blend scenario against the Reference scenario are shown in Figure 1.13. Trends are similar to the Base Load Balanced Blend scenario, with net costs increasing starting in 2026, when Connecticut must procure new zero carbon resources. The increase is again partially offset by the societal cost associated with a reduction in CO_2 emissions and the market value of the zero carbon resources. The general trend continues through 2040. The net cost to Connecticut ratepayers to purchase incremental resources needed to achieve the 100% Zero Carbon Target over the study period under the Electrification Load Balanced Blend scenario is projected to be $4.4 billion. The inclusion of societal benefits from avoided CO_2 emissions reduces that projected cost about $700 million for a net societal cost of $3.7 billion. Again, this cost does not include demand-side program costs, but it should be noted that the Electrification Load case does include a higher level of assumed energy efficiency associated with ASHP deployment than the Base Load. As previously stated, additional investment in DSM could potentially reduce ratepayer costs. The next Comprehensive Energy Strategy will seek to identify the optimum level of future investment in DSM programs that would achieve these ratepayer cost savings. In addition, if Connecticut accelerated the procurement schedule outlined in Table 1.3 to meet the 2030 GWSA goal, the costs would increase.

Figure 1.13: Differential Annual Cost – Electrification Load Balanced Blend Scenario v. Electrification Load Reference Scenario



Millstone Extension Scenarios

The Millstone Extension scenarios select the lowest cost portfolio of resources needed to meet the Regional Emissions Target, including Connecticut's 100% Zero Carbon Target, and assume that Millstone continues operating beyond its current 2029 retirement date through the 2040 modeling horizon. As further set forth in Objective 2 and the strategies in Part II below, if Millstone were to continue to operate beyond 2029, it should be supported regionally through a reformed ISO-NE wholesale market, or by some other regional mechanism. The complexities of that modeling were beyond the scope of this IRP; thus, the Millstone Extension scenarios are based on an assumption that the current contract with Millstone is extended. As further set forth below, this IRP does not recommend that Connecticut's electric ratepayers should take on that burden on behalf of the region again.

Base Load Millstone Extension (BM) Scenario

Key Findings: Base Load Millstone Extension

- Present Value Total Societal Cost: -$2.05B
- Present Value Total Ratepayer Cost: -$1.25B
- 2040 zero carbon goal will be met, as are interim annual targets
- 4.8 GW Connecticut clean energy procurements by 2040
- 8.3 GW regional fossil fuel retirements by 2040
- CT wholesale energy price decreases ~22% by 2040 due to transition from high variable cost resources to high fixed cost resources

Under the Base Load, the Millstone Extension scenario reduces the need to purchase OSW and other zero carbon resources, and thus reduces costs compared to the Balanced Blend scenario. The model begins selecting grid scale solar additions for Connecticut in 2030, and pushes other procurements back several years as compared to the Balanced Blend scenario. Under the Base Load Millstone Extension scenario, Connecticut is able to meet the annual CO_2 emissions reduction target amount in every year over the modeling horizon, including the 2030 electric sector goal set by GC3, as shown by Figure 1.14. Millstone's existing contract is combined with other Connecticut clean energy contracts ("CT Existing Contracts") through early 2029 because it is an existing contract. A modeled extension of that contract is then demonstrated by the Millstone Extension bar through 2040. This scenario assumes that a contract extension would result in all of Millstone's environmental attributes being assigned to Connecticut, consistent with the current contract.[50] Due to this, Connecticut would need just over half of the clean energy additions that are needed under the Base Load Balanced Blend scenario to meet each year's target. Table 1.4 includes the resources by type allocated to Connecticut each year.

[50] *See* PURA Docket No. 18-05-04, *Implementation of June Special Section Public Act 17-3*, Dominion Energy Nuclear Connecticut, Inc. Unredacted Power Purchase Agreements, January 1, 2020.

Figure 1.14: Connecticut Incremental Resource Allocation, Base Load Millstone Extension Scenario

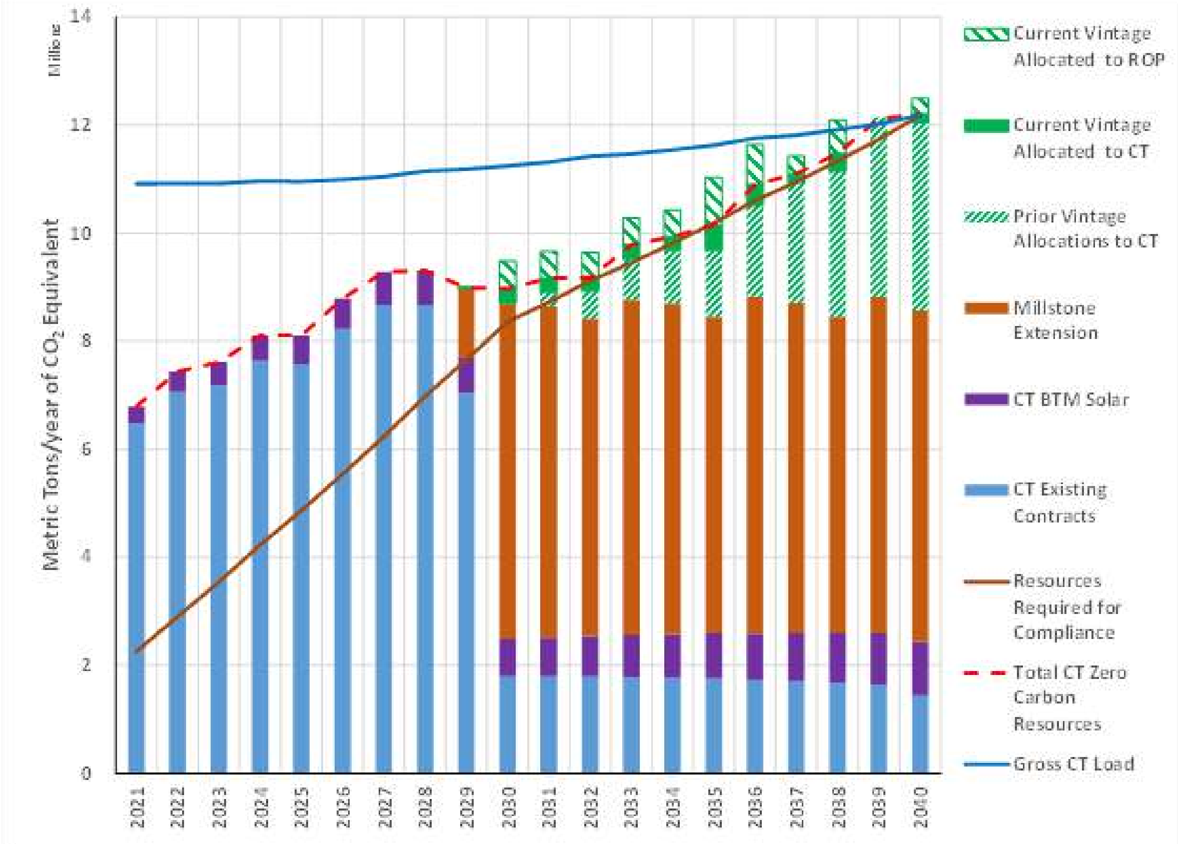


Table 1.4: Cumulative Incremental Resource Capacity, Base Load Millstone Extension Scenario

Calendar Year	Cumulative Incremental Resource Allocation CT Storage (MW)	CT Solar (MW)	CT LBW (MW)	CT OSW (MW)
2021	0	0	0	0
2022	0	0	0	0
2023	0	0	0	0
2024	0	0	0	0
2025	0	0	0	0
2026	0	0	0	0
2027	0	0	0	0
2028	0	0	0	0
2029	0	7	0	0
2030	0	348	0	0
2031	0	687	0	0
2032	170	1,024	0	0
2033	170	1,360	0	0
2034	170	1,693	0	0
2035	170	2,025	238	0
2036	170	2,315	238	129
2037	170	2,304	238	392
2038	207	2,292	238	917
2039	524	2,281	238	1,180
2040	865	2,269	238	1,446

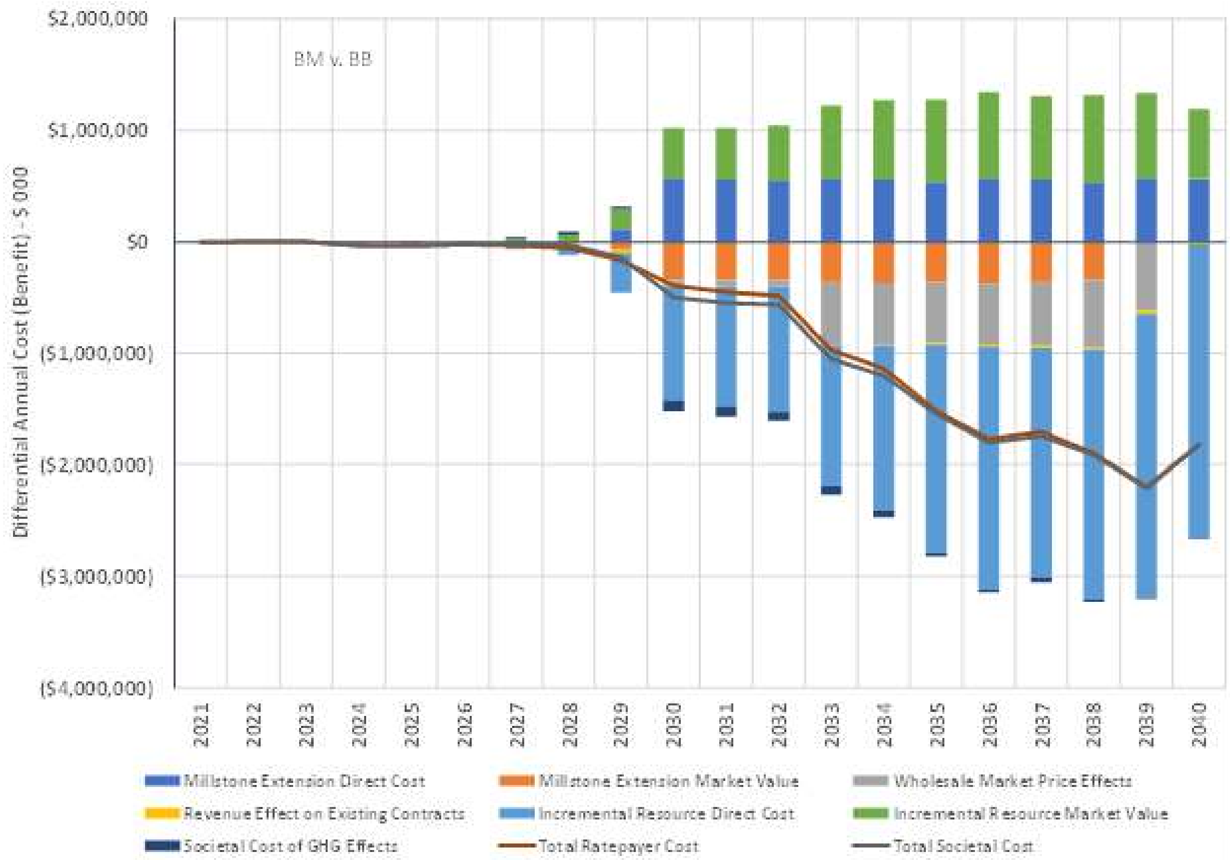
APPENDIX A3

Figure 1.15 shows the costs projected by the model under the Base Load Millstone Extension scenario compared to the Base Load Balanced Blend scenario (not the Base Load Reference scenario). Cost differentials against the Base Load Reference scenario can be found in Appendix A3.[51]

In 2029, the Base Load Millstone Extension scenario becomes cheaper, as modeled, than the Base Load Balanced Blend scenario "Incremental Resource Direct Cost"), or the avoided cost of deploying more new, renewable zero carbon resources than the Base Load Balanced Blend scenario because of Millstone's continued operation.

[51] The assumed cost of the Millstone PPA extension is the current contract price, $49.99/MWh, adjusted for inflation at 2 percent each year.

Figure 1.15: Differential Annual Costs – Base Load Millstone Extension Scenario vs. Base Load Balanced Blend Scenario



Compared to the Base Load Balanced Blend scenario, the net present value to ratepayers of the Millstone Extension scenario, calculated over the 20-year modeling period at a nominal discount rate of seven percent, is a savings of $5.0 billion. Compared to the business-as-usual Base Load Reference scenario, which also assumes Millstone retires in 2029, the net present value to ratepayers of extending Millstone's contract is a savings of $1.25 billion. Again, these benefits are primarily produced by the avoided incremental resource additions needed over the course of the study period.

Electrification Load Millstone Extension (EM) Scenario

Similar trends occur under the Electrification Load Millstone Extension scenario. Regional clean energy additions are minimized as compared to the Electrification Load Balanced Blend scenario, and, in fact, align more closely with additions expected under the Base Load Balanced Blend scenario. The Electrification Load Millstone Extension scenario also decreases the total operating reserve amounts compared with the Electrification Load Balanced Blend scenario as fewer VER resources are needed to meet the carbon constraints, which also means greater stability in energy output levels.

Key Findings: Electrification Load Millstone Extension

- Present Value Total Societal Cost: -$1.5B
- Present Value Total Ratepayer Cost: -$0.63B
- 2040 zero carbon goal will be met, as are interim annual targets
- 6.8 GW Connecticut clean energy procurements by 2040
- 8.7 GW regional fossil fuel retirements by 2040
- CT wholesale energy price decreases ~26% by 2040 due to transition from high variable cost resources to high fixed cost resources.

The Electrification Load Millstone Extension scenario has the highest level of retirements of the Electrification Load Zero Carbon Policy scenarios (see Appendix A3). This is because even under an increased regional energy load, the consistent availability of reliable nuclear energy reduces the overall amount of resource additions needed to meet capacity requirements, and reduces the amount of "fast-ramping"(usually fossil fuel-powered) resources needed to be retained for peak demand periods to balance the clean energy resource additions. In other words, as previously shown by Figures 1.10 and 1.11, the Zero Carbon Policy scenarios must meet a higher absolute operating reserve requirement in order to preserve reliability under the Electrification Load than the Base Load, coincident with the increased need for renewable VERs to meet the load and Regional Emissions Target. But, if Millstone continues to operate, the need for a higher absolute operating reserve requirement is avoided, and more fossil units can retire. Whereas in the Base Load scenarios, lower load means lower absolute reserve requirements and therefore greater retirement levels, in the Electrification Load scenarios, higher load means higher reserve requirement and therefore lower retirement levels across the scenarios.

APPENDIX A3

The Electrification Load Millstone Extension scenario delays incremental clean energy additions by about four years for Connecticut as compared with the Electrification Load Balanced Blend scenario, as demonstrated by Figure 1.16. The year 2029 shows the beginning of the modeled Millstone extension, and a very small resource addition amount. Millstone's extension is fully captured by the Millstone Extension bar for the remainder of the study period, which minimizes the amount of additions needed to meet the 100% Zero Carbon Target as compared with the Electrification Load Balanced Blend scenario. Table 1.5 shows the cumulative resources allocated to Connecticut by year.

Figure 1.16: Connecticut Incremental Resource Allocation, Electrification Load Millstone Extension Scenario

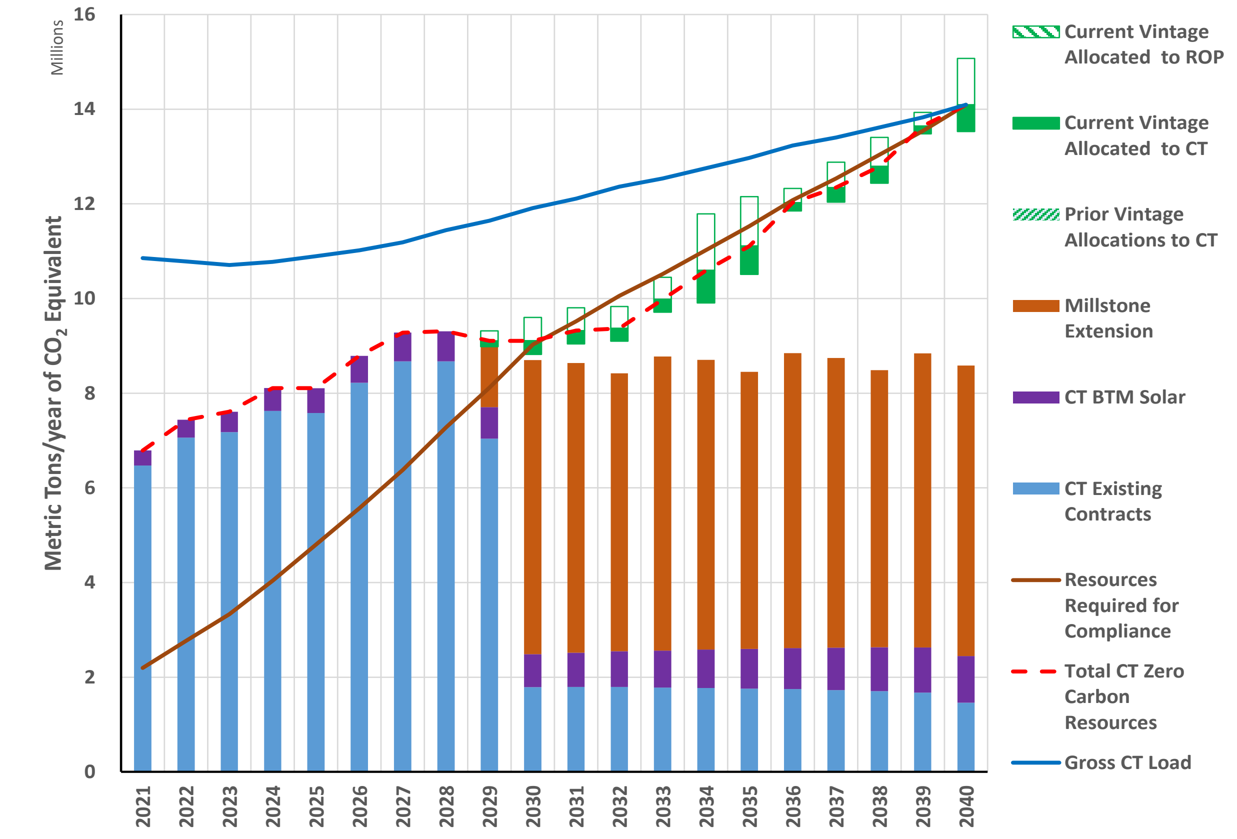


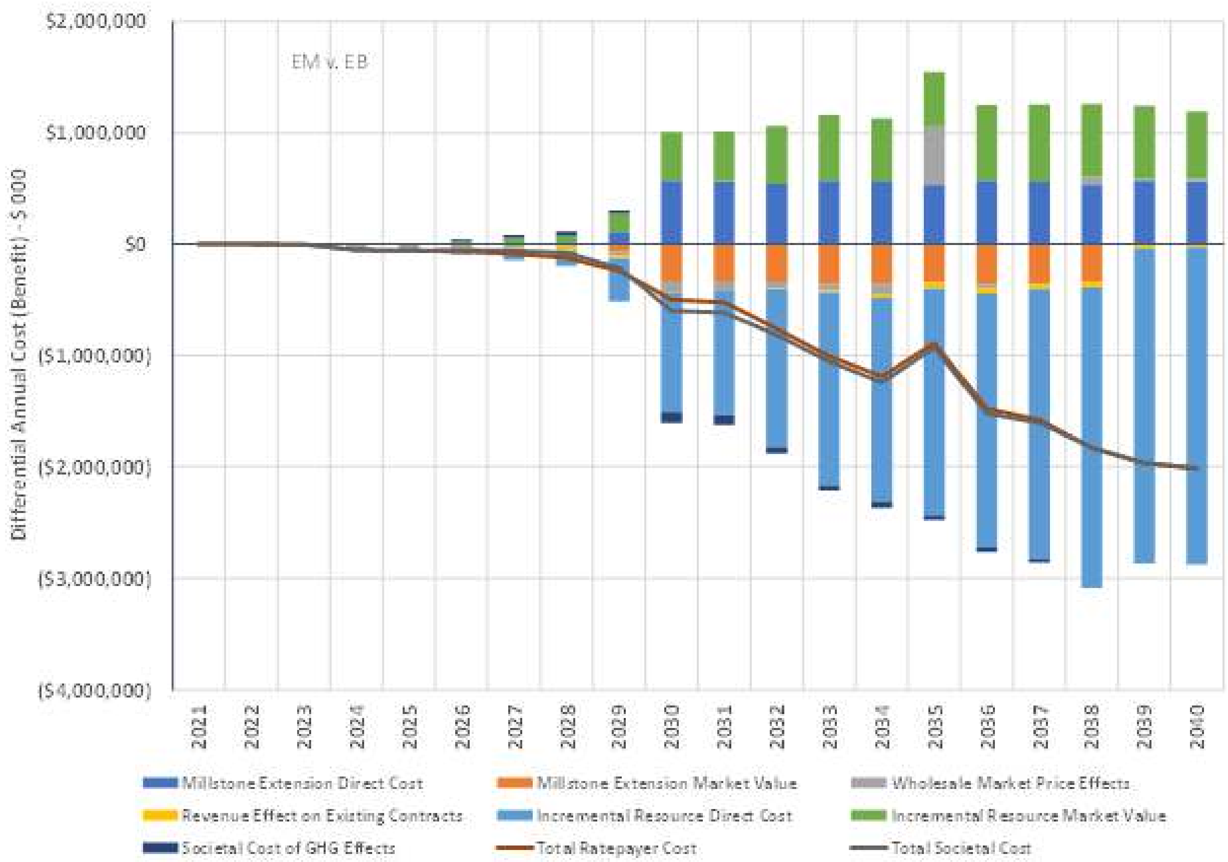
Table 1.5: Cumulative Incremental Resource Capacity, Electrification Load Millstone Extension Scenario

Calendar Year	Cumulative Incremental Resource Allocation			
	CT Storage (MW)	CT Solar (MW)	CT LBW (MW)	CT OSW (MW)
2021	0	0	0	0
2022	0	0	0	0
2023	0	0	0	0
2024	0	0	0	0
2025	0	0	0	0
2026	0	0	0	0
2027	0	0	0	0
2028	0	0	0	0
2029	0	161	0	0
2030	0	526	0	0
2031	0	888	0	0
2032	183	1,249	0	0
2033	183	1,608	0	0

2034	183	1,965	256	139
2035	183	2,321	438	420
2036	183	2,309	438	841
2037	240	2,474	438	1,115
2038	490	2,462	438	1,679
2039	855	2,449	438	2,116
2040	1,220	2,437	438	2,713

The Electrification Load Millstone Extension scenario annual benefits, as shown in Figure 1.17, are similar to those under the Base Load Millstone Extension scenario, with annual net benefits generally increasing after 2028. Under this scenario, the model projects ratepayers will still see a net benefit with a present value savings of $5.0 billion compared to the Electrification Load Balanced Blend scenario, and a net benefit of $625.0 million compared to the Electrification Load Reference scenario. This amount increases to a net benefit of approximately $1.5 billion when the societal avoided costs of GHG effects are accounted for.

Figure 1.17: Differential Annual Costs – Electrification Load Millstone Extension Scenario vs. Electrification Load Balanced Blend Scenario



BTM Solar PV Emphasis Scenarios

The BTM Solar PV Emphasis (BTM Emphasis) scenarios select the lowest cost portfolio of resources needed to meet the region's aspirational energy policy goals, including Connecticut's 100% Zero Carbon Target, assuming that the level of BTM solar PV deployment effectively doubles over the Reference scenario. This increase equates to an additional 190 MWs of BTM solar PV being deployed in the region each year on average for both load cases. The scenarios also assume that 55 MWs of those additional 190 MWs on average are deployed in Connecticut each year.[52] Because BTM solar PV is a load modifier, this reduces the gross load (net of energy efficiency) that must be met by other energy resources, but also changes the hourly shape of net load as solar PV can only produce during the day. Therefore, the model's selection of incremental resources is different from the Balanced Blend scenarios.

Base Load BTM Solar PV Emphasis (BS) Scenario

Key Findings: Base Load BTM Solar PV Emphasis

- Present Value Total Societal Cost: $4.01 B
- Present Value Total Ratepayer Cost: $4.61 B
- 2040 zero carbon goal will be met, some interim years fall short
- 8.6 GW Connecticut clean energy procurements by 2040
- 10.7 GW regional fossil fuel retirements by 2040
- CT wholesale energy price decreases ~22% by 2040 due to transition from high variable cost resources to high fixed cost resources.

Under the Base Load, the BTM Emphasis scenario results in the largest quantity of cumulative regional additions at 32 GW, and the most retirements at 10.8 GW. This quantity is primarily increased by the assumed greater deployment of BTM solar PV resources across the region, which offsets some of the resources expected for selection under the Balanced Blend, such as OSW. The key variable is that unlike the Balanced Blend, where the model selects the resources based on least-cost deployment, this scenario forces an amount of capacity that relies on increased individual (i.e. ratepayer) participation in solar PV programs across the region into the model. Then, the model has to select enough resources to meet capacity and reliability needs at all hours while still meeting the GHG emissions constraint.

Connecticut will still need to procure 8.6 GW of clean energy resources by 2040 in this scenario, approximately the same as in the Base Load Balanced Blend. Figure 1.18 shows the cumulative resources allocated to Connecticut by year in order to meet the necessary emissions reduction targets to achieve the 100% Zero Carbon Target. Like in the Base Load Balanced Blend scenario, under the BTM PV Emphasis scenario, Connecticut exceeds the necessary annual reductions until the retirement of Millstone in 2029, and then needs to procure enough resources to offset the loss of that resource and meet growing demand. The inclusion of additional BTM solar helps to fulfill a small portion of that need. Table 1.6 shows the cumulative resources allocated to Connecticut by year.

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[52] See Appendix A1 for further information about BTM solar PV deployment assumptions used in the modeling.

Figure 1.18: Determination of Connecticut Incremental Resource Allocation, Base Load BTM Solar PV Emphasis Scenario

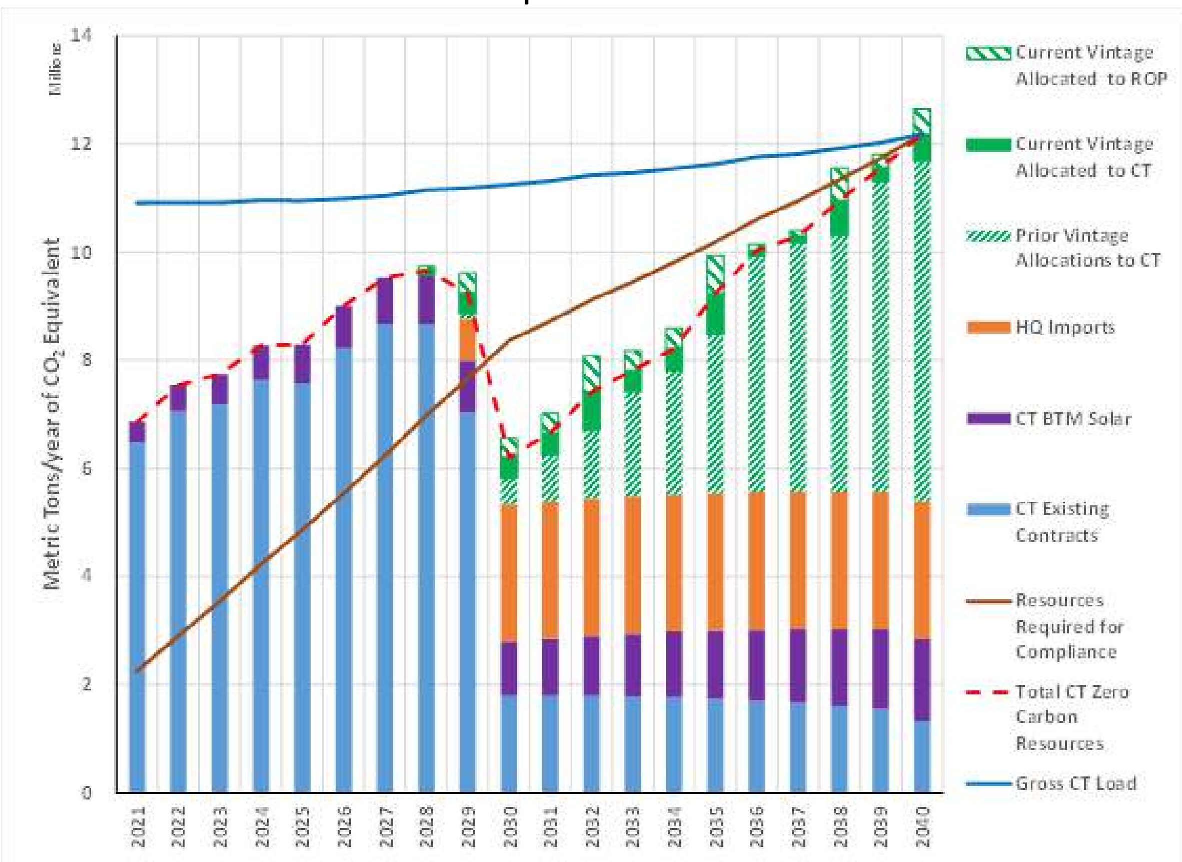


Table 1.6: Cumulative Incremental Resource Capacity, Base Load BTM Solar PV Emphasis Scenario

Calendar Year	Cumulative Incremental Resource Allocation CT Storage (MW)	CT Solar (MW)	CT LBW (MW)	CT OSW (MW)
2021	0	0	0	0
2022	0	0	0	0
2023	0	0	0	0
2024	0	0	0	0
2025	0	0	0	0
2026	0	0	0	0
2027	0	0	0	0
2028	0	105	0	0
2029	0	624	0	0
2030	0	1,140	0	0
2031	0	1,653	0	0
2032	260	2,163	363	0
2033	260	2,672	363	0
2034	260	2,870	363	197
2035	260	3,188	363	794
2036	308	3,348	363	1,391
2037	308	3,498	363	1,588
2038	760	3,481	623	1,984
2039	760	3,463	623	2,588
2040	1,279	3,446	623	3,221

APPENDIX A4

The Base Load BTM Solar Emphasis scenario annual net costs are shown in Figure 1.19. Generally, the cost of achieving zero carbon by 2040 results in a net cost both with and without societal benefits. Under this scenario, ratepayers will still see a projected net present value cost of an additional $846 million over the cost of the Base Load Balanced Blend, for a total cost of $4.6 billion compared to the Base Load Reference scenario. This amount is slightly offset by the inclusion of an estimated $609 million in societal avoided costs of GHG, bringing the total societal cost to just over $4 billion. The large "Wholesale Market Price Benefits" value in 2033 was driven by capacity prices when battery resources become the marginal resource a year earlier relative to the Base Load Balanced Blend scenario, which is the baseline in the graph below.[53] Further information on costs and benefits are included in Appendix A4.

[53] Battery resources do become the marginal resource in every scenario, just at different times. For most of the study period, the marginal resource identified was a conventional fossil resource. In the early 2030's, batteries are needed to meet resource adequacy targets. The cost of battery additions therefore set the capacity price. For more information on the capacity price calculations, see Appendix A3.

Figure 1.19: Differential Annual Costs – Base Load BTM Solar PV Emphasis Scenario v. Base Load Balanced Blend Scenario

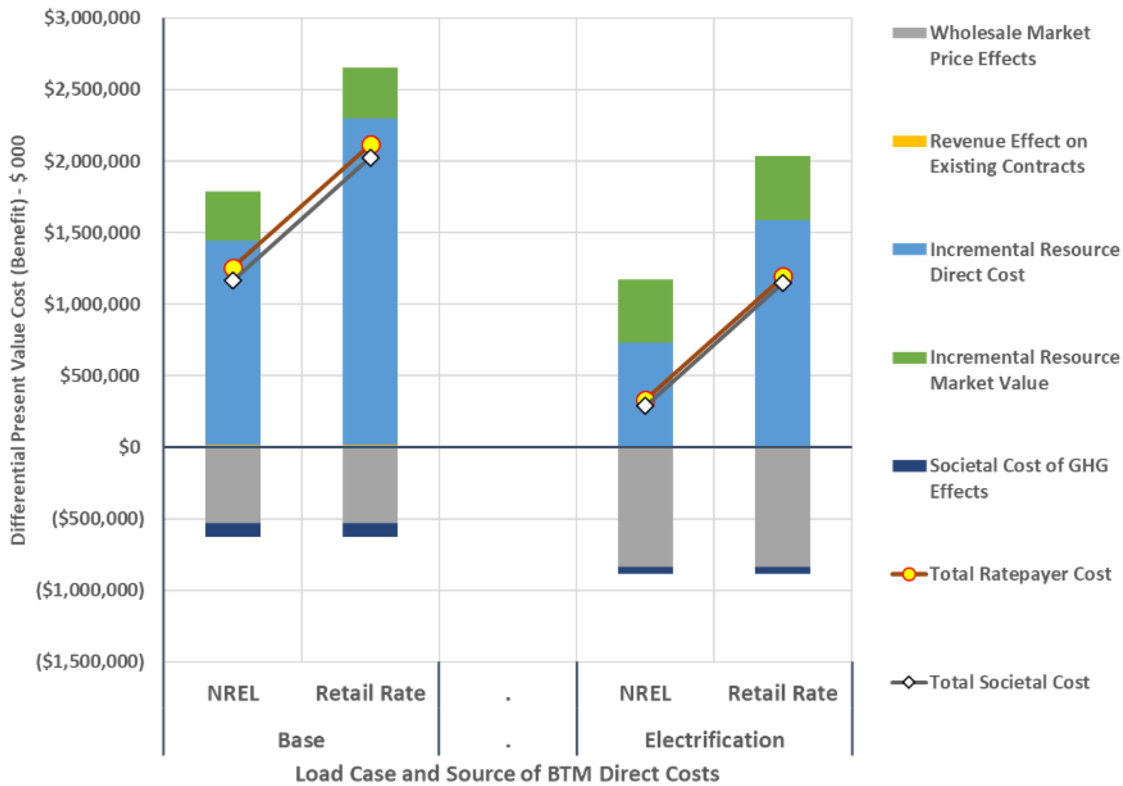
In addition, DEEP analyzed the cost differential between a BTM solar program that compensates based on projected cost of deploying the unit compared to a program that compensates based on the residential retail rate, effectively comparing the cost of a potential successor tariff structure with the cost of existing net metering.[54] The Department notes this comparison is for illustrative purposes and should not necessarily be used to establish a tariff rate pursuant to Section 16-244z of the Connecticut General Statutes.

In addition, as noted in the Introduction, this IRP is not a full cost-benefit analysis of policies supporting different zero carbon resources; rather, it analyzes the comparative resource price and emissions impacts on the regional electric supply from pathways to meet the 100% Zero Carbon Target. This IRP also assesses the price and emissions impacts based on current policy structures and those impacts can change in future IRPs as dynamic pricing structures are more widely adopted and the capabilities of technologies like BTM solar paired with energy storage on a modernized grid offers new value. Figure 1.20 further demonstrates

[54] The residential retail rate used in this sensitivity analysis is Eversource's Rate R, effective January 1, 2020, inclusive of the average generation rate from July 1, 2020 and January 1, 2020. This rate is escalated 2 percent. This rate is used as an illustrative example. The cost of deploying the unit was based on NREL studies on the cost of deploying solar, as discussed in more detail in Appendix A1.

how deploying additional BTM solar units at different compensation levels affects the present value of net costs by comparing the costs based on National Renewable Energy Laboratory (NREL) cost data versus the Connecticut residential rate under each load level.[55] The baselines for comparison are the Balanced Blend scenarios.

Figure 1.20: Present Value Cost of BTM Solar Compensated at the Cost System Deployment Compared to the Residential Retail Rate



Because Figure 1.20 compares the present value electric system costs and benefits of the same amount of BTM solar, based upon two different compensation structures, the relative comparison of one structure against another will remain the same, regardless of additional cost or benefit categories added. It is important to note that these compensation structures were applied for illustrative purposes and that DEEP does not recommend that these cost assumptions be used as the tariff rate to be established by PURA in Docket No. 20-07-01 for the residential solar PV successor tariff.

Figure 1.20 serves as an illustration of the impact of different levels of compensation with an estimated present value based on the cost assumptions described above. The NREL cost data indicates that residential solar PV is being successfully deployed at average prices of approximately $0.105/kWh across the US, while here in CT the price paid for solar PV is much higher because it is tied to the retail rate (under the current net metering regime) plus an incentive from the Connecticut Green Bank.[56] The NREL figures suggest Connecticut could still see successful deployment at a lower price than the retail rate.

[55] As indicated in Appendix A1, BTM solar costs were estimated using NREL's 2019 ATB database.

[56] National Renewable Energy Laboratory, *2020 Annual Technology Baseline: Residential PV Systems.*

The state could deploy a higher of quantity of BTM solar PV to reach the 100% Zero Carbon Target at the same ratepayer cost, if the price is set optimally. PURA issued an Interim Decision as part of the implementation process of Connecticut General Statutes Section 16-244z(b) which required PURA to establish a rate for residential solar based upon competitive solicitations or "on the average cost of installing the generation project and a reasonable rate of return that is just, reasonable and adequate, as determined by the authority, and shall be guided by the Comprehensive Energy Strategy prepared pursuant to section 16a-3d." [57, 58] PURA adopted a "cost plus" rate for residential solar.[59] To achieve historical deployment, PURA held a return on equity of 10% is appropriate and indicated that a compensation rate of approximately $0.29/kWh is necessary to achieve that deployment rate.[60] The current electric rates are around $0.23/kWh, meaning the rate approved by PURA is near the average rate a customer could expect to receive over the commercial operation of a rooftop solar system under the old net metering rate.

Electrification Load BTM Solar PV Emphasis (ES) Scenario

The Electrification Load BTM Solar PV Emphasis scenario projects similar outcomes to the Base Load BTM PV Emphasis scenario. Again, compared with the other scenarios under the Electrification Load, this scenario will result in the largest amount of cumulative regional additions (inclusive of BTM resources) by 2040, primarily driven by the amount of increased BTM PV assumed at the outset. Connecticut will need to procure 10.6 GW of grid scale resources, approximately 40 percent of the regional amount.

Key Findings: Electrification Load BTM Solar PV Emphasis

- Present Value Total Societal Cost: $4.2 B
- Present Value Total Ratepayer Cost: $4.9 B
- 2040 zero carbon goal will be met, though some interim years fall short
- 10.6 GW Connecticut clean energy procurements by 2040
- 7.5 GW regional fossil fuel retirements by 2040
- CT wholesale energy price decreases ~26% by 2040 due to transition from high variable cost resources to high fixed cost resources

Retirement levels are similar to the other scenarios that include Millstone's retirement. Therefore, under the Electrification Load, about 30 percent fewer MW of fossil resources retire over the modeling horizon in order to maintain reliability.

Figure 1.21 shows the cumulative resources allocated to Connecticut by year in order to meet the necessary emissions reduction targets to achieve the 100% Zero Carbon Target under this scenario. The trajectory towards the 2040 goal in the Electrification Load is like that of the Base Load for the BTM Solar PV Emphasis scenario. Table 1.7 shows how the various incremental resources are allocated to Connecticut by year.

[57] Conn. Gen. Stat. Sec. 16-244z(b).

[58] The modeling prepared for this IRP was not prepared for the purposes of PURA Docket No. 20-07-01.

[59] *See* PURA Docket No. 20-07-01. *PURA Implementation of Section 3 of P.A. 19-35, Renewable Energy Tariffs and Procurement Plans.* Interim Decision. Page 36. February 10, 2021.

[60] *Id* at Page 38.

Figure 1.21: Determination of Connecticut Incremental Resource Allocation, Electrification Load BTM Solar PV Emphasis Scenario

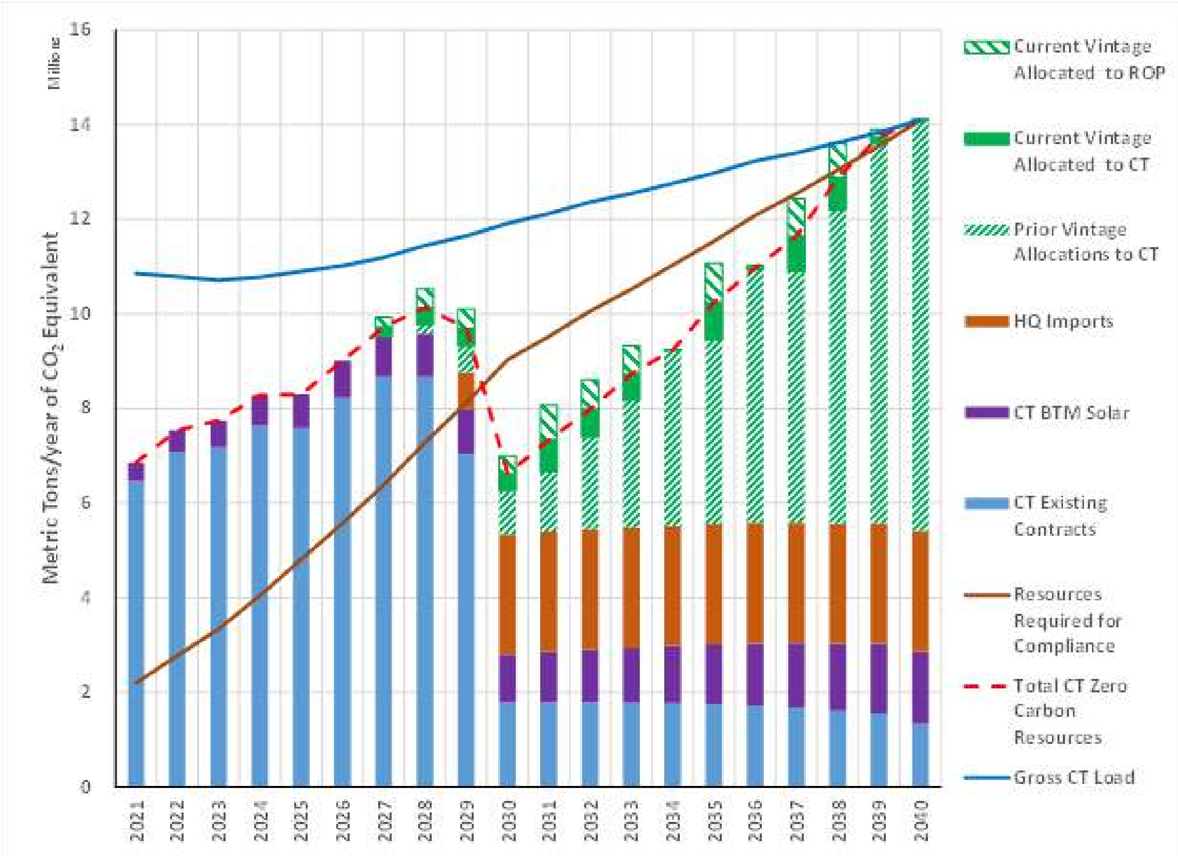
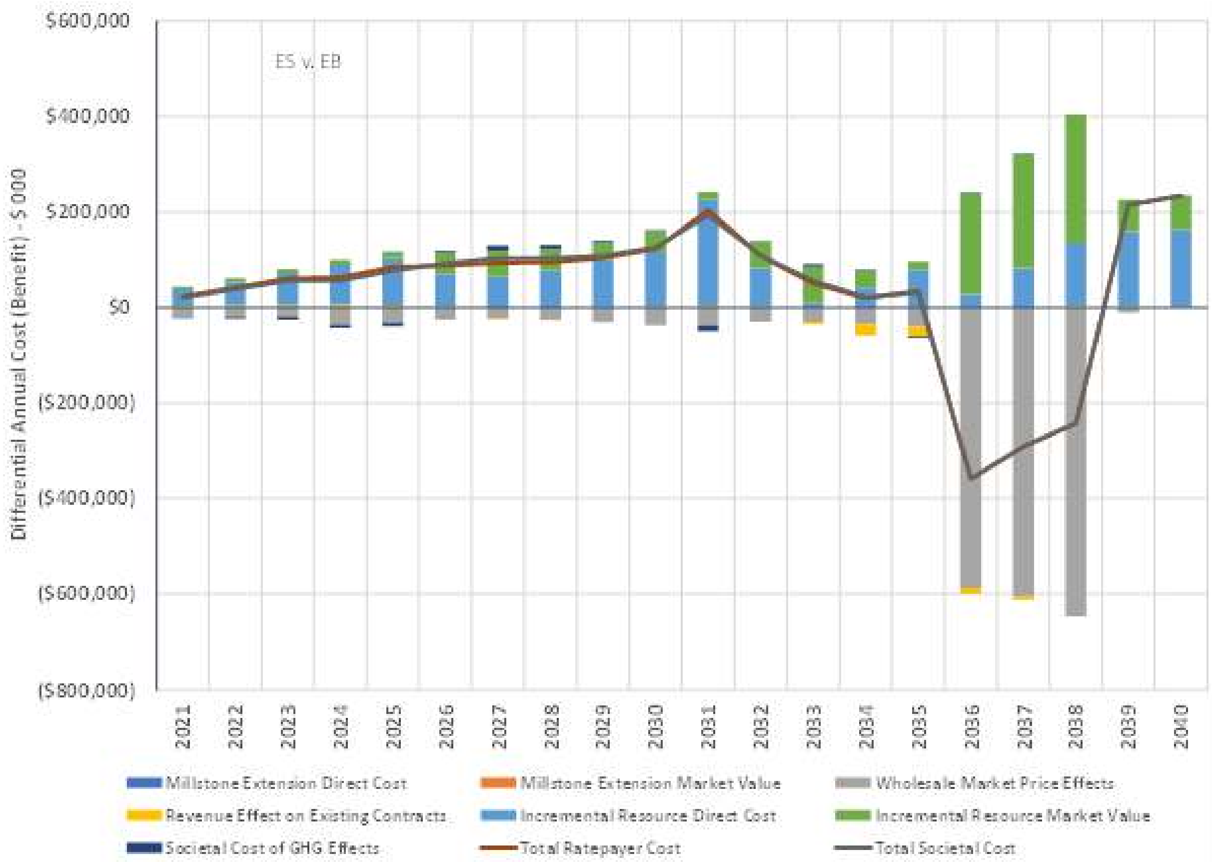


Table 1.7: Cumulative Incremental Resource Capacity, Electrification Load BTM Solar PV Emphasis Scenario

Calendar Year	Cumulative Incremental Resource Allocation CT Storage (MW)	CT Solar (MW)	CT LBW (MW)	CT OSW (MW)
2021	0	0	0	0
2022	0	0	0	0
2023	0	0	0	0
2024	0	0	0	0
2025	0	0	0	0
2026	0	0	0	0
2027	0	265	0	0
2028	0	743	0	0
2029	0	1,220	0	0
2030	240	1,694	0	0
2031	240	2,165	336	0
2032	480	2,635	336	182
2033	480	3,046	336	547
2034	960	3,090	336	911
2035	960	3,139	336	1,653
2036	960	3,183	336	2,212
2037	1,080	3,188	336	2,793
2038	1,560	3,172	336	3,958
2039	1,560	3,156	576	4,742
2040	1,560	3,164	576	5,326

The Electrification Load BTM Solar PV Emphasis scenario annual net costs are shown in Figure 1.22. As with the Base Load scenario, the cost of achieving zero carbon over 2040 with additional BTM PV produces a net cost, even with societal benefits factored in. Under this scenario, the model projects that ratepayers will still see a net present value cost of an additional $529 million over the cost of the Base Load Balanced Blend scenario, for a projected total cost of $4.9 billion compared to the Electrification Load Reference scenario. When avoided societal costs of GHGs are accounted for, the costs are offset by an estimated $704 million in societal avoided costs of GHG. Costs in most years are dominated by the "Incremental Resource Costs" (light blue bars), which include the gross costs of the added BTM resources in Connecticut. These costs are incurred from 2021 on, but they are reversed from 2032 through 2034. The "Wholesale Market Price Effects" (gray) bars represent energy and capacity effects on a cost-to-load basis. Cost-to-load benefits increase significantly from 2036 to 2038 due to capacity price difference, like the Base Load scenarios.

Figure 1.22: Differential Annual Costs –Electrification Load BTM Solar PV Emphasis Scenario v. Electrification Load Balanced Blend Scenario



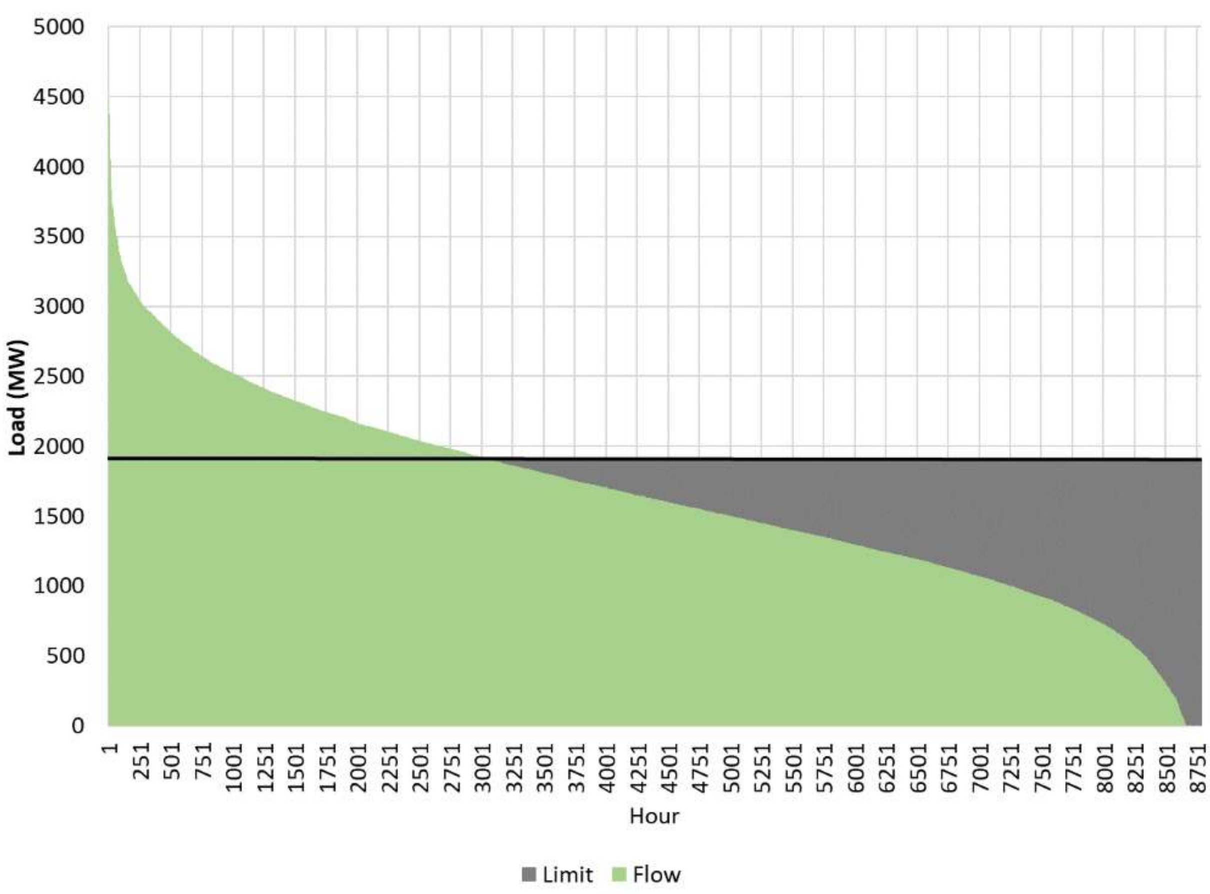
No Transmission Constraint Scenarios

Transmission lines and infrastructure are limited by factors like thermal and voltage capacity. Where line capacity is limited by transmission constraints, grid congestion produces inefficiencies and losses. The No Transmission Constraints scenarios (Transmission scenarios) are a sensitivity analysis that applies relaxed transmission constraints to the resources selected in both Balanced Blend scenarios. This analysis is used to determine how relieving lines that would otherwise experience energy flows above the line limits affects the resource buildout while still meeting the region's aspirational energy policy goals, including Connecticut's 100% Zero Carbon Target. In other words, the goal of these scenarios is to test what would happen to the modeled resource portfolio if electricity was able to flow freely throughout New England, without being constrained by points on the grid by limits on the transmission lines that prevent the free movement of supply to load.

Appendix A3

Transmission congestion points were identified by evaluating flows for all hours in 2040 to determine which interfaces would have flows above the line limits absent constraints. For example, Figure 1.23 below shows the hourly 2040 Southern Maine to New Hampshire flows from the Base Load Transmission scenario in green (Line/Transmission Flow) compared to the limit in grey (Line/Transmission Limit), also noted with a black line. In all other Base Load scenarios, the hourly flow limit on this interface is 1,900 MW, as indicated by the black line. Relaxing this constraint resulted in 3,078 hours in which the flow on the interface exceeded the known 1,900 MW limit. Increasing the limit on the interface by 1,000 MW reduces the number of times the limit would have been exceeded to just 13 percent of occurrences. Further analysis on other interface flows can be found in Appendix A3.

Figure 1.23: Southern Maine to New Hampshire Interface Flows, 2040 All Hours



The transmission system's ability to support increasing amounts of clean energy resources is vital to meeting climate goals in the coming decades. While this scenario does not account for the costs of the upgrades required to achieve an unconstrained system, it provides information that will allow for more strategic planning and investment.

Base Load No Transmission Constraint (BT) Scenario

The modeling results in the Base Load No Transmission Constraint scenario for regional additions and retirements are nearly identical to the results in the Base Load Balanced Blend scenario. However, the BT scenario results in less curtailment of some resources, and the reduced, or deferred, need for various incremental resources in the later years of the study period. Connecticut therefore will need to have procured approximately the same number of MWs from clean energy resources as it would in the Base Load Balanced Blend scenario by 2040, but all energy is more efficiently allocated across the region in the BT scenario, and less clean energy is constrained or curtailed.

Key Findings: Base Load No Transmission Constraint

- Present Value Total Societal Cost: $2.8 B
- Present Value Total Ratepayer Cost: $3.3 B
- 2040 zero carbon goal will be met, some interim years fall short
- 8.5 GW Connecticut clean energy procurements by 2040
- 10.7 GW regional fossil fuel retirements by 2040
- CT wholesale energy price decreases ~25% by 2040 due to transition from high variable cost resources to high fixed cost resources

Figure 1.24 demonstrates Connecticut's trajectory towards the 2040 goal under this scenario. It is very similar to that of the Base Load Balanced Blend scenario. Table 1.8 displays the annual resource allocations to Connecticut.

Figure 1.24: Determination of Connecticut Incremental Resource Allocation, Base Load No Transmission Constraint Scenario

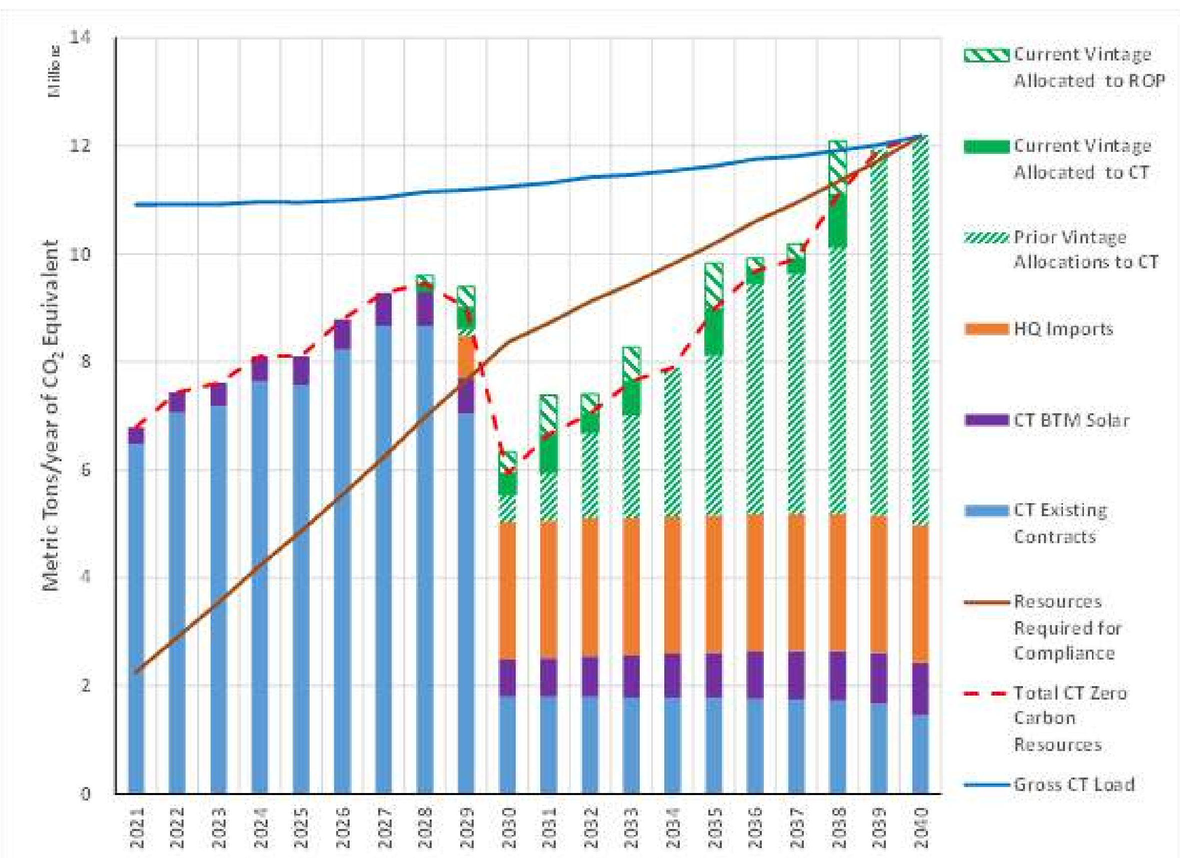


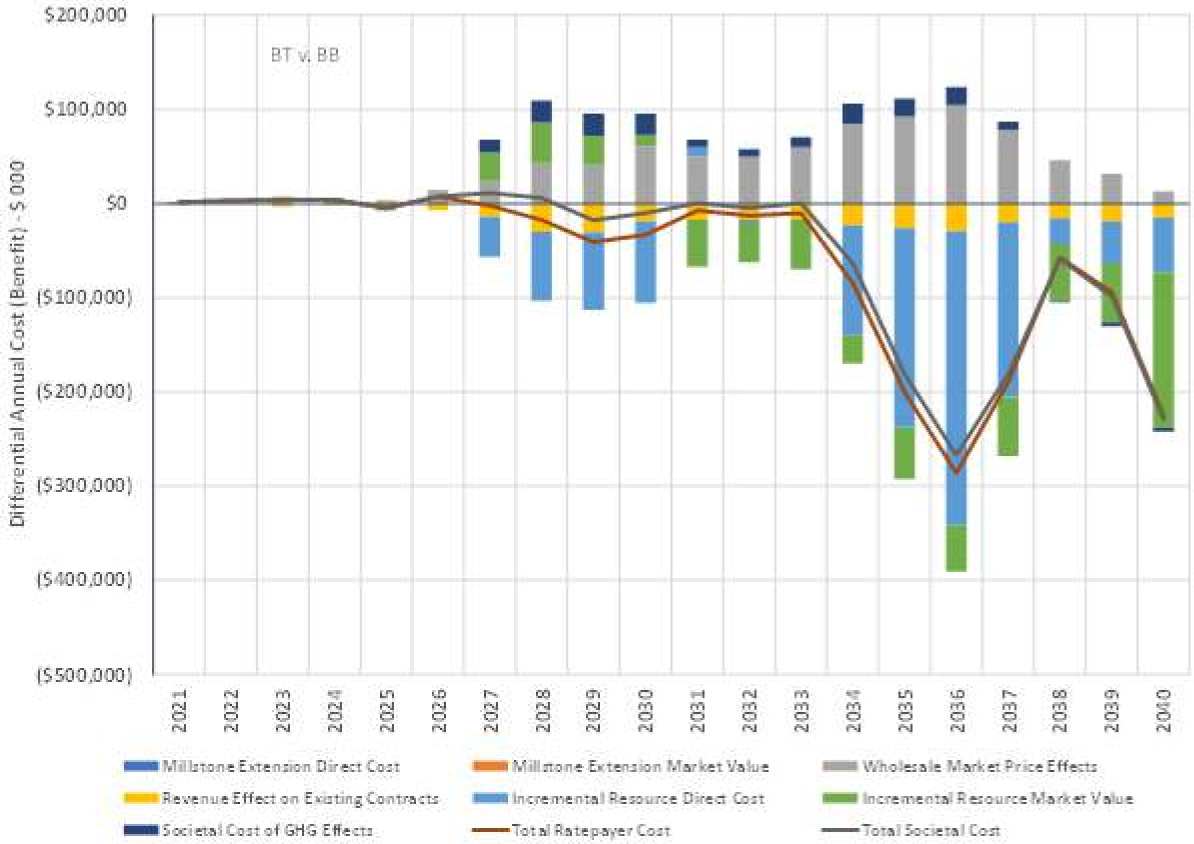
Table 1.8: Vintage Incremental Resource Allocation, Base Load No Transmission Constraint Scenario

Calendar Year	Cumulative Incremental Resource Allocation CT Storage (MW)	CT Solar (MW)	CT LBW (MW)	CT OSW (MW)
2021	0	0	0	0
2022	0	0	0	0
2023	0	0	0	0
2024	0	0	0	0
2025	0	0	0	0
2026	0	0	0	0
2027	0	0	0	0
2028	0	192	0	0
2029	0	682	0	0
2030	0	1,170	0	0
2031	163	1,655	344	0
2032	408	2,137	344	0
2033	408	2,617	344	186
2034	408	2,604	344	373
2035	408	3,038	344	933
2036	408	3,320	344	1,308
2037	408	3,304	344	1,505
2038	862	3,287	344	2,482
2039	862	3,271	344	3,262
2040	1,246	3,255	344	3,653

The key difference between the Base Load Balanced Blend scenario and the Base Load No Transmission Constraint scenario is the overall cost. Throughout the first half of the study period, and some of the second, costs remain about the same as the Base Load Balanced Blend scenario. However, in 2033, ratepayers will begin to see a financial net benefit. By alleviating constraints in the existing transmission system, the model projects that ratepayers will see a cumulative financial benefit of $400 million in present value relative to the Base Load Balanced Blend scenario. This is driven primarily by about $500 million in incremental resource direct cost savings because, without transmission congestion, more expensive resources are displaced from the portfolio. Wholesale market price effects are projected amount to $300 million present value, reflecting the lost wholesale price benefits associated with the various technologies in the Base Load Balanced Blend scenario.

As previously stated, this simplified analysis does not include the costs of transmission upgrades, which are difficult to project. Thus, while the net benefits are not reflective of the total cost or benefit to ratepayers, this analysis illustrates the potential value of alleviating transmission constraints and the comparative value of addressing infrastructure upgrades as a strategy for preparing for the 100% Zero Carbon Target.

Figure 1.25: Differential Annual Cost – Base Load No Transmission Constraint Scenario v. Base Load Balanced Blend Scenario



Electrification Load No Transmission Constraint (ET) Scenario

As with the BT scenario, the Electrification Load No Transmission Constraint scenario's additions and retirements are very closely aligned with those in the Electrification Base Load Balanced Blend scenario. However, the No Transmission Constraint scenario avoids the need for nearly a gigawatt of clean energy additions. As found in the BT scenario, alleviating points of congestion helps allow energy to more efficiently flow across the region to the places that need it.

Likewise, the analysis indicates that Connecticut will need to procure 10.5 GW of grid scale clean energy resources by 2040 under this scenario, about 430 MW less than under the Electrification Load Balanced Blend scenario.

Key Findings: Electrification Load No Transmission Constraint

- Present Value Total Societal Cost: $2.99 B
- Present Value Total Ratepayer Cost: $3.6 B
- 2040 zero carbon goal will be met, though some interim years fall short
- 10.5 GW Connecticut clean energy procurements by 2040
- 7 GW regional fossil fuel retirements by 2040
- CT wholesale energy price decreases ~35% by 2040 due to transition from high variable cost resources to high fixed cost resources

Figure 1.26 graphs the trajectory towards the 100% Zero Carbon Target for Connecticut's electric supply under this scenario. As with the other scenarios, the Electrification Load No Transmission Constraint scenario meets the 100% Zero Carbon Target in 2040 but falls short in some interim years after Millstone's projected retirement in 2029. However, it should be noted that this scenario is able to meet the target with fewer incremental resource additions. Table 1.9 displays the annual resource allocations to Connecticut under this scenario.

Figure 1.26: Determination of Connecticut Incremental Resource Allocation, Electrification Load No Transmission Constraint Scenario

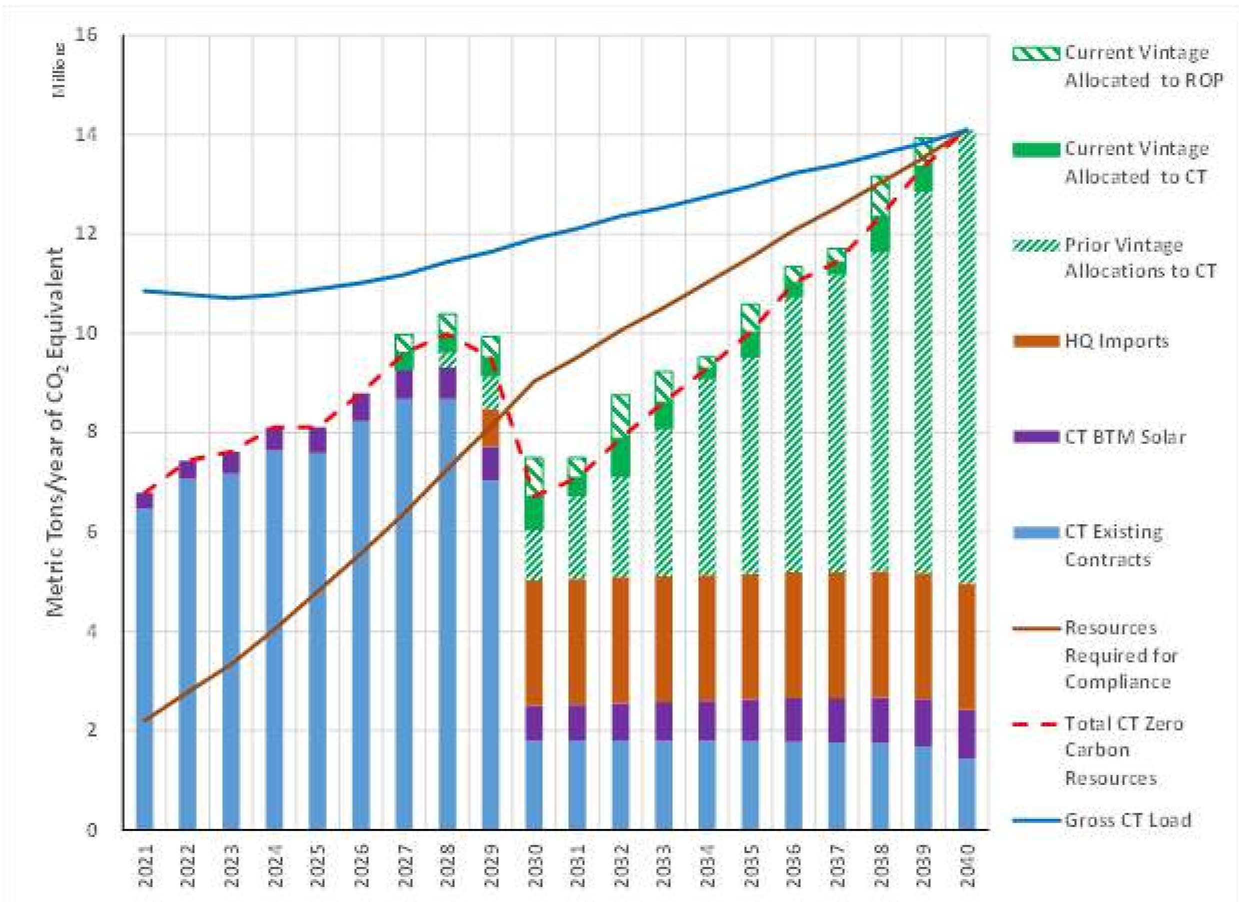


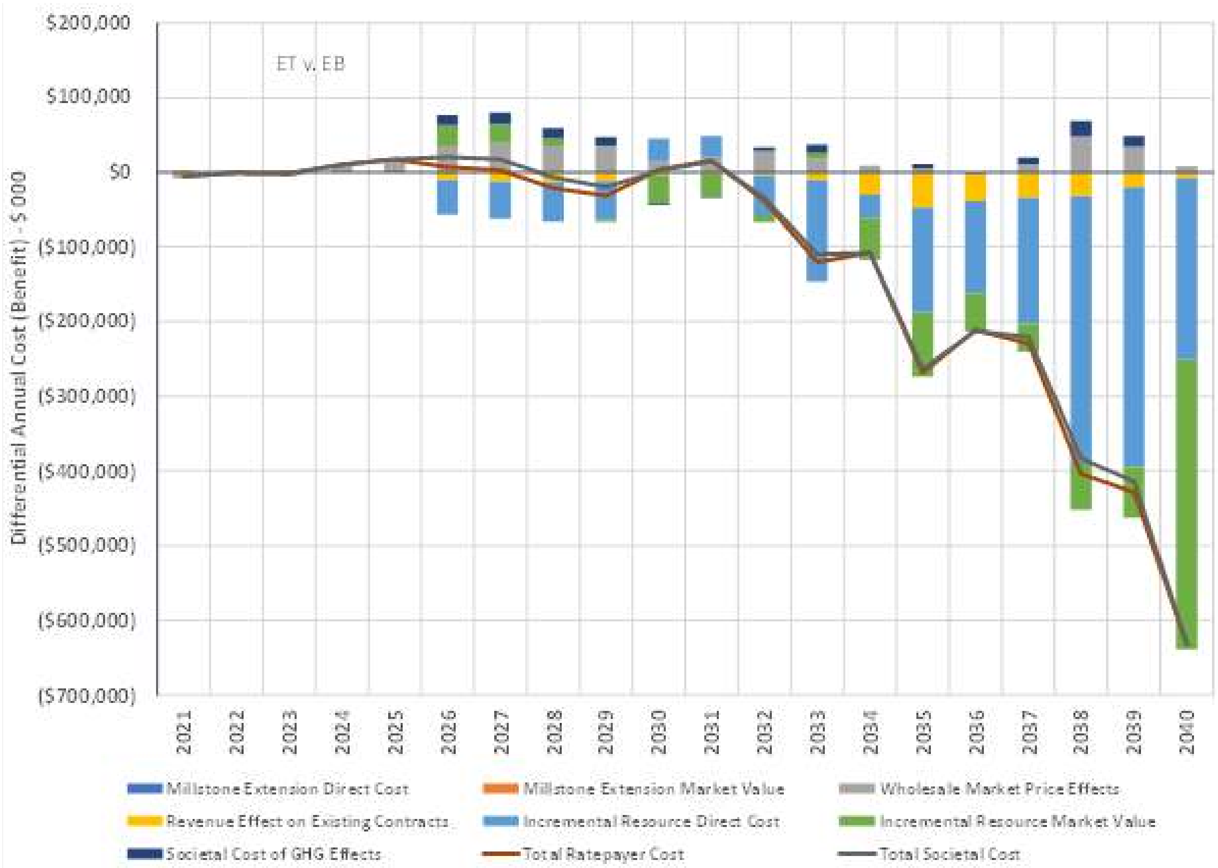
Table 1.9: Cumulative Incremental Resource Capacity, Electrification Load No Transmission Constraint Scenario

Calendar Year	Cumulative Incremental Resource Allocation CT Storage (MW)	CT Solar (MW)	CT LBW (MW)	CT OSW (MW)
2021	0	0	0	0
2022	0	0	0	0
2023	0	0	0	0
2024	0	0	0	0
2025	0	0	0	0
2026	0	0	0	0
2027	0	432	0	0
2028	0	895	0	0
2029	0	1,355	0	0
2030	232	1,813	325	0
2031	232	2,269	325	0
2032	465	2,722	558	177
2033	465	3,095	558	535
2034	930	3,079	558	1,070
2035	930	3,064	558	1,615
2036	930	3,125	558	2,332
2037	1,055	3,109	558	2,692
2038	1,519	3,093	558	3,452
2039	1,519	3,078	558	4,397
2040	1,519	3,063	558	5,343

Under the Electrification Load, the No Transmission Constraint scenario shows small changes in net cost compared to the Balanced Blend scenario through 2030, followed by increasing net benefits in the later years, shown in Figure 1.27. This is driven primarily by incremental resource direct cost reductions because, without transmission constraints, more expensive resources are displaced from the portfolio of selected resources. Ratepayers are projected to see an overall net benefit in this scenario of $699 million present value as compared to the Electrification Load Balanced Blend scenario. When avoided societal costs of GHG emissions are accounted for, the overall net benefit increases to $752 million.

As referenced in the Base Load No Transmission Constraint scenario section, this analysis does not account for the costs of transmission upgrades, but it does highlight the potential value of these upgrades. Particularly in an electrified future where load has increased to support deployment of EVs and air source heat pumps (ASHPs), and the amount of variable energy resource capacity is higher than ever, it is necessary to weigh the options to meeting a zero carbon electric supply. Transmission upgrades may be a more cost-effective way to support these strategies.

Figure 1.27: Differential Annual Costs – Electrification Load No Transmission Constraint Scenario v. Electrification Load Balanced Blend Scenario



Reliability Modeling

APPENDIX A2

As mentioned at the beginning of this Objective, this IRP sought to meet a 100% Zero Carbon target for Connecticut's electric sector by 2040 while also maintaining and ensuring reliability of electric service. The modeling was therefore held to both a 2040 emissions constraint, and a Planning Reserve Margin constraint meant to ensure reliability.[61] Additional modeling was also conducted to project the loss-of-load-expectation (LOLE) metric, or the hours when the expected production cannot meet the expected demand, for the capacity expansion schedules of the Base Reference, Base Balanced Blend, Electrification Reference, and Electrification Balanced Blend scenarios by utilizing ISO-NE's GE Multi-Area Reliability Simulation (MARS) modeling tool. ISO New England regularly uses MARS to conduct its Installed Capacity Requirement (ICR) analysis for the Forward Capacity Auction (FCA) and for various economic studies. Additional details on this modeling process can be found in Appendix A2.

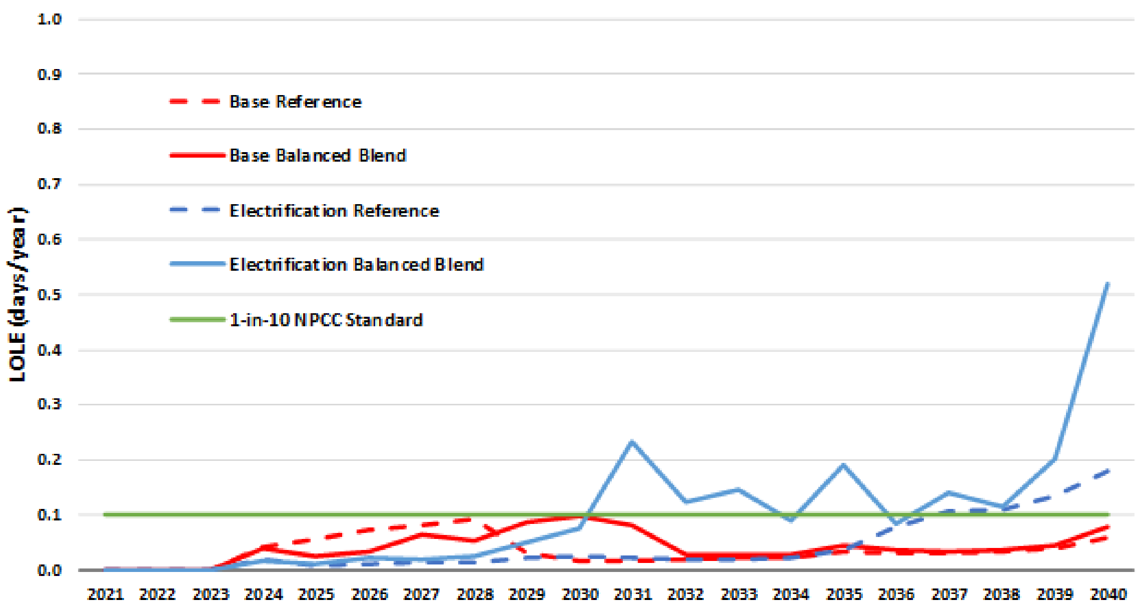
Conducting this analysis with the ISO-NE MARS model allowed DEEP to test and compare the reliability of a 100% zero carbon generation mix under different load levels. The inputs and assumptions of this modeling exercise can be found in Appendix A2. In sum, the Base Balanced Blend scenario maintained the NPCC LOLE standard throughout the study period, and the Electrification Balanced Blend scenario will

[61] Additional information about the planning reserve margin constraint is available in Appendix A1.

likely exceed this standard, particularly in the later years after the retirement of Millstone and the addition of variable energy resources.

The final MARS runs, based on Aurora's automated capacity expansion plan results with a few manual resource adjustments in import-constrained areas, resulted in LOLE values below the 0.1 day/year standard for all months and subareas in the two Base load scenarios, and in all but a few final years for the two Electrification load scenarios as shown by Figure 1.28. Under both Balanced Blend scenarios, a spike occurs around the 2029 retirement of Millstone. Under the Electrification scenarios, the 0.1 day/year threshold is exceeded several times after that point as load significantly increases, and the amount of intermittent resources used to meet that load increases. The Electrification load Balanced Blend sees it's highest LOLE in 2040 with .519 days/year.

Figure 1.28: ISO-NE System Annual LOLE by Scenario



The MARS modeling methods are very conservative in order to maintain reliability under various conditions. While adding new resource capacity could help reduce LOLE results, it is also likely that refinements to the methods for developing data inputs and the operation of MARS could achieve the same results. For example, for the Electrification Balanced Blend scenario, additional battery capacity and some undone retirements were manually added to reduce LOLE in the final years.

Maintaining reliability as intermittent resources increase will remain a key challenge and planning objective for Connecticut in pursuit of a 100% zero carbon goal. Energy storage technologies, demand response programs, and other solutions will continue to be critical in ensuring resource adequacy with limited, or no traditional capacity resources. Further discussion of these resources and their potential is included in Objective 5.

Strategies to Achieve Objective 1

A 100% Zero Carbon Electric supply is necessary for Connecticut to meet its economy-wide target of 80% emissions reductions below 1990 levels by 2050. The modeling results described above show that there are multiple, achievable paths to a 100% Zero Carbon Electric sector, and provides several key insights that inform this IRP's recommendations for continuing the decarbonization of the electric sector in a manner that is both reliable and affordable for ratepayers. Modeling is, of course, not a perfect predictive tool for what will actually happen, and none of the scenarios modeled are an expression of a preferred policy or procurement strategy. Rather, the scenarios indicate key contingencies that can have a significant effect on the pace of emission reductions, the cost of achieving those reductions, and the quantities of different types of resources that could be utilized to meet the 2040 goal under various circumstances.

Part II of this IRP lists several strategies in furtherance of Objective 1*, Decarbonizing the Electricity Sector*. Many of these strategies also support other Objectives that will be discussed further below. Based on the modeling above, there are several contingencies to consider, including:

- <u>The Millstone nuclear facility continues to play an outsized role in Connecticut's— and the region's—decarbonization pathways.</u> As noted above, the modeled Millstone Extension scenario achieves the 100% Zero Carbon Target at a lower cost ($5.0 billion lower net present value to ratepayers) than the Base Load Balanced Blend scenario. The Millstone Extension scenario as modeled results in greater fossil fuel retirements and produces net savings for ratepayers ($1.25 billion in net present value) as compared to the business-as-usual Base Load Reference scenario, because it avoids the need for the region to procure comparatively larger quantities of new zero carbon resources to replace the Millstone facility. Connecticut must identify strategies that protect ratepayers against the potential of supplier-side market power in the wholesale markets, and create equitable cost-sharing mechanisms amongst all ratepayers that benefit from resources such as Millstone **(Strategy 5)**.
- <u>The timing and quantity of procurement of new renewable resources will depend on a variety of factors.</u> The IRP modeling results above indicate that new procured renewable generation will need to be available beginning as early as 2025. However, a variety of factors could influence a procurement timeline, including whether market conditions and rules change in the near future **(Strategy 2)**, the rate of electrification of the building and transportation sector, and whether modeled or contracted resources are able to achieve commercial operation. The scenarios require substantial additions of hydropower and grid-scale renewables like solar, but whether they materialize depends on their ability to meet siting and other challenges. Moreover, already-contracted resources can also run into challenges. These challenges can increase costs and slow or even stop development. Increased transparency on siting and permitting rules will help improve development efficiency and reduce delays **(Strategy 10).** While acknowledging the need to monitor these and other conditions, this IRP relies on the modeled resource capacity needs to develop a schedule of procurements, which is particularly important for offshore wind **(Strategy 5)** since it takes several years to plan.
- <u>BTM resources are currently more expensive than grid scale resources, but that price gap could be narrowed</u> if the tariffs for BTM resources are updated to reflect declining technology costs in subsequent PURA proceedings, and siting availability for grid scale resources become more limited to protect natural resources and land use and to reduce environmental quality impacts **(Strategy 10).** At that point, consideration could be given to scaling BTM specifically to play a larger role in decarbonization, and associated cost impacts.
- <u>The deployment of different quantities of variable renewable resources like wind and solar will also require deployment of "balancing" resources or reserves, to ensure grid reliability without</u>

compromising emission reduction benefits. Connecticut must recognize and value technologies that will help balance and optimize the variable energy capacity needed to meet Objective 1, while also avoiding emissions. This includes continuing to invest in load reduction measures such as cost-effective energy efficiency and expanding demand response through the C&LM Plan and other efficiency measures **(Strategy 12)** and supporting the development of storage resources **(Strategy 13).**

- Investing in transmission to remove constraints may be a more cost-effective way to reach the 100% Zero Carbon Target. Transmission upgrades can reduce spillage of energy from clean energy resources, and generate up to $400 million in ratepayer benefits, relative to the Base Load Balanced Blend. However, these benefits need to be compared to ratepayer costs to fully understand the value of this approach. Connecticut will coordinate with other states to consider cost-effective transmission investments in advance of further procurements **(Strategy 4)**. The potential for transmission upgrades is discussed in more detail in Objective 5.

All of these contingencies are further addressed in the Strategies in Part II of this IRP, but the key conclusions provided by the analysis above are that Connecticut can feasibly reach a 100% Zero Carbon Target by 2040 needed to support the State's GWSA climate goals. Frequent evaluation of existing and proposed strategies, and the contingencies highlighted above will allow Connecticut to refine and optimize its progress towards this goal **(Strategy 5)**.

Other factors that will have a significant influence on Connecticut's ability to achieve Objective 1 include reforms to the regional wholesale electricity markets, accounting methods used in Connecticut's RPS compliance and Greenhouse Gas Inventories, and the participation of municipal energy co-ops. While monitoring the contingencies highlighted above, Connecticut needs to simultaneously pursue reform of wholesale electricity markets to ensure the efficient deployment of new resources needed to meet this decarbonization goal, and equitable mechanisms to share the costs of retaining existing resources like Millstone **(Strategy 2)**. Additionally, Connecticut should pursue changes to the State's RPS that will enhance its ability to meet the 100% Zero Carbon Target at a lower cost to ratepayers. This includes investigating whether it is in the best interest of ratepayers to retain RECs procured by the EDCs, on behalf of all ratepayers **(Strategy 7)**; increasing the integrity of the RPS compliance obligation by eliminating the impact of behind-the-meter resources **(Strategy 8)**; and phasing down the value of biomass RECs eligible as a Class I renewable energy source to diversify the resources supported by Connecticut's RPS **(Strategy 14)**. DEEP will initiate both its own proceedings and request that PURA open dockets to review these modifications.

Lastly, a number of programs and policies designed to advance the goals set by the GWSA have been implemented by the state's two EDCs and paid for by their ratepayers over the year, who constitute the majority of the state's energy load. Such policies include the RPS, energy efficiency investments through the C&LM programs, grid-scale renewable and zero-carbon energy procurements, the LREC/ZREC program, and the RSIP program. Together these initiatives have contributed to reducing electricity-sector GHG emissions 29 percent since 1990, 36 percent since their peak in 1997, and 31 percent since

2001.[62] Electric ratepayers of the state's EDCs fund the programs described above as well as the Millstone contract, thus, those ratepayers' contributions to the GWSA are clear.

The remainder of Connecticut's energy load comes from municipal electric cooperatives who serve approximately 6 percent of the state's electric supply.[63] While this IRP only addresses the electricity supply for the state's EDCs, the collective contributions of the state's municipal electric cooperatives towards the GWSA economy-wide targets are relevant to determining the relative decarbonization investment required by the state's EDCs to achieve electric sector emission reductions towards the GWSA goals. Municipal electric cooperatives are developing programs for decarbonization, as indicated by a presentation by the Connecticut Municipal Electric Energy Cooperative (CMEEC)[64] and written comments submitted by CMEEC in this IRP proceeding,[65] albeit at a pace that is "slower and more considered" than the EDCs.[66] CMEEC further stated that it and its customers should be held accountable for compliance with the GWSA and Governor Lamont's Executive Order 3, but at an approach and timeline tailored to their customers' needs. Currently, the municipal electric cooperatives do not have reporting requirements tied to the GWSA, despite the fact that the GWSA applies statewide.[67] In its written comments, CMEEC offered to submit reports to DEEP on the progress of its carbon reduction in a manner that will allow DEEP to account for such contributions in determining progress toward the State's goals. Such reporting by the municipal electric cooperatives is necessary to provide more complete information for them as well as for DEEP, PURA, and the EDCs. This information will help all parties determine and coordinate the respective amount of investment required in the state's electric sector to meet the state's economy-wide targets, and determine if contribution to EDC ratepayer-backed clean energy investments is recommended for municipal electric cooperatives that are not making progress towards decarbonization. DEEP will issue a letter to the municipal electric cooperatives requesting metrics on their progress in deploying clean energy to develop a holistic view of Connecticut's clean energy portfolio before the end of 2021 **(Strategy 1).**

[62] Connecticut DEEP, *2017 Connecticut Greenhouse Gas Emissions Inventory*, published 2020, *available at* https://portal.ct.gov/-/media/DEEP/climatechange/2017_GHG_Inventory/2017_GHG_Inventory.pdf

[63] U.S. Energy Information Administration, *Annual Electric Power Industry Report*, Form EIA-861 detailed data files, 2019, *available at*: https://www.eia.gov/electricity/data/eia861/

[64] See, Presentation by Connecticut Municipal Electric Energy Cooperative in DEEP's January 22, 2020 technical meeting related to this IRP, *DEEP Technical Meeting Integrated Resource Plan CMEEC Insights*.

[65] CMEEC Written Comments, submitted October 29, 2019. http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/51c7b27775ac0827852584a8005e43e8/$FILE/Ltr%20DEEP_IRP%20Comments_10-29-2019.pdf

[66] *Id.*

[67] As recipients of funding from the RGGI proceeds, municipal electric cooperatives do have reporting requirements related to their expenditures of those funds. See RCSA § 22a-174-31(f)(6)(C)(ii).

Objective 2: Securing the Benefits of Competition & Minimizing Ratepayer Risk

As discussed in Objective 1, Connecticut has made substantial progress over the last two decades in reducing carbon emissions from the electricity sector. Over the coming two decades, additional deployment of clean energy resources is needed to achieve the necessary scale of emission reductions to combat climate change. This IRP focuses on ways to achieve that deployment at minimal cost, and with maximum benefit, to Connecticut ratepayers.

Unfortunately, Connecticut's participation in the regional wholesale electricity market constructs, as presently designed and implemented by ISO-NE, has become a significant barrier to cost-effective clean energy deployment strategies, while increasing regional reliance on natural gas to an extent that has threatened reliability. As a result, Connecticut ratepayers are exposed to greater risk and duplicative costs. This section examines these challenges, including the circumstances that have led to this point, implications for state jurisdictional clean energy programs such as the Renewable Portfolio Standard, and potential process and substantive improvements that are needed to realign state and regional markets, for the benefit of Connecticut's ratepayers.

Connecticut's Aims for Restructuring

In the late 1990s, Connecticut undertook efforts to restructure (or "deregulate") its electric industry with the intent of harnessing cost savings through (1) participation in a competitive wholesale marketplace for electricity generation, and (2) providing for competition and consumer choice in retail electricity sales. Before deregulation, Connecticut's utilities were vertically integrated monopolies that owned the generation, transmission, and distribution of energy. The costs and risks of any investments made by the utilities were placed directly on ratepayers. Thus, a central aim of deregulation was that ratepayers would no longer be responsible for paying for cost overruns, obsolete technology choices and stranded assets associated with monopoly utilities developing power plants on a cost-of-service basis. Instead, private ("merchant") power developers would compete in a deregulated market, taking on the risks and rewards of their investments, and ratepayers would reap the benefits of lower cost electricity supplied through a more efficient market.

In the decades since its inception, the regional electricity market, which is administered by ISO-NE and overseen by the Federal Energy Regulatory Commission (FERC), has evolved—at times over Connecticut's strong objection—from a tool for the achievement of shared reliability and cost savings, to a system that impairs Connecticut's ability to achieve its clean energy goals and maintain grid reliability in a cost-effective manner.[68]

[68] ISO-NE administers separate markets for energy, capacity, and ancillary services.

The regional market's design has evolved primarily around the investment needs of natural gas plants, allowing them to receive capacity payments in spite of their inability to run when called upon during winter cold snaps due to limited fuel availability. As a result, the region's reliance on natural gas plants has greatly increased, thwarting the entry of renewable and state-sponsored resources. The outcomes of the existing market are thus incompatible with Connecticut's long-term goals.

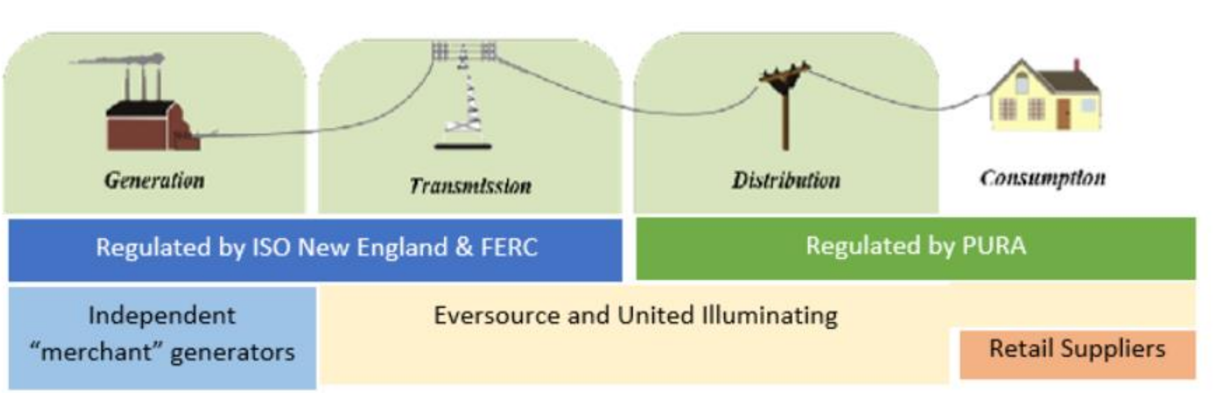
The regional market's design has evolved primarily around the investment needs of natural gas plants, allowing them to receive capacity payments in spite of their inability to run when called upon during winter cold snaps due to limited fuel availability.

Changing market rules have also intruded on the states' lawful authority under the Federal Power Act (FPA), undermining state authority over resource selection. Over time, ISO-NE market rules that recognized states' authority to self-supply outside of the market have been eliminated, while other rules, originally designed to prevent market manipulation by participants, are now being used inappropriately to hinder states' efforts to implement clean energy laws. The result is that Connecticut ratepayers must now pay twice to receive the same service need: once through standard service or alternative retail supply offers for Connecticut's share of the costs of ISO-NE markets, and again through a component of UI and Eversource distribution rates for the clean energy resources that Connecticut has had to contract with directly in order to achieve the State's laws and mandates, as further set forth in Objective 3 below.

The Regulatory Framework: Before and After Deregulation

The interstate electricity market is composed primarily of generators, which produce electricity; transmission providers, which deliver electricity from generators to re-sellers and purchasers; and load serving entities (LSEs), which are either the EDCs or competitive electric suppliers that deliver and sell electricity to retail customers.[69]

Figure 2.1: The Regulatory Structure after Deregulation



[69] *Allco Fin. Ltd. v. Klee*, 861 F.3d 82, 88 (2d Cir. 2017) (*Allco*).

The Federal Power Act (FPA) divides regulatory authority over these segments among federal and state authorities, and "envisions a federal-state relationship marked by interdependence."[70] The FPA vests with the FERC exclusive regulatory authority over both the "transmission of electric energy . . . and the sale of such energy at wholesale in interstate commerce."[71] The Federal Energy Regulatory Commission's regulatory authority "extend[s] only to those matters which are not subject to regulation by the States."[72] States "regulate energy production,"[73] including "questions of need, reliability, cost, and other related state concerns,"[74] as well as other local activities, including local distribution facilities,[75] and retail sales.[76]

Changes at the state and federal level in the mid-to-late 1990s resulted in significant restructuring of the electric industry in Connecticut and the broader New England region. Prior to 1998, Connecticut's EDCs were vertically integrated monopolies that recovered the costs of generation and distribution assets from electric ratepayers based on the "cost of service" plus a reasonable rate of return, all of which was regulated by the State's Department of Utility Control (DPUC; now the Public Utilities Regulatory Authority, or PURA). However, during the late 1970s through the 1990s, several converging trends caused policymakers to reconsider the vertically integrated monopoly model. Nuclear power plants had been hailed as an energy source that would make electricity "too cheap to meter." However, soaring cost overruns associated with new nuclear construction caused significant ratepayer impacts on those utilities that had invested in nuclear energy. Ratepayer risks associated with building large multi-unit plants on a cost-of-service basis caused policy makers to consider the economics of cheaper, smaller-scale fossil generation to reduce risk and lower costs. At roughly the same time, the perceived success of deregulating the telecommunications and airline industries and the belief that competition in the electric generation industry would lower costs and shift risk away from ratepayers. [77]

At the federal level, FERC took action to facilitate wholesale competition and ensure fair and nondiscriminatory access to transmission services.[78] Further, FERC encouraged the establishment of independent system operators (ISOs) and Regional Transmission Operators (RTOs) to operate regional transmission grids on behalf of transmission owners, and to facilitate market-based wholesale electric rates for the efficient management and reliable operation of the transmission system.[79] The Commission

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[70] *Hughes v. Talen Energy Mktg., LLC*, 136 S. Ct. 1288, 1300 (2016) (*Hughes*) (Sotomayor, J., concurring).

[71] 16 U.S.C. § 824(b)(1). The Public Utility Regulatory Policies Act of 1978 carved out a limited exception to the FPA that permits states to set wholesale prices for certain cogeneration facilities and small power production facilities less than 80 MW that sell power to local electric utilities, so long as those prices reflect a utility's avoided costs. *See* 16 U.S.C. § 824a-3.

[72] 16 U.S.C § 824(b)(1). FERC's regulation of wholesale transactions does not consider environmental impacts. *Grand Council of the Crees v. FERC*, 198 F.3d 950, 957 (D.C. Cir. 2000).

[73] *Hughes* at 1299, 1300 (Sotomayor, J., concurring).

[74] *Pac. Gas & Elec. Co. v. State Energy Res. Conservation & Dev. Comm'n*, 461 U.S. 190, 194, 205 (1983). *See also Californians for Renewable Energy, Inc. v. CAISO*, 117 FERC ¶ 61,072, P 10 (2006) (state has authority over generation facilities and environmental impacts).

[75] *Conn. Light & Power Co. v. FPC*, 324 U.S. 515, 531 (1945).

[76] *Hughes* at 1292; *FERC v. Elec. Power Supply Ass'n*, 136 S. Ct. 760, 766 (2016).

[77] *Resource Assessment of Millstone Pursuant to Executive Order No. 59 and Public Act 17-3*, PURA Docket 17-07-32, pp. 6-8.

[78] *See, e.g.,* FERC Orders 888 and 889; and FERC Order 2000.

[79] FERC Order 2000.

oversees ISO/RTO markets, and is in charge of approval of initial market rules and design. Changes in either also require FERC approval.

At the state level, with the enactment of Public Act 98-28 in 1998, Connecticut joined 17 states and the District of Columbia in deregulating retail electricity sales and requiring the divestment of all utility generation assets.[80] The objective of the Act was to no longer source conventional power generation on a cost-of-service basis funded by captive ratepayers, with the intent of harnessing the benefits of power supply competition, including lower prices and reduced risk for ratepayers.[81] While Public Act 98-28 directed utility divestment of generation, Connecticut retained authority over the State's generation mix. Section 25 of the Act established the state's Renewable Portfolio Standard, which required increasing percentages of Connecticut's load to be supplied by Class I and Class II renewable energy resources. Section 33 of the Act established funding for C&LM programs run by the electric distribution companies.

The Department of Public Utility Control's implementation of the deregulation statute focused on divestment of utility generation assets and establishing a competitive market for retail supply offers. The intent was that by requiring the utilities to divest their generation assets, a competitive retail supply market would emerge, thus reducing costs to ratepayers. However, because many of the generation assets held by the utilities had higher book values than market values, the utilities were left with "stranded" costs. These stranded costs were allowed to be recovered from ratepayers through the Competitive Transition Assessment (CTA) charge, which were in excess of $2.1 billion for the EDCs nuclear assets alone.[82]

New England's Electricity Markets: The Early Years

Following the establishment of ISO-NE, the New England wholesale electricity markets opened on May 1, 1999.[83] At their inception, the wholesale markets involved primarily energy and ancillary services (E&AS) markets, and a monthly capacity auction intended to ensure resources would be available to produce energy in the future for resource adequacy.[84] Upon its formation as an RTO, ISO-NE entered into a legal document known as the Participants Agreement, which formalized a stakeholder process for input and advice to ISO-NE by New England Power Pool (NEPOOL) participants (a group of utilities, generation suppliers, transmission owners, and end users), as well as individual market participants that are not members of NEPOOL. ISO-New England's market rules and operations are vetted by these stakeholders through this process.

In the early years of ISO-NE operations, pre-existing infrastructure deficiencies left the region dependent on out-of-market actions to preserve reliability. For example, at the time, southwestern Connecticut was experiencing congestion caused by transmission constraints. In order to remediate this congestion and ensure that generators required for reliable system operations would continue to be online, ISO-NE

[80] Vermont did not deregulate, and New Hampshire did not require its regulated utilities to divest their generation assets.

[81] *See* P.A. 98-28 § 2; https://www.cga.ct.gov/2006/rpt/2006-R-0526.htm

[82] *Resource Assessment of Millstone Pursuant to Executive Order No. 59 and Public Act 17-3*, PURA Docket 17-07-32, pp. 7-8.

[83] *New England Power Pool*, 100 FERC ¶ 61,286 (2002).

[84] *Devon Power LLC*, 115 FERC ¶ 61,340 P 5 (2006) (describing New England's capacity procurement mechanisms in place between 1998 and 2002).

entered into numerous reliability-must-run (RMR) agreements with needed resources that were threatening retirement. Generators operating under RMR agreements are obligated to remain in operation for a period of time in exchange for the revenue certainty provided by a contract, cost-of-service rate. The above market costs were paid for entirely by Connecticut ratepayers. Following the submission of RMRs covering more than 1,700 megawatts (MW) of generating capacity located within Connecticut (and particularly the constrained southwest Connecticut area), FERC expressed concern that the widespread use of RMR agreements was inhibiting the functioning of the region's competitive markets.[85] In response, FERC directed that a location-specific capacity requirement be developed.[86] This market mechanism would provide generators with an additional revenue stream, thereby helping to ensure that needed facilities would remain in operation without the need for out-of-market RMR agreements. Subsequent region-wide negotiations and litigation at FERC ultimately led to the creation of the Forward Capacity Market (FCM) structure—a version of which is in place today.[87, 88]

The Mandatory Capacity Market Construct

The Forward Capacity Market established annual capacity auctions to procure, three years in advance, sufficient capacity to meet the region-wide, annual Installed Capacity Requirement (ICR)[89] during an ensuing, one-year commitment period.[90] To achieve this purpose at "least cost," ISO-NE administers an annual, descending clock auction—the Forward Capacity Auction (FCA)—in which supply resources compete to obtain Capacity Supply Obligations (CSOs)—the responsibility to provide electric energy during the relevant commitment period if called upon to do so. In procuring a mix of resources to satisfy the region's resource adequacy needs, the FCA treats all capacity within a zone as fungible. Resources are selected based on one criterion—cost—and without regard for a resource's contribution to fuel diversity, technology, or emissions characteristics. Even the focus on "least cost" is misleading. The capacity market is designed around the relatively low fixed cost and high variable cost of natural gas generation as opposed to the tendency of higher fixed cost and zero variable cost of zero carbon resources.

The cost of the capacity purchased through the auction is paid by load-serving entities (LSEs) in proportion to each LSE's load-share of the region's total capacity requirements.[91] In creating a new revenue stream for generators, the FCM was intended "to [address] the compensation problems faced by generating resources that are needed for reliability but could not obtain sufficient revenues in the markets to continue operation."[92] At its inception, a key element of the FCM was the right on the part of LSEs to use owned or contracted-for generation resources to offset CSOs, thereby effectively reducing the amount of capacity the LSE must purchase from the auctions.[93] In other words, an LSE had the ability to satisfy its capacity supply requirements through arrangements outside the FCM, and to procure through the FCM

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[85] *Id., at* P 29, 31

[86] *Id.*

[87] *Devon Power LLC*, 103 FERC ¶ 61,082, PP 29, 31 (2003).

[88] *Devon Power LLC*, 115 FERC ¶ 61,340 (2006) (subsequent history omitted).

[89] The ICR is "the level of capacity required to meet the reliability requirements defined for the New England Control Area." ISO-NE Tariff § I.2.2.

[90] *See Devon Power LLC*, 115 FERC ¶ 61,340 (2006), *order on reh'g*, 117 FERC ¶ 61,133 (2006), *aff'd in relevant part sub nom. Me. Pub. Utils. Comm'n v. FERC*, 520 F.3d 464 (D.C. Cir. 2008).

[91] *Id.* P 20.

[92] *Id.* P 62.

[93] *Id.* P 20.

any additional capacity necessary to meet the LSE's residual needs (those beyond the contracted-for amounts). The FCM design thus did not overturn—but instead accommodated—state generation policies. If a state directed its EDCs to purchase capacity from a specific resource or type of resource, the self-supply rights preserved in the original FCM design meant that the EDC could use those contracts to offset the amount of capacity it was obligated (as an LSE) to purchase through the FCM.

Over the past decade, the self-supply rights that were originally a centerpiece of the settlement that created the FCM have been gutted. Under the current capacity market design, new self-supplied resources must meet minimum offer bid requirements. The MOPR sets a price floor below which no new entrant may offer its capacity unless it can demonstrate that its actual costs fall below that floor price. Higher bids increase the risk that a resource will not clear the auction; capacity that fails to clear is not counted toward meeting the LSEs' capacity requirement.

To guarantee that a resource that has been contracted for outside of the auction will clear the FCA and be counted toward satisfying a part of an LSE's capacity obligations, an LSE offering that capacity into the FCA typically would seek to offer as a "price taker"—that is, the resource would be willing to stay in the auction and take on a capacity obligation at any price, no matter how low. Application of the MOPR, however, prevents these resources from participating as price takers, and instead requires them to bid at their going-forward costs, *without* taking into account the revenues these resources receive through their state-sponsored contracts. This effectively prices zero carbon resources like wind and solar out of the market. The MOPR thus creates significant risk that the LSE's customers will have to pay for capacity twice for resources supporting state policy goals: once through the long-term contract to secure that capacity, and a second time through the FCM, because only FCM-cleared capacity is counted toward an LSE's capacity obligations.

Mitigation measures like ISO-NE's MOPR are intended to prevent the inappropriate exercise of market power and thus protect against artificial price suppression and other efforts to distort the market price.[94] But ISO-NE's MOPR has gone well beyond its market-protection purposes, and is applied to state-sponsored resources that are not being procured to exert market power or suppress FCM prices. The minimum bid rules approved by FERC and in place in New England have confused unlawful "price suppression" with the natural price-reducing effect of states' lawful efforts to pursue their legitimate policies and buyer-side preferences that increase the availability of low-cost and clean supplies.

The MOPR effectively prohibits the states from exercising their authority under the FPA to choose their preferred source of generation. FERC's position is that all electrons are the same regardless of where the generation is coming from and should be valued the same.[95] Most New England states have rejected FERC's policy position through enactment of decarbonization legislation saying, in effect, that not all electrons are the same and that the states prefer electrons from zero carbon resources. Because the FPA grants FERC authority over wholesale energy sales in interstate commerce, state laws that are found to intrude on FERC markets are likely to be preempted by FERC-approved tariffs. As a result, the states are forced to work outside the market and incur significant extra costs as FERC has, in recent years, been very

[94] *See ISO New England*, 158 FERC ¶ 61,138, P 48 (2017) ("The purpose of the [MOPR] is to prevent net buyers, in general, from bidding resources in such a manner as to suppress FCM prices").

[95] 169 FERC ¶ 61,239 https://www.pjm.com/-/media/documents/ferc/orders/2019/20191219-el16-46-000-el18-178-000.ashx

active in approving tariff rules that undermine state policy goals. This is the equivalent of the federal government directing that if states want to buy electric vehicles, they also have to buy combustion engine vehicles even if those combustion vehicles are not needed and would remain in the garage.

Conflict between State Policies and ISO-NE Markets

As noted above, the FCM construct focuses exclusively on selecting "least-cost" resources using a narrow calculation that excludes state revenues (which lower a resource's going-forward costs of providing capacity), favors natural gas generation, and ignores externalized environmental and other costs. This design does not make qualitative distinctions among resource types (e.g., on the basis of whether a resource is carbon-emitting). In addition, because the FCM has become the exclusive procurement mechanism for capacity in ISO-NE,[96] it is, by design, in direct conflict with state policies that seek to value criteria other than cost. To meet state policy mandates, states (and their ratepayers) must therefore support development of their preferred resources outside the FCM, and pay both for those resources and for FCM-selected capacity.[97] The New England states (through the New England States Committee on Electricity or NESCOE) have argued that applying the MOPR to state-supported resources will require ratepayers to pay for more capacity than is needed, and at excessive prices.[98] ISO-New England disagreed, asserting that state authority would have to give way when it conflicts with market design—and not the other way around:

> The primary reason consumers might pay for more capacity than is needed is because the state-sponsored resources are unlikely to clear in the FCA based on costs, but will be built anyway pursuant to state initiatives. If the states choose to build uneconomic resources outside of the FCM pursuant to current or future initiatives to further various policy interests, the states, not the FCM, are responsible for the procurement of redundant capacity.[99]

As described in more detail in the following sections, this hubristic perspective by the ISO-NE represents a fundamental misunderstanding of cooperative federalism and the delicate balance that Congress struck when enacting the Federal Power Act.

Connecticut's Environmental and Clean Energy Policies

Preventing environmental damage resulting from energy generation has long been a State policy in Connecticut. Public Act 98-28, the same statute that deregulated Connecticut's energy sector, established Connecticut's energy efficiency programs, the Clean Energy Fund (predecessor of the Connecticut Green

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[96] ISO-NE Tariff § III.13 ("To be eligible to assume a Capacity Supply Obligation for a Capacity Commitment Period through the Forward Capacity Auction, a resource must be accepted in the Forward Capacity Auction qualification process in accordance with the provisions of Section III.13.1").

[97] While the sponsoring consumers bear those extra costs, the fuel diversity, resilience, and other characteristics of the sponsored resources tend to benefit the entire market.

[98] *See, e.g. New England States Committee on Electricity v. ISO New England Inc.*, Complaint and Motion to Consolidate Proceedings of New England States Committee on Electricity (Dec. 28, 2012), Docket No. EL13-34-000 and ER12-953-001, eLibrary 20121228-5266.

[99] *New England States Committee on Electricity v. ISO New England Inc.*, ISO New England Inc.'s Answer in Opposition to Motion To Consolidate, Motion for Summary Dismissal Of Complaint, and Answer To Complaint at 13 (Jan. 14, 2013), Docket No. EL13-34-000 and ER12-953-001, eLibrary No. 20130114-5160.

Bank), and the State's Renewable Portfolio Standards (RPS). The Act explicitly declared that "the generation of electricity must be achieved in a manner that does not endanger the public health or safety and that minimizes negative environmental impacts."[100] Subsequently, in 2004, and revised in 2008 and 2018, the State set greenhouse gas emission reduction as an important State policy and established economy-wide greenhouse gas emission reduction targets for 2020, 2030, and 2050.[101]

Beginning in 2008, Connecticut's IRP observed that, despite the State's ambitious renewable energy procurement targets, "the growing demand for renewable electric generation created by these targets may outpace the development of eligible supplies," needed to displace conventional generation.[102] The 2012 IRP projected a gap between available renewable energy supply and the amount of renewable energy needed to meet Connecticut's targets.[103] Previously, the 2010 IRP had also concluded that RECs, energy, and capacity market revenues would be insufficient to meet Connecticut's clean energy goals and displace unneeded fossil generation.[104] This finding also indicated that the "optimal strategy for meeting the State's RPS requirement is to procure renewable energy as a part of a New England regional market."[105] Thus, the State enacted policy mechanisms in furtherance of these environmental and climate goals, including authorizing State-run procurements for long-term energy and REC contracts for a variety of renewable and zero carbon resources beginning in 2013.[106]

In addition to pursuing increased renewable generation development to meet Connecticut's climate goals, Connecticut has undertaken measures to "conserve energy resources by avoiding unnecessary and wasteful consumption," and "consume energy resources in the most efficient manner feasible."[107] As early as 2008, the IRP has emphasized aggressive pursuit of demand-side management resources such as energy efficiency as a cost-effective means to reduce customer costs, gas usage, and environmental emissions," while increasing economic activity in the state.[108]

Connecticut has at times been compelled to take action to accomplish reliability and other goals. In 2005, facing increasing electric rates and congestion in certain areas of the state, the legislature passed June

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[100] Conn. Gen. Stat. § 16-244(6) & (9).

[101] P.A. 04-252, *An Act Concerning Climate Change* (2004); P.A. 08-98, *An Act Concerning Connecticut Global Warming Solutions* (2008). P.A. 18-82, *An Act Concerning Climate Change Planning and Resiliency* (2018).

[102] The Brattle Group, Connecticut Light & Power, and The United Illuminating Company, *Integrated Resource Plan for Connecticut,* January 1, 2008, *available at* https://portal.ct.gov/-/media/DEEP/energy/IRP/2008IRPpdf.pdf

[103] Connecticut Department of Energy and Environmental Protection, *2012 Integrated Resource Plan for Connecticut,* January 14, 2012, *available at* https://www.ct.gov/deep/lib/deep/energy/irp/2012_irp.pdf.

[104] The Brattle Group, Connecticut Light & Power, and The United Illuminating Company, *Integrated Resource Plan for Connecticut*, January 1,https://www.ct.gov/deep/lib/deep/energy/irp/2010_irp.pdf.

[105] *Id.*

[106] Conn Gen. Stat. §§ 16a-3f; 16a-3h; 16a-3h; 16a-3j; 16a-3m. Public Act 19-71, *An Act Concerning the Procurement of Energy Derived from Offshore Wind* (2019).

[107] Public Act 92-106, *An Act Concerning the External Costs and Benefits Associated with Energy Generation and Revenues Received by an Electric Public Service Company Pursuant to the Clean Air Act Amendments of 1990,* amended this section to provide additional preference to conservation over other equivalent energy alternatives by adding Subdiv. (9).

[108] The Brattle Group; Connecticut Light & Power; The United Illuminating Company. 2008. *Integrated Resource Plan for Connecticut*. https://www.ct.gov/deep/lib/deep/energy/irp/2008_irp.pdf

Special Session Public Act 05-01 which authorized grants for customer-side distributed resources and long-term contracts with new generating facilities to reduce federally mandated congestion charges (FMCCs).

Connecticut also considers fuel diversity—i.e., utilization of a variety of fuel sources to mitigate risk associated with fuel-related price volatility and supply contingencies—and fuel security—i.e., the reliable supply of the various fuels used to generate the region's electricity—as primary operational concerns in its IRPs. In 2008, the IRP highlighted two harmful potential implications from overreliance on gas: first, that it exposes Connecticut ratepayers to "high and uncertain power costs, because gas is the price-setting fuel for electricity," and, second, that "using large amounts of natural gas for electricity generation may increase the potential of gas supply disruption in the winter months when natural gas use peaks." These findings spurred a recommendation for contractual, or ownership arrangements with non-gas baseload generating resources to maintain fuel diversity and mitigate gas dependence.

Connecticut's 2014 IRP emphasized the risk of the region's natural gas-fired generators "not contracting directly for the gas capacity they need to run," which causes the "wholesale spot market price of natural gas delivered to New England [to be] significantly higher," thereby increasing retail rates for ratepayers across the region. This concern is at its peak during cold winter periods when gas supply is also being used to meet thermal loads. For example, the wholesale price of natural gas was about $1-3/MMBtu before 2012/13 and $8/MMBtu in 2012/13, but rose to almost $14/MMBtu in December through February of 2013/14, largely driven by the extended "polar vortex" cold snap. These increased natural gas prices cost New England ratepayers an estimated additional $3 billion in wholesale electricity costs. To address this risk, Connecticut enacted Public Act 15-107, which allowed DEEP to solicit proposals for a variety of resources that could help address fuel constraints, including natural gas resources as well as energy efficiency and Class I renewable energy sources.

In addition, Connecticut has contracted for 10.9 million MWh of energy from nuclear power and an additional 7 million MWh of environmental attributes from nuclear power, which in total is the equivalent of more than 65 percent of EDC load.[109]

ISO-NE Market Design Changes

Previous iterations of the ISO-NE market design have included a partial accommodation for state-preferred resources. Under the ISO's Renewable Technology Resource (RTR) exemption, up to 200 MW of renewable resources were permitted to enter the FCM without being subject to the MOPR.[110] In the event that the full 200 MW was not used in a single year, the unused portion of the exemption amount was permitted to roll forward for use in later years, subject to a 600 MW cap on those carry-overs. While imperfect, this mechanism offered at least a partial solution to the region's "pay twice" problem. State-sponsored resources utilizing the RTR exemption could bid into the FCM at a price reflective of their true marginal cost—i.e., the increased cost associated with providing capacity, recognizing that the resource had already committed, through state-sponsored contracts, to provide energy.[111]

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[109] *See* PURA Docket No. 18-05-04 *Implementation of June Special Section Public Act 17-3,* Dominion Energy Nuclear Connecticut, Inc, Unredacted Power Purchase Agreements, January 1, 2020.

[110] *ISO New England Inc.*, 147 FERC ¶ 61,173 (2014) (subsequent history omitted).

[111] *ISO New England Inc.*, Docket No. ER18-619-000, Protest of the Connecticut Public Utilities Regulatory Authority, the Connecticut Department of Energy and Environmental Protection, and the Connecticut Office of

In 2018, however, the ISO requested—over Connecticut's strong objection[112] – that FERC eliminate the RTR exemption and establish a secondary FCM "substitution auction".[113] In the substitution auction, resources that do not clear the primary FCA due to the MOPR are given a second opportunity to enter the capacity market by trading into, or taking over.[114] Connecticut opposed the substitution auction because it provides a windfall for exiting generators, and creates uncertainty for new resources about when existing generators might exit.[115] In the two years that Competitive Auctions with Sponsored Policy Resources (CASPR) have been in operation, these concerns have largely born out: only 54 MW of state-sponsored resources have cleared through the substitution auction.[116]

FERC has likewise been unsympathetic to state policies. In December 2019, FERC directed sweeping changes to the design of the capacity market administered by ISO-NE's mid-Atlantic counterpart, PJM Interconnection (PJM), to address the participation of resources receiving out-of-market state support.[117] FERC directed PJM to expand the scope of its MOPR (currently applied primarily to new, natural gas-fired resources) to include both new and existing resources, whether internal or external, that receive or are entitled to receive a state subsidy"[118] The Commission's definition of state subsidy is expansive, and includes payments or other financial benefits awarded through a state-mandated or state-sponsored process, either derived from or connected to the procurement of capacity, an attribute of the generation of electricity, or otherwise supporting the construction of new capacity resources.[119,120]

Consumer Counsel, Affidavit of Cliff W. Hamal at ¶ 29 (Jan. 29, 2018) (Hamal Affidavit), eLibrary No. 20180129-5363.

[112] *Id.*

[113] ISO New England Inc., 162 FERC ¶ 61,205 (2018).

[114] *See generally,* ISO New England Inc., *Competitive Auctions with Sponsored Policy Resources (CASPR) Key Project* (last accessed Feb. 7, 2019), https://iso-ne.com/committees/key-projects/caspr.

[115] Hamal Affidavit at ¶¶ 41-42.

[116]*See* https://www.iso-ne.com/static-assets/documents/2019/02/20190206_pr_fca13_initial_results.pdf and: https://www.iso-ne.com/static-assets/documents/2020/02/20200205_pr_fca14_initial_results.pdf

[117] *Calpine Corp. v. PJM Interconnection, L.L.C.*, 169 FERC ¶ 61,239 (2019) (PJM Order).

[118] PJM Order at P 50

[119] Specifically, FERC proposes to define "State Subsidy" as:

[a] direct or indirect payment, concession, rebate, subsidy, non-bypassable consumer charge, or other financial benefit that is (1) a result of any action, mandated process, or sponsored process of a state government, a political subdivision or agency of a state, or an electric cooperative formed pursuant to state law, and that (2) is derived from or connected to the procurement of (a) electricity or electric generation capacity sold at wholesale in interstate commerce, or (b) an attribute of the generation process for electricity or electric generation capacity sold at wholesale in interstate commerce, or (3) will support the construction, development, or operation of a new or existing capacity resource, or (4) could have the effect of allowing a resource to clear in any PJM capacity auction. PJM Order at P 67.

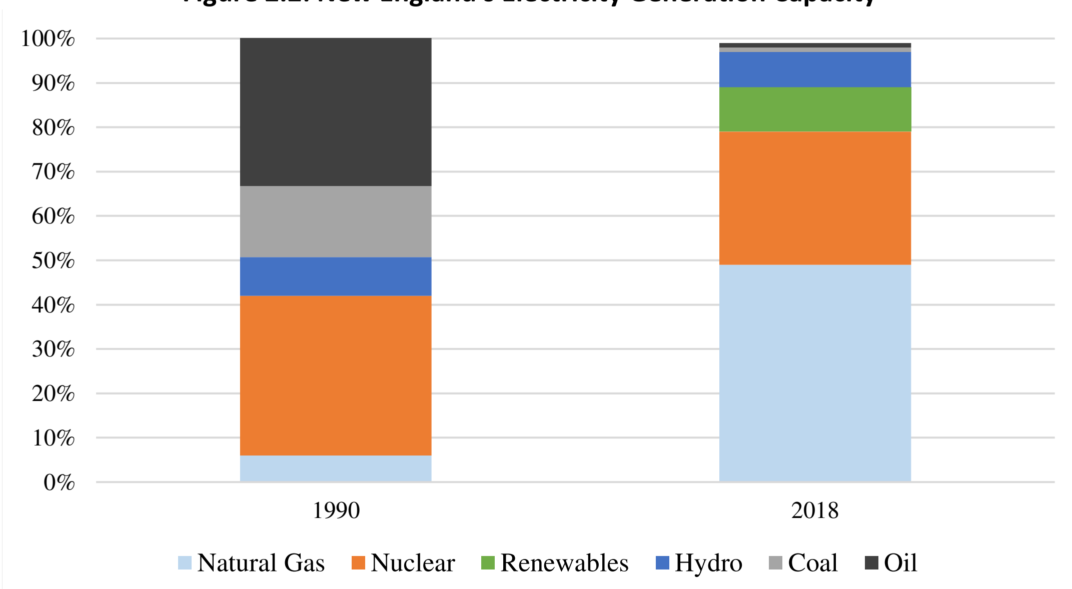
[120] Commissioner Glick has pointed out the Commission's orders have been unsympathetic to state policies: "At this point, the die is cast. Today's orders make unambiguously clear that the Commission intends to array PJM's capacity market rules against the interests of consumers and of states seeking to exercise their authority over generation facilities. For all of the reasons discussed above, there orders are illegal, illogical, and truly bad public policy. " PJM Order, at P 98. (Glick dissenting.)

If a PJM-style MOPR were adopted in New England, it could further exacerbate the "pay twice" problem by expanding the types of state support that triggers MOPR mitigation and applying the MOPR to new and existing resources. Instead of creating a market where a more diverse pool of resources can compete, this effectively ensures that the selection of natural gas power plants will continue to be selected by the FCM over renewable resources. This market structure creates significant environmental justice and air quality issues, all while artificially raising the cost of addressing them in the name of "fuel neutrality".

ISO-New England's Market Design Has Driven Overreliance on Natural Gas

At the same time that the ISO-NE has taken steps that inhibit states' ability to secure a diverse resource mix reflective of consumer preference, ISO-NE has continued to drive the market in the direction of over-reliance on natural gas. While natural gas comprised only 6 percent of the region's electric generation prior to restructuring, today, as shown below, nearly 50 percent of the region's 34,637 MW of generating capacity is fueled by natural gas:[121]

Figure 2.2: New England's Electricity Generation Capacity[122]



Increased reliance on natural gas generation has resulted in incremental reductions of conventional air pollution and carbon emissions in the region due to its displacement of coal and oil. But this increased reliance on natural gas, paired with the market's continued failure to appropriately value renewable resources, and a regional natural gas pipeline system that has not kept pace with the growth in natural-gas-fired generation, has also created a severe supply-demand problem that has exposed the region to serious reliability and fuel security concerns, particularly during more extreme weather events.[123] The New England power system's fuel security weaknesses were exposed during a January 2004 "cold snap" in which "record-high winter electricity demand coincided with the unavailability of substantial quantities

[121] ISO New England. 2019 *Regional System Plan,* October 31, 2019, *available at* https://www.iso-ne.com/system-planning/system-plans-studies/rsp/

[122] ISO New England. 2015. *Energy and Peak by Source.*

[123] ISO New England. 2015. *AD13-7-000 and AD14-8-000 Fuel Assurance Report.* https://www.iso-ne.com/static-assets/documents/2015/02/Final_for_Filing__Fuel_Assurance_Report.pdf

of [natural gas] generating capacity," and "pushed the electric system in New England close to its limits."[124] Since that time, gas resource development has continued, without any pipeline expansion—have meant that these concerns continue to persist.

Despite the region's limited gas pipeline infrastructure and the related reliability risk, ISO-NE has not considered fuel availability when qualifying gas-fired resources for participation in the FCA, or calculated how much capacity those gas resources can reasonably be expected to provide to the grid during cold weather when natural gas may not be available to generators.[125] Thus, the capacity purchased through the FCM may be unable to perform when needed—specifically, when the natural gas delivery system is constrained during cold-weather periods.[126]

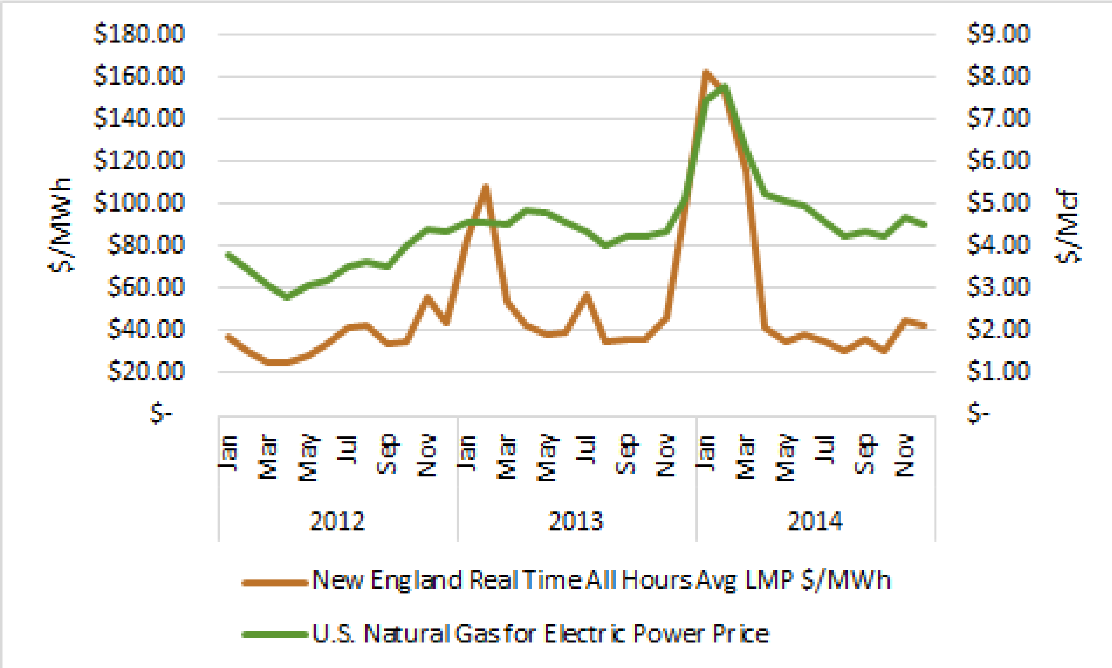
The region's gas dependence has also exposed consumers to significant price volatility. During the winter of 2013-2014, the "polar vortex" caused delivered gas prices to soar because of increased gas demand and supply constrains into New England. As a result, the cost of generation increased significantly to the point where the price of generation from burning gas and oil inverted, allowing oil units to set the locational marginal price (LMP) in more hours. The total wholesale generation cost of serving electric load in New England for the just the winter of 2013/14 was over $5 billion, compared to $5.2 billion for all of 2012. This was reflected in customers' retail rates the following year, which rose by 26 percent for Eversource customers, and 54 percent for United Illuminating (UI) customers. Figure 2.3 below demonstrates the relationship between natural gas prices and monthly average whole electricity prices over the course of 2012 to 2014. As demand for natural gas rapidly increased beginning in late 2013, prices spiked and resulted in a corresponding price spike for New England wholesale energy prices.

[124] ISO-New England. 2004. *Final Report on Electricity Supply Conditions in New England During the January 14-16, 2004 "Cold Snap".* https://www.iso-ne.com/static-assets/documents/2017/09/iso-ne_final_report_jan2004_cold_snap.pdf

[125] However, the ISO does prorate the capacity value of wind and solar resources.

[126] Petition of ISO New England Inc. for Waiver of Tariff Provisions (May 2018 Petition), Brandien Test., Ex. ISO-1, at 11-12, ISO New England Inc., No. ER18-1509 (May 2, 2018), eLibrary No. 20180502-5089.

Figure 2.3: Average Monthly Electricity and Natural Gas Prices between 2012 & 2014[127, 128]



The ISO-New England's efforts to date to address the region's fuel security issues have been ineffective. In recent years, ISO-NE has sought and obtained FERC approval to spend tens of millions of ratepayer dollars on programs to pay fossil fuel-fired generation to firm up fuel supplies ahead of the 2015-2016, 2016-2017, and 2017-2018 winters.[129] ISO-New England also developed and obtained approval of its Pay-for- Performance (PFP) program to correct the FCM's failure to ensure that cleared capacity would have the fuel to run when needed.[130] Under the PFP program, capacity resources are subject to penalties if they do not run when called upon during emergency, "shortage events." Ultimately, instead of resolving these issues efficiently, each of these initiatives have increased costs to ratepayers and the problems continue to persist.

The ISO-New England itself has acknowledged the inability of these measures to address the problem fully. The ISO-New England has concluded "even once fully implemented, PFP cannot be expected to resolve the region's fuel security challenges by itself."[131] In January 2018, ISO-NE issued its Operational Fuel-Security Analysis (OFSA), which "identified fuel-security risk—the possibility that power plants will not have or be able to get the fuel they need to run, particularly in winter—as the foremost challenge to

[127] U.S. EIA Wholesale Electricity and Natural Gas Market Data www.eia.gov/electricity/wholesale/#history

[128] ISO-NE Monthly Zonal Pricing Reports. https://www.iso-ne.com/isoexpress/web/reports/pricing/-/tree/zone-info

[129] *See ISO New England Inc.*, 144 FERC ¶ 61,204 (2013) (approving winter reliability program for 2013-2014 winter); ISO New England Inc., 152 FERC ¶ 61,190 (2015) (approving winter reliability program for 2015-2016, 2016-2017, and 2017-2018 winters).

[130] *ISO New England Inc.*, 147 FERC ¶ 61,172 (2014).

[131] May 2018 Petition at 16.

a reliable power grid in New England."[132] Among other things, the OFSA concluded that fuel constraints and recent retirements of several of the region's large, non-gas resources had left New England exposed to potential rolling blackouts beginning in 2024 if any one of several "critical" facilities in the region were unavailable.[133]

The OFSA's findings prompted one of those critical resources, the Boston-area Constellation Mystic Power, LLC ("Constellation") Mystic power plant ("Mystic"), to use its status as the basis for obtaining an RMR agreement. In 2018, Constellation threatened to retire Mystic and its nearby liquefied natural gas (LNG) terminal supplier if it was not given a cost-of service contract at a rate that Constellation deemed sufficiently profitable. That threat induced ISO-NE to enter into a two-year RMR contract with Constellation that guarantees the plants' owners 100 percent of the Mystic plant's cost-of-service and more than 90 percent of the cost-of-service of the LNG- terminal. The contract is expected to cost consumers hundreds of million dollars a year, or approximately $484 million.[134] Roughly a quarter of these charges will be paid by Connecticut ratepayers, or approximately $121 million.

Clean energy resources, such as efficiency, hydropower, offshore wind coupled with storage, and nuclear generation, are scalable alternatives that help to reduce the region's natural gas dependence—a fact ISO-NE has acknowledged.[135] These resources also achieve important state climate and air quality goals. And yet, ISO-NE's actions continue to discount the value of those solutions, while increasing the costs to consumers to provide them.

In addition, despite the 2018 ISO-NE OFSA[136] that concluded the retirement of Millstone would lead to rolling blackouts during extended cold periods because the region would run out of fuel, the ISO-NE failed to propose any meaningful mechanism to retain the Millstone facility and share the costs fairly across the region. Subsequently, Dominion announced that economic pressures put the Millstone units at risk of retiring. The ISO-New England and the current energy market construct failed to offer a solution to retain this generation asset, which ISO-NE itself determined was critical to the region's reliability, from retiring. The Connecticut General Assembly enacted Public Act 18-50, which authorized the entry by the State into a contract for Dominion Nuclear Energy's Millstone Generating Station in Waterford, Connecticut. The Department and PURA evaluated the impacts if Millstone were to shut down, reviewed Dominion's confidential financial records associated with the Millstone facility, and concluded that the plant was at risk of retiring. Given the alternative of catastrophic rolling blackouts, $5.5 billion in replacements costs and a 25 percent increase in greenhouse gas emissions if Millstone were to shut down, DEEP supported the selection and negotiation of a power purchase agreement (PPA) to prevent Millstone from retiring

[132] ISO New England Inc., Operational Fuel-Security Analysis at 4 (Jan. 17, 2018), https://www.iso-ne.com/static-assets/documents/2018/01/20180117_operational_fuel-security_analysis.pdf.

[133] *Id.* at 32.

[134] *See generally*, *Constellation Mystic Power, LLC*, 165 FERC ¶ 61,267 (2018).

[135] ISO New England Inc., Petition for Waiver of Tariff Provisions 24-25 (May 2, 2018), eLibrary No. 20180502-5089 ("There are many infrastructure solutions that can address the fuel system constraints in the region in the long term[,] . . . includ[ing] . . . firm renewable energy (e.g., imports of hydro energy, or off-shore wind coupled with significant electricity storage), and investments in energy efficiency measures").

[136] available at https://www.iso-ne.com/static-assets/documents/2018/01/20180117_operational_fuel-security_analysis.pdf

before 2029.[137] The State was able to cut the overmarket subsidy in half through contract negotiations. The contract is backstopped by Connecticut utilities and their ratepayers, but the contract ultimately benefits the entire New England region.

In sum, Connecticut embraced deregulation in 1998 as a means to secure generation supply through competition at a lower cost, and reduced risk, to the State's ratepayers. The State paid a high price for this opportunity, writing down $2.1 billion in losses with the sale of the utility-owned generation. The State did not intend to surrender its authority under the Federal Power Act to determine the resource mix serving its citizens and further State policy goals, evidenced by the multiple pieces of legislation passed by the General Assembly to increasingly direct the State's energy supply to a renewable and zero carbon mix. But slowly, over time, ISO-NE and FERC have undermined that authority by effectively eliminating the state's self-supply rights. At the same time, the ISO-NE market has struggled to maintain reliability, instead saddling Connecticut ratepayers with costly out-of-market RMR contracts in the mid-2000s; expanding the region's reliance on natural gas; and exposing ratepayers to retail price spikes, threats of rolling blackouts during periods of prolonged cold weather, and exercises of market power by non-pipeline natural gas resources such as the Mystic LNG facility as well as the Millstone nuclear facility. Approximately 90 percent of the equivalent of Connecticut's projected EDC load in 2025 is now under contract to nuclear and zero carbon resources needed to meet State clean energy goals and regional reliability needs, but the State continues to be assessed 100 percent of its load share of the ISO-NE market costs.[138] Wholesale energy market prices are at all-time lows, and the regional fuel security situation is greatly improved—benefits that the entire New England region enjoys as a result of Connecticut's investments. Connecticut has advocated vigorously in the ISO-NE stakeholder process and at FERC to oppose these inequities, but those concerns have largely been ignored. The present circumstance is inequitable, unjust, and unreasonable, and it cannot continue.

Connecticut finds itself at a crossroads, and is faced with a difficult choice: continue to push for changes to a broken market design through a process that has generally proven unresponsive to State needs, or pursue an exit from a regional arrangement that has become incompatible with the achievement of Connecticut's long-term goals. In collaboration with the other New England states, Connecticut has been working toward a regional solution to these market design flaws that will account for Connecticut's and the region's policy objectives, including fulfillment of clean energy mandates. As the initial step in such a potential regional solution, Connecticut and the rest of the New England states recently announced a joint Vision Statement.[139] In this statement, the states announced their commitment to pursuing a new, regionally-based market framework that will account for and support the States' clean energy laws in a reliable and affordable manner. The Vision Statement laid out five fundamental principles that any such regional solution must reflect. This multi-state process has the potential to produce a unified market

[137] Connecticut DEEP and PURA. Resource Assessment of Millstone Pursuant to Executive Order No. 59 and Public Act 17-3, Determination Pursuant to Public Act 17-3. February 1, 2018.

[138] The projected EDC load uses ISO New England CELT data, net of municipal EDC load, for the year 2025 as that is when all current contracted resources are expected to be operational.

[139] The Vision Statement is available at New England States Vision Statement | NESCOE. In addition, Governor Lamont joined with five other New England governors to announce the joint effort in a joint statement, which is available at: http://nescoe.com/resource-center/govstmt-reforms-oct2020/.

design that can finally secure a clean, reliable, affordable electricity supply for Connecticut ratepayers through a competitive regional market.

Securing the Benefits of Competition in State Jurisdictional Markets

Because the region's wholesale electricity markets have evolved in such a way that they are not procuring the types of resources needed to meet the State's clean energy and other public policy goals, Connecticut has, over the years, implemented a number of programs and mechanisms to drive investment in those resources. These programs include competitive procurements for grid-scale renewable resources and programs for behind-the-meter generation. Importantly, the State has maintained the same commitment to utilizing competition to achieve cost savings and minimize ratepayer risk when designing these state jurisdictional programs as it did in restructuring the generation sector in 1998. The continuing divergence of regional markets and state programs, and the accelerated focus on decarbonization objectives, has created opportunities for refinement of these programs to better serve ratepayers and address inequities. This section assesses recent trends and progress in these programs.

Connecticut's Renewable Portfolio Standard

Connecticut's RPS has served as a key policy tool in reducing the State's reliance on large, fossil fuel generators and spurring investment in alternative energy sources since 1998. The Renewable Portfolio Standard was designed to bring online renewable energy resources supporting State policy goals that were not otherwise being supported in the regional markets. The REC market was designed to provide the "missing money" between energy market revenues and the revenue necessary for a renewable energy project to come online. Each year, electric suppliers in Connecticut must comply with the RPS by procuring and properly settling the necessary amount of RECs to meet the percentage targets for each given RPS Class. REC market prices are primarily influenced by supply and demand for renewable energy resources. States establish their demand by setting RPS targets, signaling to the renewable energy market that there is willingness to pay for the development.[140]

However, REC sales to suppliers alone have historically been insufficient to receive financing to develop renewable energy resources because such investments are not made based on spot market pricing. Instead, renewable energy resources are developed based on long-term contracts for energy and/or RECs, which states support entering into to meet the RPS goals. The shift to long-term contracting as a means to achieve RPS and decarbonization goals led to Connecticut conducting a number of procurements to support renewable and zero carbon energy resources and provide the necessary revenue certainty to these resources through long-term contracts, both at the grid-scale and distributed generation levels.

Competitive Procurements for Grid-Scale Renewable Resources

The Department conducted its first procurement of renewable energy in 2011 using authority from Section 127 of Connecticut Public Act 11-80. Section 127 directed that 30 MW of Class I renewables be procured through an open, competitive RFP, and the state's EDCs were authorized to own and operate no more than 10 MW each of that authority. The average price of solar projects developed by the EDCs was $212.79/MWh, while the price of the solar project selected by DEEP through a competitive procurement was $123.12/MWh. Since that time, DEEP has opposed utility-only procurements. Utilities—through their affiliates—are allowed to bid projects into the State's procurements, competing on equal footing with other non-utility bidders. While procurements in other states like Massachusetts are run by the utilities themselves, Connecticut has assigned to DEEP the responsibility for procurement of these

[140] One REC is equivalent to one megawatt hour of energy produced by an eligible resource.

resources, to maintain the competitiveness of the solicitation and act as a check on potential utility conflicts of interest.

APPENDIX A6

Since 2011, DEEP has conducted nine procurements, resulting in contracts for 710 MW of grid-scale solar, 1,108 MW of offshore wind, 34 MW of incremental energy efficiency to the energy efficiency programs, 52 MW of fuel cells, energy and environmental attributes from 10.9 million MWhs of nuclear power, and additional environmental attributes associated with 2.85 million MWhs of nuclear power. Table 3.1 below shows DEEP's existing procurement authority, including how much of that authority has been utilized and how much authority is remaining. In total, DEEP is *authorized* by statute to procure up to 110 percent of the load associated with the state's two EDCs from renewable or zero carbon energy resources.[141] To date, Connecticut has procured the equivalent of 95 percent of the EDCs' load in the forms of energy and/or environmental attributes associated with renewable energy sources. Contracted zero carbon resources will provide the equivalent of 91 percent of the EDC's load by 2025.[142] A full list of projects resulting from DEEP's procurements that successfully negotiated contracts is included in Appendix A6.

[141] Based on an EDC load of 25,257,413 MWh in 2020. Eversource, Correspondence, 2019 Annual RAM Filing, PURA Docket No. 20-03-01, PURA Annual Review of the Rate Adjustment Mechanism of the Conn. Light & Power Co. (Apr. 8, 2020); The United Illuminating Co., Compliance Filing, Semi-Annual TAC, NBFMCC, and Umbrella Filing, PURA Docket No. 20-03-02, PURA Annual Review of the Rate Adjustment Mechanism of The United Illuminating Co. (Jul. 21, 2020).

[142] Based on projected load for the EDCs in 2025, when all current contracted procurements are expected to be operational.

Table 2.1: DEEP's Grid-Scale Procurement Authority

	Authorized (MW)	Authorized (MWh)	Authorized (% of Load)	Procured	Remaining
Section 6[143]			4.00%	2.74%	1.26%
Section 7[144]			5.00%	0.00%	5.00%
Section 8[145]			6.00%	5.85%	0.15%
PA 15-107[146]			10.00%	3.22%	6.78%
PA 17-3[147]		12,000,000	47.51%	46.18%	1.33%
	Additional Millstone Environmental Attributes			*11.28%*	
PA 19-71[148]	2,000	9,460,800[149]	37.46%	14.69%	22.77%
Sec. 17 of PA 19-35[150]	10	83,220	0.33%	0.00%	0.33%
TOTAL			**110.30%**	**83.96%[151]**	**26.34%**

As the cost for developing and deploying zero carbon resources declines, DEEP has been able to capture these declines on behalf of all ratepayers through competitive procurements. From the first purchases for grid-scale solar in 2011 to its most recent procurement for grid-scale solar in 2019, DEEP saw the average price for selected projects decline 65 percent, from $182.90/MWh to $64.23/MWh (nominal). This rate of change is relatively consistent with national data trends, which have shown that during the same time period levelized PPA prices for utility scale solar have decreased by 74 percent.[152] Figure 2.4 shows the average selected price and average selected size of solar projects in recent competitive procurements. See Appendix A6 for details on Connecticut's solar procurements.

[143] Conn. Gen. Stat. § 16a-3f. Eligible projects for this procurement include Class I renewable energy sources.

[144] Conn. Gen. Stat. § 16a-3g. Eligible projects for this procurement include Class I renewable energy sources and verifiable large-scale hydropower.

[145] Conn. Gen. Stat. § 16a-3h. Eligible projects for this procurement include run-of-the-river hydropower, landfill methane gas, biomass, fuel cell, offshore wind or anaerobic digestion, provided such source meets the definition of a Class I renewable energy source, or energy storage systems.

[146] Conn. Gen. Stat. § 16a-3j. Eligible projects for this procurement include passive demand response, Class I renewable energy resources, Class III renewable energy resources, energy storage systems, and verifiable large-scale hydropower.

[147] Conn. Gen. Stat. § 16a-3m. Eligible projects for this procurement include nuclear, hydropower, Class I renewable energy sources, and energy storage systems.

[148] Conn. Gen. Stat. § 16a-3n. Eligible projects for this procurement include offshore wind and associated transmission.

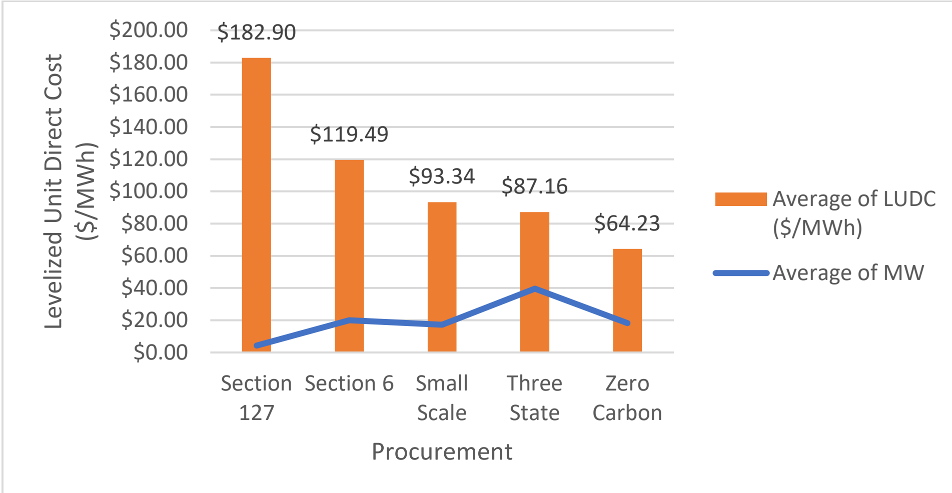
[149] Assumes an OSW capacity factor of 54%.

[150] Conn. Gen. Stat. § 16a-3p. Eligible projects for this procurement include anaerobic digestion.

[151] Of the 83.96% total energy and/or RECs/environmental attributes under contract, 81.38% is associated with zero carbon energy.

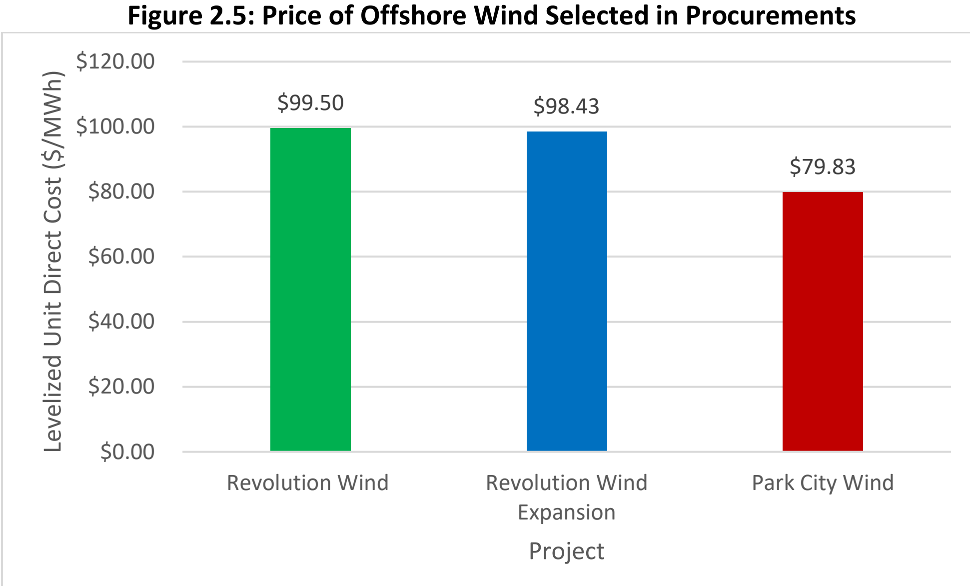
[152] Lawrence Berkley National Lab. Utility Scale Solar 2019 Edition Report. 2019. *Available at* https://emp.lbl.gov/utility-scale-solar .

Figure 2.4: Average Price and MWs of Grid-Scale Solar Selected in Procurements[153]



In addition, DEEP has seen price declines for offshore wind resources over an even shorter period. From 2017 to 2019, selected offshore wind project pricing declined 20 percent, from $99.50/MWh to $79.83/MWh (nominal).

Figure 2.5: Price of Offshore Wind Selected in Procurements



In order to meet energy policy and climate goals, the New England and surrounding states have conducted several procurements since 2009 to spur development of offshore wind and bring these resources online. Connecticut has been active in evaluating and procuring OSW resources as part of its efforts to meet its GWSA, including three project selections totaling 1,108 MW. This accounts for approximately 19 percent of the State's electric load under contract with its EDCs. The Department has authority to procure an additional 1,196 MW of OSW specifically under Public Act 19-71. Additionally, OSW is a Class I resource

[153] The Section 6 procurement resulted in only one solar project selection, Fusion Solar. Thus, this bar is the actual project price, not an average price.

eligible under other DEEP procurement authority. Nearly 15 percent of EDC load is available for additional procurement authority for all Class I resource types, equivalent to 3.8 million MWhs, where OSW would be eligible.[154] Public Act 19-71 specifically requires DEEP to establish in this IRP the quantity of offshore wind energy needed, and timing and schedule of solicitations that seeks to procure that needed quantity of offshore wind, which is discussed in more detail in Part II.[155]

The New England states have selected and/or contracted for 3,142 MW of OSW, all of which interconnect at ISO-NE pool transmission facilities (PTFs). New York is siting 1,010 MW of OSW in New England waters with interconnections directly onto the New York grid. The Block Island project is the only operational OSW off the New England coast, and Vineyard Wind Phase 1 will be the next project to go through the BOEM permitting process. Table 2.2 demonstrates the wind procurements in the last decade. Costs per MWh have declined over the years while procurement size has grown for the New England states, as shown by the comparatively low costs of the Park City Wind contract Connecticut procured in 2019.

Table 2.2: Offshore Wind Projects Selected by Connecticut and Neighboring States

Project	Year Selected	Procuring State	MW	Levelized Unit Cost	
				Nominal $/MWh	2020 $/MWh
Park City Wind[156]	2019	CT	804	$75.59	$58.31
Mayflower Wind[157]	2019	MA	800	$77.76	$59.63
Empire Wind[158]	2019	NY	816	$118.64	$89.74
Sunrise Wind[159]	2019	NY	880	$110.37	$84.48
Revolution Wind[160]	2018	CT	200	$99.50	$79.04
Revolution Wind[161]	2018	CT	104	$98.43	$78.19
Vineyard Wind Phase 1[162]	2018	MA	400	$89.49	$72.52
Vineyard Wind Phase 2[163]	2018	MA	400	$78.61	$62.45
Revolution Wind[164]	2018	RI	400	$98.43	$78.19
Block Island Wind Farm[165]	2010	RI	30	$340.50	

[154] Assuming a capacity factor of 54%, this equals approximately 815 MW of offshore wind.

[155] Section 3, Public Act 19-71, An Act Concerning the Procurement of Energy Derived from Offshore Wind.

[156] Redacted

[157] MA DPU Docket No. 20-16/17/18, Exhibit JU-3-A, Exhibit JU-3-B

[158] NYSERDA, "Launching New York's Offshore Wind Industry: Phase 1 Report", No. 19-41, Oct. 2019 (revised). Assumes COD of 2025. Contract includes capacity.

[159] NYSERDA, Launching New York's Offshore Wind Industry: Phase 1 Report, No. 19-41, Oct. 2019 (revised). Contract includes capacity.

[160] Docket 18-06-37 EL-2 CONFIDENTIAL

[161] Docket 18-05-04 EL-74 CONFIDENTIAL

[162] MA DPU Docket No. 18-76/77/78, Exhibits JU-3A, JU-3B. Procured as two phases under two separate contracts and different pricing schedules. Assumes COD of 2023.

[163] MA DPU Docket No. 18-76/77/78, Exhibits JU-3A, JU-3B. Procured as two phases under two separate contracts and different pricing schedules. Assumes COD of 2023.

[164] RI PUC Docket No. 4929, Schedule NG-1

[165] RI PUC Docket No. 4185, Amended Power Purchase Agreement as of June 30, 2010.

The modeling results detailed in Objective 1 demonstrate that Connecticut's commitment to zero carbon resources through grid-scale competitive procurements has put the State on the path to successfully achieving its 100% Zero Carbon Target by 2040. Because of the success of these procurements, the model projects that new grid-scale resources would be needed in 2027 under the Base Load Balanced Blend scenario, and 2026 under the Electrification Load Balanced Blend scenario, assuming that the Millstone units retire in 2029. In the event that Millstone does not retire in 2029, the model projects that Connecticut will not need new resources until 2029 in the Base and Electrification Load Millstone Extension scenarios. Under all of the scenarios and both load cases, the model projected that Connecticut will not need new OSW specifically until the early 2030s, as stated in Objective 1.

These modeling results are not a procurement schedule, but they do provide insights for when actions may need to be taken. Near-term actions that are necessary to unlock more zero carbon renewable investment are: 1) reforming the wholesale energy markets to ensure these resources can compete, and 2) address transmission constraints through planning or procurement. With ample supply of renewable and zero carbon resources under contract, the state is not in danger of falling short of its goals while undertaking those near-term actions (2021-2022); technology prices for resources like offshore wind will likely decline further during that time, and market reforms will ensure ratepayers get full value for procured resources in the capacity market.[166] In the meantime, DEEP will monitor the numerous contingencies described in Strategy 5 to determine if additional Class I zero carbon resources are needed in 2026 or sooner (note that procurements must be held several years in advance of the desired commercial operation date for new resources).

Distributed Renewable Resource Programs

As noted above, over the last decade, the use of competitive RFPs for grid-scale renewables has enabled the State to secure quantities of new resources needed to meet the State's greenhouse gas goals at prices that have declined over time in line with falling technology costs. The State has also embraced, where possible, competitive models for programs and incentives intended to support distributed renewable generation facilities. When programs supporting distributed generation are not suitable for the competitive procurement structure because it would be administratively challenging to target the intended customer base using an annual or semi-annual procurement (i.e. residential customers), the State also relies upon administratively-determined tariffs that aim to reflect the actual cost of installing these resources, similar to the goal of the competitive procurements.

Existing Program Structures and Progress to Date Distributed generation (DG) refers to small-scale energy resources, generally connected to the distribution system and located at or close to the end user. Distributed generation facilities include many different configurations and involve different types of electric utility customers. Historically, Connecticut has offered five ratepayer-funded DG incentive programs, some of which can be paired together for a participant: net-metering and virtual net-metering (VNM), which compensate for energy produced; the LREC/ZREC and the RSIP programs, which compensate for RECs produced; and the Shared Clean Energy Facilities program (SCEF), which compensates for both energy and RECs produced (see Table 2.3). These programs are in the process of transitioning into new incentive programs to support the same units through a more comprehensive and

[166] National Renewable Energy Laboratory. Annual Technology Baseline: Offshore Wind. 2020. https://atb.nrel.gov/electricity/2020/index.php?t=ow

transparent incentive structure under PURA's purview, as discussed in more detail below. Distributed generation facilities receive federal benefits in the form of tax credits, as well as property tax exemptions, which further reduce or offset the cost of deployment.[167] Interestingly, these programs compensate somewhat similar-sized facilities at very different prices.

Table 2.3: Connecticut Ratepayer-Funded Distributed Generation Incentive Programs

Program Participant Beneficiary	Facility Type	Energy Incentive	Environmental Attribute (RECs)
Residential customers who install Class I renewables on their premises	BTM Class I renewable facility that is less than 2 MW	Net Metering (uncapped). Average 22.5 cents/kWh incentive.[168]	Residential Solar Incentive Program (RSIP) *or* LREC/ZREC. Average 1.4 cents/kWh incentive.[169]
Commercial & industrial (C&I) customers who install Class I on their premises	Class I renewable facility that is less than 2 MW (LREC) or 1 MW (ZREC)	Net Metering (uncapped). Average 10 cents/kWh incentive for Eversource Rate 30 customers.[170]	LREC/ZREC. Average $7.12 cents/kWh incentive.[171]
Municipal, state, or agricultural customers who install a Class I/III facility on their premises ("host"), plus "benefited" accounts designated by the resource host	Class I or III renewables that are 3 MW or less	Virtual Net Metering. Average 10 cents/kWh incentive for Eversource Rate 30 customers.[172]	LREC/ZREC. Average $7.12 cents/kWh incentive.[173]
Subscribers who are electric distribution company customers	Class I renewable facility that is 4 MW or less	Shared Clean Energy Facilities (SCEF) program. Average 16.6 cents/kWh incentive from the pilot program.	

Further details on the structures of each of these programs are listed in Table 2.4 below.

[167] For example, the federal investment tax credit allows a deduction from federal taxes of a certain percentage of the cost of installing renewable energy like solar. In addition, Connecticut exempts from taxation certain renewable energy used for residential purposes and authorizes municipalities to abate property taxes on certain grid-scale renewable energy projects. Conn. Gen. Stat. Sec. 12-81(57).

[168] Based on average Eversource and UI 2019 rates for residential customers.

[169] Based on $0.3785 $/watt incentive in 2019. Green Bank, Supplemental Response to CAE-11, PURA Docket No. 20-07-01 *PURA Implementation of Section 3 of Public Act 19-35, Renewable Energy Tariffs and Procurement Plans*.

[170] Based on average 2019 rates. DEEP recognizes there are many different rates a commercial or industrial customer could participate in through the net metering program, and Eversource's Rate 30 is included as an illustrative example.

[171] Based on average accepted 2019 bid price in the LREC/ZREC program.

[172] Based on average 2019 rates. DEEP recognizes there are many different rates a commercial or industrial customer could participate in through the net metering program, and Eversource's Rate 30 is included as an illustrative example.

[173] Based on average accepted 2019 bid price in the LREC/ZREC program.

Table 2.4: Compensation Structures for Connecticut's Distributed Generation Incentive Programs

	Customer Eligibility	Resource Eligibility	Program Cap	Compensation Structure
Energy Compensation Programs for Distributed Generation				
Net Metering	Residential	CT Class I, 2MW or less	None	(1) netting out all volumetric (kWh) charges for energy produced within a given billing month; and (2) netting out all kWh charges for energy produced in excess of monthly consumption for a 12-month banking period. Customers are compensated for any unused credits at the end of the 12-month period at the wholesale electricity rate.
Virtual Net Metering	Municipal, state, and agricultural hosts	CT Class I or III, 3MW or less	\$20 million; plus additional \$6 million for municipalities, and \$3 million for agricultural customers	(1) netting kWh generation charges and a declining percentage of transmission and distribution kWh charges for all energy produced within a given billing period; and (2) netting kWh generation charges and a declining percentage of transmission and distribution kWh charges produced in excess of monthly consumption for a 12-month banking period. Customers are compensated for unused credits at the retail electricity rate at the end of the 12-month period.
Compensation Programs for Environmental Attributes				
LREC/ZREC	All	CT low-emission Class I, 2MW or less for LREC; CT zero-emission Class I, 1MW or less for ZREC	\$8 million per year; final auction in 2021	Projects are selected through a competitive auction structure in which the EDCs select all eligible resources within the available budget, ranked based on lowest price to highest price. Projects sell their RECs to the EDCs over 15-year contracts.
RSIP	Residential	Solar PV systems	350MW	The Green Bank provides incentives to customers for installing solar PV by directly paying the contractor or system owner to reduce the homeowner's upfront costs of installation or monthly lease payments. The program receives funding from 15-year contracts, called Solar Home Renewable Energy Credits (SHRECs), for the EDCs to purchase the RECs from the Green Bank at \$5 below the ACP or the small ZREC price, whichever is lower.
SCEF	Statutorily required mix by PA 18-50, Section 7	CT Class I	25MW annually for six years; Pilot capped at 6MW	Competitive procurement selects projects and then purchases both RECs and energy from the project on a 20-year contract

Together, these programs have succeeded in supporting the deployment of an accelerating amount of distributed generation in recent years. This accelerated pace is demonstrated in Figure 2.6, which shows incremental additions to the net metering and virtual net metering program, and Figure 2.7, which shows incremental additions accepted into the LREC/ZREC program. In addition, Figure 2.7 demonstrates the success of the competitive procurement structure, as an increased number of projects are accepted into the LREC/ZREC program using the same annual budget. The LREC program also had a higher number of solar participants in 2019, increasing the MWs accepted into the LREC program.

Figure 2.6: Annual Incremental Additions to Net Metering and Virtual Net Metering, 2005-2019

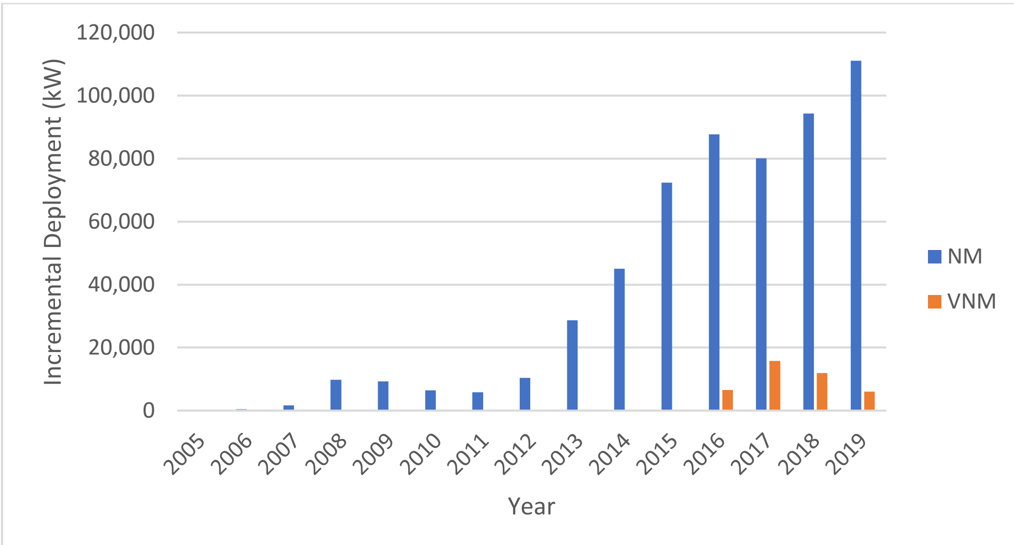
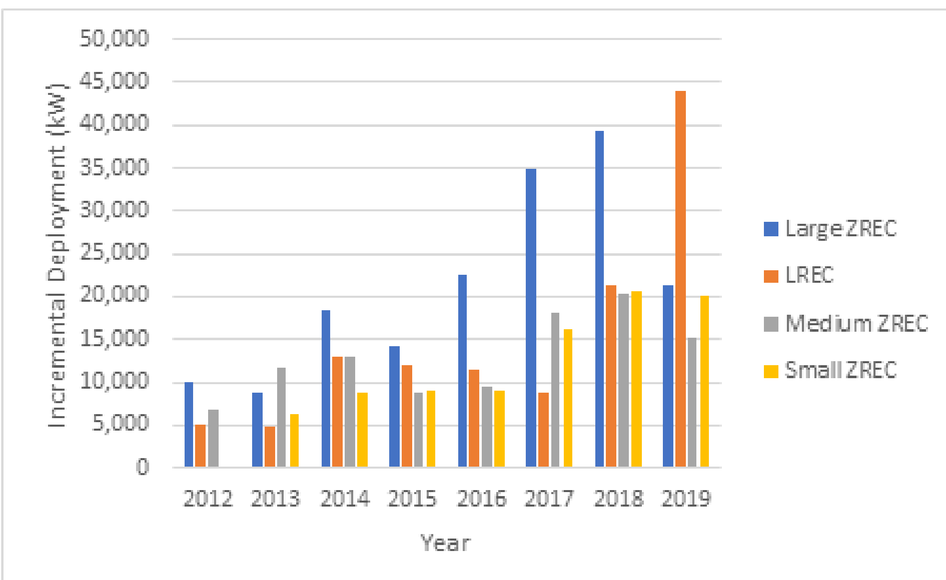


Figure 2.7: Annual Incremental Additions to LREC/ZREC, 2012-2019

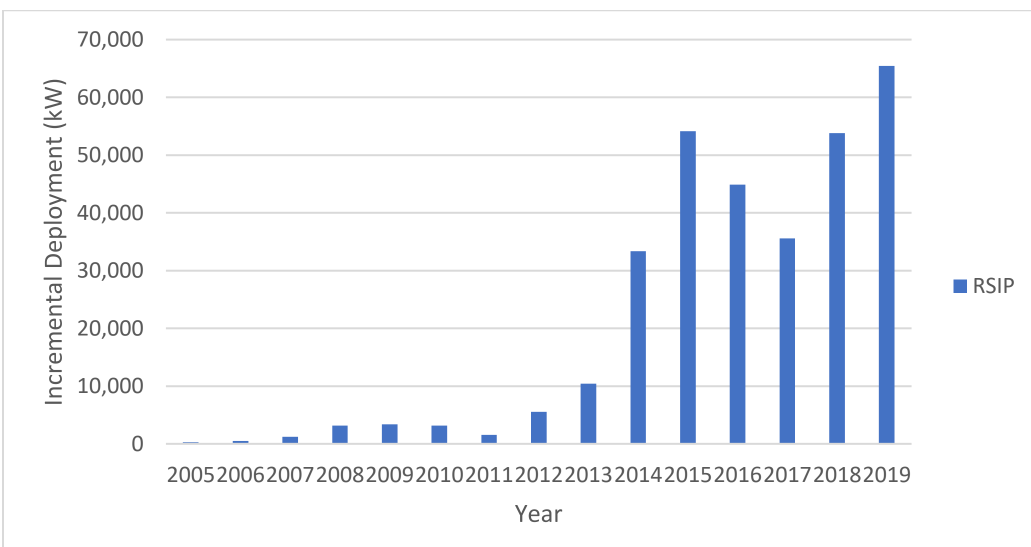


Fuel cells, which are also RPS Class I eligible, have been significant participants in the LREC programs as well. The LREC program, which provides a 15-year contract for the purchase of RECs generated by smaller, distributed fuel cells, has led to 60 installed fuel cells throughout the State and an additional 14 projects in development, totaling 45 MWs. For the duration of the contracts, the LREC program will provide an estimated $300 million in total incentives to fuel cells once the projects are operational. Additional fuel cell projects will be supported in the upcoming final 2 years of the LREC/ZREC program, as well as an additional 50 MW supported through the successor tariff procurements beginning in 2022. In addition, larger fuel cell installations are supported through long-term contracts resulting from grid-scale procurements. The fuel cell projects selected in DEEP's 2017/18 Best in Class procurement total 52 MW and will receive an estimated $1 billion in total contract revenue over the 20-year term. The fuel cell projects resulting from the procurement authority in Section 127 of Public Act 11-80 total 10.6 MW and will receive an estimated $323 million in total contract revenue over the 20-year term.

In addition to their ability to participate in the LREC successor programs, fuel cells will continue to be a part of Connecticut's energy future as the legislature also directed the EDCs to procure 30 MW of new fuel cell resources under Public Act 21-162. The Department has estimated that this will result in an additional $14 million per year investment in fuel cells by Connecticut's ratepayers.[174]

Figure 2.8 shows incremental additions accepted into the Green Bank RSIP program, which exclusively provides incentives to residential customers installing solar PV systems, as noted by Table 2.4. Together, Connecticut's multiple DG programs have supported the development of hundreds of megawatts across thousands of individual projects to date, as shown by Table 2.5.

Figure 2.8: Annual Incremental Additions to Green Bank's RSIP, 2005-2019[85]



[174] Based on the price of recently selected fuel cell projects in other procurements.

Table 2.5: Program Participation, UI and Eversource, as of July 10, 2020

Program	Cumulative Program Acceptance	Customer Participation
Net Metering	576.88 MW[175]	45,000 customers
Virtual Net Metering	86.18 MW (48.40 MW municipal, 24.7 MW agricultural, 11 MW state)[176]	84 projects
LREC/ZREC	481.81 MW[177]	2,575 projects
RSIP	340.77 MW[178]	43,025 customers
Shared Clean Energy Facility	5.22 MW[179]	3 projects

Valuing Distributed Renewable Resources

In the draft Value of Distributed Energy Resources in Connecticut (Value of DER Study), DEEP and PURA assessed the value that distributed energy resources like rooftop solar, grid-scale solar, rooftop solar paired with energy storage, standalone energy storage, fuel cells, and energy efficiency provide to the State.[180] The draft Value of DER Study attempted to quantify as many values as possible, and where explicit quantification was not possible, the study qualitatively discussed the values. The Department and PURA found the 25-year levelized, nominal values for the resources listed above were the following, as shown by Figure 2.9.

[175] Based on installed capacity

[176] Based on installed capacity

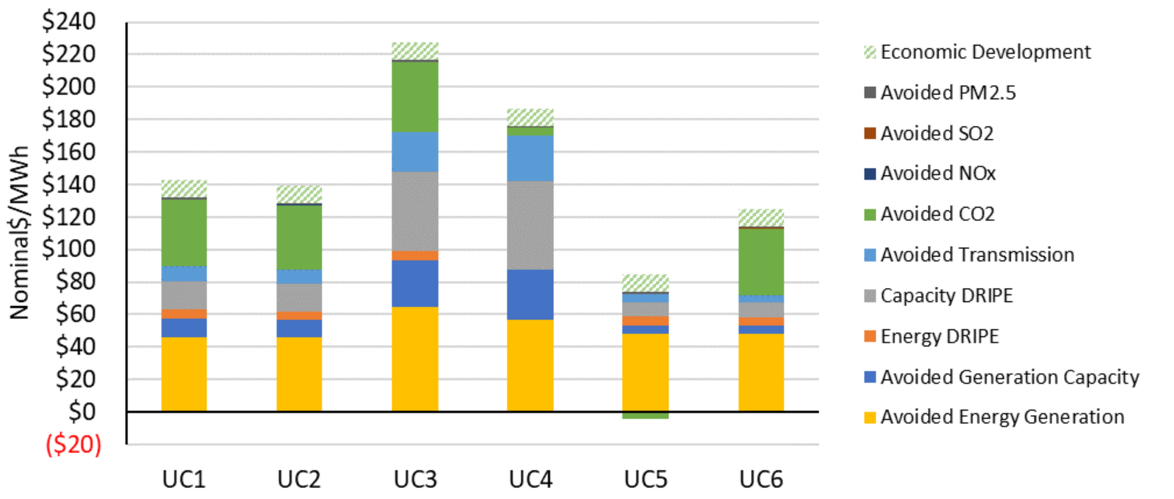
[177] Based on capacity accepted into the program

[178] Based on installed capacity

[179] Based on capacity accepted into the program

[180] DEEP and PURA, PURA Docket No. 19-06-29, *Value of Distributed Energy Resources in Connecticut*, Draft Study, July 1, 2020, *available at* http://www.dpuc.state.ct.us/dockcurr.nsf/8e6fc37a54110e3e852576190052b64d/56d151da9f6343af852585980063329d/$FILE/Value%20of%20DERs%20in%20Connecticut%20-%20Draft%20Study.pdf.

Figure 2.9: 25-Year Levelized Value of DER Use Cases per MWh of DER (nominal $)[181]



Note: Demand reduction induced price effects (DRIPE) refer to wholesale energy price reductions that result from energy efficiency and demand response programs.

Grid-scale solar facilities also provide some of these values, including avoided generation capacity and avoided energy generation, DRIPE, and avoided emissions. Distributed resources provide some unique benefits to the State that support investing in policy initiatives for their deployment, despite having higher costs than other zero carbon resources. For example, DG can be sited on rooftops to avoid additional development impacts in the state and support environmental and conservation goals; as such, rooftop configurations face fewer permitting, siting, and interconnection requirements and can be built faster. Distributed generation can support resilience by providing back-up generation power for critical infrastructure if the necessary islanding infrastructure is in place on the system, both in the context of microgrids and on a stand-alone basis, thereby potentially mitigating the urgency and thus the cost of restoration.[182]

The quantified value of most DERs in the study is generally less than the compensation received through the various available incentive programs. From the perspective of ratepayers who pay the cost of these programs, it makes sense to obtain this value at the lowest price necessary. In other words, resources should be procured or incentivized at a rate sufficient to bring them to market and maximize their value. Not all values in the study were quantified and many merit further exploration, like potential electric distribution system benefits, and system-siting.[183] The Department is committed to exploration of potential siting benefits, as further set forth in Objective 4, and notes that the potential for the realization of distribution system and resilience benefits may increase as the grid is modernized and more price-

[181] *Id.* A nominal discount rate of seven percent was used. The six Use Cases (UCs) evaluated in the Value of DER Study are: UC1: Behind-the-Meter (BTM) Solar Photovoltaic (PV); UC2: Front-of-the-Meter (FTM) Solar PV; UC3: BTM Solar PV Paired with Electric Storage; UC4: FTM Electric Storage; UC5: Fuel Cell; UC6: Energy Efficiency.

[182] Further discussion on microgrids, resilience, and grid security can be found in Objective 5.

[183] A nominal discount rate of seven percent was used. *See* DEEP and PURA, PURA Docket No. 19-06-29, *Value of Distributed Energy Resources in Connecticut*, Draft Study, July 1, 2020, *available at* http://www.dpuc.state.ct.us/dockcurr.nsf/8e6fc37a54110e3e852576190052b64d/56d151da9f6343af852585980063329d/$FILE/Value%20of%20DERs%20in%20Connecticut%20-%20Draft%20Study.pdf.

responsive rate design is implemented. Additionally, as discussed by Objective 3, DERs can help make clean energy more accessible for low-income communities, and other groups that have been historically underserved and overburdened by energy policy, so long as the benefits are directed appropriately. Finally, diversification of the suite of zero carbon resources deployed to meet our climate goals is an important benefit of resources like DG that warrants continued investment in deployment.

Figures 2.10 below shows the total MWhs expected to be produced by all zero carbon projects selected in DEEP's grid-scale procurements that have already been or are expected to be constructed over the next several years, as well as projects approved under the State's DG programs, RSIP and LREC/ZREC. Figure 2.11 shows the annual revenue received by resources participating in those programs. While grid-scale projects produce significantly more energy than DG projects, grid-scale projects are proportionately less expensive for the same amount of energy output than DG programs, particularly the RSIP program.

Figure 2.10: Annual MWhs Expected to be Produced by Resources Participating in State Programs, as of July 10, 2020

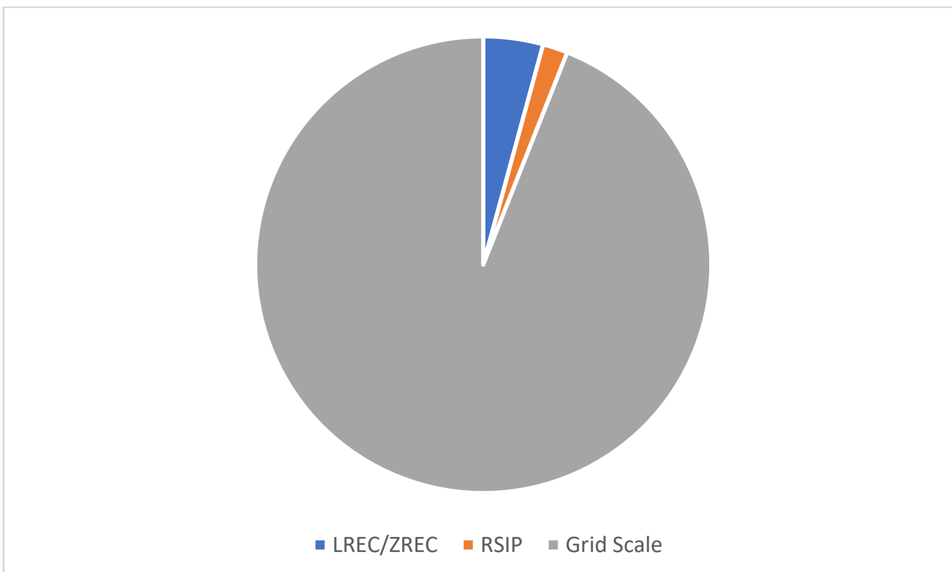
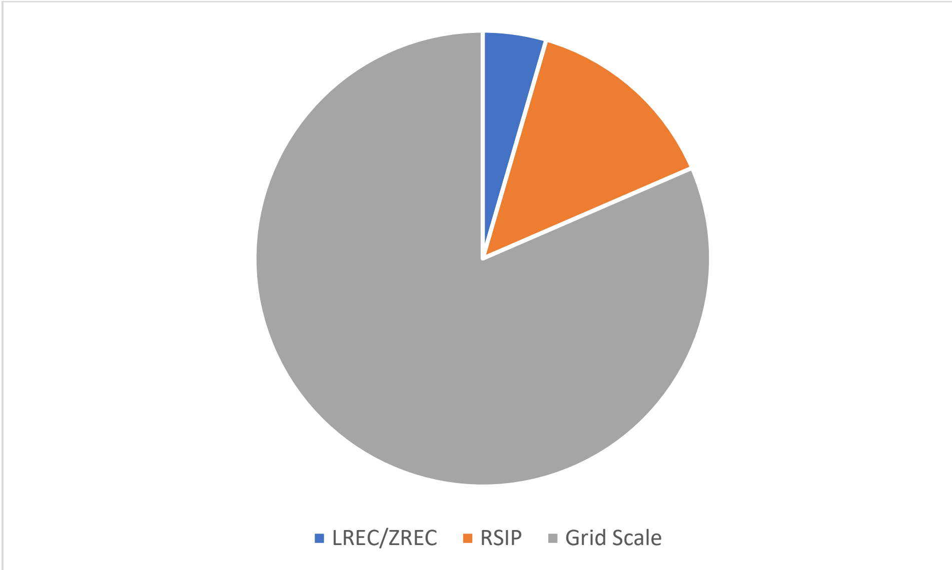


Figure 2.11: Annual Revenue Received by Resources Participating in State Programs, as of July 10, 2020[184]



The existing net metering and virtual net metering structure is tied to the retail rate for electricity, meaning the cost-effectiveness of a unit at the time of deployment depends upon a forecast of electric rates for the duration of the unit's operation. Because the retail rate changes based on the cost to the EDC of delivering power to customers and is in no way related to the distributed generation, the cost-effectiveness of a DG system can fluctuate with rate changes. For example, the 2014 Eversource rate case resulted in increased costs being recovered through demand charges rather than volumetric charges (based on kWh) for certain commercial customers, which resulted in a lesser portion of the bill that could be netted out through net metering, and thus smaller bill savings for those customers utilizing the net metering tariff.

A fixed price incentive based on a price at which the market can successfully install a unit – like that used for DEEP's grid-scale procurements – is a better incentive structure to provide revenue certainty to participants and program transparency. Competitive procurements are an effective tool for determining the fixed price the market currently needs to deploy distributed generation. This structure may not be suitable for smaller distributed generation intended to reach a large number of customers, like residential rooftop solar, because it may be too administratively complex to market to a significant number of residential customers in advance of an annual or semi-annual auction. Thus, it is more suitable to set an administrative fixed rate for these customers with the same goal of a competitive procurement, namely, to set it at a rate that ensures the unit is installed without having all ratepayers overpay for the resource. Incentive adders applied to the fixed rate could help address some of the barriers to adoption of rooftop solar for underserved and overburdened ratepayers. DEEP recommends that PURA also consider incentive adders for siting on previously disturbed land. Identified benefits to the grid could warrant additional incentives. An administrative fixed rate not only provides revenue certainty to the participant and

[184] Includes revenues received from LREC/ZREC/RSIP and net metering for distributed generation programs. Assumes all resources are online in 2019 and LREC/ZREC customers are on Eversource Rate 30 or UI Rate GC, and RSIP customers are on Eversource Rate 1 or UI Rate R.

transparency for all ratepayers, but it also allows the State to fill in any needed revenue gaps as federal tax incentives decline. Finally, it allows all ratepayers– not only renewable energy developers– to benefit from the declining costs of technologies and program efficiencies, resulting in cost savings for programs paid for by all ratepayers.

It is important to note that the BTM analysis included in Objective 1 is based upon national studies on the cost of solar and should not be interpreted to be the cost of deploying solar in Connecticut for the purposes of PURA Docket No. 20-07-01. In a sensitivity analysis, Levitan Associates, Inc. (LAI) compared the different costs to ratepayers if BTM is compensated at the national average cost of deploying the system or the residential retail rate. If BTM is compensated at the retail rate, the cost of deploying the BTM doubles. As demonstrated by Figure 1.20 in Objective 1, the successor tariff is important for creating a sustainable, least-cost compensation structure for distributed generation. This figure shows the cost of BTM systems compensated at Connecticut's current net metering rate compared to the same systems compensated at a rate based on the national cost of deploying solar, showing the former is significantly more expensive than the latter. As the State attempts to address climate change and maintain affordable electric rates, PURA must carefully balance finding a rate for the successor program that achieves continued deployment at competitive rates.

FERC Order 2222

In addition to the state jurisdictional programs that support the deployment of DG resources in Connecticut, DEEP also notes the forthcoming market opportunities made available by FERC's September 2020 Order 2222. This order will allow defined small scale distributed energy resources to aggregate together and participate in regional wholesale energy markets alongside conventional energy resources. Anticipated benefits include greater flexibility and resilience, as well as reduced costs to consumers through increased competition. In addition, providing access to new market revenues for storage, demand response and other distributed energy resources will encourage introduction of new resources while minimizing out of market ratepayer support. Not only will these new distributed resources mitigate potential load growth due to electrification, in some cases the new resources, if carefully sited, will obviate the need for new transmission buildout and improve the reliability of the existing transmission grid.[185] Challenges, of course, include coordinating the oversight of distributed resources between state jurisdictional regulators and federal markets overseen by ISO-NE. The majority of the requirements of FERC Order 2222 are being addressed in the NEPOOL Markets Committee and are expected to be filed with FERC in early 2022.[186]

Issues Affecting Connecticut's Renewable Portfolio Standard

Disposition of Contracted Renewable Energy Credits

For any RECs purchased resulting from DEEP's grid-scale procurements, the EDCs may either retain or resell those certificates, whichever is in the best interest of ratepayers.[187] Currently, the EDCs purchase the RECs and resell them into the market. This means that Connecticut ratepayers are providing the financial support needed to bring these renewable and zero carbon resources online but cannot

[185] Conversely, distributed resources not carefully sited could increase costs.

[186] On April 16. 2021, ISO New England filed a request for an extension to February 1, 2022 with FERC in Docket No. RM18-9-000. FERC approved the extension in its May 24, 2021 order. ISO New England filed a subsequent letter with FERC on September 21, 2021 providing a status update and reaffirming this goal.

[187] Conn. Gen. Stat. Secs. 16a-3f, 16a-3g, 16a-3h, and 16a-3 j; Public Act 19-71.

necessarily take credit for their production from an emissions accounting perspective because the associated environmental attributes may be sold outside of Connecticut.[188]

One of the primary objectives of the RPS and various programs is to incentivize the development of zero carbon and renewable energy is to help the State achieve its greenhouse gas reduction goals as articulated in the GWSA. It is therefore reasonable that the State take full credit for all the programs ratepayers are supporting in the State's carbon accounting. Connecticut General Statutes Section 22a-200a(a)(4) requires the DEEP Commissioner to establish the accounting to measure compliance with the statutory greenhouse gas reductions. The Department's current greenhouse gas inventory is consumption-based and attributes Connecticut's load share of regional emissions accounting for imports, line losses, and pumped storage. The greenhouse gas accounting to date has not been linked to the RECs retired by electric suppliers in Connecticut in compliance with the RPS or the RECs purchased by the EDCs pursuant to the several programs discussed above supporting renewable and zero carbon generation.

The most recent greenhouse gas emissions inventory is from2018.[189] The existing inventory structure is different from the accounting method used in this IRP, as discussed in Objective 1 and DEEP is currently revising its approach, as discussed in Strategy 7. Relatedly, this IRP recommends an investigation into whether it is in the best interest of ratepayers to retain RECs and environmental attributes purchased through energy policy programs like DEEP grid-scale procurements and DG programs.[190]

The revenues earned from reselling the RECs in energy policy programs (e.g. RSIP, LREC/ZREC, etc.) are used to offset the total cost of the contract, which lowers the net contract cost paid for by all ratepayers when it appears as a line item in the federally mandated congestion charge (FMCC).[191] While the revenue received from the sale of the RECs helps to lower the cost of individual contracts themselves, it is not clear whether this practice of REC sales is resulting in least-cost RPS compliance for ratepayers overall. For example, there are administrative costs (e.g. transaction costs and risks) to selling RECs in the wholesale market through one program only to have suppliers purchase RECs for retail-level compliance with the RPS. In determining whether it is in the best interest of ratepayers to retain or resell the RECs, it is important to look at the costs incurred and revenues earned from grid-scale procurement RECs compared to the costs incurred by LSEs to purchase a similar amount and type of RECs. The Department understands

[188] Even RECs that are ultimately sold to an energy supplier serving Connecticut creates an inefficiency as the EDCs procure the RECs through a contract and then sell the RECs to an energy supplier in Connecticut for RPS compliance often going through a broker. This system creates several inefficiencies and middlemen, unnecessarily increasing costs to ratepayers.

[189] DEEP relies on data from the EPA in developing its greenhouse gas emissions inventory, and 2018 is the most recent year this data is available. The 2018 and prior reports can be found on the DEEP website at https://portal.ct.gov/DEEP/Climate-Change/CT-Greenhouse-Gas-Inventory-Reports

[190] PURA will explore this issue as part of its investigation on the building blocks of resource adequacy and clean electric supply in Docket No. 17-12-03RE10, set to be opened following the issuance of this IRP. *See* Final Decision, Docket No. 20-01-01, *Administrative Review of the Connecticut Light & Power Company's Standard Service and Supplier of Last Resort Service 2020 Procurement Results and Rates*, at p. 14 (Dec. 2, 2020).

[191] *See* PURA Docket Nos. 20-03-01 and 20-03-02. See responses to interrogatories from DEEP to Eversource, available at http://www.dpuc.state.ct.us/dockcurr.nsf/8e6fc37a54110e3e852576190052b64d/40161584f298b1b0852585a40062a0b4?OpenDocument; and responses to interrogatories from DEEP to United Illuminating at http://www.dpuc.state.ct.us/dockcurr.nsf/8e6fc37a54110e3e852576190052b64d/1b16844f6054979f852585a0004e078e?OpenDocument

there are administrative complexities to implementing this change, but believes the benefits in achieving our statewide climate goals and potential for cost savings warrant further investigation.

Impact of BTM Resources on RPS Compliance Obligation

Connecticut's RPS requirement is based on a percentage of the load that is settled through the ISO-NE wholesale market. Connecticut's RPS applies to load net of all of the BTM resources (as well as municipal electric utilities, which are exempt from RPS requirements) and energy efficiency. Behind-the-meter solar PV and BTM fuel cells are also Class I REC eligible, producing RECs that are counted towards RPS compliance. Thus, these resources are accounted for twice: once as a load reducer and once as a generator through the production of RECs. This "double count" effectively reduces Connecticut's annual RPS percentage because as BTM resources reduce the total load for the state, it coincidentally reduces how many RECs must be purchased by load serving entities; the impact of which is illustrated in Figure 2.13.

Figure 2.13: Connecticut Class I RPS Demand and Demand Net of BTM Resources

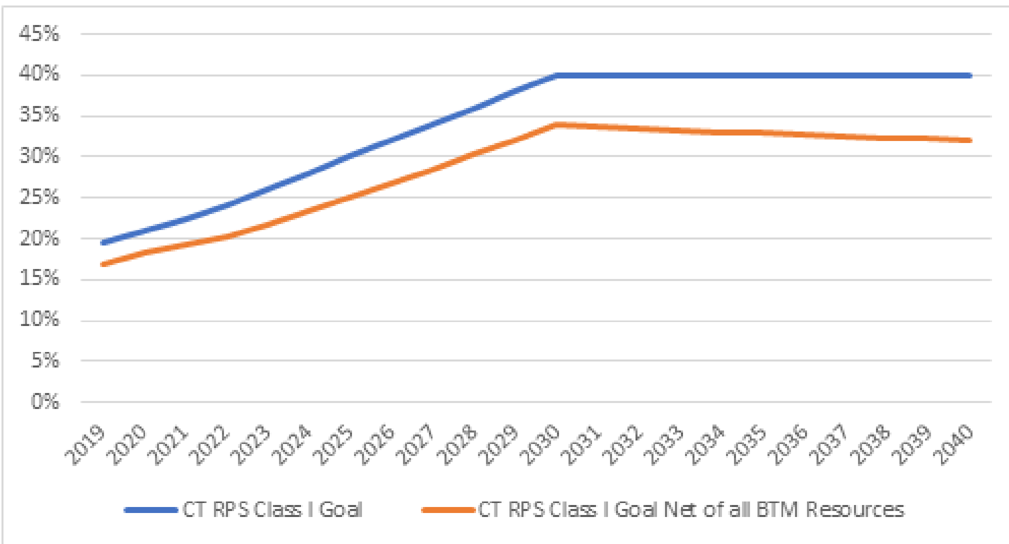


Figure 2.13 demonstrates how the impact of "double counting" BTM resources is not trivial. In 2029, counting BTM resources as both a load reducer and a Class I resource effectively causes Connecticut's projected Class I RPS requirement to be reduced from 40 percent to 33 percent. This reduced percentage is equivalent to more than 450 MWs of offshore wind that could have been supported.[192]

Strategies to Achieve Objective 2

Deregulation was perceived as a solution that would secure competitive, low-cost generation, and reduce risk to ratepayers. Instead, over the last two decades the markets established to support deregulation have caused Connecticut to forfeit its self-supply rights and authority to determine the resource mix serving its citizens. Additionally, the markets administered by ISO-NE have forced the region into over-reliance on natural gas resources while struggling to maintain reliability goals, instead falling back on expensive RMR contracts and, in the case of Millstone, Connecticut's ratepayers to support an out of market contract to prevent possible rolling blackouts impacting the region during a winter peak event.

[192] Assumes a 54 percent capacity factor.

ISO-NE has not been receptive to past efforts by the states to bring resolution to these issues. At this point, and in order to meet the 100% Zero Carbon Target as efficiently as possible, the markets must be reformed. This IRP recommends pursuing the following strategies in furtherance of Objective 2, Securing the Benefits of Competition & Minimizing Ratepayer Risks. These strategies are further explained in Section II.

At the regional level, Connecticut must pursue reforms of the New England wholesale electricity markets to resolve the issues discussed above in this Objective, including supporting the elimination of the MOPR **(Strategy 2)**. This will also include reforms to the governance structure of these markets to make them more inclusive and sustainable **(Strategy 3)**. As mentioned, any resulting changes from Strategy 2 and 3 will need to be closely monitored to determine their impact on the need for new grid-scale procurements to meet the 100% Zero Carbon Target **(Strategy 5)**. While working to achieve market reform, Connecticut will coordinate with the other New England states on evaluating transmission needs to meet state climate and energy policy goals and determine if the FERC Order 1000 public policy transmission planning process, or an alternative, is needed in the near future **(Strategy 4)**.

Enhancing competition of the clean energy markets to secure the benefits of lower costs or enhanced value for ratepayers will require Connecticut to update certain aspects of its own state-jurisdictional programs. For distributed generation programs, Connecticut should structure the successor tariff programs to achieve historic deployment levels and equitably distribute the benefits of zero carbon generation **(Strategy 6)**. This IRP also recommends addressing issues around compliance with Connecticut's RPS, including determining if having the EDCs retain RECS is in the best interest of ratepayers **(Strategy 7)**, and addressing the impact behind-the-meter resources have on reducing overall RPS compliance obligations **(Strategy 8)**. These actions will help increase competition and maximize the benefits the RPS can provide to ratepayers.

Objective 3: Ensuring Energy Affordability and Equity for all Ratepayers

DEEP's Environmental Justice Policy requires that "no segment of the population should, because of its racial or economic makeup, bear a disproportionate share of the risks and consequences of environmental pollution or be denied equal access to environmental benefits."[193] The Department is committed to incorporating environmental equity into its program development and implementation, its policy making and its regulatory activities." This policy applies equally to DEEP's energy mission.

In their report to the GC3, the Equity and Environmental Justice Working Group outlined four core concepts of equity:

1. *Distributive Equity* - relates to the distribution of benefits and costs and calls for directing resources to the most vulnerable communities.

2. *Procedural Equity* - relates to planning processes and calls for open, accessible planning processes in partnership low-income community and communities of color.

3. *Contextual Equity* - recognizes the legacy of racial and income equality, among other factors, in the development of policy.

4. *Corrective Equity* - recognizes that the most vulnerable communities often lack traditional forms of economic resources or political influence and calls for a process by which communities can hold institutions accountable.[194]

Thus, equity encompasses, but is far broader than affordability. Energy equity and justice requires a strategic focus to reduce the impacts of fossil fuel use and high energy costs on historically overburdened communities and break down historic barriers to participation in the clean energy economy in underserved communities. Connecticut must carefully consider barriers to participation or inequities in its various energy programs and how best to address them.

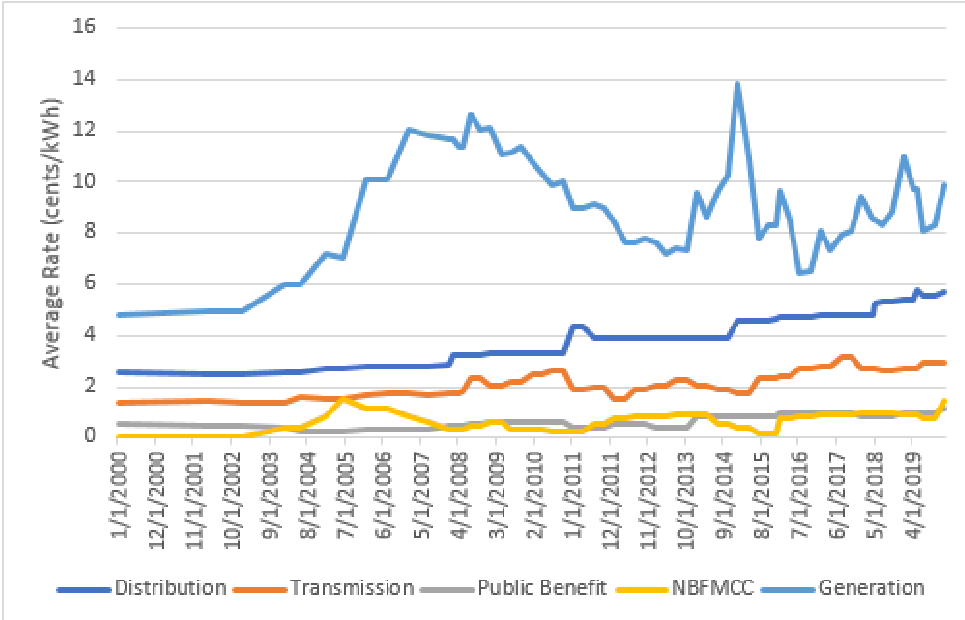
Energy Affordability

In recent years, there has been upward pressure on Connecticut's electric rates. There are several contributing factors to this. Figure 3.1 below shows the various components of the standard electric bill and how they have contributed to average electricity rates over time. Those components relevant to energy supply (the focus of this IRP) are further discussed below.

[193] *See* Connecticut DEEP. Environmental Justice Policy. https://portal.ct.gov/DEEP/Environmental-Justice/Environmental-Equity-Policy

[194] Governor's Council on Climate Change, *Equity & Environmental Working Group Report Prepared for the Governor's Council on Climate Change*, November 2020, *available at* https://portal.ct.gov/-/media/DEEP/climatechange/GC3/GC3-working-group-reports/GC3_Equity_EJ_Final_Report_111320.pdf

Figure 3.1: Historical Rate Composition in Connecticut, 2000-2019



This IRP focuses on those portions of the electric bill that relate to affordable electricity supply. The Generation rate component reflects an average of the retail price of electricity (i.e., Standard Service) supplied through the ISO-New England wholesale markets, or the full "requirements" that load-serving entities must include in supply offers to retail customers. The Generation rate includes the cost of the ISO-NE energy, capacity, and ancillary services markets, as well as the costs of RMRs and other mechanisms the ISO-NE has implemented in response to fuel security challenges and exercises of market power. The Generation rate also includes the cost of procuring Renewable Energy Certificates to meet the annual required percentage in compliance with the state's Renewable Portfolio Standard.

Retail rates for Generation have experienced volatile fluctuations in recent years, reflecting the sensitivity (discussed in Objective 2) of ISO-NE's natural gas-dependent electric market to changes in the availability and commodity prices for natural gas fuel. The highly volatile generation charge reflected in Figure 3.1 is the result of an electric system highly dependent upon natural gas powered generation in a region that does not have the infrastructure to support that level of natural gas generation in the winter during very cold weather events. As noted in Objective 2, ISO-NE's response to the over-reliance on natural gas has not been to try to create a market that encourages a diversity of resources, especially clean and renewable energy, but to prop up aging oil units and to actually discourage renewable generation through the MOPR. The state's investments in energy efficiency and renewable energy have helped to reduce the need for new power generation and mitigated to some extent the region's overdependence on natural gas, including by lowering capacity costs.

The regional markets have also failed to modernize and fully take advantage of distributed resources and non-wires alternatives, instead always responding to a system need by building more decentralized generation and new transmission wires. Thus, as Connecticut ratepayers are paying the full costs of investments consistent with state policies and a modern grid, they are also forced to pay their load share costs of the ineffectual ad-hoc regional market. The deregulated markets entered into by Connecticut policy makers to reduce costs and encourage innovation are actually having the opposite effect of increasing costs and stifling innovation.

In order to counter these systemic failures, Connecticut ratepayers have been forced to step in by entering into contracts with peaking and renewable generation that are recoverable through the non-bypassable federally mandated congestion charge (NBFMCC). The NBFMCC includes an array of different costs, some of which include the net costs of ratepayer-backed energy and REC purchase contracts that the state has entered into to ensure deployment of new renewable resources and more recently, prevent the retirement of the Millstone nuclear facility. In addition, investments in energy efficiency are supported largely through the Systems Benefit Charge (see Public Benefit, Figure 3.1). Removing the barriers to public policy resources in the ISO-New England markets, and achieving reform of the wholesale markets, as detailed in Objective 2, is a key strategy to improving the affordability of Generation supply, by reducing price volatility and costly RMRs associated with natural gas dependence, eliminating duplicative and inefficient costs associated with having to pursue clean energy objectives through separate markets, and seeking more equitable distribution of the costs of resources like Millstone that provide regional reliability and emission reduction benefits.

Impacts on Transmission Affordability

Competition is needed to cost-effectively meet our transmission needs. Over the last twenty years, there has been significant investment in transmission infrastructure in New England.[195] Regional returns on equity (ROEs) allowed by FERC in transmission rate proceedings are not only unacceptably high, they are moving higher and need to be addressed.[196] Transmission charges in New England rose from approximately $869.00 million in 2008 to $2.25 billion ten years later. The current $2.25 billion/year in network load costs represent 20 percent of total wholesale energy costs.[197] The result of this significant investment is a regional transmission system that is *currently* essentially congestion-free.[198]

However, this has come at considerable expense; transmission service costs in ISO-NE are more than double the average rates in any other RTO/ISO in the country.[199] In fact, New England is now ranked near the top nationally in load-weighted spending on transmission construction but New England ranks near the bottom in terms of circuit-miles built per megawatt-hour of load and circuit-miles per million dollars spent. In short, New England spends more on transmission and get less built then almost any other region of the country.[200] At least one reason for this is likely because, unlike other RTOs/ISOs, ISO-NE lags considerably in encouraging competition in developing transmission projects. In fact, while FERC Order 1000 expressly encouraged RTOs/ISOs to encourage competition in transmission planning, unique among

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[195] ISO New England, *2020 Regional Electricity Outlook*, p. 11, February 28, 2020, *available at* https://www.iso-ne.com/static-assets/documents/2020/02/2020_reo.pdf

[196] "Return on Equity" refers to the earnings electric utilities are allowed to earn on investments in transmission upgrades.

[197] ISO-NE Internal Market Monitor Quarterly Performance Report, Spring 2020, page 20.

[198] ISO New England, *2020 Regional Electricity Outlook*, p. 11, February 28, 2020, *available at* https://www.iso-ne.com/static-assets/documents/2020/02/2020_reo.pdf

[199] Potomac Economics, Highlights of the 2019 Assessment of the ISO-NE Markets, June 2020, page

[200] Dept. of Energy 2017 Transmission Metrics Report at pp. 40-50

RTOs/ISOs, ISO-NE has only now just completed its first competitive transmission procurement.[201] Studies have shown that cost savings on average of 20 percent to 30 percent can be expected if transmission development is open to competition.[202]

Therefore, it will be necessary that transmission planning going forward begin with a clear evaluation of how to maximize the use of the existing transmission system. In this regard, well-planned deployment of energy efficiency measures and BTM solar can obviate the need for expensive upgrades. Dynamic line ratings and system optimization software and other measures can effectively and measurably improve the efficient use of existing power lines. Only once that careful study has shown that new or upgraded transmission elements are truly needed will system planners and state officials proceed to the next step of developing new transmission projects. Transmission planning is discussed further in Objective 5.

Connecticut's Energy Affordability Gap

According to Operation Fuel's 2017 report "Home Energy Affordability in Connecticut: The Affordability Gap," Connecticut faces a significant gap in residential energy affordability, which is defined as the dollar amount by which home energy bills exceed what home energy bills would be if they were equal to an affordable percentage of income.[203] The Home Energy Affordability Gap model considers a bill "affordable" if it does not exceed six percent of annual household income. Connecticut's high electric rates result in correspondingly high household energy prices, which place a disproportionate and inequitable burden on low-income families. This burden is exacerbated by the aging, energy inefficient housing stock in the state. Approximately 30 percent of people seeking weatherization measures for their homes through the Home Energy Solutions Income Eligible Program (HES-IE), which serves those whose gross income does not exceed 60 percent of the state median income, cannot weatherize their homes due to health and safety barriers to the necessary interventions.[204] These barriers to weatherization prevent people from increasing their energy efficiency and it increases their energy bill. The average annual difference between actual and affordable home energy bills for households at or below 200 percent of Federal Poverty Level (FPL) was $1,404 per household in 2017. The aggregate Home Energy Affordability Gap (Affordability Gap) in Connecticut was more than $450 million statewide in 2017.[205] The population of households facing this Affordability Gap is substantial. According to the American Community Survey, Connecticut had roughly 320,000 households with income at or below 200 percent of the FPL.[206]

Private and public support services are not able to adequately address this Affordability Gap. The principle source of energy assistance in Connecticut is the federal Low-Income Home Energy Assistance Program

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[201] ISO New England, *2020 Regional Electricity Outlook*, p. 31, February 28, 2020, *available at* https://www.iso-ne.com/static-assets/documents/2020/02/2020_reo.pdf

[202] The Brattle Group, Cost Savings Offered by Competition in Electric Transmission, April 2019, at 10.

[203] Operation Fuel. "Home Energy Affordability in Connecticut: The Affordability Gap (2017). October 2017. Available at: https://operationfuel.org/wp-content/uploads/2017/12/2017-ConnecticutHEAG-11-27-17-RDC-edits.pdf

[204] Eversource. "Eversource Barrier Report," presented at the Energy Efficiency Board Residential Committee Meeting. July 8, 2020. https://app.box.com/s/ofikmpd7r7ubvwbwnyi98d39y8he19bk/file/688801991554

[205] *Id*.

[206] *Id*.

(LIHEAP). LIHEAP continues to cover only a fraction of the Home Energy Affordability Gap for a fraction of income-eligible households. Connecticut's LIHEAP allocation for the 2016-2017 heating season was only $78.7 million, roughly 17.5 percent of the total Affordability Gap in the state for 2017.[207]

In addition, businesses face energy affordability issues in Connecticut. High electric rates impact small businesses that often face barriers to engaging in energy savings measures such as efficiency and solar PV, especially if they rent their space. Energy costs also impact business decisions by manufacturers and other large commercial and industrial customers that use large quantities of energy.[208]

The affordability gap and the impacts from energy costs on economic development have been significantly exacerbated by the COVID-19 pandemic beginning in early 2020. As the virus spread, businesses were forced to shut down operations, causing thousands of Connecticut citizens to lose employment both temporarily and permanently. That impact is demonstrated by the levels of arrearages, or unpaid customer balances, the EDCs are currently carrying. This acute, recent trend highlights the need to emphasize affordable strategies in this IRP for meeting the state's electricity supply. PURA Docket 20-01-33 revealed that from 2015-2019 on average, UI has had between $20 and $30 million in "uncollectible" arrearages,[209] and Eversource has approximately $60 million.[210] By contrast, as of October 31, 2020, Eversource had arrearages of more than 30 days totaling nearly $265 million, almost $176 million of which was more than 120 days overdue.[211] Despite having far fewer customers, UI had arrearages of more than 30 days totaling nearly $232.5 million, the vast majority of which was more than 120 days overdue.[212]

Energy Equity

As noted above, energy equity includes, but goes beyond, energy affordability. One way to incorporate equity into clean energy deployment is to encourage deployment and workforce development in disadvantaged communities that can benefit from the economic and employment opportunities that can result. This can be particularly impactful when a developer appropriately values local labor, prioritizes contracting with minority-owned businesses, and invests in workforce training opportunities that benefit workers who are currently underrepresented in the clean energy economy. For example, in 2020, Connecticut finalized a PPA with Vineyard Wind to construct 804 MW of OSW off the coast of Massachusetts. Though the turbines will not be located on Connecticut soil, the agreement estimated $890 million in direct economic benefits for Connecticut, including investment into Bridgeport Harbor to establish it as a hub for OSW turbine construction and operations for the project selected by Connecticut and potentially neighboring states in the future. Vineyard Wind estimates 2,800 direct, full-time jobs will

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[207] *Id*.

[208] As of August 2020, Connecticut's commercial electricity rates were lower only than California, Alaska and Hawaii

[209] *See* PURA Docket No. 20-03-33, *PURA Review of Electric Distribution Companies' Method of Payment to Licensed Electric Suppliers for Uncollectible Customer Accounts,* UI Interrogatory Response EOE-001, March 19, 2020

[210] *See* PURA Docket No. 20-01-33, *PURA Review of Electric Distribution Companies' Method of Payment to Licensed Electric Suppliers for Uncollectible Customer Accounts,* Eversource Interrogatory Response EOE-001, March 19, 2020

[211] *See* PURA Docket No. 18-04-25, *PURA Investigation Regarding Issues Related to Uncollectible Accounts (Uncollectibles Investigation)*, Eversource Compliance Filing, Nov. 16, 2020.

[212] *See* PURA Docket No. 18-04-24, *PURA Investigation Regarding Issues Related to Uncollectible Accounts (Uncollectibles Investigation),* UI Compliance Filing, Nov. 13, 2020.

be created over the project's lifetime in Connecticut and plans to invest in local technical training opportunities.[213]

DERs like rooftop solar, battery storage, and active demand response measures can also provide communities with accessible and impactful opportunities to participate in Connecticut's renewable energy goals. Owning and operating these resources can reduce participating ratepayers' bills and make them more resilient. Additionally, the deployment of DERs can create economic opportunities in more localized, diverse geographies. Solar PV installers, for example, are needed anywhere there is demand for rooftop solar. With professional development and opportunities for upward mobility, entry-level solar installation jobs can also serve as stepping-stones to more advanced careers and business ownership in clean energy fields, leading to greater diversity and inclusion.[214]

However, DERs can also have accessibility and equity challenges, including high up front costs and lack of access for those who rent their homes. Though costs have declined over time and incentives and financing programs are available, eligibility is typically based on credit scores and debt-to-income ratios, creating another significant barrier for low-income households. Additionally, low-income households are less likely to own their homes, and more likely to live in multifamily housing, further limiting their ability to own or directly access DERs.[215] While the median income for solar adopters in Connecticut is trending down, the state has more work to do to reach low to moderate-income customers, and especially the lowest income customers, as less than 10 percent of Connecticut solar adopters in 2019 made less than 150 percent of the Federal Poverty Level.[216]

Barriers for renters also exist for energy efficiency and weatherization programs. Estimates show that one in ten homes in Connecticut have at least one health or safety barrier that prevents weatherization services, and that rate of prevalence is more than double in low-income homes.[217] Remediating these barriers can cost tens of thousands of dollars and there are limited funding and financing products available. In its past two Conservation and Load Management (C&LM) Plan annual update determinations, DEEP has approved a variety of proposals and issued a number of action items to increase accessibility and break down barriers to participation in the energy efficiency programs it oversees. DEEP is also currently working, and will continue to work with the Energy Efficiency Board and a wide variety of

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[213] Connecticut DEEP, RFP Pursuant to Section 1 of Public Act 19-71, *Procurement of Offshore Wind Facilities.* Notice of Final Determination. May 21, 2020. *Available at:* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/bf960f9e29e062608525856f0070badf/$FILE/2020.05.21_Final%20Determination.pdf

[214] Connecticut Department of Labor. Renewable Energy Generation Career Ladder. http://www1.ctdol.state.ct.us/lmi/green/RenewableEnergyGeneration.pdf

[215] *See* U.S. DOE Low-Income Energy Advisory Data Tool for Connecticut. https://www.energy.gov/eere/slsc/maps/lead-tool

[216] Galen L Barbose, Sydney Forrester, Eric O'Shaughnessy, Naïm R Darghouth. Residential Solar-Adopter Income and Demographic Trends: 2021 Update, LAWRENCE BERKELEY NATIONAL LABORATORY, April 2021. PowerPoint Presentation (lbl.gov)

[217] *See* EnergizeCT Presentation on Overcoming Weatherization Barriers. November 18, 2020. https://portal.ct.gov/-/media/DEEP/energy/ConserLoadMgmt/Weatherization-Barriers-Workshop-1-Slides.pdf

stakeholders through its Equity in Energy Efficiency (E3) proceeding and in parallel processes to address these and other barriers to weatherization program accessibility.[218]

Throughout this IRP, in addition to focusing on affordability, DEEP addresses access to and participation in Connecticut's energy policy programs, consistent with the direction from Governor Lamont in Executive Order No. 3 that the GC3 analyze climate mitigation and adaptation progress through an equity lens. The GC3 Equity and Environmental Justice (EEJ) Working Group was charged with developing a plan and guidelines for engaging diverse stakeholders and coordinating with other working groups to evaluate recommended strategies. This important process is currently underway. The Department is committed to ongoing engagement and coordination with the EEJ Working Group and will leverage the outcome of that process to ensure that future energy planning processes and energy policies center equity, diversity, and inclusion. The Department will focus on near-term strategies to promote energy equity, including the continuation of its E3 process, and will be guided by energy equity as it develops additional strategies in futures IRPs and other planning documents.

Strategies to Achieve Objective 3

In the pursuit of an equitable, zero carbon grid of the future, prioritizing equity and affordability is paramount. Below is a table summarizing steps that Governor Lamont and DEEP have taken in partnership with other agencies and entities to work towards ensuring energy equity and affordability during 2020 and early 2021, many of which are in process. The Department acknowledges that while these are all important and necessary steps, there is still substantial work to be done to rectify energy and environmental justice and equity issues in Connecticut. Addressing the long-standing inequities related to energy policy will require continuous work and inclusion of impacted communities and their lived experiences. Feedback on these efforts is welcome and strongly encouraged.

Table 3.1: Recent Energy Justice and Equity Actions in Connecticut

Program		**Summary**	**Recent Action**
Energy Efficiency	Equitable Energy Efficiency Proceeding	Process launched by DEEP to create new equity metrics for measuring and increasing participation in underserved communities, and develop new strategies to track and improve renter participation.	*September 2020*: DEEP issued a notice of proceeding and request for written comments. *May 2021*: DEEP issues Proposed Phase 1 Actions and Recommendations219 *July 2021*: DEEP issues Final Determination[220] containing eight goals that seek to characterize the current state of C&LM program participation across multiple dimensions of equity while taking

[218] Connecticut DEEP. Equitable Energy Efficiency Proposed Phase I Actions and Recommendations. May 6, 2021. https://portal.ct.gov/-/media/DEEP/energy/ConserLoadMgmt/E3-Proposed-Phase-I-Actions-and-Recommendations.pdf

[219] *Id.*

[220] Connecticut DEEP, *Equitable Energy Efficiency Phase I Actions and Recommendations,* July 21, 2021, *available at* https://portal.ct.gov/-/media/DEEP/energy/ConserLoadMgmt/Final-E3-Phase-I-Determination.pdf

			short-term actions to address known equity challenges and barriers.
	C&LM Plan	The 2020 Plan Update improved services for low-income households by (1) increasing insulation incentive levels, (2) expanding the 0% interest Micro Loan program to cover upfront costs, (3) streamlining the application process by allowing residents in distressed census tracts to automatically qualify for the Income-Eligible program, and (4) updating cost-benefit screening to enable increased incentives for the income-eligible program.	*March 2021:* DEEP releases the Conditional Approval of the 2021 C&LM Plan Update, adding conditions to increase participation in energy efficiency programs, address barriers for renters, and more.
	Weatherization Barrier Remediation	DEEP and the EEB hosted a workshop to engage relevant participants in identifying sustainable funding and a programmatic structure to address health and safety barriers that prevent income-eligible customers from accessing weatherization services.	*April 2021:* LIEAB approves DEEP's proposal to use a portion of LIHEAP funds to remediate health and safety barriers to weatherization in income-eligible homes. *May 2021*: Governor Lamont proposes the use of federal American Recovery Plan Act (ARPA) funding to help address health and safety barriers to weatherization and affordable housing energy retrofits.[221] *August 2021*: DEEP releases draft Request for Proposals to competitively select a program operator to run a Statewide Weatherization Barrier Remediation Program.
Distributed Generation	Shared Clean Energy Facilities (PURA Docket No. 19-07-01)	The SCEF program, authorized by CGS § 16-244z, is designed to enable customers who typically have difficulty accessing renewable energy to receive bill savings by subscribing to annual allocations of	*March 2020:* DEEP's proposed bid preference for projects planned for development on brownfields and landfills is approved by PURA for the Year 1 Procurement.[223]

[221] Governor Ned Lamont. *Connecticut's Plan for the American Rescue Plan Act of 2021: A Roadmap for a Transformative, Equitable and Healthy Recovery for our State.* April 26, 2021. https://portal.ct.gov/-/media/Office-of-the-Governor/News/2021/20210426-Governor-Lamont-ARPA-allocation-plan.pdf

[223] *See* PURA Docket No. 19-07-01. *Review of Statewide Shared Clean Energy Facility Program Requirements.* Notice of Year 1 Price Cap and Bid Preference. March 18, 2020.

		25 MW of Class I energy projects split between the two EDC territories. This six program is primarily targeted at low-income, LMI and affordable housing customers. The first program year was 2020.[222]	*December 2020:* In the 2020 Draft IRP, DEEP recommended that the low-income and LMI subscribership requirements should be increased, working towards a 100% LMI subscribership goal (Strategy 6).
	Rooftop Solar Successor Tariff (PURA Docket No. 20-07-01)	Pursuant to Public Act 19-35, PURA initiated this proceeding to establish tariffs for each EDC for residential Class I renewable energy project beginning on January 1, 2022. The original objectives in establishing this tariff include maintaining "(1) the sustained, orderly development of the state's solar industry; (2) achieving a 100% zero carbon electric grid by 2040; and (3) balancing ratepayer costs."[224] The compensation structure(s) for energy and RECs generated on residential properties will serve as the successor to the existing RSIP program.	*December 2020:* In the 2020 Draft IRP, DEEP recommended PURA structure the incentive levels to ensure that at least 40 percent of the installations are deployed at low-income households statewide, and low-to-moderate-income households in environmental justice communities to improve energy affordability for historically underserved and overburdened customers. (Strategy 6) *April 2021:* PURA releases interim decision directing the EDCs to offer a low-income adder of $0.025/kWh for all RECS generated to customers <60% SMI, and a separate adder of $0.125/kWh for all RECs generated to customers not eligible for the low-income adder but living in distressed municipality as identified by DECD.
	Distributed Storage (PURA Docket No. 17-12-03RE03)	Part of PURA's larger Grid Modernization proceeding, Docket No. 17-12-03RE03 investigates the how to deploy storage technologies in ways that bring the greatest net benefit to the electric distribution system. Potential considered benefits include resilience, providing support for DER deployment, peak shaving, and ancillary services.[225]	*December 2020*: In the 2020 Draft IRP DEEP recommended that PURA structure the incentive levels to ensure at least 40% of the installations, particularly solar paired with storage, are deployed at low-income households statewide, and to LMI households in environmental justice communities to improve energy affordability for historically underserved and

[222] Connecticut DEEP. Shared Clean Energy Facility (SCEF) Statewide Program. https://portal.ct.gov/DEEP/Energy/Shared-Clean-Energy-Facilities/Shared-Clean-Energy-Facilities

[224] *See* PURA Docket No. 20-07-01. *PURA Implementation of Section 3 of P.A. 19-35, Renewable Energy Tariffs and Procurement Plans.* Interim Decision. February 10, 2021.

[225] *See* PURA Docket No. 17-12-03RE03. *PURA Investigation into Distribution System Planning of the Electric Distribution Companies- Electric Storage.* Notice of Proceeding. October 7, 2019.

			overburdened communities (Strategy 6).[226] *July 2021:* PURA issues a final decision, supported by DEEP, that prioritizes delivering benefits to LMI and environmental justice customers and offers double the upfront incentives for participating LMI customers.[227]
Cross-Sector	GC3 Equity and Environmental Justice Workgroup	This working group implements stakeholder engagement to ensure vulnerable communities that are disproportionately impacted by climate change can meaningfully participate in the development of equitable adaptation strategies and identify any impacts from the GC3's recommendations specifically marginalized groups.	November 2020: The working group released a report that includes recommendations "with an equity lens," such as "the creation and support of an environmental and climate justice mapping tool to provide a visual representation of the relative vulnerabilities of Connecticut's communities."[228]
	New England Energy Vision	A collaboration of the six New England states to establish a unified vision for a clean, affordable, and reliable 21st century regional electric grid.[229]	March 2021: Connecticut and the other New England states host an evening public engagement session with over 200 attendees focused on education, awareness, equity and environmental justice topics. A subsequent request for comments has been issued.

This IRP recommends pursuing the following additional Strategies in furtherance of Objective 3, Ensuring Energy Affordability and Equity for all Ratepayers. As discussed in Objectives 1 and 2, reform of the wholesale electricity markets is necessary so that Connecticut ratepayers do not have to pay twice for electric generation **(Strategy 2)**, including clean energy supply needed to meet the state's decarbonization goals and mandates. Additionally, an investigation of whether retaining RECs obtained by the EDCs on

[226] *See* PURA Docket No. 17-12-03RE03. *PURA Investigation into Distribution System Planning of the Electric Distribution Companies- Electric Storage.* Brief of the Connecticut Department of Energy and Environmental Protection's Bureau of Energy and Technology Policy. April 7, 2021.

[227] *See* PURA Docket No. 17-12-03RE03. *PURA Investigation into Distribution System Planning of the Electric Distribution Companies- Electric Storage.* PURA Final Decision. July 28, 2021.

[228] Governor's Council on Climate Change, *Equity & Environmental Working Group Report Prepared for the Governor's Council on Climate Change,* November 2020, *available at:* https://portal.ct.gov/-/media/DEEP/climatechange/GC3/GC3-working-group-reports/GC3_Equity_EJ_Final_Report_111320.pdf

[229] New England Energy Vision. New England States' Vision for a Clean, Affordable, and Reliable 21st Century Regional Electric Grid. https://newenglandenergyvision.com/

behalf of all ratepayers to meet RPS requirements is in ratepayers' best interests should be conducted **(Strategy 7)**.

Customer costs can also be reduced through further deployment of cost-effective energy efficiency and demand response measures through the C&LM program **(Strategy 12)** and developing opportunities for ratepayers to actively participate in New England's energy sector through active demand response and energy storage **(Strategy 13)**. These tools can also help decrease the overall cost of electricity in Connecticut, while increasing the reliability of the grid. Equity also requires structuring the successor tariff supporting distributed generation such that all ratepayers can equitably access and participate in these programs, including residential rooftop solar **(Strategy 6)**. The successor tariffs should be structured in a way that ensures that at least 40 percent of residential solar deployments are occurring in low-income households and in low-to-moderate-income households in environmental justice communities. This includes changing the existing governing statute, Section 16-244z of the General Statutes, to ensure that those who live in affordable housing with five or more units in a building can access the benefits of the residential solar tariff. The Department also recommends increasing the low-income and low- to moderate-income subscribership requirements under the SCEF program structure, working towards a 100 percent low- to moderate-income subscribership goal.

The transition to a clean energy economy provides significant economic opportunity to our residents, businesses, and communities. The Department is coordinating with DECD and its Office of Workforce Strategy, and other stakeholders, to ensure that workforce development strategies and the clean energy economy are equitable and inclusive **(Strategy 9)**.

Objective 4: Optimal Siting of Generation Resources

Another key question to be evaluated in the IRP, as required by Section 16a-3a(d) of the General Statutes, is whether the use of generation sites in Connecticut is optimal. This section addresses historical trends and current issues related to siting of both conventional, fossil-fueled generation in the state, as well as renewable generation.

Siting of Large Fossil-Fueled Power Generation in Connecticut

For many years, Connecticut has been an attractive location for the development of fossil fuel-powered generation facilities in New England. Although Connecticut has no economically recoverable coal, oil, or gas, coastal and inland waterways as well as rail networks have provided convenient delivery points for those fuels to power generation sites along the shoreline and adjacent to navigable rivers. Hundreds of miles of high-voltage transmission lines were constructed across the state, making it possible for Connecticut-generated power to reach load centers in Connecticut, Massachusetts, and Rhode Island. In addition, three interstate natural gas pipelines cross Connecticut support essentially all of the region's natural gas fired generation. Further, since 2017, stricter environmental regulations in a neighboring state—namely, an in-state cap on carbon emissions from power plants that Massachusetts applies within its borders—have also contributed to making Connecticut a comparably lower-cost location for operating new and existing fossil-fueled generation.

Prior to deregulation, Connecticut was a net importer of power generation, producing less energy in-state than it consumed.[230] In 1996, Connecticut had 39 fossil fuel-powered generating units operating in the state, generating over nine million MWh of electricity as well as more than 11,176 tons of NOx, and 9 million short tons of CO2 emissions.[231] Over 57 percent of the electricity generated by this fossil-fueled fleet was produced with oil; 26 percent with coal, and 10 percent with pipeline natural gas.[232]

In the years following deregulation, the current basic structure of the market rules in New England took shape through the adoption of a new Market Rule 1 (MR1) in 2002. One of the most challenging issues MR1 addressed was mitigating market power in regions that were transmission constrained. In areas that were constrained, units had the ability to exercise market power, as the region could not operate reliably without the units located within the zone. On the other side of that coin, peaking units that were necessary in only a few hours of the year were at risk of not being able to profitably operate. Accordingly, MR1 allowed for Reliability Must-Run (RMR) contracts. FERC, over Connecticut's objections, adopted ISO-NE's position that RMR contract costs were to be paid only by the ratepayers in the congested area. Thus, soon after MR1 went into effect, several plants located in Southwest Connecticut entered into RMR contracts with ISO-NE, the costs of which were borne entirely by Connecticut ratepayers.

In order to help alleviate the risk of high costs to Connecticut ratepayers due to constraints in southwest Connecticut, the General Assembly enacted Connecticut General Statutes §§ 16-243m and 16-243u to allow State regulators to procure generation. As a result, Connecticut's EDCs entered into contracts for peaking capacity and base load throughout the state. It is important to note that at the time the EDCs

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[230] ISO New England, https://www.iso-ne.com/static-assets/documents/2020/09/gen_nel_iso_states.xlsx

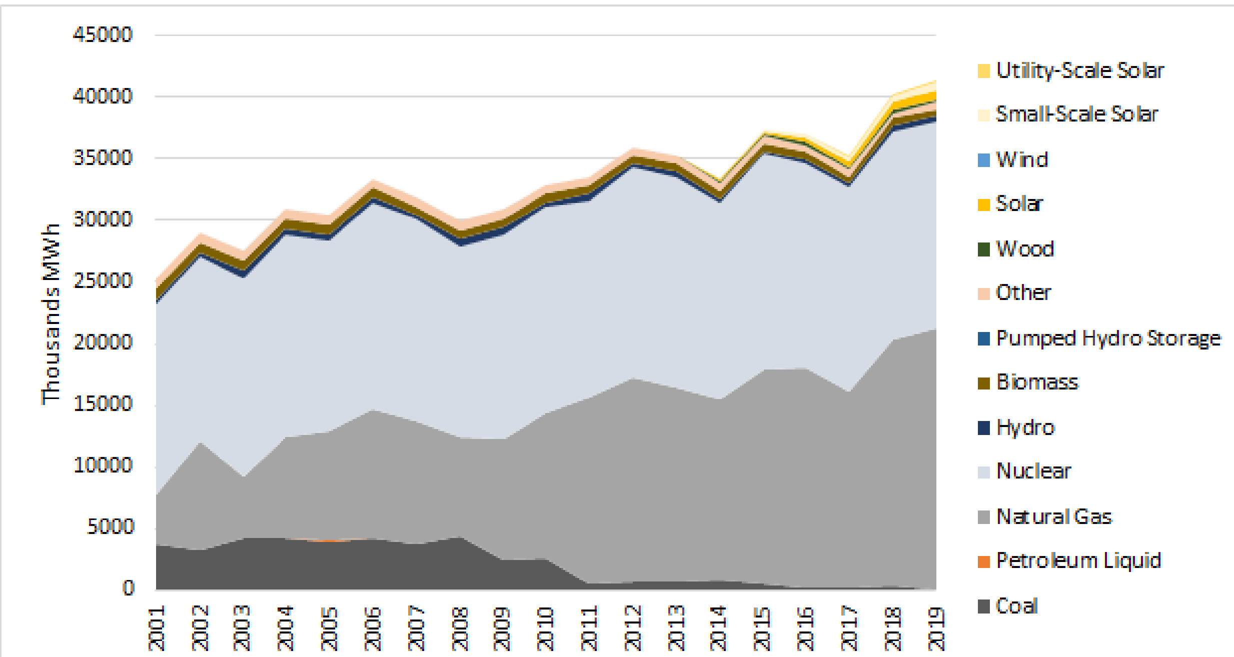
[231] U.S. Environmental Protection Agency. Air Markets Program Data. https://ampd.epa.gov/ampd/

[232] U.S. Energy Information Administration. Historic form EIA-906 Detailed Data with previous form data (EIA-759). https://www.eia.gov/electricity/data/eia923/eia906u.php

were entering into the contracts, new capacity was not being constructed without long-term contracts. That is, the market rules did not provide sufficient confidence to investors to put forward the capital necessary to develop a project. However, after Connecticut entered into those contracts, ISO-NE amended the market rules to be more favorable to new generation.[233]

Since that market rule change, the FCM has incentivized investment in new resources to replace retiring resources and growing peak demand. The markets' ostensibly fuel-neutral design has primarily incentivized the development of natural gas-powered generation, which have increasingly out-competed oil- and coal-powered plants, as discussed in Objective 2. Following RGGI's inception in 2008, the relative efficiency of natural gas was further highlighted as generation from oil and coal declined even more, as shown by Figure 4.1 below.

Figure 4.1: Annual Connecticut Net Generation by Fuel Type[234]



Today, Connecticut is a net exporter of power generation, consuming only 73 percent of the electricity generated in the state.[235] There are 54 large fossil fuel-powered generating units operating in Connecticut, comprising 6,937 MW of aggregate capacity—more than double the fossil-fueled capacity in operation in 1996. These units produce about 98 percent of the electricity generated from fossil fuels in the state, generating 16,948,025 MWh of electricity, and eight million short tons of CO_2 emissions in 2019.[236] The Killingly Energy Center natural gas power plant proposed by NTE Energy in Killingly, CT would add an additional 650 MW of capacity in 2022.

[233] See 154 FERC ¶ 61005

[234] U.S. Energy Information Administration, https://www.eia.gov/electricity/data/browser/#/topic/0?agg=2

[235] ISO New England, https://www.iso-ne.com/static-assets/documents/2020/09/gen_nel_iso_states.xlsx

[236] The 800 tons of NOx represent 23 percent of Connecticut's annual electric sector emissions, and 2 percent of statewide total NOx emissions, which are dominated by transportation-produced emissions at approximately 31,000 tons per year.

Seven of these generating units (1,965 MW in aggregate) were constructed in the 1960s or earlier and have the worst air pollution emission rates per unit of electricity produced of the entire fleet. One of the seven is the Bridgeport Harbor Station Unit 3, the state's last coal-fired power plant, which is scheduled to shut down permanently in July 2021. Most of these older units run on residual oil, and their technology is so inefficient and costly to operate that they run infrequently, producing less than 1.8 percent of the electricity, yet 3 percent of the CO_2 emissions and 28 percent of the NOx emissions in Connecticut's large fossil-fuel generating fleet. These units receive revenue streams through the ISO-NE capacity market. There does not seem to be evidence that the Pay for Performance (PFP) program instituted by ISO-NE is impacting the retirement decisions of resources, as the region has seen minimal retirements since PFP has been in place.[237] This trend may change as the PFP penalties increase.

More than 40 fossil-fuel powered generating units have been constructed in Connecticut since 1998 (4,738 MW total). While several were built through ratepayer-backed contracts to alleviate costly transmission constraints, as described above,[238] another 1,900 MW[239] have cleared in the capacity market without a contract, funded exclusively through the ISO-NE regional tariffs to meet resource adequacy requirements for the entire region. Twelve of these units are "baseload" combined cycle units, which are designed to run constantly and are powered primarily by pipeline natural gas, with diesel oil in onsite storage as a back-up fuel. In 2019, these twelve units produced 16,484,295 MWh, or 98 percent, of the total amount of power generated from large fossil-fuel fired power plants in Connecticut; as well as 96 percent of the total CO_2 emissions; and 67 percent of total the NOx emissions from those plants.

Table 4.1: Connecticut In-State Baseload Combined Cycle Units

Facility Name (*denotes location in an environmental justice community)	Primary/Secondary Fuel	MWh Produced (2019)	% of Total MWh	CO2 Emitted (2019, short tons)	% of Total CO2 emitted
CPV Towantic Unit 1	Pipeline Natural Gas (PNG)/Diesel Oil	2,525,074	15%	1,002,134	12%
Milford Power Unit 1	PNG/Diesel Oil	1,936,384	11%	805,288	10%
Milford Power Unit 2	PNG/Diesel Oil	1,870,688	11%	761,206	9%
CPV Towantic Unit 2	PNG/Diesel Oil	1,439,558	8%	569,207	7%
Lake Road Unit 2*	PNG/Diesel Oil	1,185,656	7%	775,964	10%
Lake Road Unit 1*	PNG/Diesel Oil	1,176,089	7%	803,379	10%
Kleen Unit 1	PNG/Diesel Oil	1,151,759	7%	481,846	6%
Bridgeport Energy 2*	PNG	1,139,273	7%	504,831	6%
Bridgeport Energy 1*	PNG	1,109,638	7%	514,472	6%
Lake Road Unit 3*	PNG/Diesel Oil	1,048,211	6%	723,826	9%
Kleen Unit 2	PNG/Diesel Oil	1,026,879	6%	432,886	5%
Bridgeport Harbor 5*	PNG/Diesel Oil	875,086	5%	338,463	4%

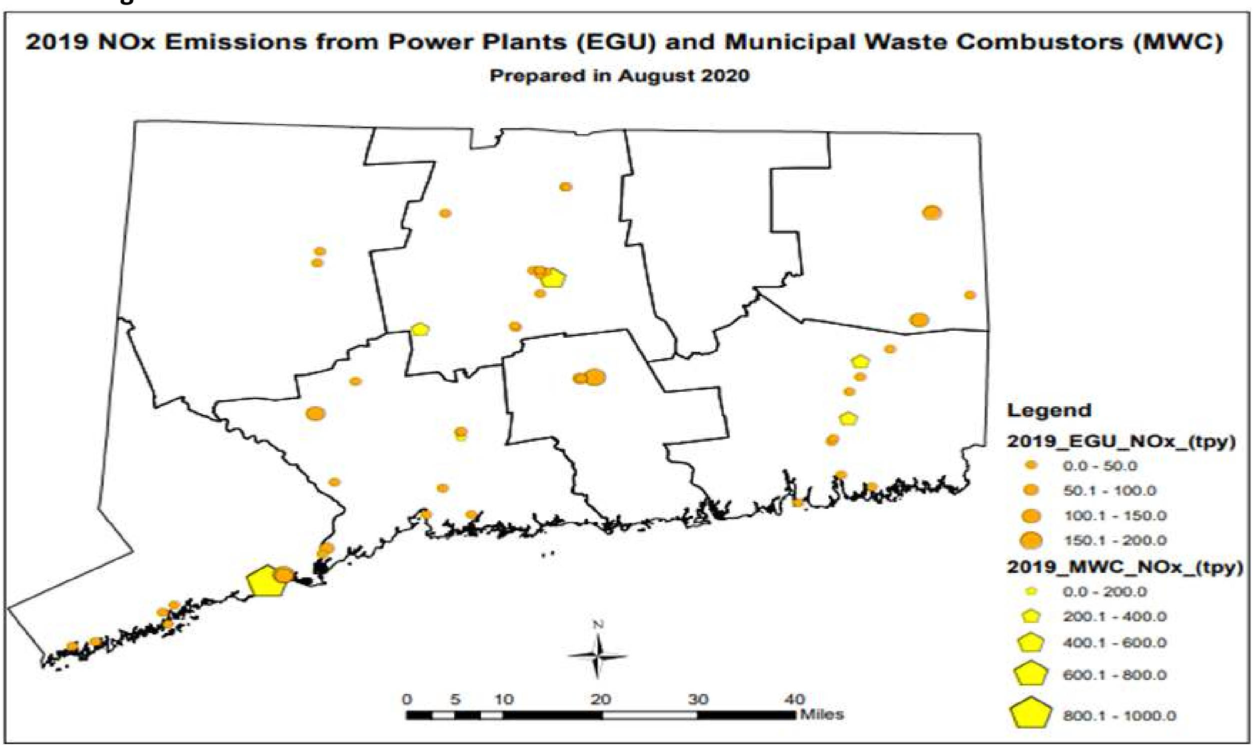
[237] ISO New England, *Forward Capacity Market Pay-for-Performance (FCM PFP) Project,* https://www.iso-ne.com/participate/support/participant-readiness-outlook/fcm-pfp-project

[238] *See* Docket No. 05-07-14PH02, DPUC Investigation of Measures to Reduce Federally Mandated Congestion Charges (Long Term Measures) (Approving 782 MW of new fossil fuel generation plants and 5 MW of energy efficiency); 08-01-01, DPUC Review of Peaking Generation Projects (Approving contracts of 678 MW of new fossil based peaking generation)

[239] 1,300 MW have already been constructed. 650 MW have cleared the market but has not yet been constructed.

Under the Base Load Balanced Blend scenario, annual CO_2 emissions across New England are projected to be cut nearly in half by 2040, with emissions offset by additional zero carbon energy purchases. SO_2 emissions in Connecticut are projected to decline by 10 percent, or 130 short tons, by 2040, with the majority of those emissions coming from WTE facilities. NO_X emissions in Connecticut are projected to decline by 25 percent, or 1,500 short tons, by 2040, again mostly coming from WTE facilities. Environmental justice communities, as defined by CGS Section 22a-20a, bear the disproportionate burden of air pollution from these large fossil power plants, as demonstrated by Figure 4.2 and Table 4.2 below.[240] Twenty-three of the state's large fossil fuel generating units are located in environmental justice communities, emitting more than 372 tons of NOx (greater than 46 percent of the NOx from the fossil-fueled power generation) annually. Some of these communities also host WTE facilities, which generate electricity from burning municipal solid waste (MSW) rather than fossil fuels and produce significant quantities of air pollution as well.

Figure 4.2: 2019 Location and NOx Emissions from Combustion Plants in Connecticut[241]



[240] "Environmental justice community" means (A) a United States census block group, as determined in accordance with the most recent United States census, for which thirty per cent or more of the population consists of low income persons who are not institutionalized and have an income below two hundred per cent of the federal poverty level, or (B) a distressed municipality, as defined in subsection (b) of section 32-9p; C.G.S 22a-20a(a)(1)

[241] Connecticut DEEP, *Connecticut's Emissions Reductions through 2019*, Presentation, 2020.

Table 4.2: Peak Demand Generators Located in Connecticut Environmental Justice Communities

Municipality	Units	MWh Produced	% of Total MWh	NOx Emitted (2019, tons)	% of Total NOx Emitted
Killingly[242]	Lake Road (3 combined cycle units)	3,409,956	20%	112	14%
Bridgeport	Bridgeport Energy (2 units); Bridgeport Harbor Station (2 units)	3,203,372	19%	239	31%
Hartford	Capitol District Energy Center, MIRA (8 jet peakers)	8,646	0%	14	1.75%
Montville	Montville Power (2 units)	11,630	0%	7	<1%
New Haven	New Haven Harbor Station (4 units)	19,691	0%	6	<1%
Waterbury	Waterbury Generation (1 unit)	11,819	0%	1	<1%[243]

In sum, Connecticut now produces more electricity than we consume in state, and we maintain thousands more MW of generation capacity than we need to serve Connecticut customers, driven by the needs of the New England region as a whole. Much of that generation capacity is fueled by natural gas and oil. These power-generating facilities generate localized financial benefits such as employment and tax revenue. Some of these facilities also benefit from tax subsidies by being exempted from the natural gas gross earnings tax.[244] They also generate localized environmental impacts, including emissions of air pollutants like NOx, SOx and fine particulate that contribute to asthma and other health impacts. Partially due to emissions from electric generators sited here to provide power to other states, Connecticut experiences some of the worst ozone pollution in the United States. Exposure to unhealthy levels of air pollution contributes to acute and chronic respiratory problems such as asthma, Chronic Obstructive Pulmonary Disease, and other lung diseases. A recent national report, Asthma Capitals 2019, ranked New Haven (#11) and Hartford (#13) among the 100 largest U.S. cities where it is most challenging to live with asthma. Connecticut's environmental permitting standards generally address these air and water impacts through unit- and technology-specific standards. As described above, however, the fact that Connecticut now hosts a disproportionate share of the region's fossil-fueled generation raises policy considerations about the cumulative air quality impacts of such facilities in the state, particularly for environmental justice and other overburdened communities.

[242] DEEP notes that Killingly was not included on the DECD list of distressed communities in 2020 and is therefore not considered an environmental justice community per CGS Sec. 22a-20a in 2020. https://portal.ct.gov/DEEP/Environmental-Justice/Environmental-Justice-Communities

[243] Conn. Gen. Stat. Section 22a-20a.

[244] *See* Conn. Gen. Stat. Section 12-264 (exempting Lake Road Generation facility as the only facility that is as "existing combined cycle facility comprised of three gas turbines providing electric generation services, as defined in section 16-1, with a total capacity of seven hundred seventy-five megawatts"

Typically, the Connecticut Siting Council relies on the fact that a power plant has cleared the ISO-NE FCA for its "determination of need" for the new facility, a key finding to support siting a new plant. As described in Objective 2, the conflicts between the ISO-NE wholesale market design and decarbonization policies of states like Connecticut have undermined confidence that the ISO-NE's markets are efficiently and effectively determining resource needs in a manner that is aligned with the New England states' collective clean energy goals. In addition to not accounting for state policies, another concern about relying on the ISO-NE capacity market to determine need is that ISO-NE has consistently over-procured resources in the market. This is exemplified by the significant decreases in the ICR between the original auctions and the final reconfiguration auctions prior to the capacity commitment period.[245] Over the first 11 capacity commitment periods (CCPs), the ICR difference between the original auction and the final reconfiguration auction was 679 MW. The third reconfiguration auction for the twelfth CCP is expected to decline by 800 MW.[246] Though not a final reconfiguration auction, the net ICR in the second reconfiguration auction for the thirteenth CCP has declined by 985 MW.[247] Significantly overestimating ICR and procuring fossil fuel-based resources that are not needed undermines confidence in relying on the capacity market to determine need. In other instances, the ISO-NE FCA clears new gas fired power plants that have been proposed to "repower" (i.e. replace) existing coal- and oil-fired powered power plants in Connecticut. From a technical standpoint, repowering can provide incremental local environmental benefits, on a unit specific basis, by reducing NOx emissions, accompanied by regional benefits in terms of comparatively lower GHG emissions if the repowering is coupled with the retirement of the resource being repowered.

An additional concern about relying on the ISO-NE capacity market for the "determination of need" is that ISO-NE has imbedded a preference for natural gas resources over renewable resources. As discussed above in Objective 2, the capacity market design fundamentally favors generation that has low fixed costs and high fixed costs, such as natural gas resources, over generation that has high fixed costs and low variable costs, such as wind and solar.

Ultimately, the wholesale markets on which Connecticut relies need to be aligned with our State's clean energy goals, and ensure that whatever fossil-fueled power generation remains operating in Connecticut and around the region is the minimum needed to maintain reliability on our path to decarbonization. The wholesale markets also need to ensure that zero carbon resources capable of providing similar services (such as hydropower, nuclear, storage, demand response, offshore wind, and other resources) are not prevented from competing with conventional fossil resources because of antiquated market designs.

As discussed extensively in Objective 1, above, GHG emissions are global pollutants, meaning that Connecticut is affected by cumulative GHG emissions, regardless of where they occur on the planet. Because Connecticut's power needs are served by a regional electricity grid, the State has pursued its decarbonization policies on a regional basis, rather than through permitting and siting processes within

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[245] *See* ISO New England, "Summary of Historical Installed Capacity Requirements and Related Values," January 22, 2021, retrieved from https://www.iso-ne.com/system-planning/system-plans-studies/installed-capacity-requirement/

[246] *See* ISO New England, "Proposed ICR-Related Values of Annual Reconfiguration Auctions (ARAs) to be Conducted in 2021," October 9, 2020, slide 10, *available at* https://www.iso-ne.com/static-assets/documents/2020/10/a02_pspc_2020_10_09ara_icr_values.pdf

[247] *Id.* Slide 20.

the state. Energy efficiency investments in Connecticut homes and businesses, and Connecticut-funded wind farms generating power off the coast of Martha's Vineyard or in rural Vermont, are all effective at displacing fossil-fueled power generation in New England. Shutting down fossil-fueled power generation in Connecticut, however, would not (by itself) be effective in reducing GHG emissions if the ISO-NE market simply ramps up investment in fossil-fueled power plants in other states in New England to meet Connecticut's demand. This could also have the unintended consequence of prolonging the life of less efficient and higher-NOx emitting existing fossil-fueled plants in Connecticut, such as those in Table 4.2, above—a serious environmental justice concern.

Estimated Effects of a Carbon Tax on In-State Electric Generation

As Connecticut works to achieve its decarbonization goals, it is worth evaluating measures from the standpoint of their ability to contribute to fossil fuel generation retirements, both in the state and around the region. Pathways pursued to meet the state's decarbonization goals must consider the impact that chosen pathways will have on fossil fuel retirements. As noted in Objective 1, different scenarios for meeting a 100% zero carbon target for Connecticut have varying impacts in terms of the amount of fossil fuel retirements that occur across the region. Resource procurements should be carefully planned to maximize fossil fuel retirements while maintaining reliability, to ensure that both GHG emission and local air quality benefits are maximized.

The State of Massachusetts has established an in-state cap on GHG emissions that applies only to generation located in that state.[248] An evaluation of the application of a similar policy in Connecticut yields some insights for policy measures that could help to ensure that large-scale fossil generation in the state (new and existing) continues to be incented to lower emissions in a manner that—in certain circumstances—does not increase rates for Connecticut electric customers, and fairly and equitably compensates ratepayers and local communities for the burdens of hosting a disproportionate share of the region's generation.

As noted above, starting around 2010, Connecticut shifted from being a net importer of electricity to a net exporter of electricity, which has been an increasing trend. In 2010, Connecticut exported about 200,000 MWh of electricity, while in 2018, Connecticut exported approximately 8.5 million MWh of electricity. Since the 2010 timeframe, approximately 3,000 MW of new natural gas plants have been, or are expected to be, constructed in Connecticut. Only about 1,200 MW of new natural gas generation has been constructed in the rest of New England.

A fee assessed on large fossil-fueled electricity generators located in Connecticut, based on the tons/MWh of carbon emissions generated, and incremental to each plant's requirement to purchase greenhouse gas emission allowances to comply with the Regional Greenhouse Gas Initiative (RGGI) would reduce plant run times in the state. Fossil fuel powered plants located in Connecticut that are 25 MW or bigger and do not receive a set-aside pursuant to 22a-174-31(f)(4)(B) or 22a-174-31(f)(4)(F) would pay the tax on each ton of carbon dioxide emitted, and the revenues would be remitted to the State. These Connecticut plants would presumably incorporate the cost of the tax into their energy price—i.e. the price they bid into the ISO-NE wholesale energy market—causing them to run less frequently (and generate fewer overall emissions of GHGs, NOx and other air pollutants) relative to other fossil-fueled power plants in the region that are not subject to the tax.

[248] *See* 310 CMR 7.74.

Wholesale energy prices would be expected to increase accordingly, and this would impact Connecticut ratepayers in two ways. First, the increase in wholesale prices would be expected to increase the cost of electricity embedded in consumers' generation rates; at the same time, it would *reduce* the cost of power purchase agreements (PPAs) and contracts for differences that are recovered through consumers' distribution rates as the energy revenues generated would be higher than expected in the original contracts. Therefore, an important consideration for designing such a tax would be to impose the tax at a level that would lower emissions and provide net neutral revenues for Connecticut ratepayers, by ensuring that the revenue from the tax and the savings on the cost of PPAs would flow back to electric ratepayers and exceed the increased wholesale electricity costs. Such a scenario would thus provide a measure of compensation to Connecticut residents for hosting such a large share of regionally used fossil-fueled generating plants.

In-State Carbon Tax Modeling Results

APPENDIX A7

A range of carbon prices was modeled to evaluate the applicability of a Massachusetts-style in-state carbon price in Connecticut. The results of this modeling (included in Appendix A7) indicate that a carbon tax of \$6.03/short ton (nominal) would result in \$23.30 million in tax revenue in the modeled year 2025, and \$9.50 million in additional revenue from existing contracts, which would more than offset the increase in wholesale energy prices associated with the tax if all of the tax revenue were credited back to Connecticut ratepayers. At the \$6.03 price, CO_2 emissions would decline by 31 percent within Connecticut as in-state facilities run less frequently. But overall CO_2 emissions would remain relatively the same region-wide (decreasing by about 1 percent), as fossil fueled power plants in other states would increase their run times to make up for the decrease in generation from Connecticut plants. In-state emissions of other air pollutants would also remain relatively the same.

Any higher carbon price would not result in a net neutral or positive price impact for Connecticut ratepayers because wholesale energy prices would increase beyond the value of the tax revenue and revenue from existing contracts. Under the highest carbon tax of \$104.54/short ton, wholesale energy prices increase by about \$5.00/MWh. A modest Connecticut-only carbon fee would generate sufficient revenue to make the tax a net benefit for Connecticut ratepayers, but it will also increase reliance on less efficient out-of-state generation that will not be subject to the tax. In addition, the increased energy market revenues of \$5.00/MWh are likely insufficient additional revenue to incentivize zero carbon resources to build based on energy revenue alone. Finally, under the consumption-based accounting method in this IRP, this tax would not help Connecticut meet its zero carbon goals because regional emissions would remain effectively unchanged.

Siting of Zero Carbon Power Generation

As the State continues to deploy zero carbon resources to achieve its climate goals, it is important to ensure that renewable and other resources needed for decarbonization can be developed and constructed in a manner that carefully balances all of our environmental goals. Zero carbon energy deployment must align with land use, natural resource, and environmental quality policies and standards. Proper planning and siting will minimize uncertainties and conflicts during siting and permitting processes. The more efficient these practices are, the faster the deployment of these renewable resources. The Department is uniquely suited to integrate these efforts as the agency responsible for energy planning, environmental protection and natural resource conservation.

Solar Siting in Connecticut

The opportunities for siting solar in Connecticut are expansive, but the potential environmental impacts of solar vary greatly based on where the panels are placed. For example, rooftop facilities provide for minimal impacts by utilizing existing buildings, preserving greenfields, and not increasing stormwater runoff. The environmental impact of ground-mounted projects varies greatly, depending on the existing use and physiographic attributes of the site. Ground mounted projects can have impacts on water and land and natural resources including stormwater and wetlands, endangered and threatened species, core forests and prime farmlands.

Sequencing of steps in the siting and development of solar facilities is complicated and many processes are intertwined. An early and thorough assessment of the challenges associated with developing a site is fundamental to smoothly navigating the regulatory process. For example, performing hydrological evaluations, biological inventories and detailed wetlands mapping early in design will facilitate minimizing environmental impacts and keeping redesign to a minimum.

The Department has been actively investing in more innovative approaches to its internal processes associated with solar siting. For example, the Natural Diversity Data Base (NDDB) process is being moved to an online platform, which will facilitate quick responses on a majority of inquiries. This will also facilitate earlier submission of a permit application or general permit registration for construction storm water activities. The Department is also currently revising its Construction Stormwater General Permit and anticipates issuing a new general permit in the very near future. Incorporated into the permit are updated requirements which will inform solar siting and storm water control design both during and post-construction. Enhancements in the revised general permit will formally establish financial assurance mechanisms and more clearly define the roles, engagement and accountability of permittees and their design qualified professionals, contractors and subcontractors, qualified inspectors, and DEEP's Soil and Water Conservation District representatives, to assure storm water controls are properly implemented and maintained in accordance with the Stormwater General Permit throughout the duration of the project.

Providing clarity, predictability, and upfront assistance to developers to ensure projects can be built quickly and with minimal siting and permitting conflicts is critical to achieving DEEP's environmental missions while supporting the State's zero carbon energy goals. The Department has undertaken a number of steps in this regard. For example, over time DEEP has adapted more eligibility requirements into DEEP-run grid scale RFPs to incorporate siting practices up front; similar requirements should also be incorporated into tariff-based procurements for ground-mounted projects as well. To help developers navigate the permitting process for solar arrays, DEEP recently published a Fact Sheet that provides information on the types of permits that may be required and the timing and sequencing of those permits.[249] The Department also encourages applicants to request a pre-application permitting meeting with DEEP staff early in the planning of a solar development project, prior to or coincident with submission

[249] Connecticut DEEP, *Information for Solar Developers: An Environmental Permitting Fact Sheet*, https://portal.ct.gov/-/media/DEEP/Permits_and_Licenses/Factsheets_General/Siting-Solar-Fact-Sheet.pdf

to the Connecticut Siting Council, to understand the regulatory and NDDB requirements and estimated timelines associated with the project.[250]

The Department has begun a stakeholder process to explore best practices and innovative approaches to better coordinate the solar siting process as further set forth in Strategy 10.[251]

Offshore Wind Siting

Offshore wind developments and peripheral structures (e.g., transmission lines) may occur on either federal submerged lands (e.g., the Outer Continental Shelf) or state submerged lands. Those on Federal lands may only be sited in lease areas designated by the Bureau of Ocean Energy Management (BOEM)[252] following review and consultation pursuant to the National Environmental Policy Act (NEPA). Despite NEPA review and consultation, project siting will limit but not avoid all impacts to the environment and industries, such as commercial fishing. Potential environmental impacts include disturbing protected species such as the North Atlantic right whale and disturbing benthic habitat; industry impacts include blocking transit lanes and disruption to commercial fishing areas.

The State of Connecticut's jurisdiction relative to projects and project elements sited on federal lands is limited. Those limitations include engagement in the NEPA review and consultation procedures, Coastal Zone Management Act consistency in some cases, and the State's Requests for Proposals (RFP) for offshore wind projects. Connecticut's engagement in the NEPA procedures may be through direct petition and/or through membership in the Atlantic States Marine Fisheries Commission and the New England Fishery Management Council, and the advisory roles those entities have with the National Marine Fisheries Service within the US Department of Commerce. Conversely, one of the direct opportunities the State has to influence the environmental and economic impacts of offshore wind development is through its procurement activity—i.e., by including terms and conditions in Requests for Proposals and model power purchase agreements for offshore wind projects financed by Connecticut ratepayers.

The Department's RFPs commonly include threshold requirements for siting and planning for environmental impacts, which DEEP can review and evaluate as part of the proposal packages from developers. This was born out in DEEP's most recent offshore wind solicitation in 2019. In addition to giving DEEP authority to procure up to 2,000 MW of offshore wind power, Public Act 19-71 required that the DEEP Commissioner establish a Commission on Environmental Standards.[253] The Commission on

[250] To request a pre-application meeting, developers can complete the Pre-Application Questionnaire (link) and submit it to https://portal.ct.gov/-/media/DEEP/Permits_and_Licenses/Factsheets_General/preappquestionnairedoc.doc

[251] Such innovative approaches could include parking lot canopies. Following the issuance of the draft 2020 IRP, DEEP received supporting public comments regarding recent studies on the potential for making use of impervious surfaces. Evaluation of such siting strategies should be taken up through the STEPs for Solar Development solar siting process discussed in Strategy 10.

[252] U.S. Bureau of Ocean Energy Management. Lease and Grant Information. *Available at:* https://www.boem.gov/renewable-energy/lease-and-grant-information

[253] Public Act 19-71. An Act Concerning the Procurement of Energy Derived from Offshore Wind. *Available at:* https://www.cga.ct.gov/2019/act/pa/pdf/2019PA-00071-R00HB-07156-PA.pdf

Environmental Standards met during the summer of 2019 to develop a report on best practices that DEEP should employ when crafting the first RFP under Public Act 19-71.254

Based in large part on the Commission on Environmental Standards' report, DEEP required the submission of an Environmental and Fisheries Mitigation Plan (EFMP) intended to improve environmental outcomes at a chosen site. Three threshold requirements of the EFMP obliged bidders to:

1) include an adaptive plan with clearly identified stakeholders, a stakeholder engagement process, a plan for pre-construction and risk assessment, a process to avoid, minimize, and mitigate risks to stakeholders throughout the project phases, and a reporting schedule on that plan;

2) address how they will inventory, avoid, minimize, and mitigate the following specific hazards: risk to commercial fisheries, risk to marine mammals and sea turtles with specific reference of underwater sound and collision, risk to birds and bats, and risk to other species; and

3) include a data reference and sharing plan that addresses coordination with relevant regional working groups and a plan to store and share inventory and monitoring data.[255]

It is very unlikely that Connecticut will see a proposal to build offshore wind turbines in Long Island Sound (Sound), which has relatively low wind potential compared to federal lease locations. It is more feasible that offshore wind projects sited on federal submerged lands will need to be interconnected via transmission lines that transverse state submerged lands, such as Long Island Sound. Should that occur, Connecticut would have another planning tool at its disposal. The Long Island Sound Blue Plan (The Blue Plan), developed by a multi-stakeholder Blue Plan Advisory Committee and awaiting approval by the state legislature,[256] is an inventory of the natural resources and human uses in the Connecticut waters of Long Island Sound and a spatial plan to guide future use of the Sound's waters and submerged lands.[257] The Blue Plan can act as a guide for developers siting transmission lines in Long Island Sound to ensure that environmentally sensitive areas and high human use areas are taken into consideration on the front end of siting and planning. The Blue Plan policies will also guide existing state permit processes that apply to transmission lines through the Sound, particularly DEEP coastal permits and Siting Council authorization.

The Department recognizes that states across the region are procuring offshore wind in the same or adjacent federal lease areas and thus are grappling with the same challenges with regard to siting and environmental and fisheries mitigation. Coordination with regional entities that are investigating these

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[254] State of Connecticut. Report and Recommendations of the Commission on Environmental Standards for Minimizing and Mitigating Environmental and Commercial Impacts of the Construction and Operation of Offshore Wind Facilities. August 7, 2019.

[255] Connecticut DEEP. Notice of Request for Proposals for Offshore Wind. August 16.2019. Facilitieshttp://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/ccf12ec6cdf19ca7852584580072434d/$FILE/2019.08.16_Final.OSW.RFP.pdf

[256] The Final Draft of the Blue Plan was submitted to the Connecticut General Assembly's Environment Committee, per statutory requirement, prior to the start of the legislative session that began on February 5, 2020. That legislative session was cut short before action was taken on the Blue Plan due to the COVID-19 pandemic. The final draft was unanimously approved by the Connecticut General Assembly on May 14, 2021. *See* Connecticut DEEP, "Long Island Sound Blue Plan – Final Draft," https://portal.ct.gov/DEEP/Coastal-Resources/LIS-Blue-Plan/LIS-Blue-Plan-Final-Draft.

[257] Connecticut DEEP, *Long Island Sound Blue Plan,* February 5, 2020, *available at* https://portal.ct.gov/DEEP/Coastal-Resources/LIS-Blue-Plan/Long-Island-Sound-Blue-Plan-Home

issues, such as the Northeast Regional Ocean Council, the Responsible Offshore Development Alliance/Responsible Offshore Science Alliance, and current efforts to establish a Regional Wildlife Science Entity for Offshore Wind, can improve our understanding of the best available science, tools, and practices for environmental and commercial fisheries mitigation and allow us to continually improve our solicitations as they pertain to planning and siting. The Department will leverage these regional approaches to developing best practices in offshore wind siting. As required by Public Act 19-71, DEEP will also utilize input from the Commission on Environmental Standards for each future solicitation pursuant to that Public Act.

Hydroelectric Imports Siting

As discussed in Objective 1, the modeling in this IRP assumed that the 1,200 MW New England Clean Energy Connect project, selected by the Massachusetts EDCs under the 83D procurement becomes operational in 2023. Additionally, the modeling assumed that two HVDC tie projects currently in the ISO-NE interconnection queue would also be eligible as candidate resource additions as proxies for additional import prices. In all scenarios except for the Millstone Extension scenarios, these projects are included as renewable energy additions, shown as "HQ Imports" in the graphs in Objective 1.

Both of these additions would require the siting and development of an additional high voltage direct current (HVDC) transmission line, crossing hundreds of miles from Canada into Massachusetts. Siting and permitting these cables in reality would likely face some significant challenges. Interstate transmission projects must acquire approvals from each state the project will traverse. This requires careful navigation of each state's unique siting criteria and environmental laws in order to demonstrate that the project is in the public interest of each state.[258]

Additionally, HVDC projects that traverse federally owned lands must obtain authorization from the managing agency, which like individual states, each have their own unique criteria for issuing right-of-way permits. These permits often intersect with multiple environmental issues covered by review under the Clean Water Act, the Rivers and Harbors Act, the Bald and Golden Eagle Protection Act, the Endangered Species Act, and the National Historic Preservation Act.[259]

The assumption that the projects selected by the model would be sited, permitted and constructed by the time they are needed is a foundational element to capacity expansion modeling. However, HVDC faces significant siting challenges in reality. Future IRPs and transmission planning processes should consider the costs, environmental footprint, and environmental justice implications of long distance HVDC compared to projects that allow more in-region clean energy to interconnect.

Equitable Siting and Development

As discussed above, fossil fuel powered, polluting electricity generators have been historically sited and constructed in disadvantaged communities where they have caused disproportionate environmental, health, and economic harms to the people who live there. Shifting to a clean energy supply comprised of both DERs and grid scale clean energy resources will reduce the health impact on these communities over time, but there are still ways in which inequity can manifest in renewable siting policies. Sometimes,

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[258] FERC, *Report on Barriers and Opportunities for High Voltage Transmission,* June 2020, *available at* https://cleanenergygrid.org/wp-content/uploads/2020/08/Report-to-Congress-on-High-Voltage-Transmission_17June2020-002.pdf

[259] *Id.*

renewable energy development in a disadvantaged community can provide economic and environmental benefits, but other times, it could be a land-use opportunity cost for the community. Connecticut is currently working to ensure that clean energy projects are first selected with equity at the center, before beginning the siting process. This will help act as an early-stage filter that ensures projects approved for construction create desirable outcomes for host communities. One example is that DEEP provides a bid preference for projects constructed on brownfields and landfills submitted into the SCEF program. This helps to incentivize development that avoids the use of greenspace, and sustainable reuse of land not suitable for other development. Table 3.1 in Objective 3 highlights some of the recent steps DEEP, other state agencies, and partnering stakeholders have taken to improve access to clean energy and efficiency resources for underserved and overburdened communities. However, DEEP notes that addressing the renewable siting and accessibility inequities of the past and present will require continuous work and engagement with affected stakeholders.

Strategies to Achieve Objective 4

The Department recommends pursuing the following strategies in furtherance of Objective 4, *Optimal Siting of Generation Resources*.

Adoption of the 100% Zero Carbon Target as the goal for the state's electricity supply **(Strategy 1)** will ensure that the state can plan for and achieve a decarbonization goal that will, in concert with similarly robust targets being adopted by other states in the New England region, minimize operation of fossil fuel generation in the region. As noted in Objective 1, the amount of fossil fuel resource retirement over the next 20 years will be influenced both by which pathway to a 100% Zero Carbon Target is pursued by Connecticut, and the level of ambition of other states' clean energy targets. Maximizing fossil fuel retirements—including baseload gas units that emit large quantities of GHGs and older peaking units that contribute the greatest amount of NOx emissions and air quality impacts in environmental justice communities—will require a policy and procurement focus on ensuring that reliability needs are met with zero-carbon resources. These will likely include transmission **(Strategy 4)**, energy conservation and demand response **(Strategy 12)**, storage **(Strategy 13)**, hydropower, or potentially continued operation of nuclear **(Strategy 5).**

In order for the level of new clean energy resources to efficiently enter the market, be sited and constructed, reforms of the wholesale electricity markets must occur **(Strategy 2).** These reforms are needed, at a minimum, to put an end to ISO-NE market rules that over-procure capacity, prevent state clean energy investments from clearing in the capacity market, and imbed preferences for natural gas and other fossil resources in the capacity market, such as providing for a full capacity rating for generating facilities reliant on pipeline natural gas that are not able to run reliably during winter cold snaps. Fully reforming the market will ensure that zero carbon resources are selected to meet public policy and reliability needs.

In addition, Connecticut must fully merge its environmental and energy policies by incorporating eligibility criteria in renewable energy procurements that reflect a consistent and appropriate balance of price and environmental quality and natural resource values, and providing transparent, predictable and efficient permitting and siting processes for renewable energy resources. The Department has initiated a stakeholder process to examine best practices in solar siting and provide transparency and predictability to developers (**Strategy 10).** As noted in Objective 2, DEEP also recommends that PURA structure the successor tariff programs to include eligibility requirements that minimize land use and environmental quality conflicts, and incentivize the use of previously disturbed sites for solar facilities. These and other strategies are needed to ensure continued, comprehensive progress in reducing emissions not only from new natural gas facilities, but also from the oldest fossil fuel power plants that are the largest emitters of harmful air pollution in environmental justice communities.

Objective 5: Upgrade the Grid to Support and Integrate Variable and Distributed Energy Resources

As noted in Objective 1, the transmission system's ability to deliver increasing amounts of variable clean energy resources is vital to cost-effective and reliable decarbonization in the coming decades. Similarly, as behind-the-meter resources become an increasingly substantial portion of Connecticut's energy supply, investments in a "modern" grid—capable of monitoring, dispatching, and/or controlling distributed solar, storage, and other resources—is also critical. Increasing quantities of zero carbon reserves—such as storage and demand response--will be needed to balance variable renewable resources to achieve a reliable, low-emission electric system. Careful planning and improvement of both transmission and distribution systems will become even more essential to ensure continued reliability and improve affordability of the electric system as electrification of thermal and transportation sectors accelerates. Additionally, as discussed in Objective 3 and 4, careful consideration for impacts on environmental justice and marginalized communities must be included in these processes.

This section discusses complementary efforts needed to reliably and efficiently integrate clean energy resources, including: (1) planning and procurement of transmission, (2) investment energy efficiency, demand response, and storage to reduce load and balance intermittent resources, and (3) the implementation of resiliency measures. It should also be noted that PURA has underway a comprehensive effort to modernize the EDCs' distribution grid, pursuant to Docket Number 17-12-03.

The New England Regional Transmission Grid

Today's wholesale electric power system, and the electric markets it supports, depends on an increasingly integrated network of high-voltage power lines, substations, and control facilities that provides numerous economic, security, environmental, public policy and reliability benefits to ratepayers. The ISO-New England is responsible for planning, developing, and operating the grid but the power lines, transformers, and substations are owned by the independent, regional transmission operators (RTOs or TOs). Under the Transmission Operators Agreement, the RTOs are obligated to maintain their transmission assets consistent with applicable safety and reliability standards under the oversight of ISO-NE. Their operations and maintenance costs, and the costs of approved new projects and upgrades are then regionalized through regional network service (RNS) rates by load share. Transmission rates are subject to FERC approval, and are directly passed through to Connecticut electric ratepayers' bills.

There is no routine proactive planning cycle in ISO-NE to facilitate the interconnection of generation resources. While the ISO-NE reliability planning process does plan ten years into the future, it does not consider public policy, and therefore does not align with State clean energy goals. For generator interconnections. The ISO-NE conducts essentially a reactive planning process analyzing reliability and congestion issues and, of course, maintains the Interconnection Queue (Queue) of transmission upgrade and service requests. Developers must submit planned projects into the Queue and projects are studied by ISO-NE in the order submitted.

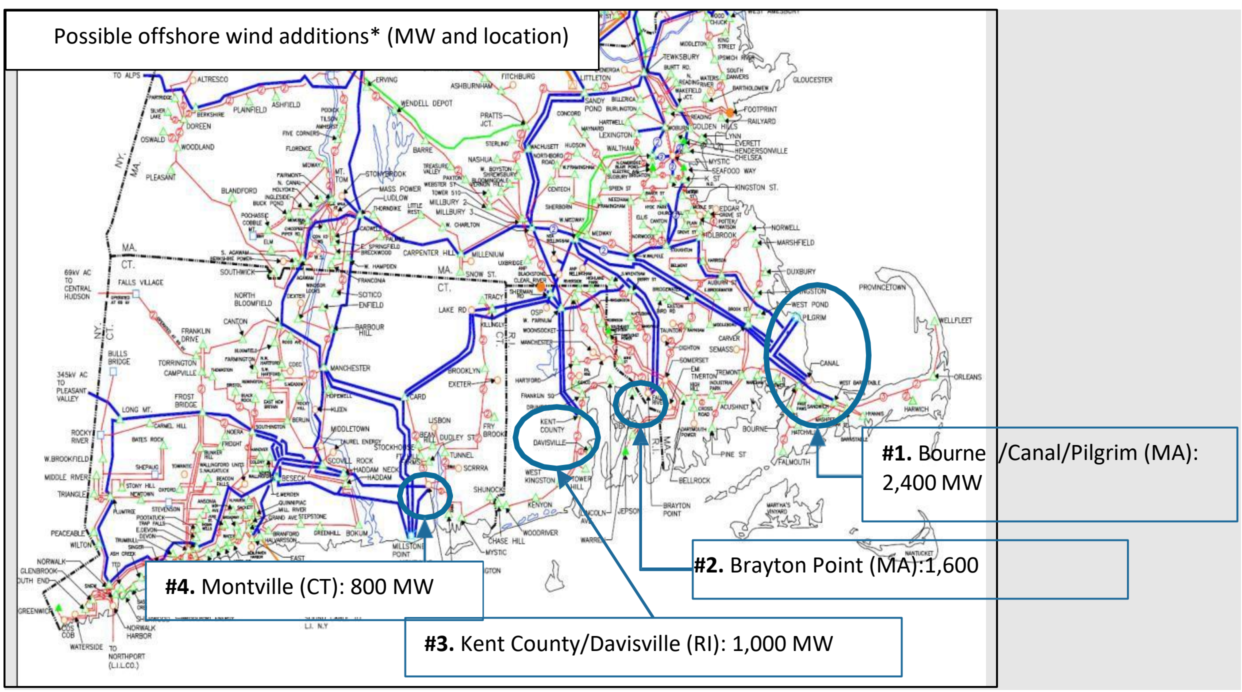
To reach State decarbonization goals it will be necessary to unlock the full potential of the clean energy resources being deployed. To do this, it will be necessary to address four issues. The first is how to both make the best use of the existing transmission assets while making the needed new transmission upgrades affordably and equitably. The second is how to fully integrate resources like offshore and land-based wind that are located far from load centers The third is how to reconfigure the topology of the grid to achieve full integration of distributed and BTM resources while adapting gird operations effectively to accommodate new clean generation resources. Finally, it will be necessary to accomplish the above listed goals through a scenario-based proactive planning process that cooperatively involves ISO-NE transmission planners with State personnel at all relevant stages of planning and development and effectively encourages competition.

Unlocking Clean Energy Resources

State decarbonization policies are changing the grid. Wind power comprises more than two-thirds of new resources in the Interconnection Queue and solar and battery resources make up another quarter.[260] Beyond this, there are hundreds of thousands of BTM solar installations currently in operation in the region and it is vital to plan for the changes in demand these resources create.[261]

Some of these resources, like large-scale hydropower, land-based and offshore wind, provide very high capacity values but are located far from load centers and need new transmission. Offshore wind, for example, located off the coast of Massachusetts and Rhode Island, can initially interconnect at only a finite number of PTFs) along the coast and many of these are already approaching the limit of their capacity with just the 3142 MW of offshore wind that Connecticut, Massachusetts and Rhode Island have already contracted. See Figure 5.1.

Figure 5.1: Coastal Transmission Interconnection Points Available for Offshore Wind Resources[262]



[260] Id., p. 13

[261] Id., p. 18.

[262] ISO New England, *2019 Economic Study Offshore Wind Transmission Interconnection Analysis*, May 20, 2020, *available at* https://www.iso-ne.com/static-assets/documents/2020/06/a4_2019_economic_study_offshore_wind_transmission_interconnection_analysis.pdf

Offshore wind is a central element of Connecticut's pathway to achieve a reliable and equitable zero carbon electric supply. Presently, Connecticut has contracted for just over 1100 MW of offshore wind, while Massachusetts has procured about 1600 MW with another 1600 MW more in the near future. Rhode Island has 400 MW under contract and will soon issue an RFP for 600 MW.[263] Therefore, the three New England states have a total of 3,142 MW already under contract and up to 5,342 with the new Massachusetts and Rhode Island procurements. Objective 1 concludes that Connecticut would eventually need an additional 3,745 MW under the Base Load Balanced Blend scenario or 5,710 MW under the Electrification Load Balanced Blend scenario, to meet the 100% Zero Carbon Target in 2040. If combined with the amount already contracted or out for RFP, OSW capacity would thus total 9,087 or 11,052 MW, under the Base Load Balanced Blend scenario or the Electrification Load Balanced Blend scenario, respectively. This amount of OSW is within the expected total capacity of the BOEM leaseholds located off southern New England, which is currently estimated at between 11 to 14 GW.

This quantity of offshore wind will not be able to interconnect into the regional grid without transmission upgrades. ISO-New England planners have stated that "[b]ased on the currently expected transmission for 2030, ISO-NE anticipates that [5,800 MW] of offshore wind additions have the potential to be accomplished without major additional 345 kV reinforcements."[264] However, there are two important caveats. The first is that these studies assume interconnection only; not full integration of the capacity of the wind farms, and not at full nameplate capacity. That means the offshore wind projects may be able to reliability interconnect to the grid, but a significant amount of the energy from those generators will not be deliverable to consumers. The second is that the ISO's 5,800 MW estimate assumes that offshore wind generators will be distributed across the interconnection points shown in Figure 5.1. If instead, offshore wind generator interconnections are clustered on Cape Cod, there may be a need for additional transmission infrastructure to reliably export power out of Cape Cod and the SEMA/RI zone into the full New England grid. ISO-New England has indicated that there may be a "hard ceiling" at some or all of the PTF points that would prevent interconnection of more than approximately 7,000 MW without extensive new transmission development on new rights-of-way. The studies to evaluate that are just beginning and will take time to complete. The clear takeaway is that potential transmission constraints need to be fully evaluated before Connecticut and other states conduct procurements for wind resources beyond those already contracted or authorized under existing statutes. Therefore, meeting the long-term goals of this IRP will require proactive planning for transmission to ensure that incremental wind turbines can be interconnected, and operate without curtailment and this, in turn, may require Connecticut to work with other New England states to initiate a procurement of transmission infrastructure to permit full integration of offshore wind resources.

In addition to unlocking offshore wind and other new grid-scale resources, transmission upgrades will be also needed to address changes caused by BTM resources. States have invested significantly in BTM solar in the past two decades, resulting more than 3,400 MW of BTM solar PV nameplate capacity in the

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263 Press Release. Raimondo calls for up to 600 MW of new offshore wind energy for Rhode Island. October 27, 2020. https://www.ri.gov/press/view/39674

264 ISO New England, *2019 Economic Study: Offshore Wind Integration,* June 30, 2020, *available at* https://www.iso-ne.com/system-planning/system-plans-studies/economic-studies/

region.[265] Today, BTM solar PV resources reduce the region's gross load by approximately three percent and have changed the nature and shape of the demand curve, particularly during the summer months.[266,267] The deployment of energy efficiency and BTM solar has already enabled a sharp drop in demand at certain times, resulting very light load conditions which then abruptly reverse as daylight hours come to an end and demand rises.[268] Light load conditions can present high-voltage and other issues which can be challenging for the grid operator to manage.[269] This, in turn, can result in the need for new voltage control systems and operating measures. Thus, even with the substantial investment in the transmission system in recent years, ISO-NE notes that it will be necessary to upgrade the system to affordably integrate VERs that affect supply, and resources that affect demand.[270]

In short, the transmission system for a traditional fossil-fuel system with dispatchable generation (*i.e.*, fossil fuel-based power plants in or near urban areas) is very different from a transmission system based on inverter technologies with generation that is variable and is often located at a distance from load (*i.e.,* windfarms or other resources located far from city centers). In fact, most of the zero carbon resources needed to meet Connecticut's policies are "inverter-based" resources, which present unique needs for transmission planning. ISO-New England recognized this and stated in its Regional Systems Plan 2019:

> The widespread addition of inverter-based technologies (which use power electronics to convert between alternating current [AC] frequencies or between AC and direct current [DC] frequencies) and distributed energy resources (most which the ISO cannot observe or control like traditional resources) would require transmission upgrades and control system improvements for reliably interconnecting these resources to the grid. Structural changes to the transmission and distribution systems are being analyzed and implemented, and new procedures put in place, to help transform the grid and improve the reliable, economical, and environmental performance of the system overall.[271, 272]

Considering the amount of inverter-based or variable energy resources that could be developed over the IRP forecast period, it will be necessary to upgrade the region's transmission grid. Interregional transmission planning is vital to ensure the most efficient development of OSW and other zero carbon resources.

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[265] ISO New England, *2020 Regional Electricity Outlook*, p. 13, February 28, 2020, *available at* https://www.iso-ne.com/static-assets/documents/2020/02/2020_reo.pdf

[266] *Id.*

[267] ISO New England, *2019 Regional System Plan*, October 31, 2109, pp. 155-159, *available at* https://www.iso-ne.com/system-planning/system-plans-studies/rsp/

[268] Id. P. 159, fn 324.

[269] Id. P. 156.

[270] Id. P. 157.

[271] Id. P. 1.

[272] Inverter-based technologies include wind, photovoltaics resources, high-voltage direct-current (HVDC) facilities, battery energy-storage systems, and flexible alternating current transmission system (FACTS) devices, which can help regulate voltages and improve the stability performance of the system. Distributed energy resources (DERs) are sources and aggregated sources of electric power not directly connected to a bulk power system. DERs include generators (i.e., distributed generators) and energy-storage technologies capable of exporting active power to an electric power system.

In September 2020, ISO-NE began a process of identifying and testing changes to transmission planning assumptions to address some of the technical issues presented by clean energy resources in the reliability planning process.[273] This effort aims to address issues such as decreased daytime load due to BTM solar, stability issues presented by inverter-based generations, and substantial increases in offshore wind generation. However, these changes are not coordinated with State clean energy goals, and do not consider public policy as a factor in determining planning assumptions. Instead, these changes to the reliability planning process are reacting to changing system conditions, and do not address the resource additions projected the modeling Objective 1.

Reducing Curtailment through Transmission Upgrades

Not only can transmission upgrades increase the amount of available zero carbon resources (i.e. unlocking land-based wind in Northern New England), but they can also increase the amount of energy available from zero carbon resources that are expected to come online. The issue of curtailment, as discussed in Objective 1, arises when the amount of energy being supplied to the grid exceeds what the grid can actually support, thus causing the excess to be “spilled” or curtailed. The modeling results indicate that zero carbon energy is curtailed across the region, particularly in the later modeled years as an increasing amount of variable energy is brought online to meet the Regional Emissions Target. Alleviating transmission constraints can reduce, but not entirely eliminate, these curtailments. Figures 5.2 and 5.3 show the amount of VERs curtailed regionally over the years, expressed in terms of percentage of resource capacity, in both the Base Load Balanced Blend and Electrification Load Balanced Blend scenarios. Figures 5.4 and 5.5 show that same information under the scenarios that eliminate transmission constraints (i.e. upgrades are implemented), showing a significant decline in curtailments and highlighting the potential value of relieving these constraints in unlocking zero carbon energy potential. This effect is further pronounced under the Electrification Load, which requires even more VER capacity to achieve the Regional Emissions Targets.

[273] *See* ISO New England, “Transmission Planning for the Future Grid,” https://www.iso-ne.com/committees/key-projects/new-englands-future-grid-initiative-key-project

Figure 5.2: VER Regional Curtailments, Base Load Balanced Blend Scenario

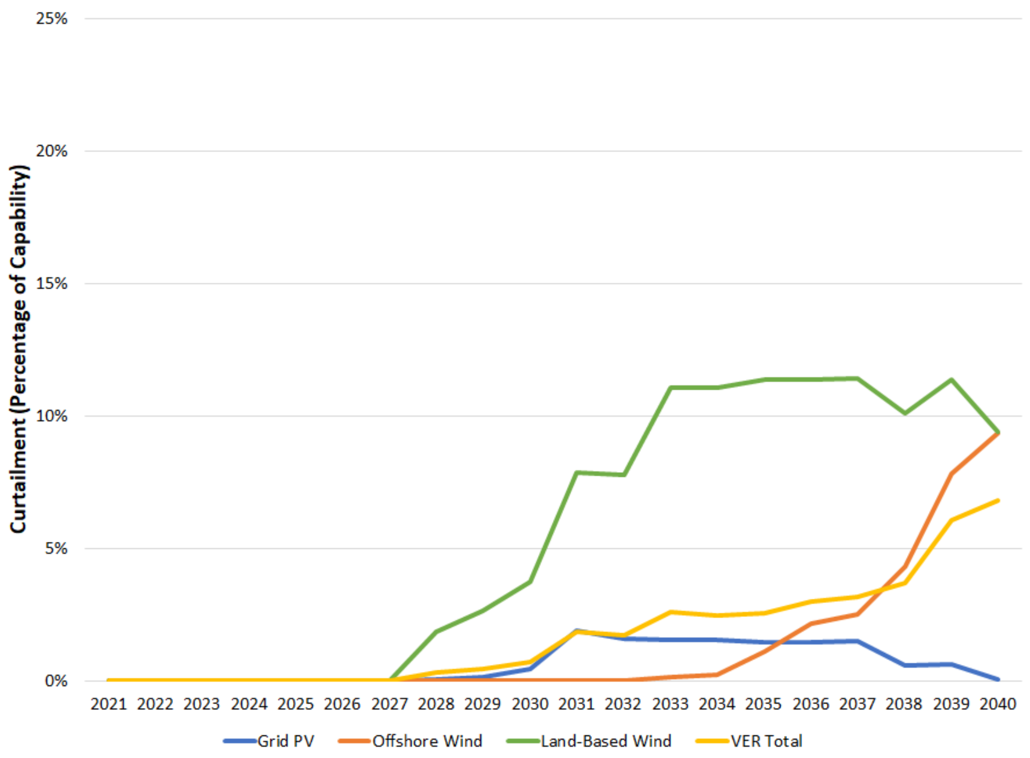


Figure 5.3: VER Regional Curtailments, Electrification Load Balanced Blend Scenario

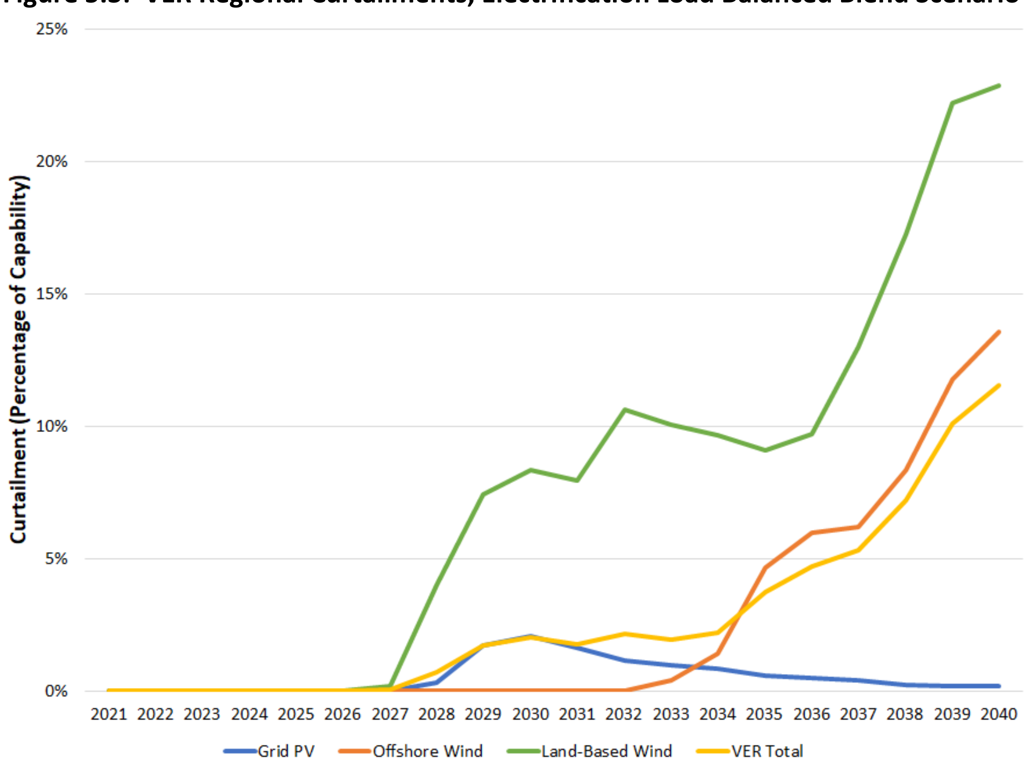


Figure 5.4: VER Regional Curtailments, Base Load Transmission Scenario

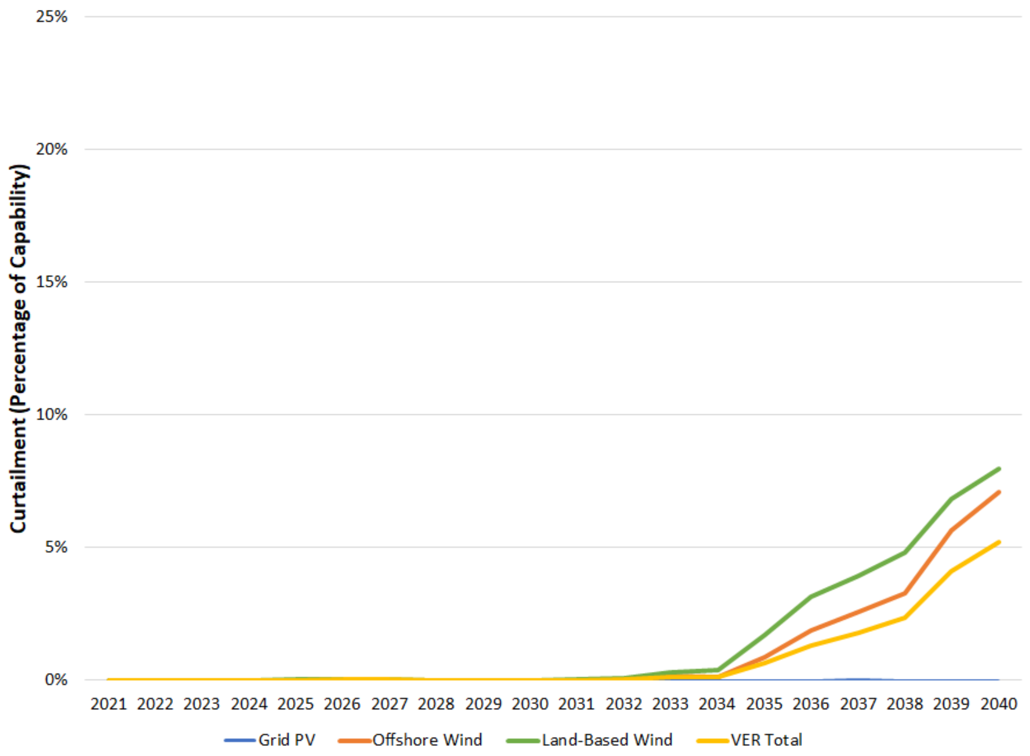
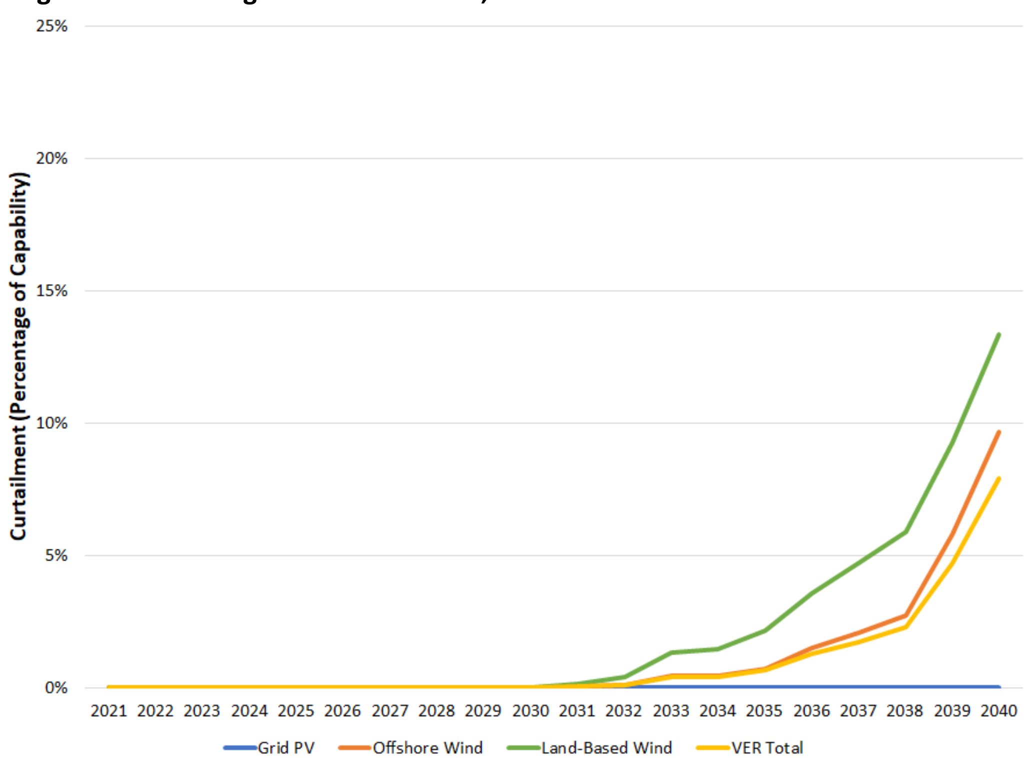


Figure 5.5: VER Regional Curtailments, Electrification Load Transmission Scenario



Transmission Upgrade Planning Needs to Begin Now

Major transmission projects in ISO-NE in recent years have faced significant delays or have simply failed.[274] An analysis performed by the Brattle Group notes that "[t]ransmission projects require at least 5-10 years to plan, develop, and construct; as a result, planning would have to start now to more cost-effectively meet the challenges of changing market fundamentals. . . ."[275] Comparatively, DEEP has successfully completed procurements for grid-scale solar with in-service dates 2-5 years later, some expected and others achieved. For DEEP OSW procurements, there is an expected in-service date five years later. The State is able to procure resources faster than the transmission grid can adapt; thus, it is critical to ensure the transmission system is capable of delivering the significant quantities of zero carbon resources identified in this IRP.

As noted above, considering the amount of inverter or VER resources planned in this IRP over the forecast period, it will be necessary to comprehensively upgrade the region's transmission grid. Interregional transmission planning is vital to ensure the most efficient development of OSW and other zero carbon resources. ISO-NE recognizes this in its 2020 Regional Electricity Outlook: "To achieve decarbonization goals, the region must be proactive in developing infrastructure that aligns with supply growth and is available when needed."[276]

Under the current ISO-NE tariff, proactive planning for clean energy integration is a challenge. To date, the basic approach to generator interconnections has been primarily reactive in that developers take a queue position on a first-come-first-served and are studied in order by ISO-NE planners. The current process is misaligned with state efforts to transition to clean energy. The region's shift toward more offshore and onshore wind, hydroelectric resources, solar PV, and battery storage continues. Yet, the FERC Order No. 1000 planning process for public policy transmission projects is not functioning as intended; in fact, in the years since Order 1000 was issued, no public policy transmission projects have been built in ISO-NE, largely due to concerns with cost allocation and a lack of transparency to and control by the states. We need an alternative to this approach, and State officials are convinced that a forward-looking, scenario-based proactive planning process is needed. Absent such a proactive transmission planning process, the region will be unable to effectively plan for the widespread integration of these clean energy resources and DERs. For example, the bulk transmission grid is required to serve less demand as a result of the ever-growing adoption of small-scale distributed generation like rooftop solar PV, but must also reliably support rapid changes in demand as the sun goes down. These issues will only intensify as the state sees growth in electrical demand due to the electrification of the transportation and heating sectors.

A proactive transmission planning process will better integrate transmission planning with state DER policies and help to anticipate the amount and type of transmission infrastructure needed; we know this clean energy transition is occurring and a planning process that acknowledges and accounts for this fact

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[274] For example, the Northern Pass project, a 192-mile long 1200 MW transmission line, was abandoned after eight years of effort in the face of significant opposition. The company took a write-down of $240 million. http://indepthnh.org/2019/07/25/eversource-gives-up-northern-pass/

[275] Chang, Judy and Pfeifenberger, Johannes, *Well-Planned Electric Transmission Saves Customer Costs: Improved Transmission Planning is Key to the Transition to a Carbon-Constrained Future*, June 2016, The Brattle Group, pp. Iii, 4. See also Transmission Incentives NOPR, Docket No, RM20-10, WIRES brief, p. 7, " time is of the essence, as state-mandated renewables goals with targets as early as 2030 are fast-approaching, while transmission projects in this country can face a timeline for development of roughly ten years or more."

[276] ISO New England, *2020 Regional Electricity Outlook*, p. 15, February 28, 2020, *available at* https://www.iso-ne.com/static-assets/documents/2020/02/2020_reo.pdf

rather than relying on a reaction-based planning model or an ineffective FERC Order No. 1000 framework is essential for a successful and cost-effective transition.

Load Reduction and Balancing through Energy Efficiency, Demand Response, and Storage

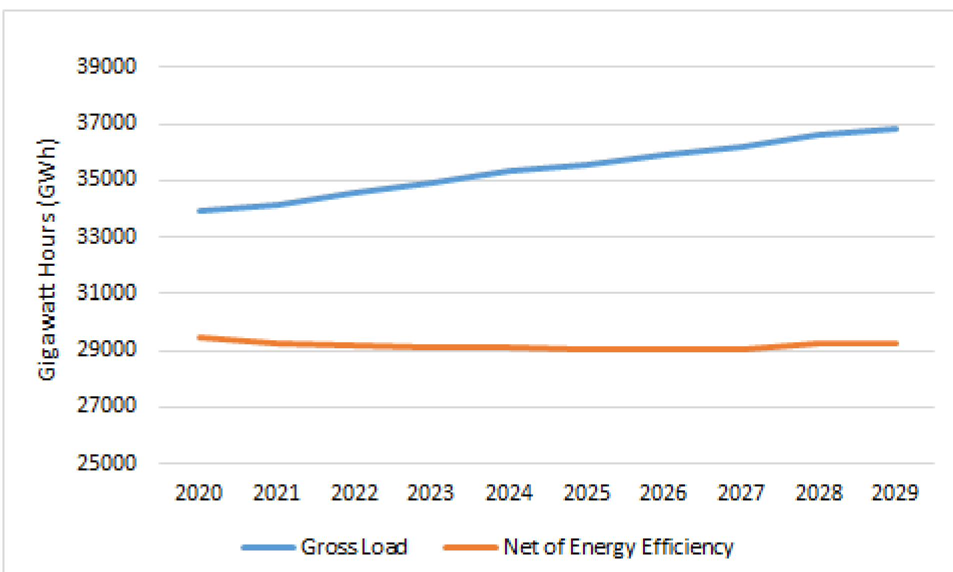
As made clear by this Objective, integrating the amount of variable energy resources, both grid-scale and behind the meter, necessary to meet the targets outlined in Objective 1 will require upgrading the existing New England transmission system to mitigate curtailments and reduce congestion. However, there also exist non-wires alternatives (i.e. measures or technologies that do not involve upgrades to the transmission system) that can help achieve these same outcomes. Non-wires alternatives typically include energy efficiency, demand response, and storage measures.

Energy Efficiency

Energy efficiency is a critical resource in Connecticut's energy mix. Not only does it help to reduce overall and peak loads, but it is also an option ratepayers can pursue to manage their energy costs by reducing their consumption. In 2019 alone, the State's C&LM programs, implemented under DEEP's authority pursuant to Connecticut General Statute Section 16-245m, reduced demand by an amount equivalent to a 149 MW power plant, saving ratepayers an estimated $67.5 million in energy costs and avoiding 228,142 tons of CO_2 emissions.[277]

Figure 5.6 demonstrates the demand reduction projected to occur through the implementation of Connecticut's energy efficiency investments at current levels over the next decade. Absent Connecticut's investments in efficiency, our energy consumption would be 14 percent higher on average each year.

Figure 5.6: Projected CT Load Net of Energy Efficiency Savings[278]



[277] *See* Connecticut Energy Efficiency Board, 2019 Programs and Operations Report, March 1, 2020, *available at* https://www.energizect.com/sites/default/files/Final-2019-Annual-Legislative-Report-WEB02262020_2.pdf.

[278] *See* ISO-NE, 2020 CELT Forecast Detail, *available at* https://www.iso-ne.com/system-planning/system-forecasting/load-forecast/

The significance of these energy savings has long been recognized by the State and by Governor Lamont, who protected the C&LM Plan budget from being diverted to the general fund in 2019 as it had been in 2017.[279] Section 16a-3a(c) of the Connecticut General Statutes requires energy efficiency and demand-reduction strategies to be prioritized as the first resource to meet the state's energy needs, before new generation resources are procured. In addition, Connecticut must meet its statutory target for energy demand reduction of 1.6 million MMBTU per year beginning in 2020 through 2025, reinforcing the importance of the C&LM programs.

APPENDIX A1

Consistent with these policies, DEEP incorporated the above projections of energy efficiency into the expected annual load through the modeling horizon of this IRP (see Objective 1 and Appendix A1). These energy savings—estimated annually by ISO-NE—are based on historical trends in Connecticut's investment in energy efficiency and resulting energy savings. In the Electrification Load scenarios, DEEP assumed increased energy efficiency would be achieved through measures corresponding to conversions to electric heat pumps, helping to mitigate the increased load necessary to meet Connecticut's climate goals. For further details on the energy efficiency projections and assumptions used in this IRP, see Appendix A1.

Energy efficiency measures are essential in all scenarios, because they help to both drive down energy consumption and GHG emissions and minimize costs by avoiding the need for additional procurements. The impact of energy savings on GHG emissions is greatest in the earlier years of the forecast while the energy market is still transitioning to zero carbon, though by 2040 the region is anticipated to achieve over 46,000 GWh of energy savings under the Base Load scenarios, and over 54,000 GWh under the Electrification Load scenarios. If load levels are higher than projected, or investment in energy efficiency does not meet projections, the costs of achieving the 100% Zero Carbon Target under all of the scenarios in Objective 1 will increase as Connecticut will need to procure more grid-scale zero carbon resources to meet the higher load.

Energy efficiency will be increasingly important in a future that looks like the modeled Electrification case described in Objective 1. To meet its broader, economy-wide greenhouse gas reduction goals, Connecticut must reduce emissions from the building sector. With approximately 45 percent of Connecticut's housing stock still relying on oil or propane for space heating, electrification through technologies like high efficiency air source heat pumps (ASHPs), geothermal heat pumps, and solar space and water heating are becoming increasingly important. However, as this heating load historically met with fossil fuels converts to electric, electricity demand will increase, as reflected in the modeled Electrification Load scenarios. Furthermore, as Connecticut electrifies its transportation sector, vehicle-charging load must be encouraged to off-peak hours and, ideally, responsive to dynamic pricing in order to prevent increased costs to the grid. Energy efficiency and demand response will remain a central and dynamic component of modern grid planning to minimize both the amount of energy needed to achieve a cost-effective, decarbonized future and some of the transmission upgrades needed support it.

279 Public Act 17-2, Section 683, An Act Concerning the State Budget for the Biennium Ending June 30, 2019, Making Appropriations Therefore, Authorizing and Adjusting Bonds of the State and Implementing Provision of the Budget.

Dynamic Approaches to Energy Efficiency Program Oversight and Maintenance of Program Funding

Recognizing these priorities, DEEP, with significant stakeholder input, directed considerable changes and improvements to the C&LM Plan programs in the 2020 and 2021 program years, and has identified key priorities for the next three-year plan, which begins in 2022. Oversight of the C&LM Plan requires responsiveness and adaptability in order to continually incorporate lessons learned and best practices in an extremely dynamic field. The three-year planning cycle is valuable insofar as it allows for annual budget flexibility and planning for longer-term issues, such as developing a schedule for evaluations. However, DEEP has taken a much more proactive approach in 2020 and 2021, in collaboration with the EEB, program administrators, vendors, and other stakeholders, to increase feedback processes and provide decisions modifying the plans as needed, rather than waiting for the next three-year planning process.

In DEEP's Conditions of Approval for the 2020 Plan Update (Conditions of Approval), issued in February 2020, DEEP directed the utility C&LM program administrators, Eversource Energy, The United Illuminating Company, Connecticut Natural Gas Corporation, and Southern Connecticut Gas (together, the "Utilities"), to implement significant reforms to the programs and incentive levels by July, 2020.[280] These initial reforms were intended to align with industry best practices, to provide increased greenhouse gas reductions, and to make the programs more equitable and accessible by reducing or, in some cases, eliminating up-front costs. The reforms included expanding the program benefits in the benefit cost calculation to include oil and propane thermal savings; increases to insulation and heat pump incentives; streamlining of eligibility processes for customers with low income, including using census tract data to determine eligibility and creating a more streamlined application for renters; focusing on heat pump conversions for customers with inefficient and expensive electric resistance heat; and conducting outreach to homeowners with crumbling foundations for building envelope and heat pump programs.[281]

Prior to the EDCs' implementation of the changes required in the Conditions of Approval, COVID-19 struck Connecticut, leading to a temporary shutdown of on-site work for the residential and small business programs.[282] DEEP led an intensive, collaborative engagement effort including the EDCs, the EEB, the vendor community, and other stakeholders, and issued multiple DEEP determinations focused on improving vendor cash flow and preparing for a return to on-site work.[283] Governor Lamont's

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[280] *See* DEEP Approval of 2020 C&LM Plan Update, Appendix A, February 11, 2020, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/16d2e80a4a780ab78525850b0057ec6a/$FILE/Approval%20of%20CLM%202020%20Plan%20Update.pdf.

[281] *See id.*

[282] *See* Conn. Energy Efficiency Programs COVID-19 Contingency Planning Letter, March 17, 2020, at pg. 1, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/8525797c00471adb8525852e006762b3/$FILE/Connecticut%20Energy%20Efficiency%20Programs%20COVID19%20Contingency%20Planning%2003172020%20Final%20Draft%20(002).pdf.

[283] *See* DEEP's Initial Action Regarding COVID-19 Contingency Planning, March 27, 2020; DEEP's Approval of Virtual Pre-Assessment Proposal, April 24, 2020; DEEP's Approval of Administrative Fee Proposal, April 24, 2020; DEEP's Approval of SBEA Incentives, May 23, 2020; DEEP's Final Determination and Health and Safety Protocols, June 11, 2020; DEEP's Determination Regarding SBEA Eligibility Modifications, July 15, 2020, *all available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/$EnergyView?OpenForm&Start=1&Count=30&Expand=6.5&Seq=43. *See also* DEEP's Determination Regarding COVID-19 Related Compliance Items, May 18, 2020, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/7a46c7415ba02f088525856c

administration provided significant industry support, with the Office of the Governor, the Department of Economic and Community Development, and DEEP collaborating with the Connecticut Green Bank and the EDCs' to provide remote seminars to clean energy contractors on available programs such as the Paycheck Protection Program and updates on unemployment insurance, and to conduct a recurring survey to measure the impacts of the pandemic on Connecticut's clean energy industry. As that work was underway, further collaboration led to DEEP's issuance of Health and Safety Protocols allowing the safe return to on-site work, along with increased incentives to help jump-start program activity and provide economic relief and stimulus to customers.[284] This dynamic approach in response to the impacts of the pandemic helped stabilize the energy efficiency industry in Connecticut.

The COVID-19 pandemic was not the first challenge to the stability of the C&LM programs and the workforce the programs support. Public Act 17-2, as amended by Public Act 18-81, diverted a total of $117 million of electric efficiency funding over three budget years (2017-2019) into the general fund.[285] The biggest impact occurred in 2018, with a reduction in the budget of 32 percent, and a 38 percent reduction of the electric savings Connecticut relies upon to avoid the cost of additional generation, transmission and distribution. Just as the C&LM programs and contractors were beginning to recover, COVID-19 caused further instability. In order to continue on the path to industry stability, achieve the energy savings Connecticut relies upon from the C&LM programs, reduce customer bills, and reduce harmful emissions, it is critical to ensure that the C&LM programs are protected from being diverted for other purposes.

DEEP's Conditions of Approval for the 2021 Plan Update, issued in March 2021, directed the Utilities to re-focus their efforts on many of the 2020 Conditions of Approval listed above that were disrupted by the COVID-19 pandemic.[286] While some of the temporary incentives for certain Residential measures and C&I programs were extended into 2021, the 2021 Plan Update marks a return to pre-pandemic incentive levels approved by DEEP in its February 2020 Determination approving the 2020 Plan Update. These incentive levels represent an increase over pre-existing incentives and were designed to expand the adoption energy saving measures. DEEP also approved changes to the 2021 Plan Update that provide additional savings opportunities for residents and businesses, while enhancing community outreach and workforce development efforts and commitment to equity and environmental justice.[287] In addition to reiterating that the 2020 Conditions of Approval that were disrupted by the pandemic, DEEP instituted new Conditions of Approval in 2021, including:

007a0de2/$FILE/DEEP%20Determination%20Re%20March%202020%20Compliance%20Items%20-%20COVID%20Related.pdf.

[284] *See* DEEP's Final Determination and Health and Safety Protocols, June 11, 2020, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/8b4f54e48303b48785258584006afccf?OpenDocument.

[285] Public Act 17-2, Section 683, An Act Concerning the State Budget for the Biennium Ending June 30, 2019, Making Appropriations Therefore, Authorizing and Adjusting Bonds of the State and Implementing Provision of the Budget; Public Act 18-81, Section 12, An Act Concerning Revisions to the State Budget for Fiscal Year 2019 and Deficiency Appropriations for Fiscal Year 2018.

[286] *See* DEEP Approval of 2021 C&LM Plan Update, March 4, 2021, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/d80f7ae5059c5efc8525868e00598e40/$FILE/Determination_Approval with Conditions 2021 Plan Update_2020 PMI Adjustment (002).pdf

[287] *See* 2021 Plan Update to the 2019-2021 Conservation & Load Management Plan, November 1, 2020, *available at*: https://portal.ct.gov/-/media/DEEP/energy/ConserLoadMgmt/FINAL-2021-Plan-Update-Filed-10302020.pdf

- the development of a secondary equity metric;
- a pay-for-performance pilot;
- a building benchmarking proposal;
- improved data collection and outreach in the rental market;
- evaluating alternative demand response program design;
- an analysis of the soft cost of air- and ground-source heat pump installation;
- an exploration of a potential residential concierge service;
- an investigation of the potential for induction cooktop incentives; and
- a targeted marketing strategy for customers with large arrearages and frequent shutoffs, among others.[288]

Equitable Energy Efficiency

All electric and natural gas ratepayers contribute to the C&LM Plan funds through a charge on their bills. It is therefore imperative to ensure that all ratepayers are able to participate in the C&LM programs. Barriers to accessibility and affordability must be identified and addressed to ensure that customers who have been historically underserved can benefit from the programs. To address concerns surrounding program affordability, DEEP issued several determinations throughout 2020 and 2021 that focused on expanding program access by reducing or eliminating up-front costs.[289]

Despite these efforts, access to the C&LM programs is still difficult for those who rent their homes and those whose homes have health and safety barriers that require remediation prior to the installation of efficiency measures, such as asbestos, mold, or lead paint. Moreover, the utilities currently do not track program participation by demographics such as race, ethnicity, or primary language spoken. DEEP therefore recently launched an Equitable Energy Efficiency Proceeding, to identify barriers to equitable participation in energy efficiency programs and pathways to address those barriers, and to develop metrics for defining equity and measuring program outcomes from an equity perspective.[290] The Department will also gather information regarding methods for more inclusive outreach to those who have faced challenges to program participation such as residents with low and moderate income,

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[288] *See* DEEP Approval of the 2021 C&LM Plan Update, March 4, 2021, *available at*: http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/d80f7ae5059c5efc8525868e00598e40/$FILE/Determination_Approval with Conditions 2021 Plan Update_2020 PMI Adjustment (002).pdf

[289] *See* DEEP Determination Regarding COVID Related Compliance Items, May 18, 2020, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/dcc3b63fe3bad459852585a60039c8c8?OpenDocument(temporarily waiving the HES co-pay and increasing several incentives offered in residential programs); DEEP Approval of SBEA Incentives, May 22, 2020 *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/fc98d76d7471d27b85258571005f8099/$FILE/22%20May%202020%20-%20DEEP%20Approval%20SBEA%20incentives.pdf (temporarily increasing incentives offered in C&I programs); DEEP Approval of 2021 Plan Update, *available at*: http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/d80f7ae5059c5efc8525868e00598e40/$FILE/Determination_Approval%20with%20Conditions%202021%20Plan%20Update%20%202020%20PMI%20Adjustment%20(002).pdf

[290] *See* DEEP's Notice of Equitable Energy Efficiency Proceeding and Request for Written Comments, September 3, 2020, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/12c36ce3c4b5a80c852585d80046845f?OpenDocument.

businesses in underserved communities, renters, and those who live in homes or own businesses with health and safety barriers.[291]

Besides alleviating barriers to participation in energy efficiency programs, Connecticut can pursue other solutions that can ensure energy efficiency as a baseline for all consumers through efficiency codes and standards. The federal government already accomplishes this through efficiency standards covering nearly 50 major products and many light bulb types that save consumers nationwide $500 in energy costs per year.[292] States can also pursue efficiency standards for products not yet preempted by the federal government. Currently there are eighteen products categories that are prime for state standards because (1) they already have an existing ENERGYSTAR or other state standard, (2) they have an existing test procedure, (3) have multiple manufacturers producing at that standard, (4) have sufficient data for measurement and verification available, and (5) are cost effective for consumers.[293] If Connecticut pursues these standards, it can lock in cost-effective and enduring energy savings by preventing inefficient products from being sold in the state. It is estimated that these products could save 100 GWh per year by 2025, and growing as high as 316 GWh per year by 2025 as these products replace older inefficient ones. Setting these standards also makes sure that the products available to all consumers are efficient, and affordable.

Similar benefits can come from pursuing high efficiency building codes, but, unlike appliance standards, there are no federal building efficiency codes. Instead, states are allowed to adopt a model code, known as the International Energy Conservation Code (IECC) which is updated every three years to ensure a minimum standard of safety, fire protection and energy efficiency. However, states may adopt updated versions at their own pace. Currently, Connecticut requires that new construction and retrofits meet the 2015 IECC, which the State adopted in 2018.[294] There currently also exists a 2018 IECC, and the 2021 version is under development which is expected to improve commercial building efficiency by about five percent,[295] and residential buildings by about nine percent as compared to the 2018 IECC.[296] Adopting up to date building energy conservation codes creates a pathway that ensures buildings are becoming more efficient into the future, guaranteeing occupants a minimum level of efficiency.

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[291] *See id.*

[292] *See* Appliance Standards Awareness Project. *Appliance Standards Rank as #2 Energy-Saving Tool in US. available at* https://appliance-standards.org/image/appliance-standards-rank-2-energy-saving-tool-us

[293] *See* Appliance Standards Awareness Project. States Go First: How States Can Save Consumers Money, Reduce Energy and Water Waste, and Protect the Environment with New Appliance Standards. July 2017. *available at* https://appliance-standards.org/sites/default/files/States%20Go%20First.pdf

[294] *See* Connecticut Department of Administrative Services. 2018 State Building Code. October 1, 2018. *available at* https://portal.ct.gov/-/media/DAS/Office-of-State-Building-Inspector/2018-CT-State-Building-Code---Effective-10-01-18.pdf

[295] Final Determination Regarding Energy Efficiency Improvements in ANSI/ASHRAE/IES Standard 90.1-2019, 86 Fed. Reg. 40,543 (July 28, 2021), *available at* https://www.govinfo.gov/content/pkg/FR-2021-07-28/pdf/2021-15971.pdf

[296] Analysis Regarding Energy Efficiency Improvements in the 2021 International Energy Conservation Code (IECC), 86 Fed. Reg. 40,529 (July 28, 2021), *available at* https://www.govinfo.gov/content/pkg/FR-2021-07-28/pdf/2021-15969.pdf

The Department recognizes that significant opportunity exists to collaborate with municipalities and established community organizations to aggregate both residential and business customers for participation in the various C&LM program offerings and to help tailor programs to the particular needs of communities. The Department will also explore best practices from other states regarding community engagement strategies.

Planning for the Future

In 2021, the C&LM Plan is entering a planning year in its three-year planning cycle. The Department is also preparing to launch the process for the next Comprehensive Energy Strategy, which will focus on decarbonizing the building sector. At the same time, decisions are expected in PURA's Equitable Modern Grid proceedings[297] regarding statewide AMI rollout, innovative rate designs, and other advances that will help unlock benefits associated with and better enable innovative approaches to energy efficiency and demand response. Through its C&LM and CES planning processes, DEEP will work with the EEB, the utility program administrators, and stakeholders, to leverage those technological advances to ensure the C&LM programs are maximizing benefits for the grid and for participating ratepayers. The Department will pursue approaches such as pay-for-performance, the expansion of active demand response and bring your own device programs. DEEP will also continue monitoring how FERC Order 2222, which will allow small scale distributed energy resources to aggregate together and participate in regional wholesale energy markets alongside conventional energy resources, could enable the C&LM programs to take advantage of more market revenues.

As Connecticut moves toward a modernized grid, significant opportunities exist to help customers interact with the grid to manage their energy use. Whole-building approaches that integrate efficiency and demand response with distributed energy resources will help maximize the benefits of all of these resources. As mentioned in Objective 3, Connecticut currently recognizes this potential in the administration of the RSIP program, requiring that participants receive an energy audit to become eligible for the program incentives.[298] This structure ensures that customers can increase the cost-effectiveness of installing rooftop solar by minimizing their energy usage, and thereby reducing the size of the array needed to meet their load. For low- to moderate- income customers, the Green Bank partners with PosiGen to provide a solar lease program that pairs with energy efficiency measures to maximize energy cost savings for participants.[299] The Green Bank supports these integrated approaches by providing programs that finance a comprehensive set of energy technologies.[300] The Smart-E program is designed for residential customers, and the Commercial Property Assessed Clean Energy (C-PACE) program is available to commercial, industrial, multifamily and nonprofit property owners. Further integration potential exists for active demand response, including through battery storage, to help customers manage their load and offer potential resilience benefits to participating customers, as discussed further below.

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[297] PURA Docket 17-12-03RE02, Docket 17-12-03RE11

[298] *See* CT Green Bank, Legislative Report on the CT Green Bank Residential Solar Incentive Program, December 31, 2020, pg. 12, *available at* https://www.ctgreenbank.com/wp-content/uploads/2021/02/RSIP-Legislative-Report-2019-2020.pdf

[299] *See id.* at 6.

[300] *See id.* at 10.

Leveraging and Developing the Clean Energy Workforce

Through the C&LM program and the clean energy programs supported by the Green Bank, Connecticut has an existing network of skilled energy efficiency and renewable energy contractors and vendors who have served residential and business customers, municipalities, and community organizations throughout the state. Clean energy jobs accounted for 2.6 percent of total jobs in Connecticut at the end of 2019, and 80 percent of those jobs are in energy efficiency.[301] There is a need for workforce development in a variety of areas, which will provide more skilled jobs to contribute to Connecticut's economic recovery. Connecticut is well positioned to leverage and build on this existing workforce to provide holistic and equitable approaches for Connecticut's residential and business utility customers to interact with a modernized grid.

Demand Response and Energy Storage

Energy efficiency helps to reduce overall electric load and therefore the necessary capacity needed to meet that load. However, as the State and region increase the amount of variable energy resources needed to meet emissions targets and replace traditional base load dispatchable resources, storage and active demand response (ADR) are needed to balance out the electric grid for resource adequacy. In this IRP, modeled storage resource selections are lithium-ion batteries, while active demand response refers to the ISO-NE definition of a "demand resource that reduces load in response to a request from ISO-NE to do so for reliability reasons, or in response to a price signal."[302] Demand side management refers to programs or policies that encourage electricity users to modify their energy consumption patterns in response to incentives like price signals.

Opportunities as Peaking Unit Substitution and VER Supplementation

APPENDIX A3

Power generated on the grid must always equal demand for a reliable system, but under a Zero Carbon electric sector, electricity generated by clean energy resources may not always match demand. If variable zero carbon resources produce more energy than is being demanded, this energy is curtailed, or "spilled." Alternatively, if zero carbon resources alone cannot produce enough energy to cover customer demand, then operating reserves are called upon to fill the gap. The modeling in Objective 1 indicates that there will be a need for significant, new operating reserve capacity due to the increased penetration of variable energy resources, with an additional 4,775 annual average megawatts (MWas) under the Base Balanced Blend scenario in 2040 and 5,270 MWas under the Electrification Balanced Blend scenario across the region.[303]

Storage and active demand response play a key role in fulfilling this additional operating reserve capacity required to meet our zero carbon goals. At the beginning of the study period, all scenarios have similar operating reserve portfolios based on the type of unit providing the services. For example, in the Base Load Reference scenario, about half of the spinning operating reserves requirement (i.e., capable of near-instant response) is met with hydro and pumped storage resources and the other half is mostly provided by combined-cycle resources. Non-spinning reserve requirements (i.e., those that cannot immediately provide reliability services) are supplied predominately by combustion turbines. By 2040, however, as

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[301] *See* CT Green Bank, Connecticut Clean Energy Report, September 2020, at pgs. 4-5, *available at* https://ctgreenbank.com/wp-content/uploads/2020/11/2020-Connecticut-Clean-Energy-Industry-Report.pdf.

[302] *See* ISO-NE, Glossary and Acronyms, *available at* https://www.iso-ne.com/participate/support/glossary-acronyms.

[303] See Appendix A3 for further detail on operating reserves.

decarbonization policies advance, the modeling indicates that battery storage and ADR resources will replace a significant share of operating reserve supply normally met by conventional resources like combined-cycle natural gas plants.

If wind or solar production is low, storage and ADR can act as reserve generation and fill the gap until the variable zero carbon resources return to their forecasted output without the need for fossil resources. With active demand response, demand can be moved to different periods of the day by having customers reduce or curtail their demand during these peak (or otherwise limited) periods. This reduction lowers the demand on the system and avoids the need to run more expensive, carbon-intensive power plants, or in the most extreme cases, the possibility of rolling blackouts during these events.

The modeling in Objective 1 allocated clean energy additions to Connecticut to meet carbon reduction targets by year, but analysis was also conducted on an hourly level to understand the degree to which clean energy and demand were imbalanced.[304] Figures 5.7(a) through (d) use box and whisker charts to demonstrate the estimated hourly demand in each month, and each hour of the day in 2040, as well as the expected clean energy balances during these same timeframes under the Base Load Balanced Blend scenario. The clean energy balance is the difference between Connecticut's 2040 demand and 2040 clean energy generation. The box and whisker charts use a central box spanning the second and third quartiles (the interquartile range, from P25 to P75), with a line at the median (P50) and whiskers extending down to the fifth percentile (P5) and up to the ninety-fifth percentile (P95). The average (mean) is shown as a red dot.

Figures 5.7(a) through (d) show that in 2040 (under a typical weather year), there are *both* parts of the year, and parts of a typical day when it will be more challenging to fully meet demand with clean energy. Generally, there are two annual (seasonal) peaks: the largest occurring during the late summer, and another during the winter months (Figure 5.7(a)). Figure 5.7(b) demonstrates that during most months of the year, there is enough clean energy generation to meet the average hourly demand, indicated by the positive, or near-zero average balance values. However, during those peak months, greater than 50 percent of hours have negative clean energy balances, meaning clean energy generation cannot fully meet demand.

[304] Further information on this analysis is available in Appendix A3.

Figure 5.7: Connecticut Hourly Demands and Clean Energy Balances in 2040, Base Load Balanced Blend

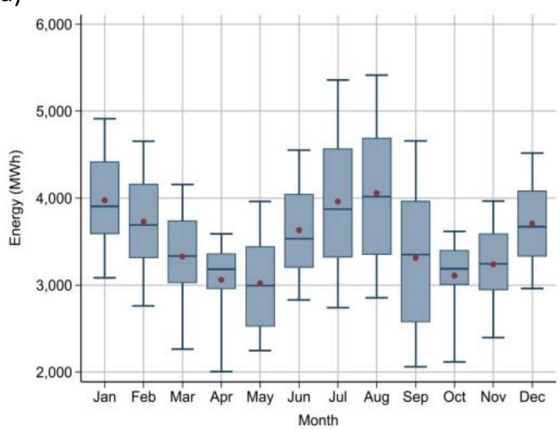
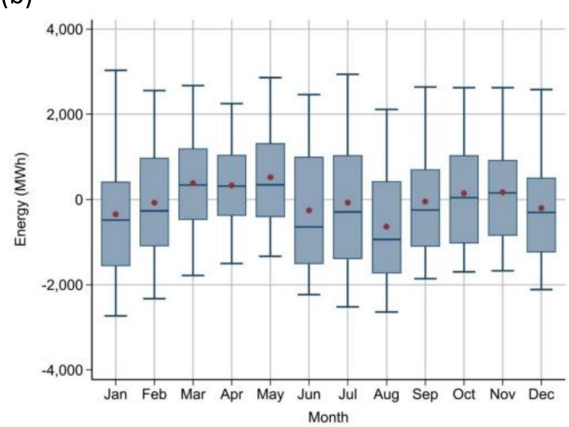
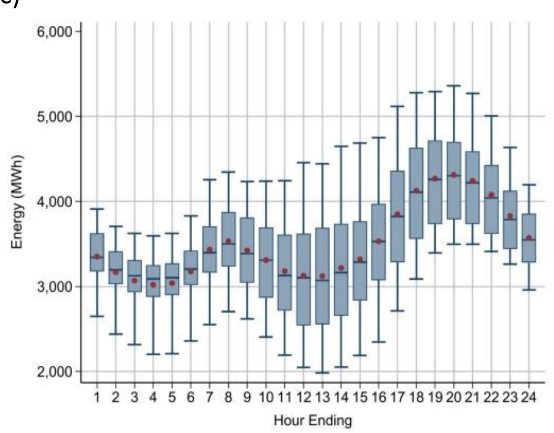
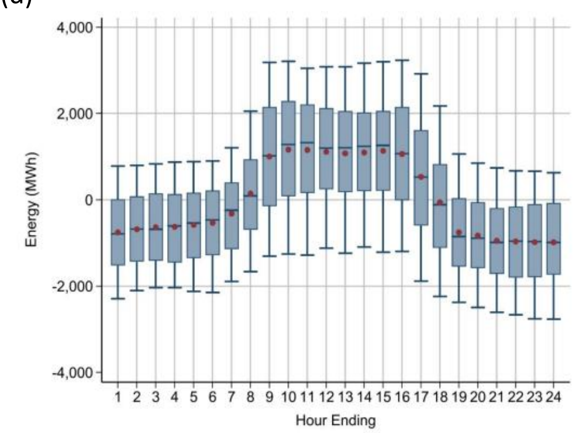
<table>
<tr><th></th><th>Demand</th><th>Clean Energy Balance</th></tr>
<tr><td>Hourly Per Month</td><td>(a)

</td><td>(b)

</td></tr>
<tr><td>Hourly Per Hour of Day</td><td>(c)

</td><td>(d)

</td></tr>
<tr><td>Notes</td><td>Demand is for Connecticut only in 2040 under the Base Load Balanced Blend scenario.</td><td>Clean energy balance refers to the difference between Connecticut's energy demand and the amount of clean energy generation available at corresponding points in time in 2040.</td></tr>
</table>

Figure 5.7(c) and (d) demonstrates demand and balance data on an hourly level per day. Figure 5.7(c) shows that peak load in 2040 occurs in the evening, consistent with current trends. Figure 5.7(d) shows that in many hours of a day, primarily during the early morning and evening hours, clean energy generation is only able to meet demand about 25 percent of the time.

These graphs highlight points in time during which resources like wind and solar will likely be unable to generate enough energy to meet demand due either to weather conditions or peak demands. However, this also signals opportunities for resources like active demand response and energy storage to help fill those gaps by shaving peak demands or supplying stored clean energy during low output periods.

It should be noted that it is currently difficult to identify any path that completely balances Connecticut's hourly clean energy supply and demand given the candidate resource options considered (e.g. VERs, hydro imports, and battery storage), and current technology capabilities. For example, some of the shortfall periods can last more than eight hours, as shown by Figure 5.7(d), and sometimes up to several days, which exceeds the storage duration presently contemplated for battery and pumped storage projects.

Despite this, there may be incremental potential for storage and active demand response technologies to begin meeting demand during these periods and reducing the need for fossil dispatching generation.

Opportunities for Curtailment Minimization

Storage and active demand response can help maintain reliability while reducing reliance on expensive peaking fossil-generating resources during periods of insufficient VER output. Alternatively, if variable zero carbon resources produce more energy than demand requires, then generation from these resources must be limited or curtailed. The curtailment analysis provided in Appendix A3 highlights that a significant amount of renewable generation is curtailed due to export constraints in Southeastern Massachusetts and Rhode Island (SEMA/RI) and Northern New England. Approximately 4.1 TWh of variable energy generation, equivalent to 6.8 percent of grid-scale wind and solar capability, is curtailed in 2040 in the Base Load Balanced Blend scenario. Similarly, 9.2 TWh of variable energy generation, equivalent to 11.6 percent of grid-scale wind and solar capability, is curtailed in 2040 in the Electrification Load Balanced Blend scenario. Land-based wind in Northern New England, Maine in particular, has the most curtailments as a portion of nameplate capability.

While transmission upgrades are one important step needed to mitigate curtailment, in some cases this can also be achieved with non-wires alternatives, including storage resources collocated with renewable generation or at constrained transmission points. This could include technology systems still under development, such as green hydrogen, which can capture excess renewable generation and convert it into stored zero carbon fuel for later use in hydrogen fuel cells. The Department plans to continue monitoring the developments of such technologies to determine if and when they should be included in the state's resource planning efforts. Alternatively, demand side management programs can move demand to higher variable supply periods, such as during midday solar peak, avoiding curtailment and also serving as a kind of storage.

FCA 15 Results

The modeling in Objective 1 anticipates that batteries will start setting the capacity price in the early 2030s as more are needed to meet resource adequacy. However, in February 2021, the ISO-NE FCA cleared the most storage in the auction's history; over 630 MW.[305] The majority of this capacity is from new resources, indicating that storage resources are becoming more cost competitive now, and may be beginning to take advantage of the opportunities created by shifting supply and demand curves. Additionally, the ISO-NE Interconnection Queue has more than 3,000 MW of new battery storage projects planned throughout the region signaling that this is unlikely to be a short-term trend.[306] ISO New England is currently considering how to integrate these resources into FCA 16 in February 2022.[307]

Current Efforts to Deploy Storage and Active Demand Response in Connecticut

There are currently multiple efforts underway in Connecticut to increase the deployment of storage and active demand response. In the draft Value of DER study, DEEP and PURA found that the value of BTM

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[305] *See* FCM 15 Results, slide 5, *available at* https://www.iso-ne.com/staticassets/documents/2021/03/a8_fca15_auction_results.pdf

[306] ISO New England. 2021 Regional Electricity Outlook, page 15; https://www.iso-ne.com/static-assets/documents/2021/03/2021_reo.pdf

[307] *Id.*

solar PV increases when paired with electric storage.[308] This is primarily driven by the increased amount of capacity demand reduction induced price effect (DRIPE) that occurs when the two technologies are paired, relative to BTM solar PV alone.[309] The value of DRIPE is derived from the change in the capacity market (FCM) clearing price caused by the addition from a resource. In the case of BTM solar PV plus storage, demand from the grid can be offset in more hours than if only BTM solar PV was available. This effect is demonstrated by UC3 (i.e. "Use Case 3- BTM Solar PV Paired with Electric Storage" from the draft Value of DER study) in Figure 2.9 in Objective 2 above. Following extensive analysis and stakeholder engagement on how to develop and initiate an electricity storage incentive program in Connecticut, PURA has released a final decision under the Grid Modernization docket number 17-12-03RE03. This decision laid out a pathway of deployment targets for residential and commercial storage, totaling 580 MW by 2030, and upfront and performance incentives necessary to meet those targets.[310] The targets are set in three-year increments, and PURA has committed to reevaluating these targets and incentives during each period.

DEEP will continue to monitor the deployment of storage resources accomplished through the program established in docket number 17-13-03RE03. It should be noted that this program intentionally does not utilize the entire 1,000MW of storage resources authority granted by Public Act 21-53. Programs created or modified to deploy the remaining 420MW of storage authority will develop in the coming years and these must be carefully monitored as well. Notably, the vast majority of the resources in the ISO-NE interconnection queue are proposed to be developed in Massachusetts, Rhode Island, and parts of northern New England, with relatively few Connecticut. This is because Connecticut does not currently share the same congestion issues found in these areas. Therefore, Connecticut will need to determine what other use cases could attract storage to the state, and whether this current procurement authority can help accomplish it. While market reforms described in Objective 2 are under way, Connecticut should consider what innovative and resilient applications exist or are developing for storage resources until the market economics for deployment in Connecticut improve.

Active demand response strategies are one of the key priorities of the C&LM Plan, as these can help reduce energy prices and price spikes during summer and winter peak demand.[311] While energy efficiency programs provide passive demand reduction, the Plan continues to evolve programs that provide active demand response.[312] In 2020, several demand response pilot programs have transitioned to full-fledged

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[308] *See* DEEP and PURA, Value of Distributed Energy Resources in Connecticut Study, July 1, 2020, at pg. 10, PURA Docket No. 19-06-29.

[309] *See* ISO-NE, Glossary and Acronyms, *available at* https://www.iso-ne.com/participate/support/glossary-acronyms.

[310] PURA, Docket No. 17-12-03RE03, *PURA Investigation into Distribution System Planning of the Electric Distribution Companies- Electric Storage,* Final Decision, July 28, 2021, *available at:* http://www.dpuc.state.ct.us/2nddockcurr.nsf/8e6fc37a54110e3e852576190052b64d/6991ef77ba07bae185258752007994f7/$FILE/171203RE03-072821.pdf

[311] *See* 2019-2021 Conservation and Load Management Plan, November 19, 2018, at pgs. 89, 149, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/8525797c00471adb8525834a005f8ce2?OpenDocument.

[312] *See id.*

programs.[313] The 2020 Plan has a goal of 39.8 MW load reduction from demand response.[314] The programs target a variety of residential and commercial customers and include demand reduction strategies that are technology agnostic.[315] Different technologies are suited to different dispatch strategies.[316] Commercial and industrial programs are being designed around targeted dispatch, daily dispatch and winter peak demand.[317] Certain technologies, such as batteries and thermal storage can reduce load on a daily basis without affecting customer comfort or operations.[318] As Connecticut moves toward building and vehicle electrification, strategies can be developed to include these markets in demand reduction programs to help mitigate their impact on peak. For example, EV charging load is expected to increase and is seen as a load with the flexibility needed to be part of a demand response offering. Research suggests that 80 percent of charging is done at residences and may be generally coincident with system peaks if not managed or incented to occur in off-peak hours.[319]

Not limited solely to summer peak demand reductions, the demand response programs can also be useful for ramping (ISO-NE dispatch only), load curtailment, distribution system operational needs and shortage events, as well as winter demand reduction needs.[320] Demand response can also be applied in natural gas programs, which can provide electric sector benefits in the form of fuel security during peak days in the winter months while Connecticut relies on natural gas electric generation. Automation and advances in technology make it possible to manage customer loads in new ways with strategies that bring additional values to the utilities and the customer.[321]

Ensuring Grid Security

Achieving a clean, reliable electric power supply essentially means nothing if that power cannot reach end uses that will increasingly rely on it in pursuit of reducing and mitigating the impacts of climate change. The grid of the future must therefore not only be clean and reliable, but secure and resilient. As defined by Public Act 20-5, "'resilience' means the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from deliberate attacks, accidents, or naturally occurring threats or incidents, including, but not limited to, threats or incidents associated with the impacts of climate change."[322] It is crucial that Connecticut, and New England continuously identify threats to the grid and solutions to both prevent and quickly resolve them.

Weather-Based Threats

Today's electric grid faces significantly more threats than when it was originally constructed, the greatest of which are from natural disasters caused by climate change. For example, transmission lines and

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313 *See* 2020 C&LM Plan Update, November 1, 2019, at pg. 15, *available at* https://portal.ct.gov/-/media/DEEP/energy/ConserLoadMgmt/Final-2020-Plan-Update-Text-11-1-19.pdf?la=en&hash=CABA7269C026532212943AF4C2F710BD.

314 *See id.* at 91.

315 *See id.* at 8.

316 *See id.* at 21.

317 *See id.*

318 *See id.*

319 *See id.* at 16.

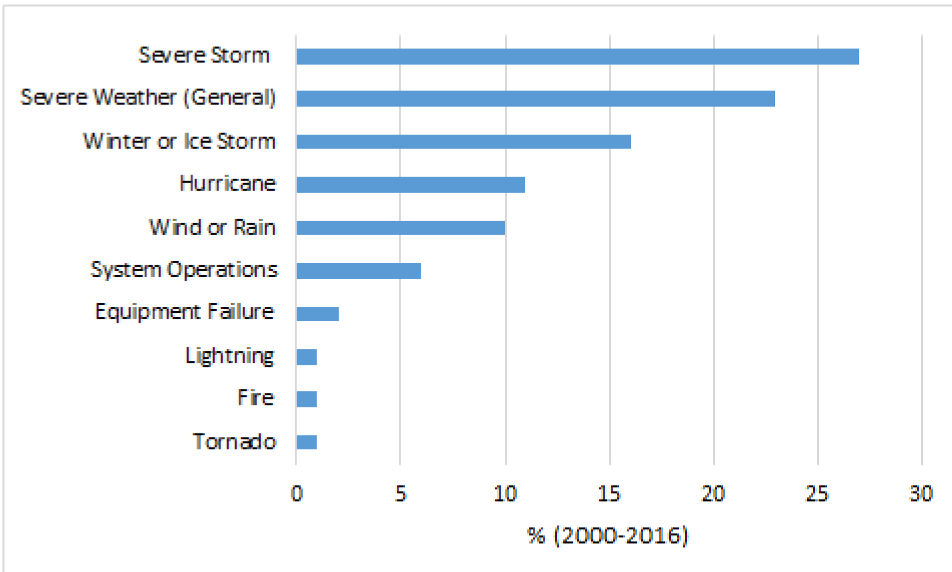
320 *See* 2019-2021 Conservation and Load Management Plan, at pg. 89.

321 *See id.*

322 Public Act 20-5.

transformers are highly sensitive to high ambient air temperatures, and damage from storms. A 2019 Oakridge National Lab report on climate vulnerabilities of the electric grid reported that the vast majority of outage events in the U.S. are caused by severe weather, like high temperatures, or severe storms, as shown by Figure 5.6. In Connecticut, power outages have been experienced due to downed wires and poles damaged directly by wind and precipitation or from falling trees and branches or other storm debris. Power outages have also been caused by coastal flooding. Coastal flooding during Tropical Storm Irene in 2011 and Hurricane Sandy in 2012 flooded the Pequonnock and Congress substations. These two substations, and an additional three owned by United Illuminating, are in the 100-year floodplain and face increasing risk of being flooded by rising seas levels. Efforts are underway at the substations to flood-proof them using barriers and pumps, elevate critical electrical components, or in the case of Pequonnock, rebuild the substation further inland and elevate it above the floodplain including accounting for sea level rise. The Pequonnock substation and nearby Singer substation in the South End of Bridgeport will be further protected by the planned Resilient Bridgeport coastal flood defense system that will prevent floodwaters from entering the neighborhood entirely during coastal storms.

Figure 5.6: Causes of Large U.S. Electric Disturbance Events Affecting ≥50,000 Customers[323]



Cybersecurity Threats

Like many other jurisdictions, Connecticut is pursuing a variety of grid modernization efforts, which will enhance the efficiency of grid operations and communication, increase the adoption of "smart" devices, and improve the ability of distributed generation resources to interconnect to the grid. But, as the grid

[323] Oak Ridge National Laboratory, *Extreme Weather and Climate Vulnerabilities of the Electric Grid: A Summary of Environmental Sensitivity Quantification Methods*, August 16, 2019, *available at* https://www.energy.gov/sites/prod/files/2019/09/f67/Oak%20Ridge%20National%20Laboratory%20EIS%20Response.pdf

becomes increasingly "smart," the threat of cyberattacks on the grid is also growing. Multiple federal,[324] regional,[325] and state jurisdictional[326] risk assessments have all indicated that cyberattacks have the potential to cause widespread power outages. As more and more sectors and technologies are electrified, the potential impact of a cyberattack and resulting outage is multiplied.

Outages caused by physical damage or cyberattacks to the transmissions system often have more widespread impacts. The components of the bulk power system are federally regulated for reliability by FERC, which includes cybersecurity standards. Certified by FERC, the North American Electric Reliability Corporation (NERC) develops and establishes Critical Infrastructure Protection (CIP) cybersecurity reliability standards that transmission service providers, owners and operators are all subject to.[327] Additionally, in April 2021, DOE announced a 100-day effort to address "persistent and sophisticated threats" to the national electric grid in partnership with the electricity industry and the Cybersecurity Infrastructure Security Agency (CISA).[328]

The reliability, and therefore cybersecurity, of the distribution grid, however, is primarily overseen by state utility regulators. On the distribution grid, key areas of vulnerability to cyberattacks include the industrial control systems used to remotely monitor and control operations, global positioning systems (GPS) used in grid operations, and networked "smart" consumer devices, and DERs and DER aggregators.[329] Smart devices and DERs are particularly vulnerable given their interconnection and interoperability standards that allow remote management and network communications, though individual systems would have little impact on the local power system requirement if compromised. However, in aggregate, these devices have the potential to significantly affect grid reliability, especially as more of them communicate over internet-based systems.[330] As pointed out in a 2017 Sandia National Laboratories report, "if one company could remotely update the settings of hundreds of megawatts of power equipment, anyone with access to that control network would be able to make malicious changes to those devices as well."[331] These distribution-side advancements can and will serve valuable roles in meeting Connecticut's energy and climate goals, but they must be protected from cybersecurity threats.

Connecticut has actively been prioritizing electric sector cybersecurity preparedness planning and measures through PURA's participation in the National Association of Utility Regulatory Commissioners'

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[324] U.S. Government Accountability Office, *Critical Infrastructure Protection: Actions Needed to Address Significant Cybersecurity Risks Facing the Electric Grid,* August 2019, *available at* https://www.gao.gov/assets/gao-19-332.pdf

[325] ISO New England, Cybersecurity to Protect the Grid and Marketplace, Accessed April 8, 2021, https://www.iso-ne.com/about/what-we-do/in-depth/cybersecurity-initiatives

[326] PURA, *2020 Connecticut Public Utility Annual Cybersecurity Report*, April 5, 2021, *available at* https://portal.ct.gov/-/media/PURA/2020-Connecticut-Public-Utility-Annual-Cybersecurity-Report.pdf

[327] FERC Order 706

[328] *See* U.S. DOE Press Release dated April 20, 2021. *Biden Administration Takes Bold Action to Protect Electricity Operations from Increasing Cyber Threats. Available at:* https://www.energy.gov/articles/biden-administration-takes-bold-action-protect-electricity-operations-increasing-cyber-0

[329] U.S. Government Accountability Office, *Electricity Grid Cybersecurity: DOE Needs to Ensure Its Plans Fully Address Risks to Distribution Systems,* March 2021, *available at* https://www.gao.gov/assets/gao-21-81.pdf

[330] Lai, C. et. al, *Cyber Security Primer for DER Vendors, Aggregators, and Grid Operators*, December 2017, Sandia National Laboratories.

[331] *Id.*

(NARUC) cybersecurity planning processes, PURA's own annual collaborative cybersecurity review with the electric, natural gas, and water public service utilities,[332] and through each individual utility's own cybersecurity plan.[333] Remaining at least one step ahead of potential cyber threats must continue to be a priority for the state as part of its resilience planning.

Increasing Storm Resiliency

The increasing risk of damage from storms means that Connecticut must continuously evaluate new and existing resilience measures that can protect the grid and the reliable delivery of electricity. Conventional resilience approaches like vegetation management, grid hardening and undergrounding wires can help mitigate storm and weather damage. Resilience can also be increased through on-site backup generation and the development of microgrids.

Microgrids

A microgrid is "a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid and that connects and disconnects from such grid to enable it to operate in both grid-connected or island mode."[334] During grid outages, which could be widespread or local, caused by natural means or a cyberattack, temporary or long-term, a microgrid operating in "island" mode enables a connected community, critical facilities and infrastructure, or a business to maintain power, avoiding adverse productivity impacts or health hazards. Particularly when paired with renewable DERs, microgrids can provide clean, sustainable resiliency for those connected loads.

Recognizing this potential, in response to the significant power outages experienced during the storms Irene, Sandy and Alfred, Connecticut created the Microgrid Grant and Load Program (Microgrid Program) under Public Act 12-148.[335] This act directed DEEP to establish a program that awards grants, matching funds, and low-interest financing to critical facilities using bond funding.[336] The purpose of the Microgrid Program has been to solicit applications to build microgrids in geographically diverse locations in order to

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[332] Connecticut Public Utilities Regulatory Authority. 2020 Connecticut Public Utility Annual Cybersecurity Report. April 5, 2021. https://portal.ct.gov/-/media/PURA/2020-Connecticut-Public-Utility-Annual-Cybersecurity-Report.pdf

[333] Eversource. PURA Dkt. 17-12-03RE02, *PURA Investigation into Distribution System Planning of the Electric Distribution Companies- Advanced Metering Infrastructure,* Eversource Grid Modernization Cyber Security Plan Revision 1, July 15, 2020, *available at* http://www.dpuc.state.ct.us/dockcurr.nsf/8e6fc37a54110e3e852576190052b64d/2ea5aad2d7ee96af852585b6005ac03a/$FILE/Cyber%20Security%20Plan%20Final%20July%202020%20ES%20GridMod.pdf

[334] Public Act 12-148, Section 7.

[335] *Id.*

[336] "Critical facility" means any hospital, police station, fire station, water treatment plant, sewage treatment plant, public shelter or correctional facility, any commercial area of a municipality, a municipal center, as identified by the chief elected official of any municipality, or any other facility or area identified by the Department of Energy and Environmental Protection as critical (as defined by Connecticut General Statues, Section 16 243y, as modified by Public Act 13-298, Section 34, and Public Act 16-196, Section 1). In identifying other facilities or areas as critical, DEEP considers the extent the applicant can demonstrate that the facility is critical and serves a public need. DEEP has identified the following additional facilities as critical: military bases, communications towers, fueling stations, food distribution centers, and mass transit. In addition, DEEP considers as critical facilities those facilities that have some or all of the following characteristics: provide support for national security; act as a command center; act as an emergency shelter; provide access to food, fuel, money, or medication.

support critical facilities during times of electricity grid outages. To date, DEEP has conducted four requests for applications for the Microgrid Program:

- Round 1: March 2014; seven grants were awarded totaling approximately $12.8 million
- Round 2: March 2014; two grants were awarded totaling approximately $5.1 million
- Round 3: November 2015; one grant was awarded totaling $424,000
- Round 4: August 2017; three grants were awarded totaling approximately $13.1 million

Each round has enabled the design and development of multiple microgrids around the state, as shown in Table 5.1.

Table 5.1: Connecticut Microgrid Grant & Loan Program Awarded Projects

Name of Project	Projected/Actual Date of Completion	Program Award	Status
ROUND 1			
Wesleyan University	March 2014	$ 693,819	Operational
Woodbridge	February 2018	$ 3,000,000	Operational
Hartford - Parkville	March 2017	$ 2,063,000	Operational
University of Hartford	August 2015	$ 2,270,333	Operational
Fairfield	April 2016	$ 1,167,659	Operational
Bridgeport	April 2018	$ 2,975,000	Operational
Windham	April 2017	$ 709,350	Operational
ROUND 2			
Milford	September 2021	$ 2,909,341	Under Construction
University of Bridgeport	November 2016	$ 2,180,899	Operational
ROUND 3			
Wesleyan University - expansion project	December 2017	$ 424,000	Operational
ROUND 4			
DOM Microgrid LLC	May 2022	$ 3,872,538	Under Construction
Coventry Microgrid	November 2021	$ 4,000,000	Under Construction
SUBASE New London	TBD**	$ 5,224,415	Contract Negotiation

Emerging Solutions

Microgrids are a critical tool in the climate resilience toolbox, but they are not the only one. Not all critical infrastructure power outages can be solved solely by a microgrid or a microgrid may not be the most cost effective or practical solution. In the case of the threats to our substations from coastal flooding, relocation, elevation or protection of those structures was the way to prevent the power outage. Installing pump stations and nature-based solutions or green infrastructure, like a stormwater park, than can mitigate flooding in the first place can also protect our grid and prevent power outages. A microgrid can be a critical part of enhancing a communities' resilience, but they are just one part of the puzzle.

Recognizing a need to expand Connecticut's toolbox to address critical infrastructure resilience, DEEP's Microgrid Program has been expanded under Public Act 20-5 to establish the Microgrid and Resilience Grant and Loan program to support microgrids or resilience projects. Under the revamped program, the grants and loans may provide assistance with community planning, including assistance with the cost of design or engineering for resilience projects, or be used as non-federal cost share for grant or loan applications. The funds must also be prioritized for projects that benefit vulnerable communities, including environmental justice communities in the state. The planning funds and non-federal cost share authorization in Public Act 20-5 are critical towards making Connecticut more competitive for federal funds, such as FEMA's Building Resilient Infrastructure and Communities (BRIC) Program. The BRIC Program was designed to support states, local communities, tribes and territories as they develop projects to mitigate risks they face from natural disasters and hazards. This program is making $1 billion available for resilience projects in FY21, but in order to unlock those dollars, each applicant must provide a 25 percent match and submit an application for projects with well-developed conceptual design, full cost estimates, a benefit-cost analysis, and a preliminary environmental assessment. This program and other federal resilience programs are expected to continue to be funded at high levels going forward, and therefore the DEEP is evaluating how to best leverage these funds to bring more federal funds into the state, including planning and building a project pipeline. Under the Biden Administration's Justice40 initiative, the FEMA BRIC program is also scoring projects more highly that benefit communities with a high indicator of social vulnerability using the Social Vulnerability Index. This prioritization aligns with the statutory requirements for the use of the microgrid and resilience funds to benefit vulnerable populations, further underscoring the high potential to leverage these state funds to gain federal dollars to build more resilient communities.

Strategies to Achieve Objective 5

Whether through market reform or ongoing procurements by Connecticut and neighboring states, New England can expect the amount of variable energy resource capacity to increase significantly over the next twenty years as states strive to meet their climate goals. The existing transmission system must evolve to support these resources. As discussed in Objective 5, current transmission planning has considered interconnection of these resources only, rather than full integration of wind resources' total nameplate capacity. This IRP recommends pursuing the following strategies in furtherance of Objective 5, *Upgrade the Grid to Support and Integrate Variable and Distributed Energy Resources*. It is critical that Connecticut coordinates with the other New England states to evaluate transmission needs to meet state climate and energy policy goals **(Strategy 4)**. To accomplish this, the state will also need to determine if the FERC Order 1000 public policy transmission planning process, or an alternative, is needed in the near future. Connecticut may also need to work with other New England states to initiate a transmission procurement.

While upgrading the region's transmission infrastructure to accommodate an influx of variable energy resources in the future is necessary, there are additional measures Connecticut can deploy to reduce and balance loads such as energy efficiency, demand response, and energy storage resources **(Strategy 12)**. Additionally, Connecticut must support the development of energy storage resources that will be critical to reliably integrating variable energy resources and provide important resiliency services **(Strategy 13)**.

This IRP further recommends the following focus for the existing C&LM programs:

- Continue the Equitable Energy Efficiency process and the Health and Safety Barriers Working Group in partnership with the EEB to identify and address barriers to participation in energy efficiency programs.
- Continue to identify and implement best practices and innovative approaches, in alignment with PURA's Equitable Modern Grid proceedings, to transform the C&LM plan to integrate intermittent resources and promote a smart, interactive, equitable grid.

- Further update the cost-benefit test, and reevaluate the approach used in the regional avoided cost study utilized by the Utilities to evaluate programs and measures.
- Restructure the Utilities' performance incentives to align with specific program goals and metrics.

Finally, as Connecticut continues to modernize its grid, it will need to simultaneously pursue strategies that help increase resiliency and security of all critical infrastructure. Expanding the existing Microgrid Grant Pilot Program to allow funding for projects that include other resiliency measures in accordance with Public Act 15-5 gives the state more tools to effectively plan for the impacts of climate change. Specifically, DEEP will focus on coordinating data from the EDCs, municipalities and state agencies to identify highest impact sites for resiliency measures and emergency planning (**Strategy 16)**.

Objective 6: Balancing Decarbonization and Other Public Policy Goals

Reducing greenhouse gas emissions from the electric sector towards achievement of the GWSA goals is a key focus of this IRP.[337] So, too, is ensuring that electric supply meets other policy goals and standards, reflected in the state's RPS. Connecticut's RPS predates the GWSA, and includes among its objectives not only reducing GHG emissions, but also supporting fuel diversity, reducing dependence on fossil fuels, creating a hedge against volatile oil and natural gas commodity prices, lowering air emissions, promoting clean energy jobs and economic development,[338] and supporting certain technologies for managing Connecticut's waste disposal needs. In evaluating pathways to reach a 100% Zero Carbon Target for electric supply by 2040, the IRP recognizes the need for strategies that gradually harmonize the state's decarbonization efforts with the broad public policy goals of the RPS and other state policy goals. This IRP focuses on near-term issues and opportunities for four technologies included in the RPS: anaerobic digestion, WTE facilities, and biomass.

Waste-to-Energy Facilities

APPENDIX A3

Connecticut produces over two million tons of municipal solid waste (MSW) annually, over 80 percent of which is disposed at Connecticut's five active WTE plants. The result of this high reliance on WTE is a reduction in methane and transportation-related emissions associated with landfilling. The State's policy in minimizing landfilling is set by Connecticut General Statutes Section 22a-228(b) and is consistent with the Environmental Protection Agency (EPA)'s waste management hierarchy for preferred waste management practices. Despite the benefit provided relative to not landfilling MSW, these plants, which represent about 198 MW of nameplate capacity, are estimated to produce roughly 800,000 tons of CO_2 annually as detailed in Appendix A3. They are also significant sources of NO_x and SO_2 emissions. As demonstrated by Table 4.2 in Objective 4, locations of the largest plants in communities with at-risk and minority populations raises serious public health and environmental justice concerns.

While these resources have high at-the-stack emissions intensities, their continued operation provides important waste disposal capacity and stabilizes costs for municipalities while Connecticut and its local governments seek a transition to more sustainable materials management strategies. Thus, this IRP removed WTE resources from the list of resources that are eligible to retire during the modeling period. Additionally, in order to maintain transparency in the carbon accounting for each model run, DEEP has included emissions from WTE units in the 2040 Regional Emissions Target. However, DEEP recognizes that in an ideal carbon accounting methodology Connecticut cannot, for convenience, attribute emissions associated with WTE plants in Connecticut to other states. If those resources continue operating in 2040 and Connecticut purchases the RECs from those facilities, then generated emissions will need to be offset by additional zero carbon energy purchases beyond what is modeled in this IRP or offset in some other way.

In addition to carbon dioxide emissions, WTE plants located in the State produce significant NO_x and SO_2 emissions. Because these resources are designated as "must-run" for purposes other than

[337] *See* Conn. Gen. Stat. Section 16a-3a(a).

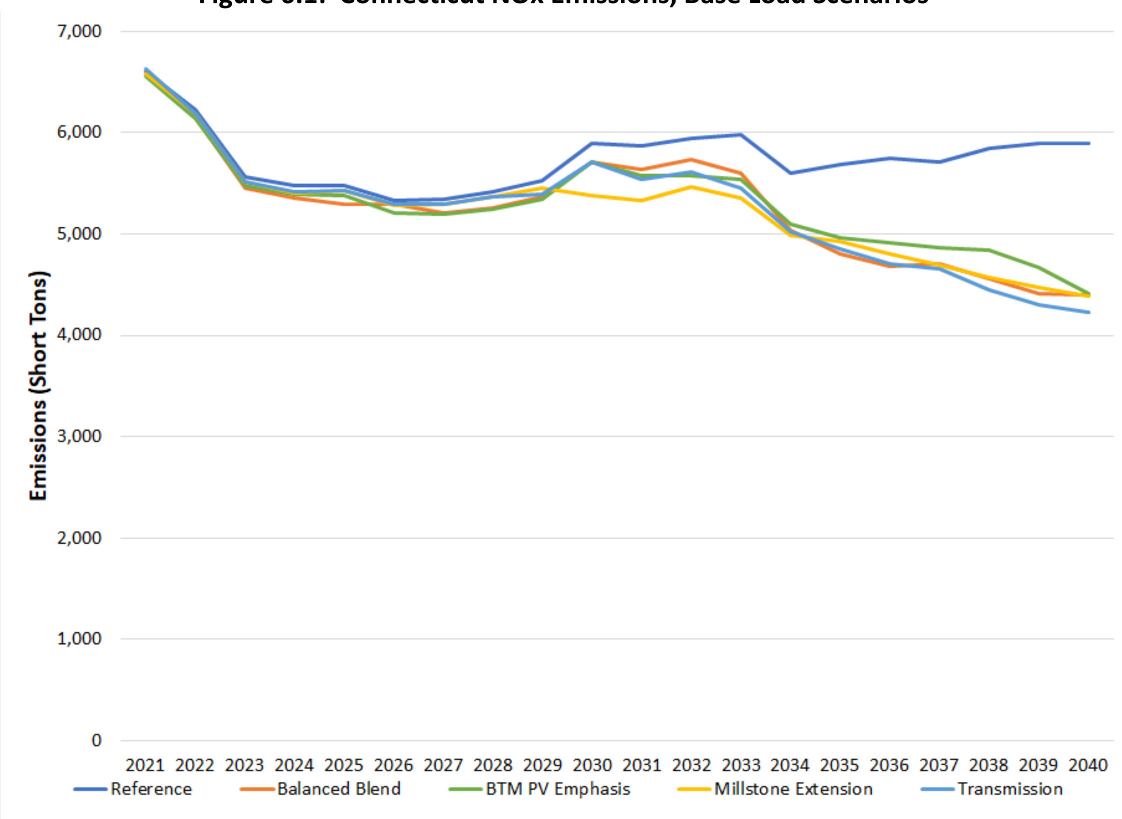
[338] Connecticut DEEP, *Restructuring Connecticut's Renewable Portfolio Standard,* Final Draft, page 1, April 26, 2013, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/6c38cc027dda2d0a85257b590049aa48/$FILE/DEEP%20RPS%20Study%20Final%20042613.pdf

reliability, they cannot be displaced by other zero carbon resources. Thus, the amount of NO_x and SO_2 can only diminish so much, as demonstrated in Table 6.1 and Figure 6.1 below. Accounting for these greenhouse gases in this way allows Connecticut to transparently account for the impacts its current waste management system has on other policy goals, such as reducing emissions from its electric sector. In future IRPs, DEEP will continue to assess the role of WTE in our solid waste management goals and whether other emerging technologies are needed to meet the 100% Zero Carbon Target for 2040. Additionally, DEEP will explore whether accounting for emissions at the point of generation is appropriate or whether life-cycle accounting is more appropriate for WTE facilities.

Table 6.1: Connecticut Annual SO_2 Emissions by Scenario
(Short Tons)

Scenario	*2025*	*2030*	*2035*	*2040*
Base Reference	1,350	1,386	1,162	1,208
Base Balanced Blend	1,348	1,367	1,115	1,069
Base BTM Solar Emphasis	1,348	1,367	1,121	1,098
Base Millstone Extension	1,349	1,374	1,120	1,079
Base Transmission	1350	1,377	1,128	1,064
Electrification Reference	1,336	1,372	1,152	1,189
Electrification Balanced Blend	1,335	1,359	1,123	1,068
Electrification BTM Solar Emphasis	1,330	1,351	1,115	1,064
Electrification Millstone Extension	1,335	1,362	1,109	1,082
Electrification Transmission	1,334	1,358	1,106	1,057

Figure 6.1: Connecticut NOx Emissions, Base Load Scenarios



Connecticut's Class II RPS energy resource classification was amended in 2017 to be exclusively limited to WTE facilities by Public Act 17-144. This Act also increased the amount of power the EDCs are required to purchase from Class II resources (or Class I) to four percent of load served by load serving entities rather than three percent beginning in 2018. Only WTE facilities permitted by DEEP are eligible for Class II RECs. Thus, the Class II RPS requirement is intended to provide support for resources critical to our State solid waste management goals and policy.

Table 6.2 below shows the estimated number of Class II RECs that will be available over the next decade based on projected WTE production. If Connecticut facilities do not produce enough to meet the Class II target, there could be a shortage that firms up the REC prices relative to the alternative compliance price (ACP), and could create an additional outlet for Class I surplus if Class I REC prices fall below the ACP.[339]

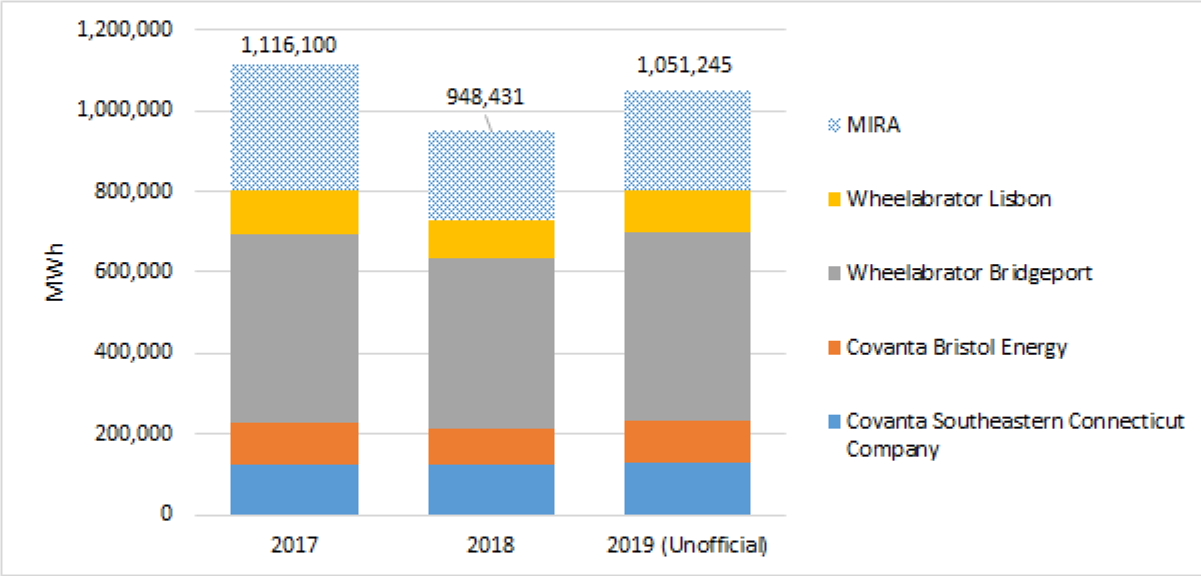
Table 6.2: Projected Class II RECs in Connecticut

Year	Class II MWhs
2020	1,010,280
2021	1,015,628
2022	1,025,419
2023	1,033,339
2024	1,044,240
2025	1,049,004
2026	1,056,311
2027	1,063,880
2028	1,074,898
2029	1,079,725

Currently, the five operating WTE facilities in Connecticut generate roughly 1,000 GWh of energy annually, as shown by Figure 6.2. If this level of generation is maintained, these facilities can continue to satisfy the requirements for the Class II RPS. However, there are factors that create uncertainty as to whether this is sustainable.

[339] Based on Renewable Energy Market Outlook reporting provided by Sustainable Energy Advantage, LLC.

Figure 6.2: Annual Energy Generation from Connecticut Waste-to-Energy Facilities[340]



The Hartford Resource Recovery facility owned by the Materials Innovation and Recycling Authority (MIRA), the second largest WTE facility in the state, may be taken offline in coming years due to the poor condition of equipment and high costs to operate and maintain. In July of 2020, MIRA submitted its 2021 Annual Plan of Operations, stating that more than $300 million in electric ratepayer or taxpayer support would be needed for capital improvements to the facility, in the absence of which MIRA would convert the facility to a transfer station sending in-state generated MSW to landfills located out of state. MIRA's 2021 plan was rejected by DEEP as being incomplete and inconsistent with statute and State policy.

As shown in Figure 6.2, if the MIRA facility ceases operating, remaining WTE plants in Connecticut will only generate about 800 GWh of energy annually; just above 3 percent of eligible RPS load. Thus, at the time of drafting this IRP, the Class II structure is sufficient to support the output from the operating WTE facilities. The Department will continue to monitor MIRA's plans and the Class II market to determine if a restructuring is needed to maintain the current supply/demand balance equilibrium for Class II RECs depending on plant operations.

If the MIRA facility shuts down, it will cause the state to backtrack on its progress towards maintaining self-sufficient disposal capacity in the state, and will contribute to greater reliance on out-of-state landfills for disposal, in conflict with the state's waste hierarchy of preferred disposal options. For these reasons, it is critical that Connecticut considers and implements policies, including energy policies, that can help states and municipalities adopt more sustainable materials management programs and policies that reduce reliance on disposal via WTE or landfilling. Such policies include measures that reduce or divert reusable material from the waste disposal stream, including recyclable paper, plastic, glass, and metal, and organic materials such as food scraps and yard waste which currently make up a significant portion of disposed municipal solid waste.

[340] U.S. Energy Information Administration. Form EIA-923 detailed data with pervious form data. https://www.eia.gov/electricity/data/eia923/

However, implementing these policies will require funding for education, outreach, and administration. In the State of Massachusetts, like Connecticut, WTE facilities receive ratepayer support through inclusion in the Massachusetts RPS. The level of REC subsidy provided to WTE facilities in Connecticut is substantially higher, on a MWh basis, than the REC subsidy provided for similar facilities in Massachusetts. Under Massachusetts' RPS structure, WTE facilities are required to reinvest 50% of REC revenues in Sustainable Materials Recovery Program that help to support disposal alternatives (such as local recycling, composting, reuse, source reduction, and enforcement activities) and limit overreliance on WTE over time.[341]

An alternative approach to funding that Connecticut should consider is to allocate Class II RPS alternative compliance payment (APC) revenue towards sustainable waste management programs. As stated above, the MWh generated by the existing WTE plants in Connecticut are meeting the Class II demand requirement (4%) by a razor's edge. If the MIRA facility retires, it will create a scarcity of Class II RECs in Connecticut, which will likely have to be compensated for with ACP by the EDCs and suppliers. Currently, ACP for Class II is set at $25 per un-met REC.[342] Under C.G.S Sec. 16-244(h) and Sec. 16-245(k), the revenue generated by the ACP is refunded to all electric ratepayers and is used in part to help offset the cost of clean energy contracts.[343] The loss of MIRA will result in a supply drop of approximately 280,000 MWh (RECs) per year, as shown in Figure 6.2. This will equate to approximately $7,000,000 per year in ACP revenue if the entire gap in Class II RECs is met with only ACP by suppliers.

In order to access those funds for sustainable waste management, the State would need to pursue statutory amendments so that the ACP received for compliance with the Class II requirements of the RPS would be instead directed into a sustainable waste management grant program. Caps could be placed on the amount of ACP revenues placed in such a grant so that some of the ACP is still returned to ratepayers as originally intended. Additionally, there would need to be a change that prevents suppliers from being able to meet Class II compliance with Class I RECs going forward. This approach would help to take the subsidies paid to WTE generators and redirect them into initiatives that accomplish the same goals more sustainably.

These are changes that should be considered in Connecticut to ensure the RPS is not only helping to retain WTE facilities for reliable disposal in the near term, but preparing the state to reduce reliance on WTE and landfills in the medium- to long-term.

Anaerobic Digestion Facilities

According to a 2015 waste characterization study, approximately 22 percent of residential waste sent to disposal consists of food scraps, and an additional 11 percent consists of other organic material such as yard waste. If these materials can be diverted from waste disposal, they can provide a valuable feedstock for composting and anaerobic digestion facilities, while significantly reducing tonnage disposed at WTE

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[341] *See* 310 CMR 19.300.

[342] Conn. Gen. Stat. Sec. 16-244(c)(h)(1)

[343] Conn. Gen. Stat. Sections 16-244(h)(1) and 16-245(k), state that after 2013 the money goes back to ratepayers to offset costs of certain contracts and tariffs. Any excess amount remaining from such payment shall be applied to reduce the costs of contracts entered into pursuant to subdivision (2) of subsection (j) of section 16-244c, and if any excess amount remains, such amount shall be applied to reduce costs collected through nonbypassable, federally mandated congestion charges, as defined in section 16-1.

(or landfills). Anaerobic digesters located on farms also provide benefits by using anaerobic digestion systems for manure management and can accept organic feedstocks from off-farm sources to generate revenue from tipping fees, while helping to divert organic material from disposal.

Anaerobic digesters are an important technology that will play a key a role in helping to manage the state's various waste needs, including reducing reliance on WTE and landfilling. While the state has only limited deployment of anaerobic digesters at present, it will be critical to support deployment of these facilities in accessible locations around the state to help minimize the cost of transporting diverted organic material to digesters. Anaerobic digesters produce compost material and biogas. The biogas can either be converted to electricity, or to renewable natural gas. Configuring anaerobic digesters to produce renewable natural gas can be preferable, given the possibility to utilize this fuel as compressed natural gas (CNG) for medium- and heavy-duty trucks, or to offset other uses of conventional natural gas. However, this opportunity can be limited by access to natural gas distribution systems and other infrastructure. Anaerobic digestion is eligible as a Class I renewable resource under Connecticut's RPS, and programs such as the virtual net metering program have been instrumental in supporting investment in the state's first large-scale anaerobic digestion facility in Southington. DEEP currently has authority to offer long-term energy and REC purchase agreements for anaerobic digestion, which will be critical for ensuring a build-out of needed digester facilities, but utilizing this authority requires anaerobic digesters to be configured to produce electricity. Securing companion authority to be able to offer such purchase agreements for the production of renewable natural gas would enable DEEP to support deployment of anaerobic digesters in configurations that match the needs of particular facility locations.

PURA's adoption of "interconnection standards and tariffs for biogas derived from the decomposition of farm-generated organic waste or source separated organic material that has been processed through gas conditioning systems to remove impurities, including, but not limited to, water, carbon dioxide and hydrogen sulfide" opens up the possibility to more easily commoditize biogas.[344] DEEP has indicated strong support for these efforts and will continue to monitor resulting anaerobic digestion developments throughout the state.

Biomass and Landfill Methane Gas Facilities

Legislation enacted in 2013 through Section 5 of Public Act 13-303 required DEEP to propose a schedule for gradually phasing down the value of Class I RECs produced by biomass and landfill methane gas (LMG) resources. The 2014 IRP recommended a gradual phase-down of REC values for Class I biomass and LMG beginning in 2018. The 2018 Comprehensive Energy Strategy reaffirmed DEEP's position to restructure the eligible Class I technologies to focus on the development of new, zero carbon resources in New England and recommended initiating the phase-down of the REC value of biomass after the publication of the next IRP.[345]

[344] PURA Docket No. 19-07-04, *Adoption of Gas Quality and Interconnection Standards for the Injection into the Natural Gas Distribution System of conditioned Biogas Derived from Organic Material,* Final Decision, page 1, June 2, 2021.
[345] Given the low percentage of Class I RECs produced by LMG as compared to biomass, this IRP focuses on biomass, and a phase-down of LMG will be considered in the next IRP.

At the time of Public Act 13-303, biomass made up the majority of the RECs settled for Class I compliance in Connecticut. In 2012, biomass made up over 80 percent and in 2013, biomass made up 65 percent.[346, 347] This is because even as the costs of zero-carbon resources continue to decline, resources like biomass are often lower-cost than other Class I eligible technologies, and RECs from biomass is therefore selected by energy suppliers to meet compliance first. In recent years, declining energy market revenues and other challenges have resulted in the closure of a number of biomass facilities, particularly in Northern New England, resulting in a shrinking, though still significant, portion of Class I RECs settled in Connecticut. The most recent PURA RPS decision for compliance year 2017 showed that biomass facilities currently account for approximately 45 percent of Connecticut's RPS, still more than any other technology.[348] Figure 6.3 shows the percentage of Class I RECs settled in Connecticut that come from biomass facilities has declined from 81 percent to 45 percent. Assuming prices traded at $40/REC in 2017, Connecticut's Class I RPS provided $73 million of ratepayer support to the biomass industry in that year alone.

While there are about 470 MWs of biomass generation throughout New England that are eligible for CT Class I RECs, most of the facilities are located out of state and do not support the forestry and waste management goals of Connecticut. Currently, the only in-state eligible biomass plant is Plainfield Renewable Energy, which has a nameplate capacity of 42 MW.[349] Note that Public Act 13-303 exempts from any phase-down any facility that has a Connecticut ratepayer-backed power purchase agreement.

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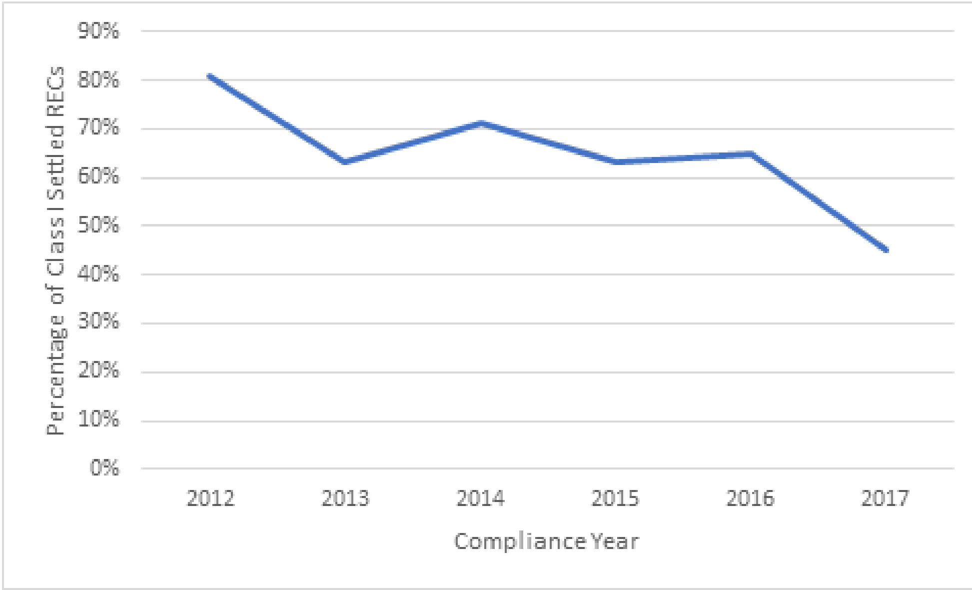
[346] Connecticut PURA, Docket No. 13-06-11, *Annual Review of Connecticut Electric Suppliers' and Electric Distribution Companies' Compliance with Connecticut's Renewable Energy Portfolio Standards in the Year 2012*, Final Decision, February 11, 2015, *available at:* http://www.dpuc.state.ct.us/DOCKHISTPost2000.NSF/8e6fc37a54110e3e852576190052b64d/8d0c8935f9117fe18525829c00735a7c?OpenDocument

[347] Connecticut PURA. Docket No. 14-05-35. *Annual Review of Connecticut Electric Suppliers' and Electric Distribution Companies' Compliance with Connecticut's Renewable Energy Portfolio Standards in the Year 2013,* Final Decision, December 23, 2015, *available at:* http://www.dpuc.state.ct.us/DOCKHISTPost2000.NSF/8e6fc37a54110e3e852576190052b64d/7742091ba46d54c78525829c00724c72?OpenDocument

[348] Connecticut PURA. Docket No. 18-06-28 *Annual Review of Connecticut Electric Suppliers' and Electric Distribution Companies' Compliance with Connecticut's Renewable Energy Portfolio Standards in the Year 2017*, Final Decision, July 1, 2020, *available at:* http://www.dpuc.state.ct.us/DOCKCURR.NSF/0/211a83eea44855a885258598005ece70/$FILE/180628-062920.pdf

[349] ISO New England. 2019. 2019 Capacity, Energy, Loads and Transmission Report. Available at https://www.iso-ne.com/system-planning/system-plans-studies/celt

Figure 6.3: Percentage of Class I RECs Settled in Connecticut by Biomass



In support of this IRP, DEEP modeled the regional and Connecticut REC market, both with and without the biomass phasedown schedule articulated in the 2018 CES.[350] The purpose of this study was to estimate for each scenario:

- The theoretical potential for Connecticut Class I certified biomass/LMG to meet the State's Class I demand in each year from 2019 to 2040;
- How many Connecticut Class I eligible biomass/LMG RECs are expected to be generated annually through 2040;
- How many biomass/LMG RECs are expected to settle in Connecticut Class I; and
- The percentage of Connecticut Class I compliance that will come from biomass/LMG annually from 2020 to 2040.

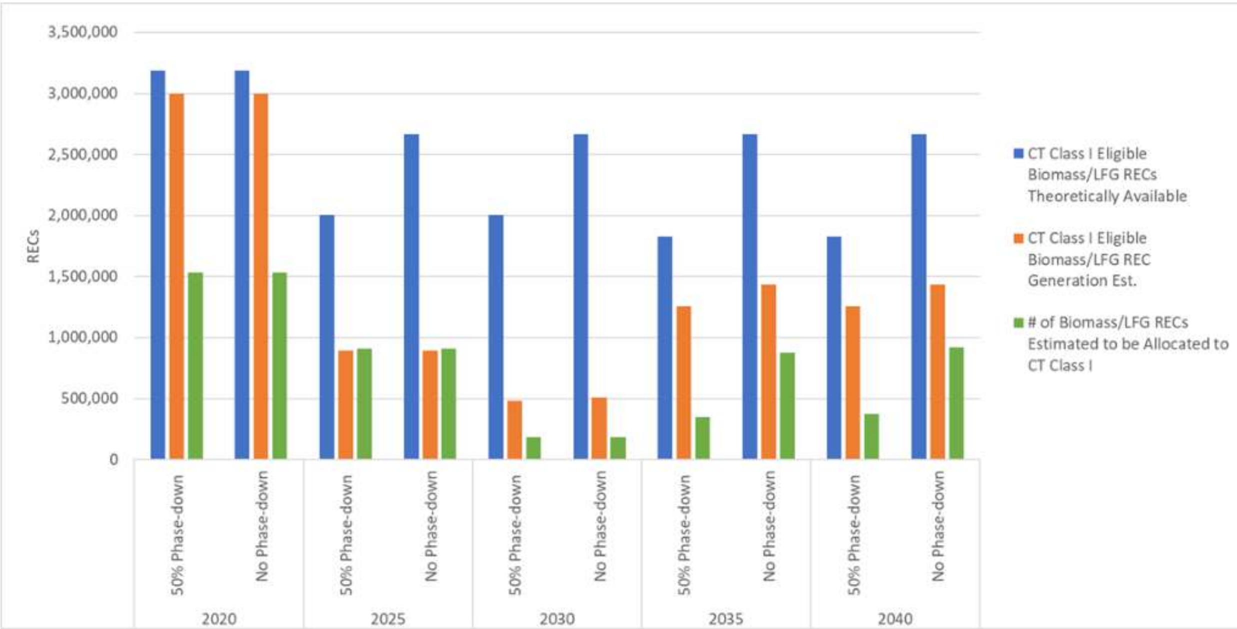
The Department relied on Sustainable Energy Advantage's (SEA) proprietary Renewable Energy Market Outlook (REMO) models for this analysis. These models consider supply, demand, and price dynamics throughout the six New England states and neighboring control area markets. The models estimated energy, capacity, and REC revenues for each eligible biomass generator, and compared those values to each generator's operating costs. In cases where costs exceeded revenues for extended periods of time, that plant's operation was assumed infeasible. Each scenario included the maximum theoretically available supply, and then estimated the supply actually expected to meet demand. It should be noted that since this analysis was conducted in early 2020, policy decisions leading to biomass closures in mid-2020, policies related to imports from New York, and conditions caused by the COVID-19 pandemic are impacting near- and mid-term markets. Thus, there could be less participation from biomass facilities than was originally predicted by this analysis.

In absence of these recent changes, the analysis found that the biomass facilities projected to be settled in Connecticut decline over time both with and without the phasedown, though the phasedown results in

[350] This modeling was based on analysis provided under contract by Sustainable Energy Advantage, LLC.

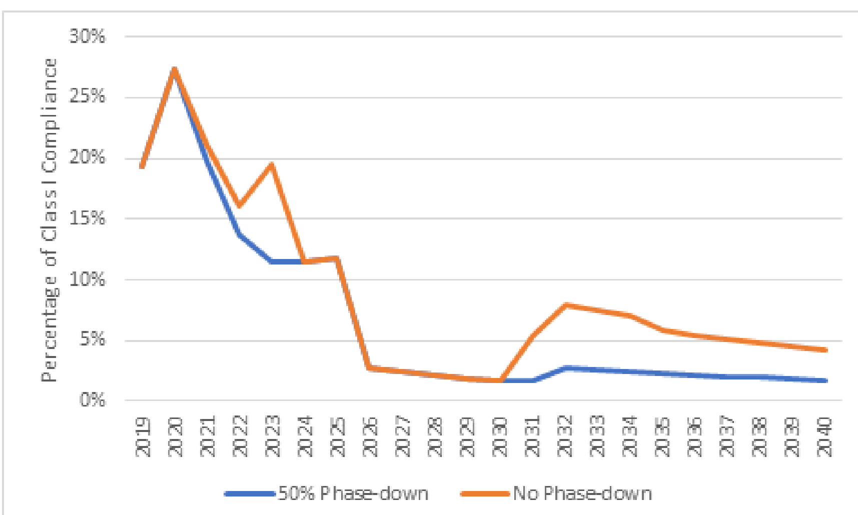
slightly less biomass likely to be settled in Connecticut after 2030. In other words, the biomass phasedown has a small impact on biomass regionally as plants are projected to close down even absent Connecticut's phasedown. Figure 6.4 compares the Class I REC supply forecast with and without the biomass phase down, as articulated in the 2018 CES.

Figure 6.4: Biomass RECs Settled in Connecticut, With and Without Phasedown



In 2019, approximately 19 percent of the State's Class I REC requirement will have been met by biomass and LMG. In 2028, both with and without the phasedown, just 2 percent of the State's Class I REC requirement is projected to come from biomass and LMG. That 2 percent is projected to remain relatively constant through 2040 with the phasedown, and it is projected to increase slightly without the phasedown as Class I REC supply is needed to meet increasing demand and biomass facilities operate to fill the need. Figure 6.5 displays this trend.

Figure 6.5: Percentage of Connecticut Class I Compliance Met with Biomass and LMG RECs



Strategies to Achieve Objective 6

In Part II, the IRP recommends pursuing the following strategies in furtherance of Objective 6, *Balancing Decarbonization and Other Public Policy Goals*. The state has a wide variety of statutory environmental and other public policies that are reflected in electricity supply programs like the Renewable Portfolio Standard. By adopting a 100% Zero Carbon Target for 2040 **(Strategy 1)**, the state will have the ability to engage in long-term planning and investment over the next twenty years to support an optimized harmonization of decarbonization and other public policy objectives in a transparent and predictable way, such as seeking self-sufficiency in waste disposal options through development of more sustainable waste management approaches and funding mechanisms **(Strategy 15)**. Consistent with recommendations in the 2018 Comprehensive Energy Strategy, this IRP calls for phasing down the value of biomass RECS eligible for Connecticut’s Class I RPS in order to increase participation from other eligible, zero-carbon resources **(Strategy 14).**

Part II: Strategies

Part I of the IRP examined in detail considerations for achieving six key objectives for Connecticut's electricity supply:

1. Decarbonizing the Electricity Sector
2. Securing the Benefits of Competition & Minimizing Ratepayer Risk
3. Ensuring Energy Affordability and Equity for all Ratepayers
4. Optimizing Siting of Generation Resources
5. Upgrading the Grid to Support and Integrate Variable and Distributed Energy Resources, and
6. Balancing Decarbonization and Other Public Policy Goals.

As noted in the summaries following each objective, Part II of the IRP now addresses strategies, emphasizing near-term actions for achieving those objectives. Because the objectives are interrelated, in many cases a single strategy advances multiple objectives. These strategies are detailed below, with the related objective(s) identified for each.

1. Establish the 100% Zero Carbon Electric Supply target as the policy goal of Connecticut

Objectives: 1, 3

Efforts at the international, national, regional, and local level to reduce and eventually eliminate the greenhouse gas emissions that are driving climate change must accelerate to keep up with the quickening pace of climate destabilization. The emergence of megafires, rapid loss of Arctic sea ice, degeneration of Antarctic glaciers and ice shelves, the growing number of superstorms, the increased prevalence and intensity of heat waves, the disproportionate negative effects on overburdened and underserved communities, and a lengthening list of other indicators signal the extraordinary urgency of rapidly decarbonizing the economy. As noted in Objective 1, these climate change impacts are already affecting Connecticut, and efforts to reduce carbon emissions in the near-term will be enormously cost-effective in terms of avoiding more costly climate change impacts, including reducing threats to human health and safety, in the longer term.

The modeling summarized in Objective 1 reveals that there are multiple pathways to achieving a 100% Zero Carbon Electric Sector goal, and that there are a variety of resources—distributed and grid-scale solar, hydropower, nuclear, land-based and offshore wind, as well as storage, efficiency, and demand response—that can be deployed in different combinations to meet the goal. One consistent finding was that Connecticut's existing clean energy procurements, distributed generation programs, and energy efficiency services have already put the state on a trajectory towards this goal. Other states and jurisdictions have similarly concluded that rapid electric sector decarbonization is feasible, such that 18 states, plus Washington D.C. and Puerto Rico, have already adopted similar targets.

Given these concerns, the modeling results, and the statutory authority provided to DEEP to approve a plan for the procurement of energy resources in the IRP,[351] DEEP sets a goal to achieve zero carbon emissions in the electric sector by 2040 in this IRP.

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[351] *See* Conn. Gen. Stat. § 16a-3a(a).

The current greenhouse gas emissions reduction targets for the State are outlined in Conn. Gen. Stat. Sec. 22a-200a(a). A 100% zero carbon electric sector by 2040 goal is consistent with this mandate. Under Conn. Gen. Stat. Sec. 22a-200a(a), the General Assembly required that the State "shall reduce the level of emissions of greenhouse gas," "[n]ot later than January 1, 2050, to a level at least eighty per cent below the level emitted in 2001." By setting a zero carbon goal in the electric sector for the state by 2040, DEEP is ensuring that the State meets this minimum reduction of 80%, and does so "[n]ot later than January 1, 2050." Further, if the electric sector is 100% carbon free by 2040, it will provide the State with flexibility in other sectors of the economy if reducing carbon emissions to the 80% threshold by 2050 proves to be more difficult in those sectors.

As part of the IRP under Conn. Gen. Stat. Sec. 16a-3a(b), DEEP must "prepare an assessment of . . . the impact of current and projected environmental standards, including, but not limited to, those related to greenhouse gas emissions . . . and how different resources could help achieve those standards and goals." As to current environmental goals and standards, on September 3, 2019, Governor Lamont issued Executive Order No. 3. This Executive Order required DEEP to "analyze pathways and recommend strategies for achieving a 100% zero carbon target for the electric sector by 2040."[352] This clearly articulates an environmental goal for the State to achieve a 100% zero carbon target for the electric sector by 2040; recent court and regulatory decisions in the state also recognize this goal. Further, based on carbon reduction goals in other states, and the federal zero carbon goal in the electric sector identified by the Biden Administration, DEEP projects that environmental standards in much of the Northeast and Mid-Atlantic regions will include zero carbon targets in the electricity sector by 2050, and in some cases, much sooner. Consistent with these current and projected goals and standards in other states and at the federal level, and in light of Executive Order No. 3, DEEP determines that it is reasonable and appropriate to establish a goal of zero carbon in the electric sector by 2040 as part of this IRP.

Conn. Gen. Stat. Sec. 16a-3a provides DEEP with further authority to set a zero carbon target by 2040. Under subsection (a), DEEP must:

> [A]pprove the Integrated Resources Plan for the procurement of energy resources . . . to meet the projected requirements of customers in a manner that minimizes the cost of all energy resources to customers over time and maximizes consumer benefits *consistent with the state's environmental goals and standards*, including, *but not limited to*, the state's greenhouse gas reduction goals established in [Conn. Gen. Stat. §] 22a-200a."[353]

As discussed previously, Conn. Gen. Stat. § 22a-200a provides the State's minimum greenhouse gas emissions reduction requirements. However, the State has other "environmental goals and standards" relating to greenhouse gas emissions, such as Executive Order No. 3, and the statute permits DEEP to consider such environmental goals as part of the IRP. This further supports DEEP's decision to establish a goal of zero carbon in the electric sector by 2040, and to lay out a procurement plan to accomplish such goal, as part of this IRP.

DEEP's establishment of this goal in the IRP is important because it will permit the Public Utilities Regulatory Authority to implement this plan by conducting any procurements identified in the IRP as

[352] Executive Order No. 3 at pp. 4-5.
[353] Conn. Gen. Stat. Sec. 16a-3a(a) (emphasis added)

necessary to achieve the goal of zero carbon emissions in the electric sector by 2040.[354] Decarbonization of the electric sector is the linchpin of a multi-sector decarbonization strategy that includes the electrification of transportation and heating, to the extent that reducing the emission content of electric "fuel" for buildings and transportation uses also improves the emissions reduction associated with electrification. Technologies for decarbonization of the electric sector are widely available, and the costs of the technologies are declining. Moreover, a 2040 target—now two decades away--provides an important long-term signal to the market that will facilitate more efficient planning and investment over time. A 2040 target for a zero carbon electric supply complements the Global Warming Solutions Act (GWSA), which already requires significant economy-wide reductions in the state, by providing more clarity about the expected reductions for the electric sector in achieving the broader GWSA goal. In essence, a 2040 target provides Connecticut with more flexibility to allocate its dwindling 2050 emissions budget under the GWSA to economic sectors where decarbonization is more technically challenging: aviation, heavy-duty vehicles, industry, agriculture, and waste.

Connecticut's municipal electric cooperatives serve approximately 6 percent of the state's electric supply. While municipal electric cooperatives are taking steps toward decarbonization, currently, they do not have reporting requirements tied to the GWSA, despite the fact that the GWSA applies statewide. CMEEC submitted comments in this IRP proceeding supporting providing reports to DEEP regarding its carbon reductions.[355] Such reporting would provide more complete information to DEEP, PURA, the EDCs, and the municipal electric cooperatives to help all parties determine and coordinate the respective amount of investment required in the state's electric sector to meet the state's economy-wide targets. DEEP will send a letter to initiate coordination with CMEEC to establish a standardized approach for reporting carbon reductions and will seek statutory changes to the state's climate goals and reporting requirements to require municipal electric cooperatives to submit clean energy and other relevant information to DEEP following the release of this IRP.

The recommended strategies listed below all contribute towards meeting the 100% Zero Carbon Target, but can also be refined and leveraged to both increase cost-effectiveness and begin meaningfully addressing systemic inequities caused by reliance on fossil fuels. Connecticut's efforts to implement this target should highlight the importance of taking all appropriate measures to minimize costs and maximize equity. Future IRPs can closely monitor the State's progress toward meeting the 2040 goal and make recommendations for near-term actions to maintain that progress.

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[354] *See* Conn. Gen. Stat. Sec. 16a-3b(b) ("When the Integrated Resources Plan Contains an option to procure new sources of generation, [PURA] shall develop and issue a request for proposals, shall publish such request for proposals in one or more newspapers or periodicals, as selected by the authority, and shall post such request for proposals on its Internet website.")

[355] *See* CMEEC Written Comments, submitted October 29, 2019, http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/51c7b27775ac0827852584a8005e43e8/$FILE/Ltr%20DEEP_IRP%20Comments_10-29-2019.pdf

2. Pursue reform of wholesale electricity markets

Objectives: 1, 2, 3, 5

As detailed extensively in Objective 2, regional wholesale electricity market constructs, as presently designed and implemented by ISO-NE, have created significant barriers to cost-effective clean energy deployment strategies, and have increased regional reliance on natural gas to an extent that has threatened reliability. Additionally, these barriers have created complications for state jurisdictional clean energy programs, also detailed in Objective 2.

Connecticut must be assured that its clean energy resources will be valued, or "counted," in the ISO-NE capacity market to avoid duplicative costs of conventional fossil generation—which, in the recent past, has often been targeted for development in our state. The ISO-NE's market design, transmission planning, and system operation must value Connecticut's investments in clean energy generation, including behind-the-meter resources, to ensure that those resources are operated efficiently and that spillage or curtailment is minimized. Finally, Connecticut deserves a market that equitably shares the costs of retaining resources, like Millstone, that provide regional reliability benefits.

The barriers presented by the ISO-NE's current market design are not a reason to abandon competition, or the efficiencies provided by a regional grid. Exiting the ISO-NE market by taking back resource adequacy is an option that cannot be counted out, but the state's first priority must be to advance new regional market designs, in collaboration with the other New England states, that can recapture the benefits of regional, competitive market designs that achieve the states' respective public policy goals. A "unified" market design that achieves public policy goals will provide lower cost decarbonization more effectively.

For this reason, Connecticut DEEP has prioritized collaboration with the other New England states to secure changes to the wholesale markets. On October 14, 2020, Governor Lamont was joined by the Governors of Massachusetts, Maine, Rhode Island, and Vermont in a statement calling for a clean, affordable, and reliable regional electric grid that employs transparent decision-making processes and relies on competitive market outcomes to fully support clean energy laws. Among other things, the Statement and an accompanying Vision Statement issued by the New England States Committee on Electricity (NESCOE) calls for reforms to the regional wholesale markets by pursuing a new, regionally-based market framework that adheres to certain bedrock principles. Key among these principles is the requirement that any new market framework must use market-based mechanisms to meet the states' decarbonization mandates and maintain resource adequacy at the lowest cost to ratepayers. Just as important, a reformed market framework must include effective mechanisms that will fully accommodate existing and future long-term contracts for clean energy resources executed pursuant to state law. These two principles help to ensure that Connecticut's state-sponsored resources will be appropriately recognized and compensated in the regional market, thereby ensuring that Connecticut can reach its greenhouse gas reductions mandates from the electric sector at the lowest possible cost.

Among the potential market designs discussed during the technical meetings were a Forward Clean Energy Market (FCEM) and accompanying Integrated Clean Capacity Market (ICCM).[356] The states also received

[356] As part of the Vision Statement process, the states convened two technical meetings related to wholesale market design reform to provide the states an opportunity to explore wholesale market design options that can achieve the desired principles. In addition to these two market design-focused technical meetings, the New

presentations about an energy-only market design (which has no capacity market component) and market designs that rely on a residual capacity market construct (i.e., ISO-NE only procures the capacity needed in the region that is not otherwise procured by the states). The states also received written comments from interested stakeholders about the discussion and topics covered at the wholesale market design technical meetings.[357] The states continue to discuss the various approaches raised in the technical meetings and written comments and intend to release a report that will outline key findings and recommendations, including for next steps as soon as practicable.

Finally, as discussed in Objectives 2 and 4, Connecticut hosts a disproportionate share of the region's fossil fuel generation capacity, and much of that investment has been driven in recent years by a capacity market framework that has imbedded preferences for natural gas resources, despite claims of resource neutrality by the ISO-NE. The capacity market design fundamentally favors generation with low fixed costs and high variable costs, such as natural gas, over generation that has higher fixed costs and lower variable costs, such as wind and solar. This discriminatory framework has favored the selection of natural gas resources in the ISO-NE capacity market and deepened the reliability risks associated with the region's natural gas dependence. Connecticut must therefore continue to push for the elimination of, or substantial reform to, the MOPR to ensure that state-sponsored resources are no longer precluded from the ISO-NE FCM because of imbalances that prioritize natural gas.

It is also important to note that through legislation enacted in September 2020, the Connecticut General Assembly has recognized the urgent need to address wholesale energy market reform, and directed DEEP to prepare a report evaluating whether Connecticut ratepayers benefit from Connecticut's reliance on wholesale energy markets administered by the ISO-NE and recommending alternative approaches for Connecticut to more effectively meet its need for clean, reliable, and affordable electricity generation supply that relies on competitive, reduces ratepayer risk, and ensures the State's public policy goals are achieved.[358] The Department intends to submit to the General Assembly the information detailed in Objective 2 in consideration of that requirement.

3. Reform governance structure surrounding ISO-New England markets

Objectives: 2, 3, 5

The ISO-New England's disregard for state policies and consumer impacts— detailed in Objective 2— may be a consequence of its governance structure, which lacks any accountability mechanism that would require ISO-NE to take actions that are consistent with states' policy objectives. Moreover, any new market design that emerges in response to Strategy 2 (above) to achieve state public policies must have appropriate involvement of state entities. Reforming governance structures is therefore an important near-term strategy that the State should pursue, through advocacy in the appropriate NEPOOL, FERC, or other venues, to achieve the State's energy supply Objectives.

England states also hosted technical conferences focused on governance reform and transmission planning, as well as a session that focused on equity and environmental justice issues.

[357] Recordings of the technical meetings, presentation materials, and written comments received by the states are publicly available at https://newenglandenergyvision.com/wholesale-market-design.

[358] Public Act 20-5, An Act Concerning Emergency Response by Electric Distribution Companies, The Regulations of other Public Utilities and Nexus Provisions for Certain Disaster-related or Emergency-related Work Performed in the State, § 14, September Special Session (2020).

At present, the ISO-NE governance structure falls short in providing a process that is accessible and transparent for ratepayers affected by ISO-NE's decisions. As detailed in the Vision Statement, ISO-NE board meetings are completely closed to the public. The only visibility that ratepayers or policymakers have into the decision-making process of the ISO-NE Board ("the Board") is through extremely high-level summaries provided by ISO-NE management and scant agendas released by the Board. Additionally, the states lack any real voice in determining the composition of the Board. Board members are selected through a Joint Nominating Committee. The six sovereign New England states get a single, shared vote in this committee. In contrast, up to seven incumbent Board members each get a vote, and market participants and other stakeholder get up to six votes. Thus, all six New England states together get a combined 1/14th of the vote in nominating a new Board member.

Governance and process changes at ISO-NE that facilitate transparency and accountability to consumers will lead to better decision-making. Some near-term changes that could be considered include providing for ISO-NE Board meetings and NEPOOL stakeholder meetings to be conducted in an open and efficient manner. Governance changes should be aimed at recalibrating the roles of the New England states and ISO-NE with respect to resource adequacy to account for and accommodate the states' Federal Power Act authority to exercise control over the generation mix.

As state policies effect significant changes in the resource mix, there are increasing benefits from a collaborative partnership between states and the ISO-NE Board and management. States play critical roles in public policy resource selection, siting, and permitting, as well as (through utility commissions like PURA) in regulating investment in electric distribution systems, an increasingly critical role as BTM resources expand. A governance structure that enables greater collaboration between the states and ISO-NE will enhance the ISO-NE's ability to carry out its responsibilities to plan the transmission system, operate the electric grid, and design markets that are increasingly affected by state policies. Examples of governance changes that could enhance this collaboration include:

- Requiring the ISO-NE, in developing market and rule changes, to assess the impact of any change on the achievement of state policy objectives; where ISO-NE concludes that a proposed change will have a negative impact, prepare and publish a cost-benefit analysis demonstrating that the value of the anticipated benefits exceed the negative impact the change is anticipated to have on state pursuit of environmental objectives; and
- Adoption by the ISO-NE Board of Directors of the obligation to: (1) consider state alternatives to any ISO-NE rule changes; and (2) in those instances in which state alternatives are not adopted, provide a response to the States, explaining the bases for the Board's rejection and any cost-benefit or other studies justifying the Board's action.

As initially outlined in the Vision Statement, the states convened a technical meeting to engage with stakeholders on governance reform. In this technical meeting, the states explored best practices and potential reforms that could be adopted to improve governance and transparency at ISO-NE and in the NEPOOL stakeholder process. The states also received written comments from interested stakeholders about the discussion and topics covered at the governance reform technical meeting.[359] The states continue to digest and discuss the various reforms raised in the technical meeting and written comments

[359] A recording of the technical meeting, presentation materials, and written comments received by the states are publicly available at https://newenglandenergyvision.com/governance-reform.

and intend to release a report that will outline key findings and recommendations, including for next steps as soon as practicable.

4. Coordinate with regional states on evaluating transmission needs to meet state climate and energy policy goals

Objectives: 1, 2, 3, 5

As indicated in Objective 1, Connecticut will need 3,745 MWs of offshore wind resources and 352 MWs of land-based wind by 2040 to meet its zero carbon goals under the Base Load Balanced Blend scenario, and 5,710 MWs of offshore wind and 557 MWs of land-based wind under the Electrification Load Balanced Blend scenario. In total, the model projects that the region will need a maximum of 10,555 MWs of OSW under the Base Load, and 15,405 MWs under the Electrification Load by 2040. However, as discussed in Objective 5, the region's transmission infrastructure is unable to support the necessary OSW needed over the next two decades to meet the Regional Emissions Target. ISO-New England studies have revealed that, despite the substantial investment in the transmission system in recent years, it will be necessary to upgrade the system to affordably integrate these new resources.[15] In this context, "affordable integration" will mean both maximizing the VER interconnection capability of the grid, while minimizing the energy lost from zero carbon resources due to curtailment.

As demonstrated in Objective 5, upgrading the transmission system can significantly reduce curtailment of VERs over the next two decades. With reduced curtailment, less clean energy will be wasted, thus reducing any oversupply needed to meet reliability and emissions requirements. As a result, the modeling also shows that eliminating or reducing transmission constraints could also reduce the overall ratepayer costs of achieving the 100% Zero Carbon Target.

Under the current ISO-NE tariff, proactive planning is a challenge. To date the approach has been primarily reactive in that developers take a queue position on a first-come-first-served basis and are studied in order by ISO-NE planners. In order to address state policies, a scenario-based proactive planning process is needed. The New England states highlighted this issue in their Vision Statement and addressed it further in the transmission planning-focused technical conference.[360] In addition, the need for proactive scenario-based planning was included in the Visions Initiative Report to the Governors. Further, ISO-NE has committed to pursuing the tariff reforms it believes it needs to undertake the proactive planning process requested by the New England states and state officials and staff will continue to engage with ISO-NE on this issue. It is hoped that the needed tariff changes will be available as early as the 1st Quarter of 2022. In addition, there have been important changes at the Federal Energy Regulatory Commission. The new Commission leadership has indicted that transmission reform is a central element of its agenda and has opened a broad new rulemaking docket, RM21-17, that will examine many important changes designed to accommodate state public policy goals and make transmission planning for efficient. The Department is already in preliminary discussions with its regional partners to participate actively in that docket.

Although the modeling results in Objective 1 reveal that OSW resources beyond what has already been procured are not likely to be needed in operation until the early 2030's, Connecticut and the other New

[360] A recording of the technical meeting, presentation materials, and written comments received by the states are publicly available at https://newenglandenergyvision.com/transmission-planning/.

England states must waste no time in establishing comprehensive and advanced transmission planning that will enable a clean energy grid. This is particularly important because experience has shown that it takes ten or more years to plan and deploy new transmission infrastructure. This includes the possibility to collaborating with sister states in a procurement of transmission resources associated with future offshore wind generation. In this regard, the Biden Administration has publicly announced its commitment to improving the nation's infrastructure, including energy infrastructure and its goal to develop as much as 30 gigawatts of offshore wind by 2035. The Department will be reviewing its transmission planning for future possible procurements of OSW consistent with these federal initiatives. In addition, DEEP will collaborate with other New England states, particularly within the context of the work being done in furtherance of Objective 2 and Strategy 2, to address transmission challenges with increased variable energy resource penetration.

5. Monitor conditions to determine when to conduct new grid-scale renewable procurements, including offshore wind

Objectives: 1, 2, 4, 5

Competitive procurements have been an effective tool to deploy the zero carbon resources needed to meet the State's climate goals at the least cost for all ratepayers, given the failure of the regional markets to support state policy goals, as discussed in more detail in Objective 2. With the continuing price declines in renewable technologies over the past decade, in the absence of meaningful regional market reform, DEEP is poised to capture clean energy at a just and reasonable price for all ratepayers using competitive procurements that result in long-term contracts for developers.

The modeling results indicate Connecticut has made significant progress towards securing zero-carbon resources to meet medium- and long-term GHG emissions goals, with approximately 90 percent of the state's load contracted to zero carbon resources (including nuclear, offshore wind, and solar) by 2025. This includes approximately 19 percent of the state's EDC load that will be under contract to offshore wind by 2025. As noted above, none of the modeling scenarios and assumptions detailed in Objective 1 are intended as preferred pathways for meeting the state's goals. Rather, they provide insights about the various contingencies that should inform the state's energy procurement strategy. This strategy discusses those contingencies and provides estimates of when procurements for grid-scale renewable resources should be initiated—including specifically, procurements for offshore wind.

It should be noted that when discussing below when resources are needed, this refers to the date that the resources are needed to be in operation. Given the lead times needed between procurement, project selection and when projects begin operation, the timing of a procurement would need to be some years earlier than when the resource is needed to perform.

Millstone

The Millstone nuclear facility is the largest generating unit in New England, and also the largest zero-carbon generation facility in New England. As detailed above, the state reluctantly entered into a ten-year contract backed by Connecticut ratepayers to prevent the facility from shutting down before the end of its operating licenses (2035 for Millstone Unit 2, and 2045 for Millstone Unit 3), when no regional ISO-NE mechanism for retaining the resource was available, and after confirming that the facility was imminently at-risk of retirement. Connecticut's options in negotiating the contract were limited, but the alternative to contracting (retirement) was much more costly, both in terms of increased energy costs and GHG emissions. Preventing Millstone's retirement, among other things, prevented GHG emissions from increasing by 25 percent across the entire New England region. The costs of the contract are born entirely by Eversource and United Illuminating ratepayers.

With the ten-year contract in place, the State now has time to implement strategies that ensure that it has more zero-carbon options available by the contract's end—essential to prevent any exercise of market power and ensure competitive outcomes and minimize ratepayer risk. The modeling scenarios in Objective 1 reflect that the continued operation of the Millstone units beyond the end of current contracts (in 2029) would require the region to procure and integrate fewer MW of new renewable resources, and fewer MW of reserves (see Millstone Extension scenarios) to meet the regional emission reductions assumed in the model. Starting from that premise, ensuring that the Millstone units do not retire in 2029 becomes an important priority for reducing GHG emissions from the New England electric supply affordably and reliably.

At present, however, Connecticut's ratepayer-backed contract is the only mechanism in the region securing the continued operation of the Millstone resource. For this reason, the Millstone Extension scenarios assume that Connecticut continues to contract for, and count towards emission target compliance, the Millstone output. Under that scenario, the state has the least amount of new renewables and reserves to procure to meet the 2040 targets. No new, zero carbon resources need to be online until 2029. However, proceeding in this way would make the state very dependent on a singular nuclear resource to meet its public policy goals, with fewer renewable alternatives available to enable competition and moderate any contract extension price, or ensure that goals could still be met if the facility ceased operating for any reason or length of time. Procuring sufficient clean energy resources in *advance* of 2029 to replace Millstone would be one way to avoid that problem.

The Balanced Blend scenarios provide a view of the quantities and potential cost of Millstone replacement. Given the "lumpiness" or large size of Millstone, it would be difficult to time the new clean energy additions to coincide perfectly with the end of the Millstone contract. Erring on the side of adding replacement clean energy *after* the contract terminates produces a risk of missing mid-term GHG emission targets. Erring on the side of adding replacement clean energy *before* the contract terminates places higher cost burdens on ratepayers. With approximately 90 percent of the state's EDC load already contracted, these are real concerns from a contracting capacity and ratepayer affordability perspective. For this reason, new clean energy additions in the Balanced Blend scenario begin in 2026 (Electrification Load case) or 2027 (Base Load case), and ramp up in the early 2030s, which causes the state to underperform in meeting the GC3's 2030 planning target for several years in the early 2030s.

These scenarios reflect a somewhat binary view, where Millstone's continued operation is solely dependent on a Connecticut ratepayer contract. An alternate path opens up if other states take on a share of the above market costs of Millstone through the purchase of environmental attributes currently claimed by Connecticut. Under that circumstance, new clean energy resources could be needed even sooner than 2026 or 2027. Millstone could potentially exercise market power and raise prices to uncompetitive levels, but it is not the only resource that could do this. While Connecticut must explore cost-sharing approaches for resources like Millstone, it also needs to identify measures that can be taken at the state level that will protect ratepayers against the abuse of supplier-side market power.

Deployment of Existing Contracted Resources

Another key contingency in meeting the state's GHG emissions goals involves the deployment of projects that have already been procured, but not yet constructed. There are numerous milestones in project development, including permitting and siting approvals, financing, construction, interconnection and commissioning. The state has 2,400 MW of clean energy resources under contract that have not yet reached their commercial operation date. In recent procurements, some projects have been terminated due to external factors after the modeling of this IRP was completed.[361] Though the amounts are not significant at this time, it still creates a gap in Connecticut's progress. If those resources do not achieve commercial operation, or are significantly delayed in reaching commercial operation, an earlier procurement of replacement resources could be warranted to ensure continued progress towards the state's GHG emission targets.

Pace of Electrification of Thermal and Buildings Sectors

In 2018, the GC3 determined that Connecticut will need to achieve a 66 percent zero carbon electric supply by 2030 to meet the State's mid-term, economy-wide carbon reduction target (45 percent below 2001 levels by 2050) established in Public Act 18-82. This electric sector target was developed by assuming emissions-reduction targets of 34 percent in the buildings sector and 29 percent in the transportation sector, relative to a 2014 baseline. The modeling scenarios in Objective 1 reflect that 66 percent target for 2030. If reductions do not progress at those rates in buildings and transportation, an alternative way to achieve compliance with the mid-term target would be to accelerate reductions in the electric sector—necessitating more zero carbon resource deployment than is assumed in the modeling for this IRP.

Similarly, all of the modeling scenarios reflect the importance of monitoring the pace of electrification to determine procurement needs. Under the Electrification Load cases in each scenario, a greater quantity of new clean energy resources is needed to maintain progress towards the 2030 and 2040 emissions targets assumed in Objective 1.

Procurement-to-In-Service Lead Times

As noted above, it can take several years for a project that is selected in a procurement to achieve siting, permitting, financing, and construction of new generation facilities, such that procurements must occur several years in advance of the year when resources are needed. This procurement lead-time must be factored into planning for new clean energy additions. For example, for offshore wind, the IRP estimates that approximately 5-6 years of lead-time is needed from procurement award to commercial operation date. Grid-scale solar projects, by contract, may require half that time.

As further outlined below in Strategy 10, the delays that can occur between procurement and operation have led DEEP to consider how to optimize the steps within its jurisdiction, particularly in siting and permitting. Strategy 10 builds on the discussion in Objective 4 and recommends conducting stakeholder engagement to streamline those processes, and enhance the transparency and consistency of DEEP's preferential siting criteria. The goal of this process is to ensure that the siting and permitting processes

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[361] PURA Docket No. 17-01-11. *PURA Review of Public Act 15-107(B) Small-Scale Energy Resource Agreements.* Order No.1 UI Notice of Termination Highgate, Hinckley, Randolph, Sheldon, Winslow. October 30, 2020, *available at* http://www.dpuc.state.ct.us/2nddockcurr.nsf/8e6fc37a54110e3e852576190052b64d/6848d19438981750852587520077bc8b?OpenDocument

are efficient, but thorough and deliberate, meaning projects are strategically sited and move towards operation with minimal delay. Having greater certainty as to when projects can be expected to come online will also refine DEEP's procurement planning and sequencing.

Declining Technology Costs

As noted in Objective 2, Connecticut has witnessed significant declines in the cost of renewable technologies such as solar. In the years since DEEP began utilizing competitive procurements for grid-scale solar, selected bid prices have declined from $333/MWh to $50/MWh, and the sequencing of those procurements over time has enabled the state to secure zero emission resources at increasingly lower costs, improving affordability for ratepayers. Spacing or sequencing of procurements is an important consideration in a procurement strategy for resources that are expected to see technology costs decline over time. With respect to offshore wind, for example, as turbine sizes increase and domestic supply chain and workforce development improve due to OSW procurements throughout the region, prices are expected to decrease over time. By contrast, project costs can also be affected by the sunset or extension of federal tax credits and other time-limited incentives. Therefore, it is important to carefully monitor technology cost, pricing results in other jurisdictions' RFPs, and incentive policy changes that could affect project pricing, and factor that into the timing of procurements.

Availability of Transmission Resources

Modeling results for Objective 1 confirm the impact of transmission constraints on the state's decarbonization pathways. Under the No Transmission Constraint scenarios, curtailments are reduced, and energy can be delivered more efficiently around the region, thereby reducing the overall clean energy capacity needed to meet the Regional Emissions Target. As noted in Objective 5, the current ISO-NE transmission planning process has hindered the development of transmission resources in concert with clean energy procurements. While Connecticut, and other states like Massachusetts and Rhode Island, have been actively procuring zero carbon resources with in-service dates two to five years after selection, transmission projects continue to take nearly a decade to complete. Moreover, the amount of clean energy and OSW in particular that the states have procured to date is nearing the cap for interconnection at the limited number of PTFs along the New England coastline. Given that the modeling in Objective 1 projects a regional need of over 10 GW of OSW under the Base Load Balanced Blend, and 15 GW under the Electrification Load Balanced Blend, investment in transmission upgrades is necessary to successfully integrate these zero carbon resources.

The availability of transmission to deliver large-scale hydropower from Canada down to New England also has significant implications. The modeling recognized that despite the substantial availability of low-cost hydroelectric capacity in Canada, importing it is limited by transmission through northern New England. As revealed by the NECEC development process, siting transmission lines is a real challenge in New England. Therefore, the model limited additional hydro imports from Canada to 1200 MW past the scheduled addition of NECEC. Should additional hydroelectric imports materialize in the future, it is important to note that this could serve as a scalable alternative to nuclear resources and could potentially reduce the quantities of additional renewable resources and reserves needed to meet the Regional Emissions Target. Connecticut must continue to monitor the development of hydro imports from Canada as it plans for a 100% zero carbon electric supply.

Aligning Procurements with Other States

The Department has found that aligning solicitations for resources with neighboring states, particularly large-scale resources like offshore wind, or resources requiring a large transmission investment, is useful to potentially capture economies of scale in purchasing, and at a minimum receive additional project variations for pricing and size, contingent upon action in the neighboring state.[362]

With respect to RFPs for power purchase agreements for offshore wind, Massachusetts DOER recently acknowledged the potential benefits in aligning solicitations and noted it would work with neighboring states to evaluate the costs and benefits of coordinating procurement timelines.[363] Massachusetts DOER recommended conducting the next solicitation in 2022 and allowing for bundled generation and transmission for up to 1,600 MW. Coordination with Massachusetts and other states in the region including New York could reduce costs and avoid bottlenecking delays. Therefore, DEEP will stay engaged with regional states and endeavor to align procurement timing to leverage these benefits for Connecticut ratepayers. These procurements, which may include OSW eligibility, may occur earlier than the timeline discussed above.

As discussed in Strategy 2 and 3, Connecticut is working with other New England states on a regional solution to ISO-New England market design flaws (and governance changes) that fail to account for the state's energy policy priorities. Remedying these flaws is essential to ensure that Connecticut ratepayers receive maximum value from the clean energy resources the state procures. The best decarbonization strategy for Connecticut's ratepayers would be the design and implementation of a new unified, regional market design that will achieve the State's zero carbon energy goals. A successful regional market design would replace the State's procurement mechanism as the means to secure needed clean energy resources and enable the states to achieve their clean energy mandates through the market itself.

Taking all of the above contingencies into account, this IRP concludes that with significant quantities of clean energy under contract, no new procurements of zero carbon Class I resources are needed in 2021, nor likely in or 2022, to ensure continued progress towards the state's emission goals. Moreover, there is a critical need and opportunity to: (1) pursue reforms to the wholesale market to provide for a unified, regional mechanism to meet our public policy needs, including retaining existing zero-carbon resources like Millstone and building new clean energy resources; (2) engage in transmission planning for transmission or non-wires alternatives that are needed to enable the interconnection of additional quantities of offshore wind, and to reduce spillage of variable renewable resources; and (3) enhance the transparency, sustainability, and efficiency of siting and permitting practices through a public proceeding. These reforms are essential to achieving an effective and affordable path to decarbonizing the electric sector and will be a focus for 2021 and 2022. The success of these efforts will impact the timing of when new clean energy will need to be procured, as discussed above.

During this time, DEEP will also monitor already contracted resources to ensure that they reach planned in-service dates, and will monitor technology cost trends, incentive availability, and procurement activity

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[362] DEEP conducted a procurement in coordination with Massachusetts and Rhode Island, called the Three State RFP, in 2016/17 for renewables like solar and large-scale hydropower. In addition, DEEP aligned the timing of two of its procurements for offshore wind in 2018 and 2019 with Massachusetts.

[363] Commonwealth of Massachusetts, Department of Energy Resources, "Offshore Wind Energy Transmission under Section 21 of Chapter 227 of the Acts of 2018," (Jul. 28, 2020), *available at* https://www.mass.gov/doc/offshore-wind-transmission-letter-07-28-20/download

among neighboring states to also inform whether to initiate procurements earlier. If market reforms are unsuccessful, DEEP will reevaluate procurement strategies for grid-scale zero carbon Class I resources, to account for the potential retirement of Millstone at the end of the existing contract period, and ensure the electric sector contributes sufficient reductions to meet the economy-wide 2030 goal.

Before issuing any new grid-scale procurement, DEEP will also initiate a preparatory proceeding to gather public input and provide renewable and clean energy developers and the public the opportunity to provide feedback DEEP's procurement mechanisms. Potential areas for feedback include: enhancements to the procurement design to improve competition; alignment with transmission planning and procurement; issues related to equity and diversity; types of information required to be submitted in bids; confidentiality afforded to bidders in DEEP's procurement process and the subsequent PURA proceeding; coordination with other states in the region; aligning procurements with Connecticut's siting and permitting requirements; and other issues.

Class I Renewable Energy Procurement Schedule

Connecticut has already made significant progress towards its 100% Zero Carbon Target, in part due to its procurements of OSW resources to date, equivalent to 19 percent of the state's EDC load. Public Act 19-71[364] requires DEEP to provide a procurement schedule for OSW informed by the IRP, providing for the solicitation of resources with an aggregate nameplate capacity of 2,000 MW by 2030.

The IRP modeling demonstrates that additional zero carbon resources are needed beginning in 2026. While the model selected solar resources to fill that need, the takeaway is the amount of the resource needed, not a particular technology. DEEP does not generally conduct procurements for one specific resource. The projected need for additional zero carbon resources begins in 2026. If that does not change based on the contingencies noted above, in order to allow lead time for development, DEEP will conduct a procurement for zero carbon resources in 2023, open to Class I zero carbon resources, including OSW.

In order to comply with Public Act 19-71, based on the modeling in Objective 1 and the discussion above, the following is a more specific schedule of procurement activity for the state, including offshore wind, subject to contingencies:

- 2021 & 2022: Focus on siting and permitting enhancements, transmission planning and procurement, and market reforms needed to enable procurement of additional offshore wind resources and other zero carbon Class I resources.
- 2022: Prepare and release an updated report on market conditions and changes to the contingencies listed above, including whether a more near-term procurement of zero carbon Class I resources is necessary.
- Prior to 2028, depending on contingencies: Procure additional zero carbon Class I resources, including OSW, with sufficient time for resources to come online.

With this estimated procurement schedule, it is expected that the existing 2000 MW of OSW authority pursuant to Public Act 19-71, 1200 MW of which remains, will be fully utilized.

In order to achieve the 100% Zero Carbon Target by 2040 at the least cost, it will be important to retain flexibility in planning and executing procurements so as not to procure more resources than are needed.

[364] Section 1, Public Act 19-71, An Act Concerning the Procurement of Energy Derived from Offshore Wind, codified at Conn. Gen. Stat. § 16a-3n(a)(1).

Prices are expected to decline over time as technology advances and the workforce becomes more established. Most importantly, in the near term, it is important to solve for transmission constraints that will be key to unlocking additional OSW potential, as discussed in more detail in Objective 5. As indicated above, DEEP will monitor contingencies and update its procurement schedule for OSW and other zero carbon Class I resources no less than every 12 months to account for any changing market and policy conditions through the release of the next IRP, and will release its next updated procurement schedule in early 2022. In subsequent IRPs and proceedings, DEEP will continually refine this procurement schedule.

6. Structure the successor tariff programs supporting distributed generation to achieve historic deployment levels and equitably distribute the benefits of zero carbon generation

Objectives: 1, 2, 3, 4

Public Act 18-50 expanded the DG programs in Connecticut to ensure the success of the state's growing renewable energy industry and promote sustainable Solar PV energy growth in the region. In addition, it utilized the successes of competition in existing programs to drive down prices paid for by all ratepayers and combined separate programs purchasing energy and RECs into a single program to ease participation. Public Act 18-50, as amended by Public Act 19-35, represents a significant financial commitment to distributed generation growth in Connecticut. It authorizes: (1) unlimited residential solar; (2) 50 MW/year for six years (300 MW total) for zero emission resources as a ZREC and VNM successor; 10 MW/year for six years (60 MW total) for low emission resources as an LREC and VNM successor; and (3) 25 MW/year for six years (150 MW total) for shared clean energy facilities.

The successor tariffs will create a transparent incentive program for both energy and RECs associated with DG that provides a fixed incentive to participants. This incentive can then be adjusted for declining federal incentives on behalf of the participant and capture declining technology costs on behalf of all ratepayers.

It is important to maintain historic deployment levels of DG achieved through the RSIP and LREC/ZREC programs to continue the pace of diversifying the State's zero carbon resources and sustain the existing in-state economic infrastructure supporting these programs.[365,366,367]

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[365] DEEP has not included the virtual net metering program in this table because most, if not all, of the virtual net metering projects also participate in either LREC or ZREC. Thus, virtual net metering projects are reflected in the deployment levels of LREC and ZREC. DEEP recognizes the importance of continuing the structure of the virtual net metering program in the successor tariffs to support municipalities, the state, and agricultural customers.

[366] Connecticut DEEP, *2018 Integrated Resources Plan,* Data Request to the Electric Distribution Companies, July 10, 2020, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/$EnergyView?OpenForm&Start=1&Count=30&Expand=8.5&Seq=5

[367] Connecticut Green Bank, "Excel Spreadsheet for Residential Solar Installations in Connecticut for Information on system costs, sizes, contractors installing systems and other details," June 2, 2020, *available at* http://www.gosolarct.com/1-Get-Into-Solar/Connecticut-Solar-Market-Data

Table S1: MWs of Solar Accepted Each Year by Program, 2012-2019

Year	LREC	ZREC	RSIP
2012		16.8	5.5
2013		25.3	10.4
2014	7.0	39.8	33.3
2015	9.8	32.1	54.1
2016	2.9	41.0	44.9
2017	3.6	68.3	35.6
2018	18.8	80.1	53.8
2019	33.5	56.5	65.5

Table S2: MWs of Fuel Cells Accepted Each Year by Program, 2012-2019

Year	LREC
2012	5.0
2013	4.9
2014	6.0
2015	2.1
2016	8.6
2017	5.0
2018	2.7
2019	10.6

Based on the data in Tables S1 and S2 above, the RSIP program accepted an average of 48 MWs of solar each year between 2014 and 2019, when the program was more mature, with 65 MWs deployed in 2019. The LREC/ZREC program accepted an average of 13 MWs and 53 MWs, respectively, of solar each year during the same time. The LREC program brought an average of six MWs of fuel cells online. While the RSIP numbers are reflective of actual installations, the LREC/ZREC program typically has an attrition rate of 45 percent and installed MWs resulting from each procurement year are less than what is presented in the table.[368]

While distributed generation provides many benefits, the ratepayer cost of deploying an additional 52 MWs of DG solar per year, on average, in the Base Load BTM Emphasis scenario is $848 million above the cost of the Base Load Balanced Blend scenario, and $4.6 billion above the cost of the Reference scenario. These costs are conservative estimates because they are based on the cost of installing the distributed solar from NREL, not based on the cost of the current compensation structure under net metering paired with a REC purchase program. In developing a recommendation for targeting distributed generation installations in furtherance of the 100% Zero Carbon Target, DEEP must balance both these significant costs to all ratepayers with the benefits these installations provide to participants and the broader electric grid.

Therefore, in order to maintain at least historic distributed generation deployment levels, this IRP recommends PURA aim to deploy up to 65 MWs per year of residential rooftop solar in developing the compensation structure for the successor program in Docket No. 20-07-01 pursuant to Section 16-244z(b),

[368] Connecticut DEEP, Letter to Jon Black, Helve Saarela, and Joseph Roberts of ISO-New England, February 24, 2020, *available at:* https://www.iso-ne.com/static-assets/documents/2020/03/ctdeep_2020draft_pv_forecast_comments.pdf

consistent with peak deployment in 2019. The Department supports maintaining 2019 deployment levels to sustain the rooftop solar industry while PURA works to maximize the benefits of DG deployed on the system. In the above-mentioned proceeding, DEEP recommended structuring incentive levels to ensure at least 40 percent of the installations are deployed at low-income households statewide and low to moderate-income households in environmental justice communities, to improve energy affordability for historically underserved and overburdened customers. In line with the Department's recommendation, PURA adopted the 40 percent benchmark.[369] The Authority committed to conduct an annual proceeding to review deployment levels in order to ensure maintenance of historic deployment and Connecticut's carbon free grid by 2040 goal. [370]

The Department will continue to assess the progress made in grid modernization proceedings and other proceedings impacting distributed generation and advocate for structures that maximize the grid benefits of solar while also leveraging the benefits to participants, particularly solar paired with storage. The Department may recommend increased distributed generation deployment levels under certain conditions, including as policies are implemented to capture the grid benefits of solar paired with storage, if deployment levels above 40 percent for low-to-moderate income homes can be successfully achieved, or if PURA is able to set a rate that is more competitive with grid scale projects.

Finally, this IRP supports the existing statutory maximums for the LREC/ZREC successor program of 50 MW of zero emission Class I renewables and 10 MW of low emission Class I renewables per year, and 25 MW of SCEF. The Department recommends that PURA explore methods to ensure winning projects achieve commercial operation in the final LREC/ZREC procurement and successor procurement program for similar resources to reduce the current attrition rate. These distributed generation deployment levels – 65 MW of residential rooftop solar, 50 MW of commercial zero emission Class I, 10 MW of commercial low emission Class I, and 25 MW of SCEF – are more than the deployment levels assumed in all scenarios other than the BTM Emphasis scenario, which results in an average BTM solar deployment of 97 MWs per year from 2022-2027, inclusive of both residential and commercial BTM solar. See Figure S1 below.

To further address energy equity and affordability, the low-income and low- to moderate-income subscribership requirements under the SCEF program structure should be increased, working towards a 100 percent low- to moderate-income subscribership goal. The Department appreciates the novel design of the SCEF program and the fact that the EDCs are in the process of developing a system to obtain and maintain the program subscribership levels. As the program evolves, it is important to work towards this 100 percent low- to moderate-income subscribership goal to support energy equity and relieve energy burden for vulnerable populations, while also helping reduce arrearages that become uncollectible, the cost of which is borne by all ratepayers. In addition, in order to further address energy equity and affordability and increase participation from low-income customers, DEEP recommends expanding eligibility in the residential successor tariff to include residents of multi-unit dwellings of more than four units to ensure master metered and submetered building tenants can access the on-bill benefits of rooftop solar.

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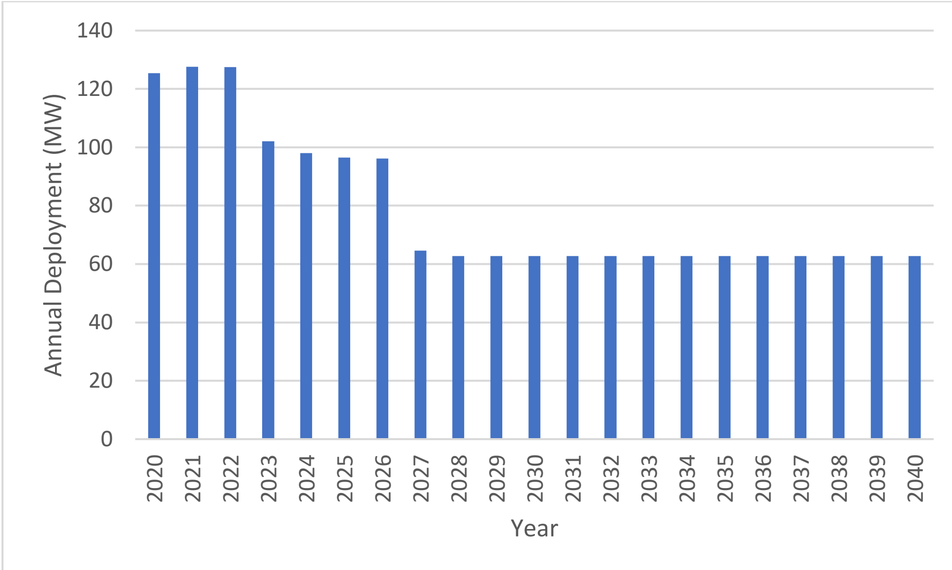
[369] PURA Docket No. 20-07-01. DEEP Written Exceptions. February 4, 2021 p.1-4. Retrieved from: http://www.dpuc.state.ct.us/dockcurr.nsf/8e6fc37a54110e3e852576190052b64d/cae0d548fc5371bd8525869900545975/$FILE/20-07-01%20Written%20Exceptions%20(final).pdf

[370] PURA Docket No. 20-07-01. Interim Decision. p. 40. February 10, 2021. Retrieved from http://www.dpuc.state.ct.us/dockcurr.nsf/8e6fc37a54110e3e852576190052b64d/a21495b0e4968ba68525869900545978/$FILE/200701-021021.pdf

Figure S1: Modeling BTM Solar Incremental Additions by Year, 2020-2040[371]



7. Investigate whether it is in the best interest of ratepayers to retain RECs procured by the EDCs on behalf of all ratepayers to meet our State climate goals

Objectives: 1, 2

The Department recommends PURA initiate a proceeding to investigate whether the EDCs should retain the RECs procured by all ratepayers in energy policy programs like DEEP's grid-scale competitive procurements and DG REC purchase programs and retire them on behalf of all electric ratepayers, including those utilizing competitive suppliers. The Department recognizes that PURA's investigation may result in a finding that a statutory change is necessary to achieve the optimal solution. The Department will submit a formal request to PURA to initiate a proceeding to evaluate the effects of REC retention by the EDCs following the release of this IRP.

In addition, DEEP is in the process of making refinements to the State's inventory reporting to align with the accounting method used in this IRP and take credit for renewable and zero carbon resources from an emissions perspective based on RECs and environmental attributes settled in Connecticut. The Department will host a public proceeding in fall of 2021 to gather stakeholder and public input on modifications to the accounting methodology. A notice of proceeding will be posted following the release of this IRP.

[371] These BTM assumptions were used in the Balanced Blend, Millstone Extension, and No Transmission Constraint policy cases. The BTM Emphasis case deployed approximately 72% more BTM on average.

8. Address the impact behind-the-meter resources have on reducing overall RPS compliance obligations

Objectives: 1, 2

As discussed in Objective 2, the State's clean energy policies effectively count BTM resources twice: once as a load reducer and once as a generator through the production of RECs. This "double count" has the unintended consequence of reducing Connecticut's annual RPS percentage because as BTM resources reduce the total load for the state, it coincidentally reduces how many RECs must be purchased by load serving entities. There are two basic approaches to reversing the effective reduction in Connecticut's Class I RPS requirement due to "double counting":

- Reduce, limit, or phase-out the eligibility of BTM resources for Class I RECs via legislation, or administrative action if possible.
- Change the way the State's Class I RPS requirement is calculated by adding BTM generation to the settled load used to determine the RPS requirement.

Both approaches have obstacles to implementation. The first approach would impact the compensation structure for the successor tariffs authorized under Section 16-244z(b) of the General Statutes because all value would be derived from the energy rather than the RECs for the average cost of installing the generation project and a reasonable rate of return. In addition, the first approach would impact the bidding structure in the procurements authorized by Section 16-244z(a) of the General Statutes because the bid prices would be tied only to the energy delivered rather than the energy and RECs delivered. This approach would heavily impact the current BTM programs, as the RSIP and LREC/ZREC program both provide compensation for only RECs. If this approach were utilized, existing BTM programs like RSIP and LREC/ZREC would need to be grandfathered to allow these RECs to continue to be sold for RPS compliance purposes.

An alternative option under this approach would be for the EDCs to not claim BTM RECs purchased pursuant to RSIP and LREC/ZREC for compliance with the RPS, but to also not sell them into the regional market (effectively 'canceling' them). It is unclear if PURA has the authority to direct the EDCs to take this action, or if legislative action would be required.

The second approach may not be administratively possible. If it is possible, it may create significant uncertainty for suppliers and the EDCs. An alternative option would be for the State to increase its RPS requirement to account for the load reduced by BTM resources, although this option would be imprecise as an estimate of future BTM deployment would be necessary.

This issue should be investigated by PURA to consider these options, and other potential alternatives, to eliminate the impact BTM resources have on reducing overall RPS compliance obligations. No change is recommended at this time to existing programs like RSIP and LREC/ZREC because it would be disruptive to the financing of those existing projects. However, the creation of the new residential solar tariff program under Section 16-244z(b) of the General Statutes (i.e. the RSIP + net metering successor program) in PURA Docket No. 20-07-01 and the structure of the competitive procurements authorized by Section 16-244z(a) of the General Statutes (i.e. the LREC/ZREC + net metering/virtual net metering successor program) starting in 2022 makes this issue ripe for consideration. DEEP will submit a formal request to PURA to initiate a proceeding to investigate the effects of BTM resources on RPS compliance in conjunction with the request identified in Strategy 7 to evaluate the effects of REC retention by the EDCs following the release of this IRP.

9. Engage in coordinated planning for workforce and economic development

Objectives: 2, 3, 5

The findings in Objective 1 highlight both Connecticut's continued reliance on energy efficiency to minimize overall load, and its growing reliance on zero carbon generation technologies in order to meet its 100% Zero Carbon Target. These needs demonstrate that a robust, skilled workforce is critical to the state achieving its goals. This IRP discusses these needs in both Objective 5, and in Strategy 5 above. The transition to a clean energy economy provides significant economic opportunity to our residents, businesses, and communities.

With respect to offshore wind, through collective investments in this emerging resource, the Northeastern states have jump started the OSW industry in the U.S., and demonstrated commitments to allow the industry to firm up the supply chain and workforce.[372] The significant amount of offshore wind procurement activity in the Northeast will likely result in economic activity for many regional ports as well as regional supply chain and work force development opportunities. Connecticut's available ports and manufacturers have features that make them attractive prospects for economic development related to offshore wind regardless of whether procurements occur in Connecticut or in neighboring states, thereby bringing the benefits of the clean energy economy to Connecticut's environmental justice communities in which key ports and manufacturers are located. Under the leadership of Governor Lamont, DEEP is currently collaborating with the Department of Economic and Community Development and other entities to develop a plan to ensure that Connecticut ports, manufacturers, and workers are well positioned to leverage the significant opportunities to be provided by this high growth clean energy industry.

Investment in energy efficiency and clean energy over the last two decades has significantly grown employment in the state's clean energy sector. As of 2019, an estimated 44,094 worked throughout the state in a variety of clean energy jobs, and if not for the conditions caused by the COVID-19 pandemic, this number was projected to increase to over 46,000.[373] Connecticut must continue to support and expand on workforce development efforts in the state including, but not limited to, the Office of Workforce Competitiveness' (OWC) green technology industry career ladders,[374] training programs provided through the C&LM programs, training and education programs at technical schools, community colleges and universities alike, and other programs.

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[372] Massachusetts has 1,604 MW of offshore wind under contract, with plans to conduct additional procurements. Rhode Island has 430 MW of offshore wind under contract, with plans to procurement up to 600 MW more. New York has 1,826 MW of offshore wind under contract, with plans to procure more.

[373] EnergizeCT. *Connecticut Clean Energy Industry Report.* September 2020. https://ctgreenbank.com/wp-content/uploads/2020/11/2020-Connecticut-Clean-Energy-Industry-Report.pdf

[374] *See* CT Department of Labor, "Connecticut Green Occupations Green Jobs Career Lattices." *https://www1.ctdol.state.ct.us/lmi/green/default.asp*

The Department will coordinate with DECD and its Office of Workforce Strategy, as well as other state agencies and stakeholders, to develop a strategic and equitable approach to clean energy economic and workforce development in Connecticut.

10. Conduct a stakeholder process to improve the transparency, predictability, and efficiency of solar siting and permitting in Connecticut

Objectives: 1, 3, 4

Under the various modeling scenarios in Objective 1, solar resources play a significant part in meeting a 100% Zero Carbon Target by 2040. Not all of the thousands of megawatts needed to meet this target will be developed in Connecticut, but many will. As discussed in Objective 4, it is critical to ensure that the process for siting and permitting ground-mounted systems is as transparent, efficient, and predictable as possible, and that renewable procurements—whether contract- or tariff-based—incorporate eligibility criteria that reflect a consistent and appropriate balance of price and environmental quality and natural resource values. Additionally, Connecticut must continue to work towards making renewable energy accessible to all, while also ensuring that

The draft IRP released in December 2020 called for a stakeholder engagement process, led by DEEP, to improve and refine solar siting and permitting practices with respect to grid-scale procurements, and to develop siting practices tailored to BTM, VNM, and LREC/ZREC solar projects. Examples of preferential siting practices include measures that prioritize the selection of projects in developed, abandoned or underutilized areas over undeveloped greenfields; preserve agricultural farmland; avoid steep slopes, minimize soil erosion and sedimentation; avoid disturbances of valued natural resources such as core forests, wetlands, and endangered, threatened or species of Special Concern and their habitats,[23] preserve sites with archaeological, historic or culturally significant resources, and avoid visual and aesthetic impacts to residential and recreational facilities.

Since the draft release, DEEP's Environmental Conservation, Environmental Quality, and Energy branches have begun to engage with developers, PURA, the Department of Agriculture, the EDCs, environmental justice advocates, environmental advocates, interested legislators, and other stakeholders to explore preferential siting practices through the use of eligibility criteria, selection weighting factors, and favorable compensation rate incentives. This process, which DEEP has titled "STEPS: Sustainable, Transparent, and Efficient Practices for Solar Development", or "STEPS" is expected to take place throughout the remainder of 2021. The Department has hosted two public scoping meetings, one during the day, and another in the evening to receive feedback on a set of proposed topics for evaluation including preferential siting criteria, benefits and challenges related to various land types, best design and construction practices, opportunities to optimize regulatory and permitting requirements, and types of incentives and other program design features.[375]

Feedback and information gathered during this process will help guide the design and refinement of Connecticut's clean energy programs and future Class I resource procurements. Incorporating best siting

[375] Connecticut DEEP, *STEPS for Solar Development Notice of Proceeding, Scoping Meeting, and Opportunity for Public Comment*, June 7, 2021, *available at* https://portal.ct.gov/-/media/DEEP/Planning/Final-solar-siting-and-permitting-engagement-notice-060721.pdf

and permitting practices in procurement criteria will ensure fair pricing and competition, reduce project risk and speed deployment. The STEPS process will allow new approaches to be developed in a transparent manner and phased in prospectively, so developers can plan for them as they are searching for sites.

11. Leverage regional coordination to develop best practices for offshore wind siting

Objective: 4

States across the region are procuring offshore wind in the same or adjacent federal lease areas as projects procured by Connecticut and navigating similar challenges with regard to siting and environmental and fisheries mitigation. The Department will continue coordinating with regional entities that are investigating these issues, such as the Northeast Regional Ocean Council, the Responsible Offshore Development Alliance/Responsible Offshore Science Alliance, and, once established, the Regional Wildlife Science Entity for Offshore Wind, to improve our understanding of the best available science, tools, and practices for environmental and commercial fisheries mitigation and allow us to continually improve our solicitations as they pertain to planning and siting. The Department will leverage these regional approaches to developing best practices in offshore wind siting and incorporate siting requirements in future solicitations. As required by Public Act 19-71, DEEP will also utilize input from the Commission on Environmental Standards for each future solicitation pursuant to that Public Act.

12. Invest in the expanded deployment of cost-effective energy efficiency and active demand response

Objectives: 1, 2, 3, 5

The modeling in Objective 1 demonstrates the importance of continued energy savings and demand reduction as a means to mitigate load growth and optimize resource additions in pursuit of a 100% Zero Carbon Electric Sector. Ensuring that load is minimized through the efficient use of energy, particularly as other sectors are electrified in order to meet the GWSA targets, helps to reduce costs for ratepayers, and load on the system. Energy efficiency can also improve indoor environmental quality for occupants, which is particularly impactful for environmental justice communities, helping to improve energy equity as called for by Objective 3. The discussion in Objective 5 also demonstrates how the addition of energy efficiency and demand response can aid in optimizing transmission upgrades. Connecticut must therefore continue to pursue and leverage all strategies sources of funding for investment in cost-effective energy efficiency and demand response.

In 2016, DEEP conducted a procurement that allowed energy efficiency to compete as an eligible resource as authorized by Public Act 15-107. In addition to over 350 MW of wind and solar, DEEP selected 34 MW of energy efficiency as part of this authority. The 34 MW of energy efficiency selected had an original completion of deployment of 2021, but installation was accelerated because of legislative sweeps to the C&LM Plan budget and savings have been delivered substantially ahead of schedule as reported in the

First Annual Measurement and Verification Report.[376] The ability to quickly deploy efficiency as compared to other energy resources represents a significant benefit, enabling energy efficiency to fill in gaps where needed to meet the 100% Zero Carbon Target. In addition, energy efficiency and demand response deliver bill savings to participating customers. Innovative electric demand response strategies can help customers and grid operators manage shifting loads, particularly as we move toward building and vehicle sector electrification. Demand reduction assets could be managed through the use of innovative control structures to be fully integrated in a modernized grid. In order to leverage these benefits, this IRP recommends authority for DEEP to procure energy efficiency and demand response that complements the existing C&LM programs. Conducting additional procurements for energy efficiency and active demand response would expedite the reduction of GHG emissions, decrease the need for new zero carbon generating resources, and help reduce customers' energy burden.

In addition to procurement authority, there has been and continues to be opportunities to leverage federal dollars to further investment in energy efficiency in Connecticut. A recent example is Connecticut's decision to use some of the American Recovery Plan Act (ARPA) funding to help address health and safety barriers to weatherization, and to administer an energy retrofit program for affordable housing.[377] DEEP will continue to leverage federal funding that becomes available to further energy efficiency, resilience, and decarbonization with a focus on underserved and overburdened communities, residents, and businesses.

An alternative approach to locking in energy efficiency and demand reduction is through the adoption of product efficiency standards and high efficiency building codes. As discussed in Objective 5, efficiency codes and standards are an effective tool for ensuring energy efficiency as a baseline for all consumers. Connecticut has not updated its list of products that must meet efficiency standards in ten years, and there is currently a set of eighteen new product categories not yet preempted by the federal government that could save Connecticut hundreds of GWh per year if implemented. Likewise, Connecticut has not updated its energy conservation building code since 2018. Increasing the stringency of its codes, in accordance with the amendments passed through the International Energy Conservation Code (IECC), will help to ensure that as new buildings and retrofits are constructed and replace older stock, overall efficiency increases. When these efficiency levels are passed by code or standard, all consumers and building occupants will have increased access to a baseline level of efficiency. DEEP should pursue updating its list of regulated product efficiency standards, in accordance with C.G.S Section 16a-48(d), and encourage the adoption of more stringent energy efficiency codes.

This IRP also recommends that the C&LM programs further develop natural gas demand response programs, to free up gas demand to be used for electricity generation and improve electric resilience during winter peaks that occur due to extreme cold weather.

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[376] Eversource Energy, PURA Docket No. 17-0-11, *First Annual Measurement and Verification Report*, March 14, 2019, *available at* http://www.dpuc.state.ct.us/dockcurr.nsf/8e6fc37a54110e3e852576190052b64d/32fde53ee1a2d406852583bd00659351/$FILE/2017-2018%20Incremental%20EE%20Bid%20Annual%20MV%20Report_Final.pdf

[377] Governor Ned Lamont. *Connecticut's Plan for the American Rescue Plan Act of 2021: A Roadmap for a Transformative, Equitable and Healthy Recovery for our State.* April 26, 2021. https://portal.ct.gov/-/media/Office-of-the-Governor/News/2021/20210426-Governor-Lamont-ARPA-allocation-plan.pdf

13. Support the development of energy storage resources that can support the reliable integration of variable renewables and avoid fossil peaking generation

Objectives: 1, 2, 3, 5

Energy storage and active demand response will play a critical role in an increasingly decarbonized electric sector by helping to shape the load of variable zero carbon resources like wind and solar to better match demand, and avoiding the need for fossil peaking generation. The modeling results in Objective 1 estimate the need for 1,060 MWs of new energy storage capacity added between 2031 and 2040 in the Base Load Balanced Blend scenario, and 1,603 MWs in the Electrification Load Balanced Blend scenario starting in 2030 to help meet the 100% Zero Carbon Target—highlighting the importance of pairing resources like storage with intermittent renewable energy sources, especially if baseload zero carbon resources like nuclear retire.

APPENDIX A1

Battery storage capital costs are predicted to significantly decline over the next two decades, as discussed in Appendix A1. Battery storage provides multiple services, depending on how it is operated and configured. With respect to the state's energy supply, battery storage located behind the customer meter can provide for increased on-site consumption of distributed solar and resilience. PURA's grid modernization dockets are establishing many of the opportunities for energy storage, including storage that provides customer and distribution system benefits.

DEEP has to date solicited bids for grid-located storage resources paired with renewables as part of several recent grid-scale resource competitive procurements. Insights from these procurements point to the need to consider valuing firmness and deliverability of energy, in addition to emissions reductions and RPS compliance, as part of bid evaluation, to more effectively evaluate the attributes that energy storage projects can bring to a resource.

The modeling in Objective 1 projects that Connecticut should begin procuring storage resources in 2027-28 in the Balanced Blend scenarios under both load cases. Public Act 21-35 authorized 1,000 MW of procurement authority, but more than half of this is allocated to behind the meter applications rather than grid scale storage, as modeled.[378] The remaining procurement authority could be used for grid scale applications, but this will likely not be enough to meet the reliability needs identified by the modeling in Objective 1. Additional procurement authority will be needed for the 2030-2040 period, and procurement structures will need to be refined and strategically planned in advance of when these resources would be needed.

While DEEP will continue to track the development of this technology, it also needs to determine what other applications of energy storage could be implemented today. As discussed in Objective 5, Connecticut does not have the same grid congestion issues that are driving project proposals in Massachusetts, Rhode Island and northern New England. Therefore, DEEP will release a request for information and notice of proceeding following the release of this IRP to begin more technical research on innovative applications for storage. DEEP will also monitor trends in alternative and nascent storage

[378] PURA, Docket No. 17-12-03RE03, *PURA Investigation into Distribution Planning of the Electric Distribution Companies- Energy Storage,* Final Decision, July 28, 2021, *available at:* http://www.dpuc.state.ct.us/2nddockcurr.nsf/8e6fc37a54110e3e852576190052b64d/6991ef77ba07bae185258752007994f7/$FILE/171203RE03-072821.pdf

technologies, such as the production of green hydrogen, and consider their potential in future iterations of the IRP.

14. Phase down the value of biomass RECs eligible as a Class I renewable energy source to diversify the resources supported by Connecticut's Renewable Portfolio Standard

Objectives: 1, 6

The Department supports the recommendation from the 2018 CES to phase down the value of biomass RECs in Connecticut's Class I RPS. Pursuant to Public Act 13-303, to implement this phasedown, eligible generation for Class I biomass RECs will be reduced after 20 years for new facilities and 15 years for existing facilities from the time they were approved as a Class I renewable energy source in Connecticut. The Department believes it is appropriate to apply the new/existing facility designations that PURA established for hydropower to biomass.[379] This phasedown schedule will provide both new and existing facilities reasonable time to amortize their investments.

After the initial 15- or 20-year license period ends, the amount of generation eligible as a Class I resource will be reduced for each biomass project, which will gradually reduce the value of Class I RECs to all biomass facilities. Class I RECs will still be generated as they have been, but the amount of generation eligible as a Class I resource in Connecticut will decline to 50 percent of the actual generation output from the facility each year. One MWh would still be required to be produced to receive a REC in Connecticut. A REC for a Class I biomass facility would not be treated any differently from CT Class I RECs from other eligible resources for the purpose of supplier compliance. The other 50 percent of the annual generation output, which is not eligible in Connecticut, will still be eligible to be sold to meet RPS requirements in other states, to the extent the resource is eligible to participate in those other state RPS programs. Implementing this phasedown schedule will help to diversify resources supported by the state, focus incentives on resources that support in-state forestry and waste management goals, and help fulfill the goals of the GWSA. Freeing up Class I RECs historically met by biomass allows more of the State's funding to be targeted towards eligible zero carbon resources, and better aligning with its 100% Zero Carbon Target. This phase down will begin to take effect in 2022.[380]

To effectuate this change, DEEP has submitted a request through the NEPOOL GIS Working Group and the Markets Committee, which was voted on and approved during the September 14, 2021 meeting. The

[379] New facilities are those that began operation after 2003 and existing facilities are those that began operation prior to 2003. An existing facility may be considered a new facility if it was abandoned for at least two consecutive years and there had been a capital investment in the structure greater than 50% of the total value of the equipment at the facility. Many existing facilities made significant investments for emission control equipment to qualify as a Class I renewable energy source. (PURA Final Decision, DPUC Declaratory Ruling Concerning "Run-of-the-River Hydropower" as that Term is Used in the Definitions of Class I and Class II Renewable Energy Source in C.G.S. § 16-1(a)(26) & (27), Docket No. 04-02- 07, 13-14 (Sep. 10, 2004).

[380] Pursuant to Section 5 of Public Act 13-303, "shall not apply to any biomass or landfill methane gas facility that has entered into a power purchase agreement (1) with an electric supplier or electric distribution company in the state of Connecticut on or before the effective date of this section, or (2) executed in accordance with section 6 or 8 of this act." Thus, this phasedown will not apply to the Plainfield Renewable Energy facility because it has an existing contract.

Department does not expect it to take significant time to make the necessary administrative changes. Additionally, as discussed in Objective 6, some facilities may be exempt from the phasedown per the criteria in Public Act 13-303. The Department will initiate a proceeding following the publication of the final draft of this IRP to allow facilities to claim exemption in advance of this phasedown being finalized.

15. Diversify the state's materials management infrastructure through investment in more sustainable materials management strategies and facilities

Objectives: 1, 2, 4, 6

The Department has committed to continuously focusing on the intersections between renewable energy, climate, and materials management goals.[138] This includes evaluating how incentives can be used to promote renewable energy from waste, and exploring opportunities for pre-development financing for anaerobic digestion and other waste conversion technologies.[139]

The state has for many years provided ratepayer support to WTE facilities through the RPS Class II tier, as those facilities have provided for an essential in-state disposal option that is preferred under the state's waste hierarchy to landfilling. In recent years, ratepayers have contributed approximately $12 million to $17 million to WTE facilities annually through the RPS. WTE facilities emit greenhouse gases and other air pollutants, but have played a key role in providing reliable disposal for large volumes of solid waste over the years.

Ensuring reliable, affordable materials management options is a prime concern for the state. Present circumstances—including the aging condition of one of the state's largest WTE facilities—make it essential that the state seek opportunities to scale sustainable waste management alternatives that can provide alternatives to WTE and out-of-state landfilling for solid waste disposal. Over time, this can reduce the state's reliance on these disposal options and improve environmental quality, especially for environmental justice communities.

The Comprehensive Materials Management Strategy (CMMS) projects that approximately 300,000 tons (15 percent) of Connecticut's MSW could be diverted from disposal at waste to energy (WTE) facilities, and instead be processed using technologies such as anaerobic digestion.[140] In order to successfully deploy anaerobic digestion statewide, it is critical to develop an efficient network for organics collection to divert organic materials from the solid waste stream and put it to beneficial use at anaerobic digestion facilities. A process to build a collaborative network began in September 2020, when DEEP joined with more than 70 municipalities statewide, committing to work together as the Connecticut Coalition for Sustainable Materials Management (CCSMM) to collectively develop a set of waste reduction strategies by the end of 2020, including organics diversion strategies.

To support these efforts, changes may be needed to both the State's organics recycling laws to require more food scraps and organic material be sent for recycling at composting and anaerobic digestion facilities, but also to its RPS laws to make sustainable funding resources available to these communities to implement these changes. Objective 6 described an approach that would involve reallocating the revenues generated by Class II ACP from suppliers to the State. This would involve a statutory change that allows the ACP received for compliance with the Class II requirements of the RPS to be directed into a sustainable waste-management grant program instead. Additionally, there would need to be an amendment that prevents suppliers from meeting Class II compliance with RECs going forward. This simple approach essentially takes a portion of the subsidies paid to WTE generators and redirects them into initiatives that accomplish the same goals more sustainably. Legislative action to implement these changes should be pursued in the 2022 session.

Finally, DEEP has authority to procure energy and Class I RECs associated with anaerobic digesters, and is seeking additional legislative authority to procure biogas from anaerobic digestion to supply the gas distribution system.[381] As it is fundamental to the ability to commoditize biogas, DEEP supports PURA's approval of the "interconnection standards and tariffs for biogas derived from the decomposition of farm-generated organic waste or source separated organic material that has been processed through gas conditioning systems to remove impurities, including, but not limited to, water, carbon dioxide and hydrogen sulfide approved in the final regulations recently issued in Docket No. 19-07-04. Again, these efforts further decarbonize the gas distribution system and aid in the use of anaerobic digestion byproduct.

In any future procurements of anaerobic digesters, DEEP will require bidders to submit well-formed feedstock acquisition plans to demonstrate a well-developed understanding of the market opportunities and challenges, and will seek to align procurements with municipal engagement to target development strategically around the state to maximize proximate access to these facilities, and limit transportation costs for hauling organic feedstocks. The Department will continue to explore how to promote the development of this technology.

16. Expand the Microgrid and Resilience Grant and Loan Pilot program

Objectives: 5, 6

Under Public Act 20-5, the microgrid program was expanded to include resilience projects in general for the first time. The program also allows additional applicants from academia and non-profits, directs the program to prioritize vulnerable communities, and allows use of the funds for non-federal cost share. In 2021 the state bond bill authorized $25 million in funding for the program as of July 1, 2021 and an additional $5 million starting in FY23. With the expansion of this program beyond solely the use of microgrids to make our communities more resilient, the agency's challenge will now be to appropriately develop a request for proposals (RFP) that: (1) meets the resilience needs of the state and its communities particularly for critical infrastructure; (2) aligns with federal funding opportunities, both in eligible projects and timing; and (3) uses an informed approach to ensure funds are being prioritized for vulnerable communities. To achieve that goal, DEEP should evaluate how to best leverage these funds for planning and building a project pipeline for resilience prior to issuing an RFP. As part of the evaluation DEEP should review recommendations of the Governor's Council on Climate Change for resilience and adaptation planning and financing and funding as well as gain an understanding of the landscape of federal climate resilience funding opportunities, including proposed programs in the federal infrastructure bills pending in Congress.

[381] Section 17, Public Act 19-35, An Act Concerning A Green Economy and Environmental Protection.

Part III: Analysis and Recommendations Concerning a Connecticut Portfolio Standard for Thermal Energy

Introduction

Connecticut's Integrated Resources Plan traditionally focuses exclusively on electricity generation, transmission and an assessment of renewable electricity generation needed to meet the Renewable Portfolio Standard. In 2019, however, the Connecticut General Assembly directed that this IRP evaluate a policy relevant to the *thermal* sector – that is, energy used for space and water heating in residential and commercial buildings. Public Act 19-35 required DEEP to consider creation of a "portfolio standard for thermal energy," including "biodiesel that is blended into home heating oil."[382]

Burning fossil fuels for thermal uses in residences and businesses accounts for approximately one quarter of Connecticut's greenhouse gas (GHG) emissions.[383] Decarbonization of thermal energy must accelerate in the coming decades in order for Connecticut to meet its statutory economy-wide targets of 45 percent GHG emissions reduction by 2030 and 80 percent reduction by 2050.[384] Air- and ground-source heat pumps, especially when powered by low- and zero-carbon electricity sources as they increasingly will be in the coming decades, are capable of drastically reducing emissions in these sectors.[385] At present, however, heat pumps represent only a small fraction of the state's heating equipment.[386] Other mature or maturing renewable thermal technologies include solar water heating, solar space heating, biodiesel blended with heating oil, renewable natural gas, geothermal energy (i.e., heat from hot rock), and compost heat recovery.[387]

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[382] Public Act 19-35, An Act Concerning a Green Economy and Environmental Protection, 2019, section 10, *available at* https://www.cga.ct.gov/2019/ACT/pa/pdf/2019PA-00035-R00HB-05002-PA.pdf. The IRP addresses electric supply needs (C.G.S. §§ 16a-3a-3b). As such, DEEP interprets Section 10 of Public Act 19-35 as requiring DEEP to investigate the creation of a portfolio standard supported by electricity ratepayers.

[383] DEEP, 2017 Connecticut Greenhouse Gas Emissions Inventory, 2020, *available at* https://portal.ct.gov/-/media/DEEP/climatechange/2017_GHG_Inventory/2017_GHG_Inventory.pdf.

[384] *See* Public Act 08-98, An Act Concerning Connecticut Global Warming Solutions, *available at* https://www.cga.ct.gov/2008/ACT/PA/2008PA-00098-R00HB-05600-PA.htm; and Public Act 18-82, An Act Concerning Climate change Planning and Resiliency, *available at* https://www.cga.ct.gov/2018/ACT/pa/pdf/2018PA-00082-R00SB-00007-PA.pdf.

[385] A significant and growing proportion of electricity consumed in Connecticut is generated from zero-carbon resources. Even if heat pumps were powered by electricity generated entirely with fossil fuels, these appliances would provide heat from renewable energy. This is because, unlike electric-resistance heating, heat pumps do not convert electricity into heat. Instead, they harness a relatively small amount of electricity to harvest a larger amount of heat energy from the atmosphere or ground – heat provided by sunlight. The "coefficient of performance" of heat pumps typically is 2-6 times greater than that of electric resistance heating due to this heat-harvesting function.

[386] Connecticut Governor's Council on Climate Change, "Building a Low Carbon Future for Connecticut: Achieving a 45% GHG reduction by 2030," pp. 36-38, *available at* https://portal.ct.gov/-/media/DEEP/climatechange/publications/BuildingaLowCarbonFutureforCTGC3Recommendationspdf.pdf.

[387] For a broad view of renewable thermal technologies, *see* International Energy Agency, Anselm Eisentraut and Adam Brown, "Heating Without Global Warming: Market Developments and Policy Considerations for Renewable Heat," 2014, https://www.iea.org/reports/heating-without-global-warming.

Key renewable thermal technologies widely deployable in Connecticut homes and businesses – heat pumps and solar water heating – face significant economic barriers: up-front capital costs and competition with fossil fuels that have enjoyed decades of extensive federal subsidies, and whose prices do not account for large environmental and health externalities.[388] [389] Connecticut and other states have developed a variety of mechanisms to partially address these barriers, from providing incentives for the purchase of heat pump equipment through state energy-efficiency programs to building-code revisions and promotion of renewable natural gas.[390]

At least fourteen states have adopted thermal renewable portfolio standard (T-RPS) programs.[391] To complement one-time purchase incentives, T-RPS programs provide ongoing financial support for production or use of low- and zero-carbon thermal energy – much as conventional RPS programs provide ongoing support for low- and zero-carbon electricity generation. The design of thermal RPS programs and the technologies or resources they support vary from state to state. In a basic design: the state designates certain categories of renewable thermal technologies as eligible to produce Renewable Energy Certificates (RECs); eligible BTUs are generated in households and businesses employing these technologies; RECs for these BTUs are aggregated by third parties (using a designated BTU/MWH equivalence factor) and tracked by the regional REC oversight body[392]; and revenues the aggregators earn by selling the RECs provide compensation for the participating households and businesses. Where they are supported in a T-RPS, heat pumps typically are compensated on the basis of estimated BTU output, while biodiesel is compensated on the basis of the BTU content of each gallon of biodiesel delivered.

In accordance with Public Act 19-35, DEEP has pursued an extensive fact-finding and stakeholder-engagement process. In November 2019, the agency issued a background document reviewing the structure and features of renewable thermal portfolio standard programs in New England states.[393] A public technical meeting the agency held on December 9, 2019, included presentations on relevant programs in Massachusetts, New Hampshire, Vermont, and 11 other states as well as panel discussions on best practices. This meeting also included presentations by, and active engagement with, representatives of the National Biodiesel Board (NBB), Connecticut Energy Marketers Association (CEMA), Massachusetts Energy Marketers Association, Kolmar Americas (which has a major biodiesel production

[388] Yale Center for Business and the Environment, "Feasibility of Renewable Thermal Technologies in Connecticut: A Field Study on Barriers and Drivers," 2017, https://cbey.yale.edu/research/feasibility-of-renewable-thermal-technologies-in-connecticut-barriers-and-drivers.

[389] *On fossil fuel subsidies, see* Environmental and Energy Study Institute, "Fossil Fuel Subsidies: A Closer Look at Tax Breaks and Societal Costs," 2019, *available at* https://www.eesi.org/papers/view/fact-sheet-fossil-fuel-subsidies-a-closer-look-at-tax-breaks-and-societal-costs#1.

[390] *See e.g.*, 2021 Plan update to the 2019-2021 Conservation and Load Management Plan, *available at*, https://portal.ct.gov/-/media/DEEP/energy/ConserLoadMgmt/FINAL-2021-Plan-Update-Filed-10302020.pdf (authorizing the state's electricity and natural gas distribution utilities to provide incentives for the purchase of electric air- and ground-source heat pumps).

[391] Clean Energy States Alliance, "Renewable Thermal in State Renewable Portfolio Standards," 2018, https://www.cesa.org/assets/2018-Files/Renewable-Thermal-RPS.pdf.

[392] In New England, this body is the New England Power Pool Generation Information System.

[393] DEEP, "Renewable Thermal Portfolio Standard Programs in New England States," Nov. 19, 2019, available at http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/47469b57e3d1a355852584c40070531d/$FILE/Background.pdf.

facility in Connecticut), two Connecticut fuel oil companies, and the Connecticut Geothermal Association.[394] The agency issued a request for written comments on December 19, 2019, regarding the framing of thermal renewable portfolio standards as well as issues relating to biodiesel in this context; and extensive comments were received.[395] A second public technical meeting scheduled for March 16, 2020 was postponed due to the COVID-19 pandemic and ultimately held July 13, 2020.[396] Two rounds of written comments were requested and received in conjunction with that meeting.

NBB, CEMA, Kolmar, and a number of fuel oil dealers have urged adoption of a T-RPS. In their vision, a T-RPS recognizing biodiesel as an eligible thermal technology would enable fuel-oil distributors to invest in needed blending and storage infrastructure, boost the amount of biodiesel blended into the fuel delivered in Connecticut, and in the process allow these distributors to contribute to decarbonization of the thermal sector.[397]

This section: (a) considers the role that biodiesel blended into heating oil can play as a means to reduce GHG emissions from the thermal sector in accordance with the state's climate goals and (b) considers a T-RPS as a potential mechanism. The analysis identifies existing barriers to the use of biodiesel blends above B20, unresolved questions regarding the air-quality impacts of biodiesel as a heating fuel, and concerns about the impacts on electric rates if a measure unrelated to the provision of electricity were included within the electric-ratepayer-supported RPS. Based on these considerations, this IRP does not recommend creation of a T-RPS that subsidizes biodiesel blended with heating oil at this time. Instead, it recommends further, more holistic study of available mechanisms and technologies to support building decarbonization in the next iteration of the Comprehensive Energy Strategy.

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[394] Technical meeting Presentations, Renewable Portfolio Standard as a Mechanism for Promoting Deployment of Renewable Thermal Technologies, DEEP, New Britain, CT, Dec. 9, 2019, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/473a61d275e0883e852584d2006b3bcd?OpenDocument.

[395] *See* DEEP, "Opportunity for Public Comment: Renewable Portfolio Standard for Thermal Resources" Nov. 19, 2019, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/47bf3b4f33bf2fbb852584d5004b5b20/$FILE/Request%20for%20comments%20-%20Revised%20FINAL.pdf.

[396] *See* DEEP, "Notice of Technical Meeting and Opportunity for Public Comment: Biodiesel as a Thermal Resource" June 24, 2020, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/a984e5cfadd86b3f85258591005b1363/$FILE/Notice%20of%20July%20technical%20meeting.pdf and "Biodiesel as a Thermal Resource," July 13, 2020, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/14b7939fcecae1b1852585c1006f5ca5/$FILE/Presentation.pdf.

[397] *See*, CEMA, "Supplemental Public Comment Biodiesel as a Thermal Resource," July 22, 2020, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/7fa9d821d3955af4852585af005eac3b?OpenDocument (CEMA argues for a T-RPS program in Connecticut, like the Alternative Portfolio Standard program in Massachusetts, that would channel revenues for biodiesel through fuel oil retailers rather than to customers, in contrast to revenues for renewable thermal energy production using other technologies that would be channeled directly to the household or business employing the technology).

Biodiesel as a thermal decarbonization strategy

Heating oil is the primary fuel used by about 40 percent of residences and perhaps 25 percent of commercial buildings in Connecticut, and it contributes 47 percent of thermal GHG emissions in these sectors.[398] Combusting a gallon of traditional heating oil produces 22.5 pounds of carbon dioxide.

Biodiesel is a liquid biofuel that in most respects is functionally equivalent to conventional fuel oil.[399] Some biodiesel, including most that is manufactured in Connecticut, is produced from waste biological feedstocks, including used cooking oil and waste food grease. Nationally, however, most biodiesel is produced with virgin feedstocks, principally soy oil. Biodiesel is routinely blended with heating oil (and diesel fuel for vehicles) and in 2016 constituted about seven percent of fuel oil distributed in Connecticut.[400] One of the clear advantages of biodiesel as a renewable thermal technology in Connecticut is that significantly higher proportions – up to at least B20, and potentially well beyond – can be burned in oil-fired boilers without necessitating alterations in that equipment.[401] Given lower lifecycle GHG emissions attributed to biodiesel (discussed below), the state's fuel-oil dealers, who have seen a 37 percent decline in residential sales since 2004[402], contend this offers a path for them to transition to delivery of clean fuels.[403] The Department requested but received no definitive information on the magnitude and cost of distribution-infrastructure upgrades that would be needed for Connecticut's fuel-oil wholesalers to provide statewide distribution of B20 and B50 blends.

This section reviews several aspects of expanding the use of biodiesel blends in Connecticut:

- nitrogen oxide emissions from biodiesel combustion;
- lifecycle greenhouse gas benefits of biodiesel, including how feedstock and production location may affect GHG emissions reductions attributable to biodiesel;
- the potential for biodiesel incentives to perpetuate use of fossil fuels;
- development of standards for blends beyond B20 and equipment to burn this fuel; and

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[398] *See* DEEP, Comprehensive Energy Strategy: Building Sector, 2018, p. 68, *available at* https://portal.ct.gov/-/media/DEEP/energy/CES/BuildingsSectorpdf.pdf; U.S. Energy Information Administration, Commercial Buildings Energy Consumption Survey, Table B5, *available at* https://www.eia.gov/consumption/commercial/data/2012/bc/pdf/b5.pdf; DEEP, "2017 GHG Inventory Final Public – supporting data," *available at* https://portal.ct.gov/DEEP/Climate-Change/CT-Greenhouse-Gas-Inventory-Reports.

[399] *See* Alternative Fuels Data Center, "Biodiesel," *available at* https://afdc.energy.gov/fuels/biodiesel.html.

[400] UConn study commissioned by CEMA, "Data on Biodiesel Concentration in CT fuel oil samples, 1/18/2016-8/26/2016," September 2016.

[401] B20 is a blend of 20 percent biodiesel and 80 percent petroleum fuel oil. B50 is 50 percent biodiesel.

[402] *See* U.S. Energy Information Administration, "Connecticut total distillate adjusted sales/deliveries to residential consumers," available at https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=KD0VARSCT1&f=A.

[403] *See*, CEMA, "Supplemental Public Comment Biodiesel as a Thermal Resource," July 22, 2020, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/7fa9d821d3955af4852585af005eac3b?OpenDocument; CEMA, "Biodiesel as a Thermal Resource," July 8, 2020, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/024233f02356cf04852585a0005db990?OpenDocument; and Sack Energy, "Comments on Biodiesel as a Thermal Resource," July 8, 2020, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/fc2892ba91d65bb1852585a40008d307/$FILE/Ct%20TREC%207-13-2020.pdf.

- other air-quality issues.

Nitrogen Oxide (NOx) Emissions

Connecticut is the only state in New England classified as a non-attainment area for ozone under federal air-quality standards, and the state's status is more likely to decline than improve as ozone standards become more stringent. NOx is a potent precursor for ozone formation, obligating the state to aggressively pursue policies to reduce NOx emissions within the state and resist developments that would introduce additional NOx emissions. Both NOx and ozone damage the human respiratory system. A gallon of fuel oil combusted in a residential boiler produces about 0.018 pounds of NOx. An emissions study cited by NBB points to lower NOx concentrations in emissions from boilers burning biodiesel relative to boilers burning conventional fuel oil.[404] However, the available literature is inconsistent on this point: some studies find lower concentrations, some higher concentrations, and some equivalent concentrations.[405] And NBB concedes that, owing to the lack of federal analytical protocol, available data on NOx emissions associated with burning biodiesel in boilers (as opposed to vehicle engines) is quite limited and the quality of data is generally poor.[406]

In the draft IRP, DEEP expressed concern that even if NOx concentrations in the exhaust of boilers burning biodiesel are somewhat lower or equivalent to boilers burning unblended heating oil, the mass of NOx emissions delivered to the atmosphere may be higher per mmBTU of fuel burned. The agency pointed out that the only study addressing mass of emissions rather than merely concentration of emissions appears to be a 2008 U.S. EPA report that found burning biodiesel made from soy oil resulted in a 12 percent increase in the mass of NOx emissions.[407] NBB subsequently commissioned an analysis by Brookhaven National Laboratory that (a) found fault with the EPA study's methodology and (b) applied an EPA protocol translating emissions concentration to mass of emissions to a range of biodiesel emissions studies. This analysis concluded that substituting biodiesel for fuel oil reliably reduces the mass of boiler NOx

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[404] *See,* Brookhaven National Laboratory, C.R. Krishna, "Biodiesel Blends in Space Heating Equipment," May 2004, *available at* https://www.nrel.gov/docs/fy04osti/33579.pdf.

[405] *See, e.g.,* Afshin Ghorbani et al., "A comparative study of combustion performance and emission of biodiesel blends and diesel in an experimental boiler," Applied Energy 88(12): 4725-4732, 2011, *available at* https://www.sciencedirect.com/science/article/pii/S0306261911004016; A. Macor and P. Pavonello, "Performance and emissions of biodiesel in a boiler for residential heating," Energy 34(12): 2025-2032, 2009, *available at* https://www.sciencedirect.com/science/article/abs/pii/S0360544208002016; Hamid Momahedi Heravi et al., "The effects of various vegetable oils on pollutant emissions of biodiesel blends with gasoil in a furnace," Thermal Science 19(6): 1977-1984, 2015, *available at* http://www.doiserbia.nb.rs/img/doi/0354-9836/2015/0354-98361500022H.pdf; Danielle Makaire et al., "The use of liquid biofuels in heating systems: A review," 33rd Task Leaders Meeting of the International Energy Agency Implementing Agreement on Energy Conservation and Emissions Reduction in Combustion, 07-11 August 2011, Lund, Sweden, *available at* https://orbi.uliege.be/bitstream/2268/95986/1/TLM_2011_Lund_110711_2.pdf.

[406] National Biodiesel Board, "Attachment A: Biodiesel and NOx Emissions in Home Heating Oil Equipment," Feb. 17, 2021, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/b4c551c6e2fcad6385258680004d0554/$FILE/FINAL%20IRP%20Comments%20Attachment%20A%20NOx%202%2016%202021.docx.

[407] U.S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory, Air Pollution Prevention and Control Division, C. A. Miller, "Characterizing Emissions from the Combustion of Biofuels," 2008, Tables 4 and 5, *available at* https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NRMRL&dirEntryId=191572.

emissions.[408] While this analysis does not definitively settle the issue, it somewhat allays DEEP's concern. The agency recognizes that any NOx impact from expanded use of biodiesel would become significant only as biodiesel blending rates ramp up markedly over a period of years, providing time for additional analyses to be performed. Under the recently passed Public Act 21-181, the proportion of biodiesel in heating oil sold in the state would not be required to exceed 20 percent until 2035, at which point a blend of B50 would be required.[409]

GHG Benefits and Lifecycle Assessment

Representatives of the biodiesel industry and fuel oil dealers have emphasized that significant reductions in GHG emissions result when biodiesel displaces fuel oil. The reductions they highlight are calculated on the basis of lifecycle analysis (LCA) studies that take into account GHG emissions (and sinks) at multiple stages for each fuel, during production and processing of raw materials, manufacturing, shipping, delivery, and eventual combustion. A recent study led by researchers at Argonne National Laboratory estimated that biodiesel produced with virgin soy oil yields lifecycle GHG reductions of 66-72 percent.[410] Biodiesel shines in such analyses primarily because growing the crops that provide the fuel's feedstocks sequesters carbon from the atmosphere, substantially offsetting carbon emissions that occur at subsequent stages.

Although lifecycle analyses are increasingly compelling as the sophistication of the research improves, it is important to recognize that the standard protocol for state-level GHG inventories, including Connecticut's, is not based not on lifecycle analysis.[411] This convention is predicated on recognition of the need for formal inventories to avoid double-counting emissions and emissions reductions that, for most fuels and other products, occur across multiple jurisdictions.[412] Piecemeal alteration of Connecticut's inventory to selectively accommodate lifecycle analysis for an individual technology, such as biodiesel, would raise challenging methodological issues.

Public Act 21-181 directs DEEP to explore a lifecycle analysis of low-carbon fuel blends in its Comprehensive Energy Strategy approved after October 1, 2021 from a variety of angles, including their possible contributions to the state's GHG targets on a lifecycle basis and the ability of a thermal portfolio

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[408] T. Butcher, "NOx emissions – Biodiesel vs Petroleum Heating Fuels," Brookhaven National Laboratory, Feb. 12, 2021, available at http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/b4c551c6e2fcad6385258680004d0554/$FILE/IRP%20Comments%20Attachment%20B%20Dr.%20Boucher.pdf.

[409] Public Act No. 21-181, An Act Concerning a Low-Carbon Fuel blend of Heating Oil , *available at* https://www.cga.ct.gov/2021/ACT/PA/PDF/2021PA-00181-R00HB-06412-PA.PDF

[410] Rui Chen, et al., "Life cycle energy and greenhouse gas emission effects of biodiesel in the United States with induced land use change impacts," Bioresource Technology 251: 249-258, 2018. The comparison is between biodiesel and diesel fuel.

[411] See U.S. Environmental Protection Agency, "State Inventory and Projection Tool," https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool.

[412] See U.S. Environmental Protection Agency, "Life-Cycle GHG Accounting Versus GHG Emission Inventories," 2010, available at https://www.epa.gov/sites/production/files/2016-03/documents/life-cycle-ghg-accounting-versus-ghg-emission-inventories10-28-10.pdf. EPA's State Inventory and Projection Tool is based on the National Inventory, which in turn is based on protocols adopted by the international community. On alignment between the federal inventory and these international protocols, see Box ES-1 in U.S. EPA, "U.S. Greenhouse Gas Inventory: Executive Summary," 2021, available at https://www.epa.gov/sites/production/files/2021-04/documents/us-ghg-inventory-2021-chapter-executive-summary.pdf.

standard to further reduce GHG emissions on a lifecycle basis.[413] DEEP will incorporate this assessment in its review of best practices for biofuel GHG accounting in the next Comprehensive Energy Strategy. The Department recognizes that two related issues – which highlight the complexity of lifecycle analysis – are important in this context:

(1) *Feedstock* – The type of feedstock used in producing biodiesel affects the relative GHG emission reductions associated with using this fuel. The GHG benefits of employing waste feedstocks are more straightforward – and more substantial – than the benefits of employing virgin feedstocks such as soy oil.[414] [415] The magnitude of biodiesel's GHG benefits, and how they compare with those of other renewable thermal technologies, ultimately is heavily dependent on the feedstock. The Department also is cognizant of the potential for use of virgin oil to negatively impact food markets.[416] Notably, Massachusetts's thermal RPS program limits support for biodiesel to fuel made with waste feedstocks.[417]

(2) *Production location* – Oral and written comments and published data provided by biodiesel advocates ultimately do not provide sufficient clarity on an issue central to understanding the environmental benefits of significantly expanded use of biodiesel within Connecticut: the relative proportions of biodiesel consumed in Connecticut that would be produced in-state, produced elsewhere in the Northeast, produced elsewhere in the United States, and imported from other

[413] Public Act No. 21-181 An Act Concerning a Low-Carbon Fuel Blend of Heating Oil, *available at* https://www.cga.ct.gov/2021/ACT/PA/PDF/2021PA-00181-R00HB-06412-PA.PDF.

[414] Attributing the lifecycle GHG emissions to the original virgin product (e.g., cooking oil), the GHG emissions attributable to the subsequent waste product (e.g., waste cooking oil) used as a biodiesel feedstock are low (primarily from local transport and processing of the feedstock).

[415] In California's Low-Carbon Fuel Standard, the Energy Economy Ratio accounts for feedstock, production location, and other factors. The Air Resources Board indicates that, by accounting for such factors, the carbon intensity of biodiesel ranges from around 10 percent of diesel to around 70 percent of diesel. *See* https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities. In the Board's quantitative model for biodiesel carbon intensity, the GHG emissions factor for rendering of virgin soy oil is 3.3 times higher than the emissions factor for rendering of used cooking oil. *See* https://www.arb.ca.gov/fuels/lcfs/ca-greet/tier1-bdrd-calculator-corrected.xlsm?_ga=2.4269299.1309740305.1606832068-1783880760.1605623460.

[416] Advocates have argued that manufacturing biodiesel with virgin soy oil (currently one of the principal feedstocks domestically and internationally) does not drive the market for soybeans – and hence does not negatively affect the global food supply and decisions about agricultural land use. However DEEP recognizes that this conclusion ultimately hinges on fossil fuel prices remaining low (a condition that will not necessarily continue to prevail) and demand for biodiesel remaining relatively modest (a condition that biodiesel advocates are actively working to change). It is clear the soy economy is now dominated by markets for protein, rather than markets for fuel, such that manufacturing incrementally more biodiesel with soy oil would not mean impinging on food use of soy oil. But it is not clear that it will remain so indefinitely. National experience with corn-based ethanol as an automotive fuel and international experience with wood as a fuel for electricity generation demonstrate that renewable energy initiatives are capable of dramatically shifting agricultural markets and agricultural land-use decisions and can have significant environmental downsides. Bringing a more holistic, long-term view of biodiesel feedstock markets into focus should be a prerequisite for incorporating biodiesel from virgin feedstocks into a portfolio standard.

[417] Massachusetts Department of Energy Resources, "Biofuels in the Massachusetts' Alternative Energy Portfolio Standard," PowerPoint presentation, February 12, 2018.

countries.[418] While the lifecycle GHG benefits of biodiesel as compared to those of fuel oil would be significant in any case, it is not clear how the lifecycle benefits of biodiesel would compare to those of other renewable thermal resources. Any benefits would be less significant for biodiesel shipped from outside the region and especially outside North America. Net benefits from reduced emissions of other pollutants (e.g., particulates) also would diminish with distance from manufacturer to boiler. Biodiesel advocates' inability to project the likely shape of the fuel's market in the coming years – although understandable, given the dynamic character of global agricultural and fuel markets – limits the accuracy of projections of the magnitude of benefits that biodiesel can be expected to provide as compared to those provided by other renewable thermal resources, especially over the long term.

Perpetuation of Fossil Fuel Use

The Connecticut Energy Marketers Association (CEMA), which represents the state's fuel oil dealers, stated: "We are confident that the potential to transition homes and businesses to B100 … is the future of the deliverable fuel industry." CEMA has publicly committed "to reduce greenhouse gas emissions based on 2001 emissions by a minimum 45% by 2030 and an 80% reduction by 2050."[419] DEEP notes that the pace of the ramp-up of biodiesel deployment CEMA envisions, if supported with public subsidies, would mean at least a decade of such subsidies for relatively low levels of biodiesel in heating fuel – in essence, subsidies for a product containing *primarily fossil fuel*. Only a schedule of more rapid acceleration to very high percentages of biodiesel in Connecticut's fuel oil supply (e.g., B75 or greater) would prevent biodiesel subsidies from, in effect, supporting long-term extensive use of fossil fuels that have already received decades of extensive federal subsidies and that still rely heavily on an ability to externalize large environmental and health costs.[420] As noted above, under Public Act 21-181 the mandatory statewide blend rate will not exceed 20 percent until 2035 and even then does not exceed 50 percent. If this requirement were paired with a T-RPS obligation for biodiesel, Connecticut would face the prospect of well over a decade of public subsidies for fuel blends containing primarily fossil oil and no mandate to go to blends beyond B50.[421]

Standards

Escalation of biodiesel blending beyond B20 cannot proceed until: Underwriters Laboratories develops protocols for boilers burning blends above B20; boiler manufacturers certify warranties under those protocols; and, more basic, ASTM International approves fuel-quality standards for biodiesel blends

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[418] *See, e.g.,* National Biodiesel Board, "Response to June 24, 2020, Notice of Technical Meeting and Opportunity for Public Comment: Biodiesel as a Thermal Resource," July 8, 2020, p. 2, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/b1ee3fdd1793cba3852585a0005df5d1/$FILE/NBB%20Comments%20-%20CT%20DEEP%20Biodiesel%20Technical%20%207-8-2020%20FINAL.pdf.

[419] CEMA, "Biodiesel as a thermal resource," July 8, 2020, p. 1, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/024233f02356cf04852585a0005db990/$FILE/DEEP%20CEMA%20Biodiesel%20as%20a%20Thermal%20Resource.docx.

[420] On subsidies and externalization of costs, see Environmental and Energy Study Institute, "Fossil Fuel Subsidies: A Closer Look at Tax Breaks and Societal Costs," 2019, *available at* https://www.eesi.org/papers/view/fact-sheet-fossil-fuel-subsidies-a-closer-look-at-tax-breaks-and-societal-costs#1%22

[421] Public Act No. 21-181 An Act Concerning a Low-Carbon Fuel Blend of Heating Oil , *available at* https://www.cga.ct.gov/2021/ACT/PA/PDF/2021PA-00181-R00HB-06412-PA.PDF.

beyond B20.[422] A timeline provided by the NBB suggests these processes will not be completed until 2024-2027. And in the meantime, even among biodiesel advocates there apparently is no consensus on whether burning blends beyond B50 would require relatively minor boiler adjustments or, instead, burner replacement.[423] Until these issues are resolved and a path to deployment of high biodiesel blends across the state's residential and commercial heating sectors is clear, a move to a portfolio standard that includes biodiesel would be premature.

Other Air-Quality Parameters

National Biodiesel Board's claims for large reductions in emissions of sulfur oxides (SOx) and particulate matter (PM) when BD is substituted for fuel oil are based largely on comparison with high-sulfur fuel oil that has not been sold in Connecticut since at least the late 1990s.[424] Although BD has lower sulfur content than the ultra-low sulfur diesel (ULSD) sold for home heating in New England since 2018 and thus can be expected to produce lower SOx and PM, emissions of SOx and PM with ULSD are already so low that the additional benefit from substituting BD would be almost negligible. Claims by Diversified Energy Specialists that failing to deploy biodiesel for home heating in environmental justice communities "perpetuates systemic inequality" may assume an unrealistically large difference between emissions from biodiesel and emissions from ULSD; but in the end the claim cannot be fully evaluated without data on the prevalence of oil-fired boilers in environmental justice communities.[425]

Based on the considerations outlined here, significant questions remain about how scalable emission reductions are for biodiesel blends above B20. The lack of standards and certifications makes an immediate move beyond B20 impossible. Lingering questions remain about whether more extensive use of biodiesel would reduce or exacerbate NOx emissions – which is a particular concern in environmental justice communities already disproportionately burdened by poor air quality. Significant questions remain about how biodiesel's GHG benefits compare with those provided by other renewable thermal technologies. Finally, looming over all of these considerations is the reality that, to avoid indirectly subsidizing fossil fuels, T-RPS support for biodiesel would need to fairly quickly be limited to support for

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[422] National Biodiesel Board, "Response to June 24, 2020, Notice of Technical Meeting and Opportunity for Public Comment: Biodiesel as a Thermal Resource," July 8, 2020, p. 15, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/b1ee3fdd1793cba3852585a0005df5d1/$FILE/NBB%20Comments%20-%20CT%20DEEP%20Biodiesel%20Technical%20%207-8-2020%20FINAL.pdf.

[423] *See*, National Biodiesel Board, "Response to June 24, 2020, Notice of Technical Meeting and Opportunity for Public Comment: Biodiesel as a Thermal Resource," July 8, 2020, p. 15, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/b1ee3fdd1793cba3852585a0005df5d1/$FILE/NBB%20Comments%20-%20CT%20DEEP%20Biodiesel%20Technical%20%207-8-2020%20FINAL.pdf, ("[H]aving the flame sensor adjusted … is recommended for blends over B50. Doing so would entail a basic service visit from a heating appliance technician"); *But c.f.*, Sack Energy, "Comments on Biodiesel as a Thermal Resource," July 8, 2020, p. 4, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/fc2892ba91d65bb1852585a40008d307/$FILE/Ct%20TREC%207-13-2020.pdf (for blends beyond B50 "there will be a need of a replacement burner. This can range in price from $650 to $1,800").

[424] *See* Shelby Neal, National Biodiesel Board, "Response to June 24, 2020 Notice of Technical Meeting and Opportunity for Public Comment: Biodiesel as a Thermal Resource," July 8, 2020.

[425] *See* Diversified Energy Specialists, "2020 Integrated Resources Plan Draft comments," Feb. 15, 2021, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/92fce2b86c1048f78525867e00567ea7/$FILE/Diversified%20Energy%20Specialists%20Comments%20on%20the%20CT%20Draft%20IRP.pdf.

very high blend levels. These issues would need to be resolved to determine circumstances under which biodiesel blended into delivered heating oil would be capable of providing meaningful net environmental and social benefits and how these benefits compare with those provided by other renewable thermal technologies.

Thermal RPS as a vehicle for thermal decarbonization

Emissions reductions in the thermal sector needed for Connecticut to achieve its GHG targets will be achieved through a combination of reducing energy losses from the building envelope, transitioning to lower or zero-emission fuels for heating, and transitioning to inherently more efficient and cleaner heating and cooling equipment. As further described in Objective 5 herein, Connecticut currently incentivizes building-envelope improvements and, to a lesser degree, electric heat pumps through the C&LM program, the State's utility-administered energy efficiency program. A variety of measures can improve the emissions profile of fuels for heating equipment, including biodiesel blended with heating oil, as well as solar water heating, solar space heating, and renewable natural gas. Other states and jurisdictions have developed, are developing, or are considering initiatives to support some or all of these measures, such as: establishing thermal renewable portfolio standards; developing group-buying programs for renewable thermal equipment; incorporating GHG emissions reduction in utilities' primary cost-effectiveness tests; changing building codes to expand use of renewable thermal technologies; mandating use of this equipment in new government buildings; promoting use of district heating; requiring thermal fossil-fuel utilities and distributors to contribute to energy-efficiency funds; instituting low-carbon thermal fuel standards; instituting carbon taxes on thermal fuels; and prohibiting new natural-gas hookups.

Public Act 19-35 requires this IRP to consider only one option: adoption of a thermal RPS. The Department has unresolved concerns about the two primary paths for employing the existing RPS as a vehicle for a thermal RPS:

T-RPS as an expansion of existing RPS – A thermal RPS *expanding* Connecticut's existing RPS – that is, imposing a thermal obligation on top of existing renewable-electricity obligations – would increase the price of electricity. It would place an additional regulatory compliance obligation on electricity suppliers, who would pass compliance costs on to electricity customers in the form of higher rates. Under this scenario, a subsidy for heating-oil retailers would be supported by electricity ratepayers. In essence, customers heating with electric technologies would subsidize customers heating with fossil fuels. This cross-subsidization would have three negative policy consequences:

- It would undermine other Connecticut climate policies, including electrification of vehicles and adoption of electric heat pumps, by making these technologies more expensive to operate.
- It would exacerbate the problem that Connecticut electric ratepayers already face the highest electricity prices in the continental United States as well as rising consumer utility expenses (due in part to escalating, climate-driven summer consumption of electric cooling[426]).

[426] DEEP analysis of National Weather Service temperature data from the weather station at Bradley Airport indicates that between 1905 and 2019, the prevalence of "cooling degree days" increased from ~640 to ~870 annually and the prevalence of days of 90˚ F. or higher increased from ~8 to ~23 annually.

- It would exacerbate the challenges of the economic downturn prompted by the COVID-19 pandemic, in which affordability of electricity is already an acute problem.

Requiring customers of Connecticut's two investor-owned electric utilities[427] to financially support non-electric resources in a T-RPS also would thwart the principle of cost causation: it would make electric ratepayers responsible for subsidizing the use of fuels that are unrelated to electricity generation, transmission, and distribution. The costs of compliance with the thermal RPS would be passed on to electric ratepayers in the form of higher electric (generation) rates. Meanwhile fossil fuel suppliers, who have no compliance obligation under the existing RPS (and are subject to no carbon surcharge, as electricity suppliers are), would financially benefit from this arrangement by enjoying a subsidy disproportionately supported by ratepayers other than their own retail customers. In contrast, a program based on the principle of cost causation would equitably distribute these costs among all thermal providers – electric, oil, gas, and propane – in proportion to the fossil-fueled thermal energy they provide.

NBB has argued that it would be cheaper for electricity ratepayers as a whole to subsidize the use of biodiesel through a thermal RPS program than to support expanded electric generation and distribution for broad use of electric heat pumps.[428] It is not clear that this is so. The next Comprehensive Energy Strategy will explore the relative value and potential of various approaches for thermal decarbonization, and only at that point will there be a firm basis for understanding the likely scope and pace of statewide heat pump deployment. At the same time, the various grid-modernization proceedings PURA is conducting are weighing new rate structures and demand-response programs, and DEEP is investigating demand-response programs within the C&LM Plan, all of which could reduce or offset any grid impacts of heat pumps. Only as this work is completed will there be a firm basis for understanding how much pressure broad deployment of heat pumps would be likely to place on grid infrastructure and electricity prices – and how the price impact of this pressure would compare with that of electricity ratepayers subsidizing non-electric fuels.

T-RPS as carve-out within existing RPS – Some biodiesel advocates have suggested that a thermal RPS should be structured as a carve-out *within* Class I of the existing RPS. The carve-out approach would help to mitigate incremental costs of the program, because it would not place additional compliance obligations on electricity suppliers. However, it would undercut traditional RPS support for needed expansion of renewable resources on the electric grid. The Class I obligation is scheduled to escalate from 21 percent in 2020 to 40 percent in 2030 in order to vigorously push the region's electricity-generation fleet toward clean technologies.[429] (More information on Connecticut's RPS is provided in the discussion of Objective 2.) Shifting part of that obligation to non-electric resources such as biodiesel inevitably would diminish the program's market support for zero-carbon electricity, which in turn would reduce the carbon-

[427] As further described in Objective 1, only the two investor-owned utilities, Eversource and United Illuminating, are subject to Connecticut's RPS requirements. Customers of the state's municipally owned utilities are not.

[428] E.g., National Biodiesel Board, "Response to June 24, 2020, Notice of Technical Meeting and Opportunity for Public Comment: Biodiesel as a Thermal Resource," July 8, 2020, p. 22, *available at* http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/b1ee3fdd1793cba3852585a0005df5d1/$FILE/NBB%20Comments%20-%20CT%20DEEP%20Biodiesel%20Technical%20%207-8-2020%20FINAL.pdf.

[429] Connecticut Renewable Portfolio Standard, *available at* https://portal.ct.gov/PURA/RPS/Renewable-Portfolio-Standards-Overview.

emissions-reduction benefit of thermal and transportation electrification – undermining the central decarbonization strategy envisioned by the Governor's Council on Climate Change.[430]

Conclusion

In light of the concerns outlined here, a thermal RPS should not be created in Connecticut to support biodiesel blended into fuel oil at this time. If there were a desire to support the biodiesel industry despite these concerns, in keeping with principles of cost causation, support for biodiesel to reduce GHG emissions associated with delivered fuel oil should be provided not by electricity ratepayers, but by delivered fuel oil suppliers and their customers. All standards, protocols, and certifications needed for high-biodiesel blends (e.g., B75 or higher) and their widespread use would need to be in place prior to any significant commitment to support biodiesel deployment. And it would be advisable to restrict allowable feedstocks to waste food oils and greases, as in the Massachusetts program. In the interim, the State can assess whether public policy aims relating to biodiesel can be achieved at lower cost through the new statewide biodiesel blending mandate in Public Act 21-181.

In the upcoming Comprehensive Energy Strategy process, in addition to the consideration of the lifecycle analyses that are called for in Public Act 21-181, DEEP will conduct a broad exploration of mechanisms – including carbon pricing, low carbon fuel standards, and a thermal RPS – to support transformation of the thermal sector, inclusive of all viable renewable thermal measures, not just biodiesel. Any mechanism established in Connecticut should adhere to the principle of cost causation, distributing the cost of subsidies equitably among the parties in proportion to their carbon emissions. It should avoid driving up electricity costs. And it should not come at the expense of diminishing the existing RPS program's incentives for clean electricity.

With respect to a thermal RPS in particular, the Comprehensive Energy Strategy will explore a number of other design factors:

- breadth of the array of renewable thermal technologies that should be included;
- whether the state should establish a formal target for deployment of renewable thermal technologies;
- the role of metering;
- whether RECs should be tradeable;
- whether priority should be given to technologies producing zero emissions at point of use;
- whether woody biomass should be included, and, if so, how the resulting air-quality impacts should be regulated;
- how the value of Alternative Compliance Payments should be established; and

430 The Council sees decarbonization of the electricity sector as the linchpin of decarbonization in the transportation and thermal sectors. *See* Building a Low-Carbon Future for Connecticut, 2018, https://portal.ct.gov/-/media/DEEP/climatechange/publications/BuildingaLowCarbonFutureforCTGC3Recommendationspdf.pdf.

- how such a program should be structured so that the administrative burden on state agencies would be manageable.[431]

Reviewing these and other issues raised in stakeholders' written and oral comments, the Comprehensive Energy Strategy will make a recommendation on whether a comprehensive T-RPS or other program reflecting cost causation and supporting resources based upon sound evidence of relative GHG reduction benefits should be established and, if so, how it should be designed. For now, this IRP recommends against creation of a T-RPS that subsidizes non-electric technologies within the existing, electricity-ratepayer-funded RPS.

[431] *See* DEEP, "Renewable Thermal Portfolio Standard Programs in New England States," Nov. 2019, http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/47469b57e3d1a355852584c40070531d/$FILE/Background.pdf.

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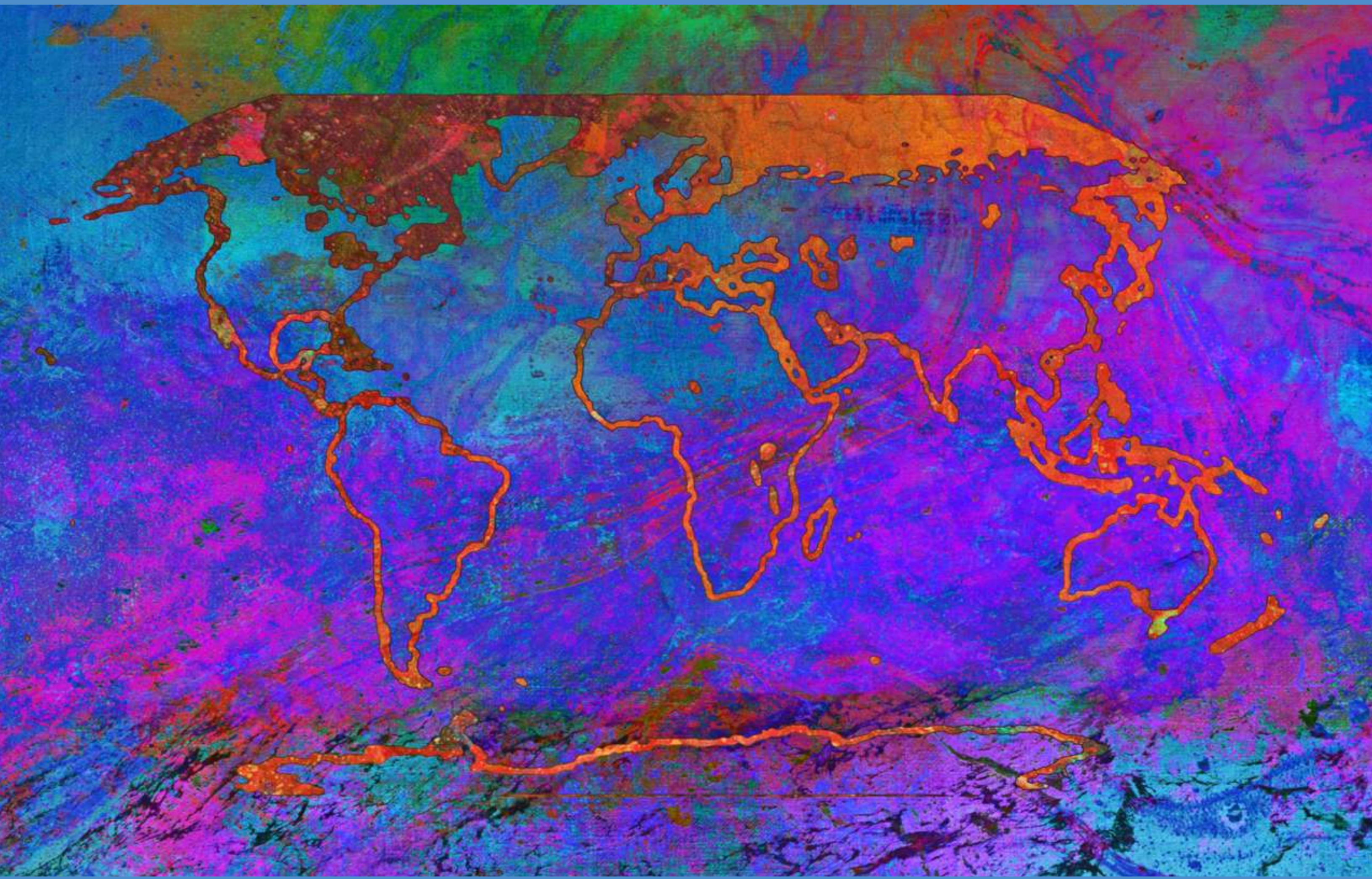
Climate Change 2021

The Physical Science Basis

Summary for Policymakers



WGI

Working Group I contribution to the
Sixth Assessment Report of the
Intergovernmental Panel on Climate Change

WMO UNEP

Summary for Policymakers

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Table of Contents

Introduction

This Summary for Policymakers (SPM) presents key findings of the Working Group I (WGI) contribution to the IPCC's Sixth Assessment Report (AR6)[1] on the physical science basis of climate change. The report builds upon the 2013 Working Group I contribution to the IPCC's Fifth Assessment Report (AR5) and the 2018–2019 IPCC Special Reports[2] of the AR6 cycle and incorporates subsequent new evidence from climate science[3].

This SPM provides a high-level summary of the understanding of the current state of the climate, including how it is changing and the role of human influence, the state of knowledge about possible climate futures, climate information relevant to regions and sectors, and limiting human-induced climate change.

Based on scientific understanding, key findings can be formulated as statements of fact or associated with an assessed level of confidence indicated using the IPCC calibrated language[4].

The scientific basis for each key finding is found in chapter sections of the main Report, and in the integrated synthesis presented in the Technical Summary (hereafter TS), and is indicated in curly brackets. The AR6 WGI Interactive Atlas facilitates exploration of these key synthesis findings, and supporting climate change information, across the WGI reference regions[5].

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[1] Decision IPCC/XLVI-2.

[2] The three Special reports are: Global warming of 1.5°C: an IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (SR1.5); Climate Change and Land: an IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems (SRCCL); IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC).

[3] The assessment covers scientific literature accepted for publication by 31 January 2021.

[4] Each finding is grounded in an evaluation of underlying evidence and agreement. A level of confidence is expressed using five qualifiers: very low, low, medium, high and very high, and typeset in italics, for example, *medium confidence*. The following terms have been used to indicate the assessed likelihood of an outcome or a result: *virtually certain* 99–100% probability, *very likely* 90–100%, *likely* 66–100%, *about as likely as not* 33–66%, *unlikely* 0–33%, *very unlikely* 0–10%, *exceptionally unlikely* 0–1%. Additional terms (*extremely likely* 95–100%, *more likely than not* >50–100%, and *extremely unlikely* 0–5%) may also be used when appropriate. Assessed likelihood is typeset in italics, for example, *very likely*. This is consistent with AR5. In this Report, unless stated otherwise, square brackets [x to y] are used to provide the assessed *very likely* range, or 90% interval.

[5] The Interactive Atlas is available at https://interactive-atlas.ipcc.ch

A. The Current State of the Climate

Since AR5, improvements in observationally based estimates and information from paleoclimate archives provide a comprehensive view of each component of the climate system and its changes to date. New climate model simulations, new analyses, and methods combining multiple lines of evidence lead to improved understanding of human influence on a wider range of climate variables, including weather and climate extremes. The time periods considered throughout this Section depend upon the availability of observational products, paleoclimate archives and peer-reviewed studies.

A.1 It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred.

{2.2, 2.3, Cross-Chapter Box 2.3, 3.3, 3.4, 3.5, 3.6, 3.8, 5.2, 5.3, 6.4, 7.3, 8.3, 9.2, 9.3, 9.5, 9.6, Cross-Chapter Box 9.1} **(Figure SPM.1, Figure SPM.2)**

A.1.1 Observed increases in well-mixed greenhouse gas (GHG) concentrations since around 1750 are unequivocally caused by human activities. Since 2011 (measurements reported in AR5), concentrations have continued to increase in the atmosphere, reaching annual averages of 410 ppm for carbon dioxide (CO_2), 1866 ppb for methane (CH_4), and 332 ppb for nitrous oxide (N_2O) in 2019[6]. Land and ocean have taken up a near-constant proportion (globally about 56% per year) of CO_2 emissions from human activities over the past six decades, with regional differences (*high confidence*)[7]. {2.2, 5.2, 7.3, TS.2.2, Box TS.5}

A.1.2 Each of the last four decades has been successively warmer than any decade that preceded it since 1850. Global surface temperature[8] in the first two decades of the 21st century (2001-2020) was 0.99 [0.84-1.10] °C higher than 1850-1900[9]. Global surface temperature was 1.09 [0.95 to 1.20] °C higher in 2011–2020 than 1850–1900, with larger increases over land (1.59 [1.34 to 1.83] °C) than over the ocean (0.88 [0.68 to 1.01] °C). The estimated increase in global surface temperature since AR5 is principally due to further warming since 2003–2012 (+0.19 [0.16 to 0.22] °C). Additionally, methodological advances and new datasets contributed approximately 0.1ºC to the updated estimate of warming in AR6[10].

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[6] Other GHG concentrations in 2019 were: PFCs (109 ppt CF_4 equivalent); SF_6 (10 ppt); NF_3 (2 ppt); HFCs (237 ppt HFC-134a equivalent); other Montreal Protocol gases (mainly CFCs, HCFCs, 1032 ppt CFC-12 equivalent). Increases from 2011 are 19 ppm for CO_2, 63 ppb for CH_4 and 8 ppb for N_2O.

[7] Land and ocean are not substantial sinks for other GHGs.

[8] The term 'global surface temperature' is used in reference to both global mean surface temperature and global surface air temperature throughout this SPM. Changes in these quantities are assessed with *high confidence* to differ by at most 10% from one another, but conflicting lines of evidence lead to *low confidence* in the sign of any difference in long-term trend. {Cross-Section Box TS.1}

[9] The period 1850–1900 represents the earliest period of sufficiently globally complete observations to estimate global surface temperature and, consistent with AR5 and SR1.5, is used as an approximation for pre-industrial conditions.

[10] Since AR5, methodological advances and new datasets have provided a more complete spatial representation of changes in surface temperature, including in the Arctic. These and other improvements have additionally increased the estimate of global surface temperature change by approximately 0.1 ºC, but this increase does not represent additional physical warming since the AR5.

A.1.3 The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019[11] is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to 0.1°C, and internal variability changed it by –0.2°C to 0.2°C. It is *very likely* that well-mixed GHGs were the main driver[12] of tropospheric warming since 1979, and *extremely likely* that human-caused stratospheric ozone depletion was the main driver of cooling of the lower stratosphere between 1979 and the mid-1990s.
{3.3, 6.4, 7.3, Cross-Section Box TS.1, TS.2.3} **(Figure SPM.2)**

A.1.4 Globally averaged precipitation over land has *likely* increased since 1950, with a faster rate of increase since the 1980s (*medium confidence*). It is *likely* that human influence contributed to the pattern of observed precipitation changes since the mid-20th century, and *extremely likely* that human influence contributed to the pattern of observed changes in near-surface ocean salinity. Mid-latitude storm tracks have *likely* shifted poleward in both hemispheres since the 1980s, with marked seasonality in trends (*medium confidence*). For the Southern Hemisphere, human influence *very likely* contributed to the poleward shift of the closely related extratropical jet in austral summer.
{2.3, 3.3, 8.3, 9.2, TS.2.3, TS.2.4, Box TS.6}

A.1.5 Human influence is *very likely* the main driver of the global retreat of glaciers since the 1990s and the decrease in Arctic sea ice area between 1979–1988 and 2010–2019 (about 40% in September and about 10% in March). There has been no significant trend in Antarctic sea ice area from 1979 to 2020 due to regionally opposing trends and large internal variability. Human influence *very likely* contributed to the decrease in Northern Hemisphere spring snow cover since 1950. It is *very likely* that human influence has contributed to the observed surface melting of the Greenland Ice Sheet over the past two decades, but there is only *limited evidence*, with *medium agreement*, of human influence on the Antarctic Ice Sheet mass loss.
{2.3, 3.4, 8.3, 9.3, 9.5, TS.2.5}

A.1.6 It is *virtually certain* that the global upper ocean (0–700 m) has warmed since the 1970s and *extremely likely* that human influence is the main driver. It is *virtually certain* that human-caused CO_2 emissions are the main driver of current global acidification of the surface open ocean. There is *high confidence* that oxygen levels have dropped in many upper ocean regions since the mid-20th century, and *medium confidence* that human influence contributed to this drop.
{2.3, 3.5, 3.6, 5.3, 9.2, TS.2.4}

A.1.7 Global mean sea level increased by 0.20 [0.15 to 0.25] m between 1901 and 2018. The average rate of sea level rise was 1.3 [0.6 to 2.1] mm yr^{-1} between 1901 and 1971, increasing to 1.9 [0.8 to 2.9] mm yr^{-1} between 1971 and 2006, and further increasing to 3.7 [3.2 to 4.2] mm yr^{-1} between 2006 and 2018 (*high confidence*). Human influence was *very likely* the main driver of these increases since at least 1971.
{2.3, 3.5, 9.6, Cross-Chapter Box 9.1, Box TS.4}

A.1.8 Changes in the land biosphere since 1970 are consistent with global warming: climate zones have shifted poleward in both hemispheres, and the growing season has on average lengthened by up to two days per decade since the 1950s in the Northern Hemisphere extratropics (*high confidence*).
{2.3, TS.2.6}

[11] The period distinction with A.1.2 arises because the attribution studies consider this slightly earlier period. The observed warming to 2010–2019 is 1.06 [0.88 to 1.21] °C.

[12] Throughout this SPM, 'main driver' means responsible for more than 50% of the change.

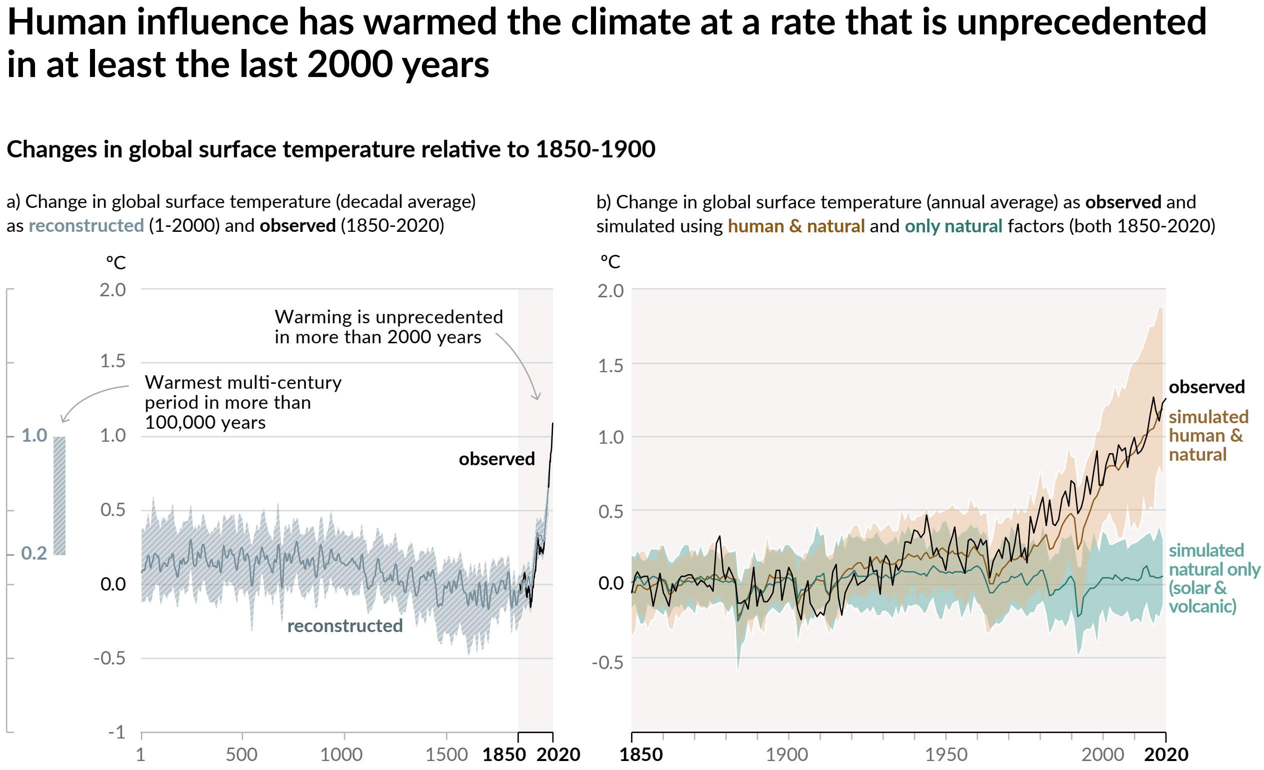

Figure SPM.1: History of global temperature change and causes of recent warming.

Panel a): Changes in global surface temperature reconstructed from paleoclimate archives (solid grey line, 1–2000) **and from direct observations** (solid black line, 1850–2020), both relative to 1850–1900 and decadally averaged. The vertical bar on the left shows the estimated temperature (*very likely* range) during the warmest multi-century period in at least the last 100,000 years, which occurred around 6500 years ago during the current interglacial period (Holocene). The Last Interglacial, around 125,000 years ago, is the next most recent candidate for a period of higher temperature. These past warm periods were caused by slow (multi-millennial) orbital variations. The grey shading with white diagonal lines shows the *very likely* ranges for the temperature reconstructions.

Panel b): Changes in global surface temperature over the past 170 years (black line) relative to 1850–1900 and annually averaged, compared to CMIP6 climate model simulations (see Box SPM.1) of the temperature response to both human and natural drivers (brown), and to only natural drivers (solar and volcanic activity, green). Solid coloured lines show the multi-model average, and coloured shades show the *very likely* range of simulations. (see Figure SPM.2 for the assessed contributions to warming).

{2.3.1, 3.3, Cross-Chapter Box 2.3, Cross-Section Box TS.1, Figure 1a, TS.2.2}

Observed warming is driven by emissions from human activities, with greenhouse gas warming partly masked by aerosol cooling

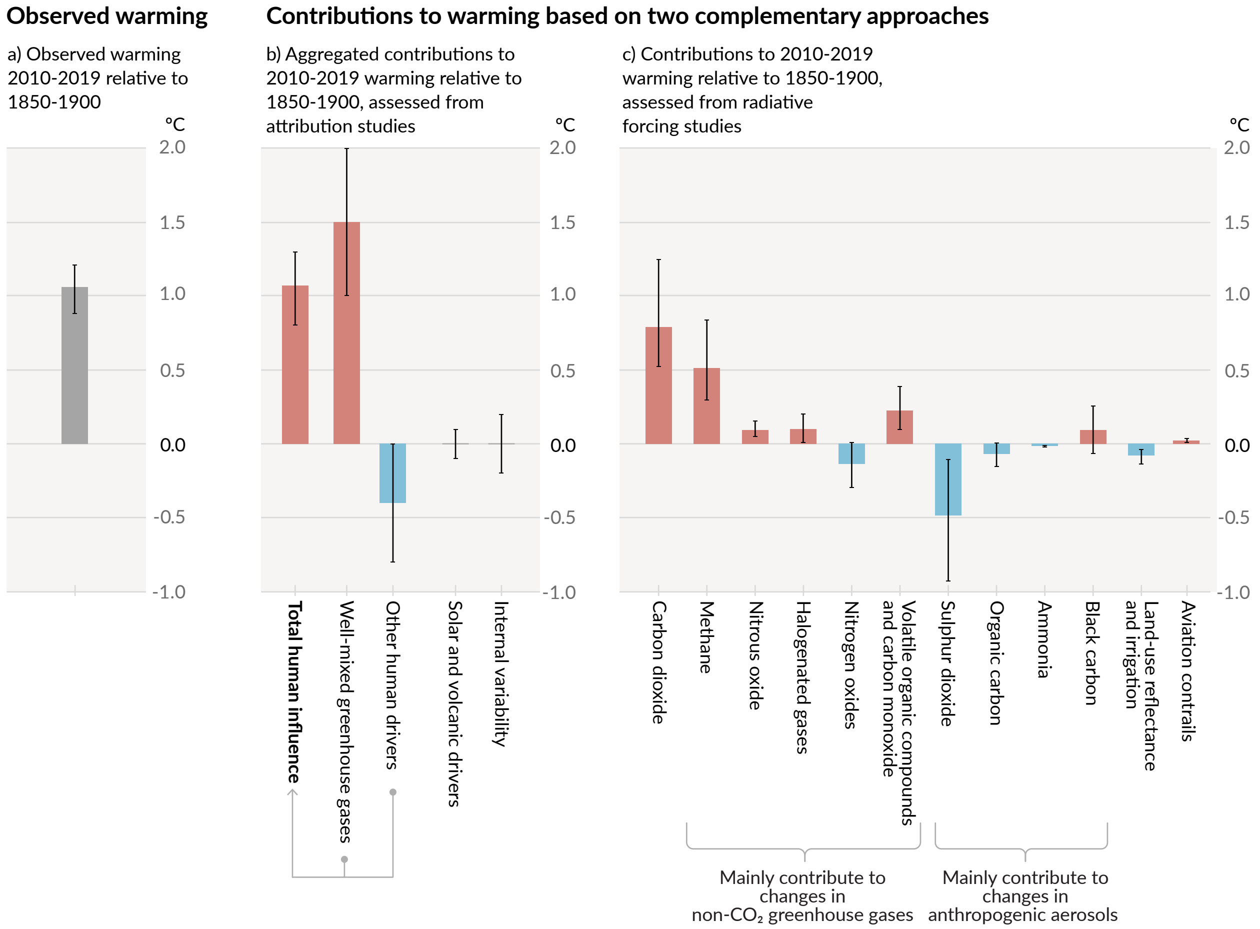

Figure SPM.2: Assessed contributions to observed warming in 2010–2019 relative to 1850–1900.

Panel a): Observed global warming (increase in global surface temperature) and its *very likely* range {3.3.1, Cross-Chapter Box 2.3}.

Panel b): Evidence from attribution studies, which synthesize information from climate models and observations. The panel shows temperature change attributed to total human influence, changes in well-mixed greenhouse gas concentrations, other human drivers due to aerosols, ozone and land-use change (land-use reflectance), solar and volcanic drivers, and internal climate variability. Whiskers show *likely* ranges {3.3.1}.

Panel c): Evidence from the assessment of radiative forcing and climate sensitivity. The panel shows temperature changes from individual components of human influence, including emissions of greenhouse gases, aerosols and their precursors; land-use changes (land-use reflectance and irrigation); and aviation contrails. Whiskers show *very likely* ranges. Estimates account for both direct emissions into the atmosphere and their effect, if any, on other climate drivers. For aerosols, both direct (through radiation) and indirect (through interactions with clouds) effects are considered.{6.4.2, 7.3}

A.2 The scale of recent changes across the climate system as a whole and the present state of many aspects of the climate system are unprecedented over many centuries to many thousands of years.

{Cross-Chapter Box 2.1, 2.2, 2.3, 5.1} **(Figure SPM.1)**

A.2.1 In 2019, atmospheric CO_2 concentrations were higher than at any time in at least 2 million years (*high confidence*), and concentrations of CH_4 and N_2O were higher than at any time in at least 800,000 years (*very high confidence*). Since 1750, increases in CO_2 (47%) and CH_4 (156%) concentrations far exceed, and increases in N_2O (23%) are similar to, the natural multi-millennial changes between glacial and interglacial periods over at least the past 800,000 years (*very high confidence*).
{2.2, 5.1, TS.2.2}

A.2.2 Global surface temperature has increased faster since 1970 than in any other 50-year period over at least the last 2000 years (*high confidence*). Temperatures during the most recent decade (2011–2020) exceed those of the most recent multi-century warm period, around 6500 years ago[13] [0.2°C to 1°C relative to 1850–1900] (*medium confidence*). Prior to that, the next most recent warm period was about 125,000 years ago when the multi-century temperature [0.5°C to 1.5°C relative to 1850–1900] overlaps the observations of the most recent decade (*medium confidence*).
{Cross-Chapter Box 2.1, 2.3, Cross-Section Box TS.1} **(Figure SPM.1)**

A.2.3 In 2011–2020, annual average Arctic sea ice area reached its lowest level since at least 1850 (*high confidence*). Late summer Arctic sea ice area was smaller than at any time in at least the past 1000 years (*medium confidence*). The global nature of glacier retreat, with almost all of the world's glaciers retreating synchronously, since the 1950s is unprecedented in at least the last 2000 years (*medium confidence*).
{2.3, TS.2.5}

A.2.4 Global mean sea level has risen faster since 1900 than over any preceding century in at least the last 3000 years (*high confidence*). The global ocean has warmed faster over the past century than since the end of the last deglacial transition (around 11,000 years ago) (*medium confidence*). A long-term increase in surface open ocean pH occurred over the past 50 million years (*high confidence*), and surface open ocean pH as low as recent decades is unusual in the last 2 million years (*medium confidence*).
{2.3, TS.2.4, Box TS.4}

[13] As stated in section B.1, even under the very low emissions scenario SSP1-1.9, temperatures are assessed to remain elevated above those of the most recent decade until at least 2100 and therefore warmer than the century-scale period 6500 years ago.

A.3 Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since AR5.

{2.3, 3.3, 8.2, 8.3, 8.4, 8.5, 8.6, Box 8.1, Box 8.2, Box 9.2, 10.6, 11.2, 11.3, 11.4, 11.6, 11.7, 11.8, 11.9, 12.3} **(Figure SPM.3)**

A.3.1 It is *virtually certain* that hot extremes (including heatwaves) have become more frequent and more intense across most land regions since the 1950s, while cold extremes (including cold waves) have become less frequent and less severe, with *high confidence* that human-induced climate change is the main driver[14] of these changes. Some recent hot extremes observed over the past decade would have been *extremely unlikely* to occur without human influence on the climate system. Marine heatwaves have approximately doubled in frequency since the 1980s (*high confidence*), and human influence has *very likely* contributed to most of them since at least 2006.
{Box 9.2, 11.2, 11.3, 11.9, TS.2.4, TS.2.6, Box TS.10} **(Figure SPM.3)**

A.3.2 The frequency and intensity of heavy precipitation events have increased since the 1950s over most land area for which observational data are sufficient for trend analysis (*high confidence*), and human-induced climate change is *likely* the main driver. Human-induced climate change has contributed to increases in agricultural and ecological droughts[15] in some regions due to increased land evapotranspiration[16] (*medium confidence*).
{8.2, 8.3, 11.4, 11.6, 11.9, TS.2.6, Box TS.10} **(Figure SPM.3)**

A.3.3 Decreases in global land monsoon precipitation[17] from the 1950s to the 1980s are partly attributed to human-caused Northern Hemisphere aerosol emissions, but increases since then have resulted from rising GHG concentrations and decadal to multi-decadal internal variability (*medium confidence*). Over South Asia, East Asia and West Africa increases in monsoon precipitation due to warming from GHG emissions were counteracted by decreases in monsoon precipitation due to cooling from human-caused aerosol emissions over the 20th century (*high confidence*). Increases in West African monsoon precipitation since the 1980s are partly due to the growing influence of GHGs and reductions in the cooling effect of human-caused aerosol emissions over Europe and North America (*medium confidence*).
{2.3, 3.3, 8.2, 8.3, 8.4, 8.5, 8.6, Box 8.1, Box 8.2, 10.6, Box TS.13}

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[14] Throughout this SPM, 'main driver' means responsible for more than 50% of the change.

[15] Agricultural and ecological drought (depending on the affected biome): a period with abnormal soil moisture deficit, which results from combined shortage of precipitation and excess evapotranspiration, and during the growing season impinges on crop production or ecosystem function in general. Observed changes in meteorological droughts (precipitation deficits) and hydrological droughts (streamflow deficits) are distinct from those in agricultural and ecological droughts and addressed in the underlying AR6 material (Chapter 11).

[16] The combined processes through which water is transferred to the atmosphere from open water and ice surfaces, bare soil, and vegetation that make up the Earth's surface.

[17] The global monsoon is defined as the area in which the annual range (local summer minus local winter) of precipitation is greater than 2.5 mm day^{-1}. Global land monsoon precipitation refers to the mean precipitation over land areas within the global monsoon.

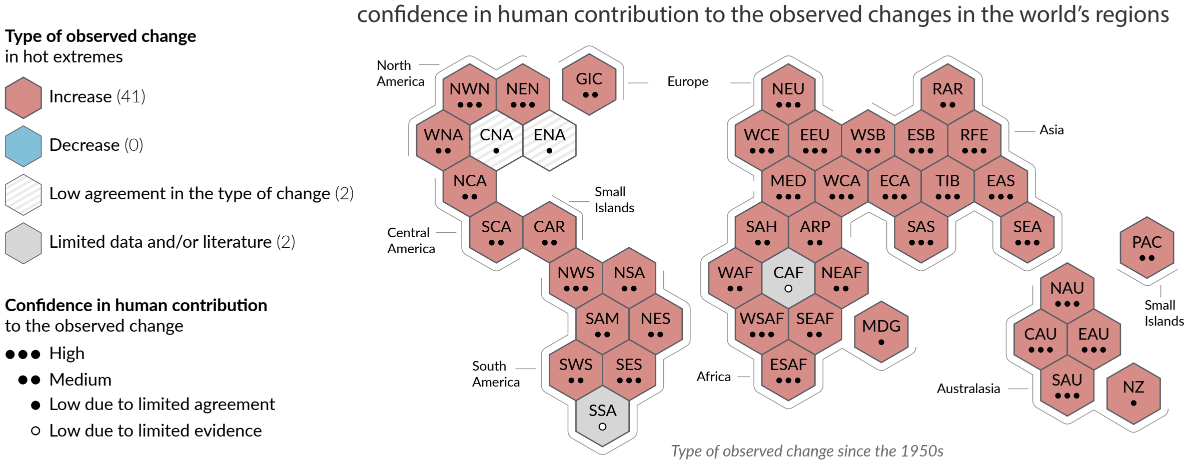
A.3.4 It is *likely* that the global proportion of major (Category 3–5) tropical cyclone occurrence has increased over the last four decades, and the latitude where tropical cyclones in the western North Pacific reach their peak intensity has shifted northward; these changes cannot be explained by internal variability alone (*medium confidence*). There is *low confidence* in long-term (multi-decadal to centennial) trends in the frequency of all-category tropical cyclones. Event attribution studies and physical understanding indicate that human-induced climate change increases heavy precipitation associated with tropical cyclones (*high confidence*) but data limitations inhibit clear detection of past trends on the global scale.
{8.2, 11.7, Box TS.10}

A.3.5 Human influence has *likely* increased the chance of compound extreme events[18] since the 1950s. This includes increases in the frequency of concurrent heatwaves and droughts on the global scale (*high confidence*); fire weather in some regions of all inhabited continents (*medium confidence*); and compound flooding in some locations (*medium confidence*). {11.6, 11.7, 11.8, 12.3, 12.4, TS.2.6, Table TS.5, Box TS.10}

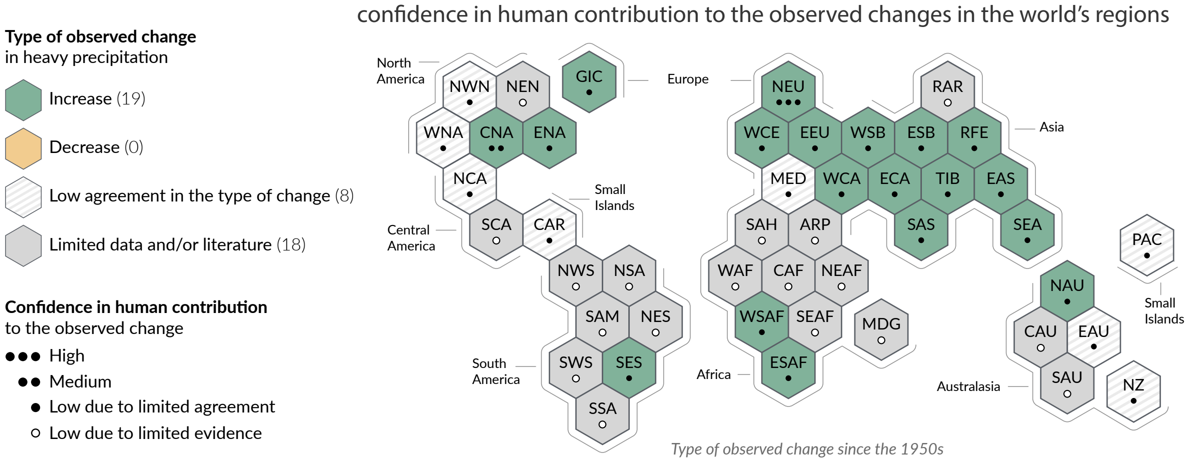
[18] Compound extreme events are the combination of multiple drivers and/or hazards that contribute to societal or environmental risk. Examples are concurrent heatwaves and droughts, compound flooding (e.g., a storm surge in combination with extreme rainfall and/or river flow), compound fire weather conditions (i.e., a combination of hot, dry, and windy conditions), or concurrent extremes at different locations.

Climate change is already affecting every inhabited region across the globe with human influence contributing to many observed changes in weather and climate extremes

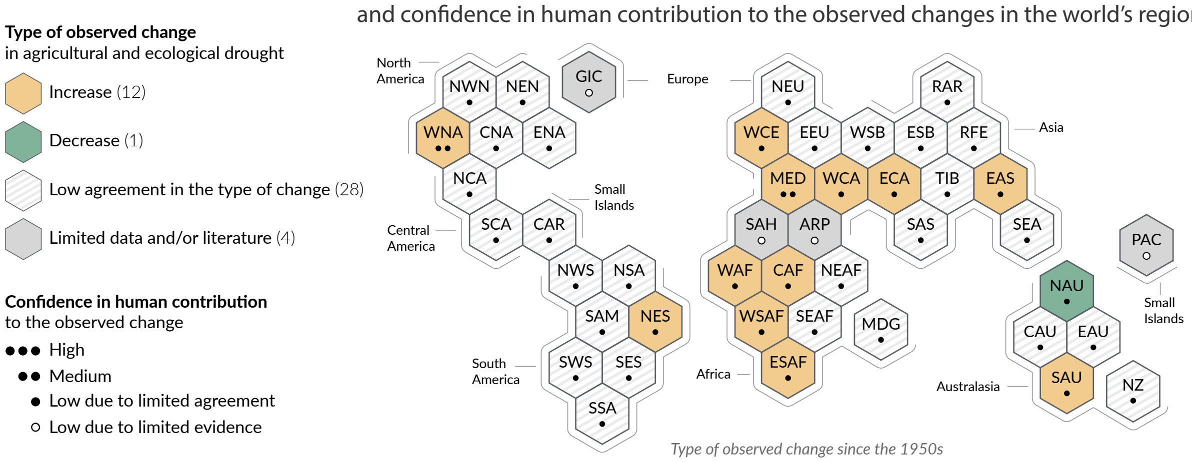
a) Synthesis of assessment of observed change in **hot extremes** and confidence in human contribution to the observed changes in the world's regions



b) Synthesis of assessment of observed change in **heavy precipitation** and confidence in human contribution to the observed changes in the world's regions



c) Synthesis of assessment of observed change in **agricultural and ecological drought** and confidence in human contribution to the observed changes in the world's regions



Each hexagon corresponds to one of the IPCC AR6 WGI reference regions

NWN *North-Western North America*

IPCC AR6 WGI reference regions: **North America:** ***NWN*** *(North-Western North America,* ***NEN*** *(North-Eastern North America),* ***WNA*** *(Western North America),* ***CNA*** *(Central North America),* ***ENA*** *(Eastern North America),* **Central America:** ***NCA*** *(Northern Central America),* ***SCA*** *(Southern Central America),* ***CAR*** *(Caribbean),* **South America:** ***NWS*** *(North-Western South America),* ***NSA*** *(Northern South America),* ***NES*** *(North-Eastern South America),* ***SAM*** *(South American Monsoon),* ***SWS*** *(South-Western South America),* ***SES*** *(South-Eastern South America),* ***SSA*** *(Southern South America),* **Europe:** ***GIC*** *(Greenland/Iceland),* ***NEU*** *(Northern Europe),* ***WCE*** *(Western and Central Europe),* ***EEU*** *(Eastern Europe),* ***MED*** *(Mediterranean),* **Africa:** ***MED*** *(Mediterranean),* ***SAH*** *(Sahara),* ***WAF*** *(Western Africa),* ***CAF*** *(Central Africa),* ***NEAF*** *(North Eastern Africa),* ***SEAF*** *(South Eastern Africa),* ***WSAF*** *(West Southern Africa),* ***ESAF*** *(East Southern Africa),* ***MDG*** *(Madagascar),* **Asia:** ***RAR*** *(Russian Arctic),* ***WSB*** *(West Siberia),* ***ESB*** *(East Siberia),* ***RFE*** *(Russian Far East),* ***WCA*** *(West Central Asia),* ***ECA*** *(East Central Asia),* ***TIB*** *(Tibetan Plateau),* ***EAS*** *(East Asia),* ***ARP*** *(Arabian Peninsula),* ***SAS*** *(South Asia),* ***SEA*** *(South East Asia),* **Australasia:** ***NAU*** *(Northern Australia),* ***CAU*** *(Central Australia),* ***EAU*** *(Eastern Australia),* ***SAU*** *(Southern Australia),* ***NZ*** *(New Zealand),* **Small Islands:** ***CAR*** *(Caribbean),* ***PAC*** *(Pacific Small Islands)*

Figure SPM.3: Synthesis of assessed observed and attributable regional changes.

The IPCC AR6 WGI inhabited regions are displayed as **hexagons** with identical size in their approximate geographical location (see legend for regional acronyms). All assessments are made for each region as a whole and for the 1950s to the present. Assessments made on different time scales or more local spatial scales might differ from what is shown in the figure. The **colours** in each panel represent the four outcomes of the assessment on observed changes. White and light grey striped hexagons are used where there is *low agreement* in the type of change for the region as a whole, and grey hexagons are used when there is limited data and/or literature that prevents an assessment of the region as a whole. Other colours indicate at least *medium confidence* in the observed change. The **confidence level** for the human influence on these observed changes is based on assessing trend detection and attribution and event attribution literature, and it is indicated by the number of dots: three dots for *high confidence,* two dots for *medium confidence* and one dot for *low confidence* (filled: limited agreement; empty: limited evidence).

Panel a) For hot extremes, the evidence is mostly drawn from changes in metrics based on daily maximum temperatures; regional studies using other indices (heatwave duration, frequency and intensity) are used in addition. Red hexagons indicate regions where there is at least *medium confidence* in an observed increase in hot extremes.

Panel b) For heavy precipitation, the evidence is mostly drawn from changes in indices based on one-day or five-day precipitation amounts using global and regional studies. Green hexagons indicate regions where there is at least *medium confidence* in an observed increase in heavy precipitation.

Panel c) Agricultural and ecological droughts are assessed based on observed and simulated changes in total column soil moisture, complemented by evidence on changes in surface soil moisture, water balance (precipitation minus evapotranspiration) and indices driven by precipitation and atmospheric evaporative demand. Yellow hexagons indicate regions where there is at least *medium confidence* in an observed increase in this type of drought and green hexagons indicate regions where there is at least *medium confidence* in an observed decrease in agricultural and ecological drought.

For all regions, table TS.5 shows a broader range of observed changes besides the ones shown in this figure. Note that SSA is the only region that does not display observed changes in the metrics shown in this figure, but is affected by observed increases in mean temperature, decreases in frost, and increases in marine heatwaves.

{11.9, Table TS.5, Box TS.10, Figure 1, Atlas 1.3.3, Figure Atlas.2}

A.4 Improved knowledge of climate processes, paleoclimate evidence and the response of the climate system to increasing radiative forcing gives a best estimate of equilibrium climate sensitivity of 3°C with a narrower range compared to AR5. {2.2, 7.3, 7.4, 7.5, Box 7.2, Cross-Chapter Box 9.1, 9.4, 9.5, 9.6}

A.4.1 Human-caused radiative forcing of 2.72 [1.96 to 3.48] W m^{-2} in 2019 relative to 1750 has warmed the climate system. This warming is mainly due to increased GHG concentrations, partly reduced by cooling due to increased aerosol concentrations. The radiative forcing has increased by 0.43 W m^{-2} (19%) relative to AR5, of which 0.34 W m^{-2} is due to the increase in GHG concentrations since 2011. The remainder is due to improved scientific understanding and changes in the assessment of aerosol forcing, which include decreases in concentration and improvement in its calculation (*high confidence*).
{2.2, 7.3, TS.2.2, TS.3.1}

A.4.2 Human-caused net positive radiative forcing causes an accumulation of additional energy (heating) in the climate system, partly reduced by increased energy loss to space in response to surface warming. The observed average rate of heating of the climate system increased from 0.50 [0.32 to 0.69] W m^{-2} for the period 1971–2006[19], to 0.79 [0.52 to 1.06] W m^{-2} for the period 2006–2018[20] (*high confidence*). Ocean warming accounted for 91% of the heating in the climate system, with land warming, ice loss and atmospheric warming accounting for about 5%, 3% and 1%, respectively (*high confidence*).
{7.2, Box 7.2, TS.3.1}

A.4.3 Heating of the climate system has caused global mean sea level rise through ice loss on land and thermal expansion from ocean warming. Thermal expansion explained 50% of sea level rise during 1971–2018, while ice loss from glaciers contributed 22%, ice sheets 20% and changes in land water storage 8%. The rate of ice sheet loss increased by a factor of four between 1992–1999 and 2010–2019. Together, ice sheet and glacier mass loss were the dominant contributors to global mean sea level rise during 2006-2018. (*high confidence*)
{Cross-Chapter Box 9.1, 9.4, 9.5, 9.6}

A.4.4 The equilibrium climate sensitivity is an important quantity used to estimate how the climate responds to radiative forcing. Based on multiple lines of evidence[21], the *very likely* range of equilibrium climate sensitivity is between 2°C (*high confidence*) and 5°C (*medium confidence*). The AR6 assessed best estimate is 3°C with a *likely* range of 2.5°C to 4°C (*high confidence*), compared to 1.5°C to 4.5°C in AR5, which did not provide a best estimate.
{7.4, 7.5, TS.3.2}

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[19] cumulative energy increase of 282 [177 to 387] ZJ over 1971–2006 (1 ZJ = 10^{21} J).

[20] cumulative energy increase of 152 [100 to 205] ZJ over 2006–2018.

[21] Understanding of climate processes, the instrumental record, paleoclimates and model-based emergent constraints (see glossary).

B. Possible Climate Futures

A set of five new illustrative emissions scenarios is considered consistently across this report to explore the climate response to a broader range of greenhouse gas (GHG), land use and air pollutant futures than assessed in AR5. This set of scenarios drives climate model projections of changes in the climate system. These projections account for solar activity and background forcing from volcanoes. Results over the 21st century are provided for the near-term (2021–2040), mid-term (2041–2060) and long-term (2081–2100) relative to 1850–1900, unless otherwise stated.

Box SPM.1: Scenarios, Climate Models and Projections

Box SPM.1.1: This report assesses the climate response to five illustrative scenarios that cover the range of possible future development of anthropogenic drivers of climate change found in the literature. They start in 2015, and include scenarios[22] with high and very high GHG emissions (SSP3-7.0 and SSP5-8.5) and CO_2 emissions that roughly double from current levels by 2100 and 2050, respectively, scenarios with intermediate GHG emissions (SSP2-4.5) and CO_2 emissions remaining around current levels until the middle of the century, and scenarios with very low and low GHG emissions and CO_2 emissions declining to net zero around or after 2050, followed by varying levels of net negative CO_2 emissions[23] (SSP1-1.9 and SSP1-2.6) as illustrated in Figure SPM.4. Emissions vary between scenarios depending on socio-economic assumptions, levels of climate change mitigation and, for aerosols and non-methane ozone precursors, air pollution controls. Alternative assumptions may result in similar emissions and climate responses, but the socio-economic assumptions and the feasibility or likelihood of individual scenarios is not part of the assessment.
{TS.1.3, 1.6, Cross-Chapter Box 1.4} **(Figure SPM.4)**

Box SPM.1.2: This report assesses results from climate models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6) of the World Climate Research Programme. These models include new and better representation of physical, chemical and biological processes, as well as higher resolution, compared to climate models considered in previous IPCC assessment reports. This has improved the simulation of the recent mean state of most large-scale indicators of climate change and many other aspects across the climate system. Some differences from observations remain, for example in regional precipitation patterns. The CMIP6 historical simulations assessed in this report have an ensemble mean global surface temperature change within 0.2°C of the observations over most of the historical period, and observed warming is within the *very likely* range of the CMIP6 ensemble. However, some CMIP6 models simulate a warming that is either above or below the assessed *very likely* range of observed warming.
{1.5, Cross-Chapter Box 2.2, 3.3, 3.8, TS.1.2, Cross-Section Box TS.1} (Figure SPM.1 b, Figure SPM.2)

Box SPM.1.3: The CMIP6 models considered in this Report have a wider range of climate sensitivity than in CMIP5 models and the AR6 assessed *very likely* range, which is based on multiple lines of evidence. These CMIP6 models also show a higher average climate sensitivity than CMIP5 and the AR6 assessed best estimate. The higher CMIP6 climate sensitivity values compared to CMIP5 can be traced to an amplifying cloud feedback that is larger in CMIP6 by about 20%.
{Box 7.1, 7.3, 7.4, 7.5, TS.3.2}

Box SPM.1.4: For the first time in an IPCC report, assessed future changes in global surface temperature, ocean warming and sea level are constructed by combining multi-model projections with observational constraints based on past simulated warming, as well as the AR6 assessment of climate sensitivity. For other quantities, such robust methods do not yet exist to constrain the projections. Nevertheless, robust projected

[22] Throughout this report, the five illustrative scenarios are referred to as SSPx-y, where 'SSPx' refers to the Shared Socio-economic Pathway or 'SSP' describing the socio-economic trends underlying the scenario, and 'y' refers to the approximate level of radiative forcing (in W m^{-2}) resulting from the scenario in the year 2100. A detailed comparison to scenarios used in earlier IPCC reports is provided in Section TS1.3 and 1.6 and 4.6. The SSPs that underlie the specific forcing scenarios used to drive climate models are not assessed by WGI. Rather, the SSPx-y labelling ensures traceability to the underlying literature in which specific forcing pathways are used as input to the climate models. IPCC is neutral with regard to the assumptions underlying the SSPs, which do not cover all possible scenarios. Alternative scenarios may be considered or developed.

[23] Net negative CO_2 emissions are reached when anthropogenic removals of CO_2 exceed anthropogenic emissions. {Glossary}

geographical patterns of many variables can be identified at a given level of global warming, common to all scenarios considered and independent of timing when the global warming level is reached. {1.6, Box 4.1, 4.3, 4.6, 7.5, 9.2, 9.6, Cross-Chapter Box 11.1, Cross-Section Box TS.1}

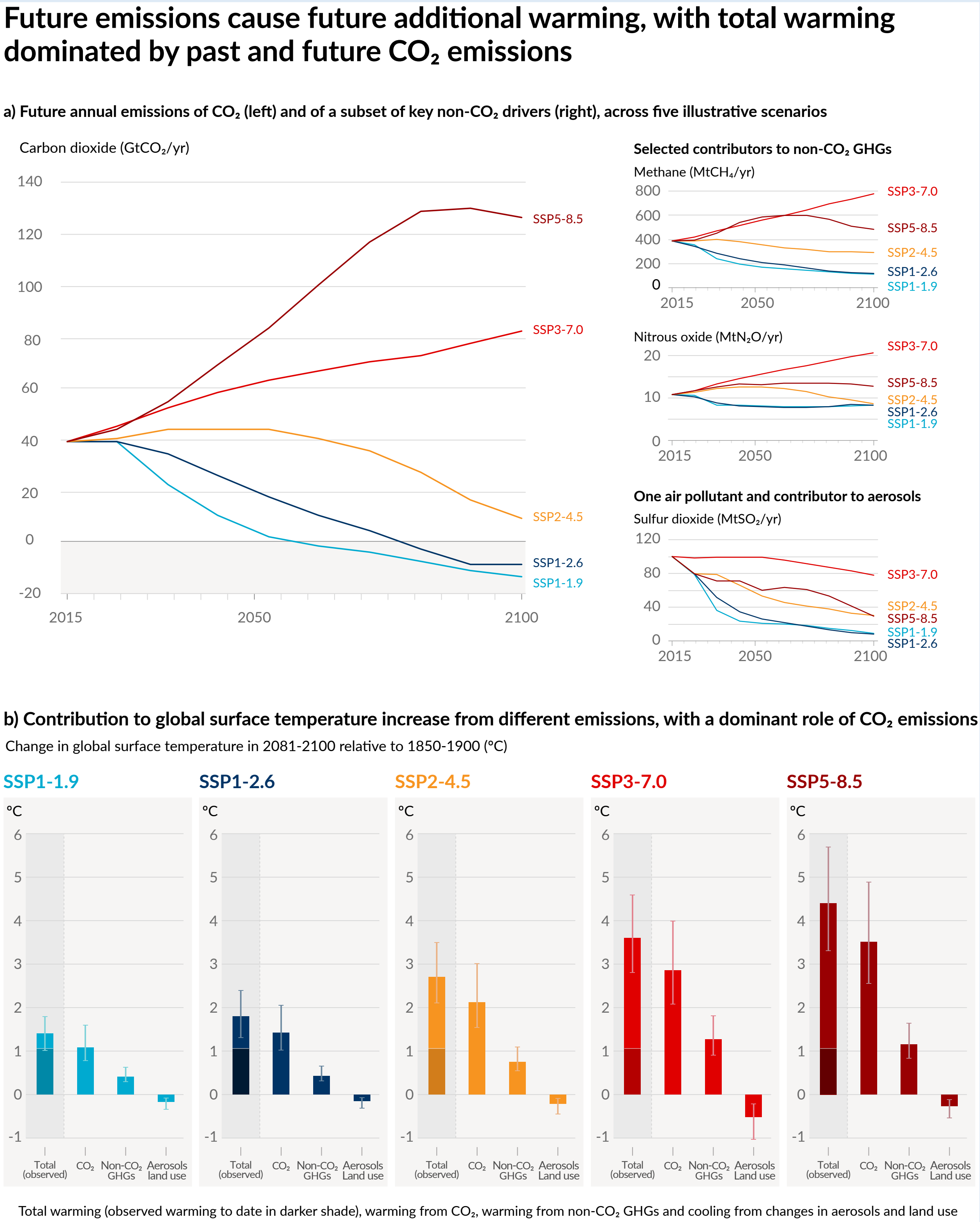


Figure SPM.4: Future anthropogenic emissions of key drivers of climate change and warming contributions by groups of drivers for the five illustrative scenarios used in this report.

The five scenarios are SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5.

Panel a) Annual anthropogenic (human-caused) emissions over the 2015–2100 period. Shown are emissions trajectories for carbon dioxide (CO_2) from all sectors ($GtCO_2$/yr) (left graph) and for a subset of three key non-CO_2 drivers considered in the scenarios: methane (CH_4, $MtCH_4$/yr, top-right graph), nitrous oxide (N_2O, MtN_2O/yr, middle-right graph) and sulfur dioxide (SO_2, $MtSO_2$/yr, bottom-right graph, contributing to anthropogenic aerosols in panel b).

Panel b) Warming contributions by groups of anthropogenic drivers and by scenario are shown as change in global surface temperature (°C) in 2081–2100 relative to 1850–1900, with indication of the observed warming to date. Bars and whiskers represent median values and the *very likely* range, respectively. Within each scenario bar plot, the bars represent total global warming (°C; total bar) (see Table SPM.1) and warming contributions (°C) from changes in CO_2 (CO_2 bar), from non-CO_2 greenhouse gases (non-CO_2 GHGs bar; comprising well-mixed greenhouse gases and ozone) and net cooling from other anthropogenic drivers (aerosols and land-use bar; anthropogenic aerosols, changes in reflectance due to land-use and irrigation changes, and contrails from aviation; see Figure SPM.2, panel c, for the warming contributions to date for individual drivers). The best estimate for observed warming in 2010–2019 relative to 1850–1900 (see Figure SPM.2, panel a) is indicated in the darker column in the total bar. Warming contributions in panel b are calculated as explained in Table SPM.1 for the total bar. For the other bars the contribution by groups of drivers are calculated with a physical climate emulator of global surface temperature which relies on climate sensitivity and radiative forcing assessments.

{Cross-Chapter Box 1.4, 4.6, Figure 4.35, 6.7, Figure 6.18, 6.22 and 6.24, Cross-Chapter Box 7.1, 7.3, Figure 7.7, Box TS.7, Figures TS.4 and TS.15}

B.1 Global surface temperature will continue to increase until at least the mid-century under all emissions scenarios considered. Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades.

{2.3, Cross-Chapter Box 2.3, Cross-Chapter Box 2.4, 4.3, 4.4, 4.5} **(Figure SPM.1, Figure SPM.4, Figure SPM.8, Table SPM.1, Box SPM.1)**

B.1.1 Compared to 1850–1900, global surface temperature averaged over 2081–2100 is *very likely* to be higher by 1.0°C to 1.8°C under the very low GHG emissions scenario considered (SSP1-1.9), by 2.1°C to 3.5°C in the intermediate scenario (SSP2-4.5) and by 3.3°C to 5.7°C under the very high GHG emissions scenario (SSP5-8.5)[24]. The last time global surface temperature was sustained at or above 2.5°C higher than 1850–1900 was over 3 million years ago (*medium confidence*).
{2.3, Cross-Chapter Box 2.4, 4.3, 4.5, Box TS.2, Box TS.4, Cross-Section Box TS.1} **(Table SPM.1)**

Table SPM.1: Changes in global surface temperature, which are assessed based on multiple lines of evidence, for selected 20-year time periods and the five illustrative emissions scenarios considered. Temperature differences relative to the average global surface temperature of the period 1850–1900 are reported in °C. This includes the revised assessment of observed historical warming for the AR5 reference period 1986–2005, which in AR6 is higher by 0.08 [–0.01 to 0.12] °C than in the AR5 (see footnote 10). Changes relative to the recent reference period 1995–2014 may be calculated approximately by subtracting 0.85°C, the best estimate of the observed warming from 1850–1900 to 1995–2014. {Cross-Chapter Box 2.3, 4.3, 4.4, Cross-Section Box TS.1}

[24] Changes in global surface temperature are reported as running 20-year averages, unless stated otherwise.

	Near term, 2021–2040		Mid-term, 2041–2060		Long term, 2081–2100	
Scenario	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)
SSP1-1.9	1.5	1.2 to 1.7	1.6	1.2 to 2.0	1.4	1.0 to 1.8
SSP1-2.6	1.5	1.2 to 1.8	1.7	1.3 to 2.2	1.8	1.3 to 2.4
SSP2-4.5	1.5	1.2 to 1.8	2.0	1.6 to 2.5	2.7	2.1 to 3.5
SSP3-7.0	1.5	1.2 to 1.8	2.1	1.7 to 2.6	3.6	2.8 to 4.6
SSP5-8.5	1.6	1.3 to 1.9	2.4	1.9 to 3.0	4.4	3.3 to 5.7

B.1.2 Based on the assessment of multiple lines of evidence, global warming of 2°C, relative to 1850–1900, would be exceeded during the 21st century under the high and very high GHG emissions scenarios considered in this report (SSP3-7.0 and SSP5-8.5, respectively). Global warming of 2°C would *extremely likely* be exceeded in the intermediate scenario (SSP2-4.5). Under the very low and low GHG emissions scenarios, global warming of 2°C is *extremely unlikely* to be exceeded (SSP1-1.9), or *unlikely* to be exceeded (SSP1-2.6)[25]. Crossing the 2°C global warming level in the mid-term period (2041–2060) is *very likely* to occur under the very high GHG emissions scenario (SSP5-8.5), *likely* to occur under the high GHG emissions scenario (SSP3-7.0), and *more likely than not* to occur in the intermediate GHG emissions scenario (SSP2-4.5)[26].
{4.3, Cross-Section Box TS.1} **(Table SPM.1, Figure SPM.4, Box SPM.1)**

B.1.3 Global warming of 1.5°C relative to 1850-1900 would be exceeded during the 21st century under the intermediate, high and very high scenarios considered in this report (SSP2-4.5, SSP3-7.0 and SSP5-8.5, respectively). Under the five illustrative scenarios, in the near term (2021-2040), the 1.5°C global warming level is *very likely* to be exceeded under the very high GHG emissions scenario (SSP5-8.5), *likely* to be exceeded under the intermediate and high GHG emissions scenarios (SSP2-4.5 and SSP3-7.0), *more likely than not* to be exceeded under the low GHG emissions scenario (SSP1-2.6) and *more likely than not* to be reached under the very low GHG emissions scenario (SSP1-1.9)[27]. Furthermore, for the very low GHG emissions scenario (SSP1-1.9), it is *more likely than not* that global surface temperature would decline back to below 1.5°C toward the end of the 21st century, with a temporary overshoot of no more than 0.1°C above 1.5°C global warming.
{4.3, Cross-Section Box TS.1} **(Table SPM.1, Figure SPM.4)**

[25] SSP1-1.9 and SSP1-2.6 are scenarios that start in 2015 and have very low and low GHG emissions and CO_2 emissions declining to net zero around or after 2050, followed by varying levels of net negative CO_2 emissions.

[26] Crossing is defined here as having the assessed global surface temperature change, averaged over a 20-year period, exceed a particular global warming level.

[27] The AR6 assessment of when a given global warming level is first exceeded benefits from the consideration of the illustrative scenarios, the multiple lines of evidence entering the assessment of future global surface temperature response to radiative forcing, and the improved estimate of historical warming. The AR6 assessment is thus not directly comparable to the SR1.5 SPM, which reported likely reaching 1.5°C global warming between 2030 and 2052, from a simple linear extrapolation of warming rates of the recent past. When considering scenarios similar to SSP1-1.9 instead of linear extrapolation, the SR1.5 estimate of when 1.5°C global

B.1.4 Global surface temperature in any single year can vary above or below the long-term human-induced trend, due to substantial natural variability[28]. The occurrence of individual years with global surface temperature change above a certain level, for example 1.5°C or 2ºC, relative to 1850–1900 does not imply that this global warming level has been reached[29].
{Cross-Chapter Box 2.3, 4.3, 4.4, Box 4.1, Cross-Section Box TS.1} **(Table SPM.1, Figure SPM.1, Figure SPM.8)**

B.2 Many changes in the climate system become larger in direct relation to increasing global warming. They include increases in the frequency and intensity of hot extremes, marine heatwaves, and heavy precipitation, agricultural and ecological droughts in some regions, and proportion of intense tropical cyclones, as well as reductions in Arctic sea ice, snow cover and permafrost. {4.3, 4.5, 4.6, 7.4, 8.2, 8.4, Box 8.2, 9.3, 9.5, Box 9.2, 11.1, 11.2, 11.3, 11.4, 11.6, 11.7, 11.9, Cross-Chapter Box 11.1, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.4, Atlas.5, Atlas.6, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11} **(Figure SPM.5, Figure SPM.6, Figure SPM.8)**

B.2.1 It is *virtually certain* that the land surface will continue to warm more than the ocean surface (*likely* 1.4 to 1.7 times more). It is *virtually certain* that the Arctic will continue to warm more than global surface temperature, with *high confidence* above two times the rate of global warming.
{2.3, 4.3, 4.5, 4.6, 7.4, 11.1, 11.3, 11.9, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.4, Atlas.5, Atlas.6, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11, Cross-Section Box TS.1, TS.2.6} **(Figure SPM.5)**

B.2.2 With every additional increment of global warming, changes in extremes continue to become larger. For example, every additional 0.5°C of global warming causes clearly discernible increases in the intensity and frequency of hot extremes, including heatwaves (*very likely*), and heavy precipitation (*high confidence*), as well as agricultural and ecological droughts[30] in some regions (*high confidence*). Discernible changes in intensity and frequency of meteorological droughts, with more regions showing increases than decreases, are seen in some regions for every additional 0.5°C of global warming (*medium confidence*). Increases in frequency and intensity of hydrological droughts become larger with increasing global warming in some regions (*medium confidence*). There will be an increasing occurrence of some extreme events unprecedented in the observational record with additional global warming, even at 1.5°C of global warming. Projected percentage changes in frequency are higher for rarer events (*high confidence*).
{8.2, 11.2, 11.3, 11.4, 11.6, 11.9, Cross-Chapter Box 11.1, Cross-Chapter Box 12.1, TS.2.6} **(Figure SPM.5, Figure SPM.6)**

warming is first exceeded is close to the best estimate reported here.

[28] Natural variability refers to climatic fluctuations that occur without any human influence, that is, internal variability combined with the response to external natural factors such as volcanic eruptions, changes in solar activity and, on longer time scales, orbital effects and plate tectonics.

[29] The internal variability in any single year is estimated to be ± 0.25°C (5–95% range, *high confidence*).

[30] Projected changes in agricultural and ecological droughts are primarily assessed based on total column soil moisture. See footnote 15 for definition and relation to precipitation and evapotranspiration.

B.2.3 Some mid-latitude and semi-arid regions, and the South American Monsoon region, are projected to see the highest increase in the temperature of the hottest days, at about 1.5 to 2 times the rate of global warming (*high confidence*). The Arctic is projected to experience the highest increase in the temperature of the coldest days, at about 3 times the rate of global warming (*high confidence*). With additional global warming, the frequency of marine heatwaves will continue to increase (*high confidence*), particularly in the tropical ocean and the Arctic *(medium confidence).*
{Box 9.2, 11.1, 11.3, 11.9, Cross-Chapter Box 11.1, Cross-Chapter Box 12.1, 12.4, TS.2.4, TS.2.6} **(Figure SPM.6)**

B.2.4 It is *very likely* that heavy precipitation events will intensify and become more frequent in most regions with additional global warming. At the global scale, extreme daily precipitation events are projected to intensify by about 7% for each 1°C of global warming (*high confidence*). The proportion of intense tropical cyclones (categories 4-5) and peak wind speeds of the most intense tropical cyclones are projected to increase at the global scale with increasing global warming (*high confidence*).
{8.2, 11.4, 11.7, 11.9, Cross-Chapter Box 11.1, Box TS.6, TS.4.3.1} **(Figure SPM.5, Figure SPM.6)**

B.2.5 Additional warming is projected to further amplify permafrost thawing, and loss of seasonal snow cover, of land ice and of Arctic sea ice (*high confidence*). The Arctic is *likely* to be practically sea ice free in September[31] at least once before 2050 under the five illustrative scenarios considered in this report, with more frequent occurrences for higher warming levels. There is *low confidence* in the projected decrease of Antarctic sea ice.
{4.3, 4.5, 7.4, 8.2, 8.4, Box 8.2, 9.3, 9.5, 12.4, Cross-Chapter Box 12.1, Atlas.5, Atlas.6, Atlas.8, Atlas.9, Atlas.11, TS.2.5} **(Figure SPM.8)**

[31] monthly average sea ice area of less than 1 million km^2 which is about 15% of the average September sea ice area observed in 1979-1988

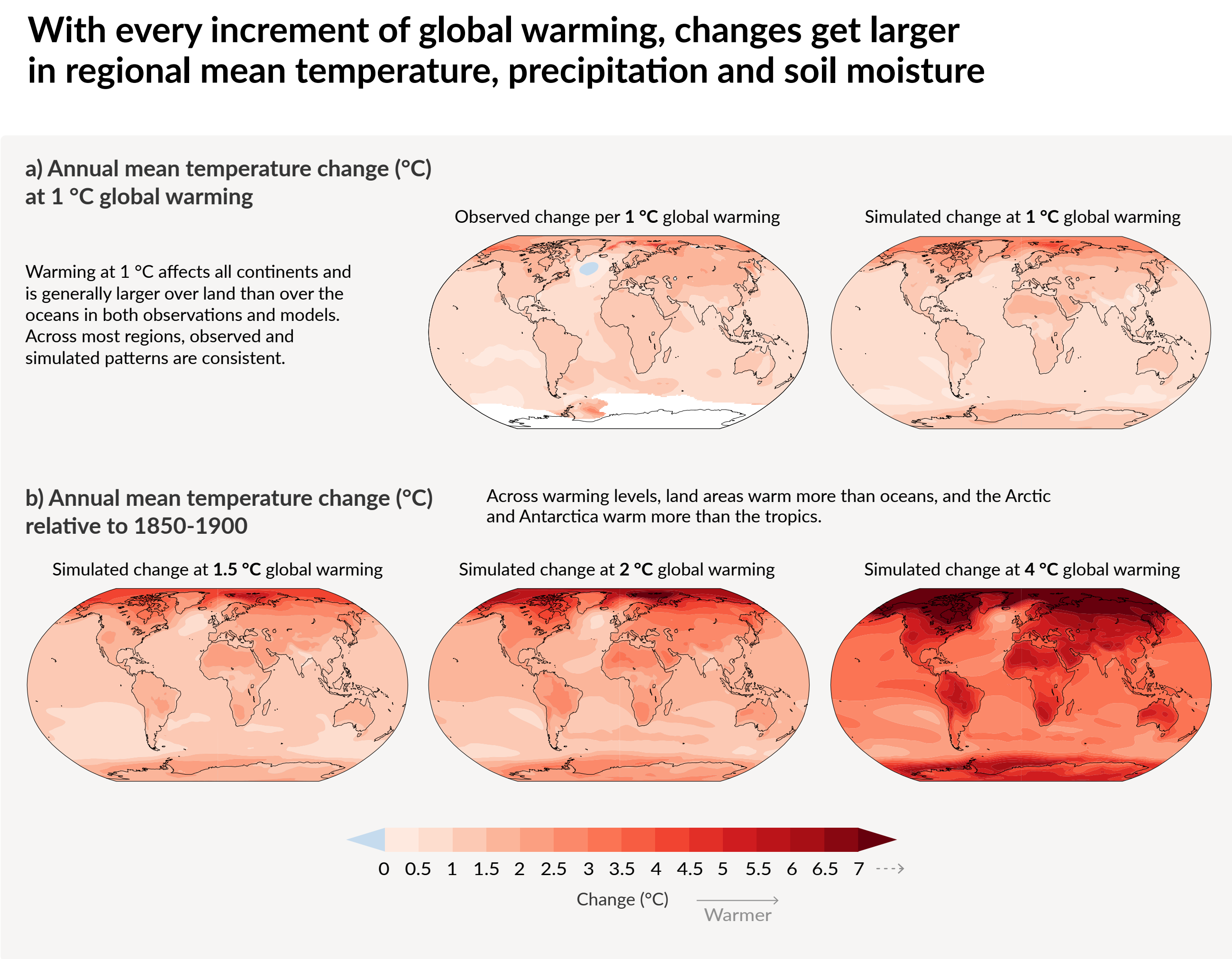
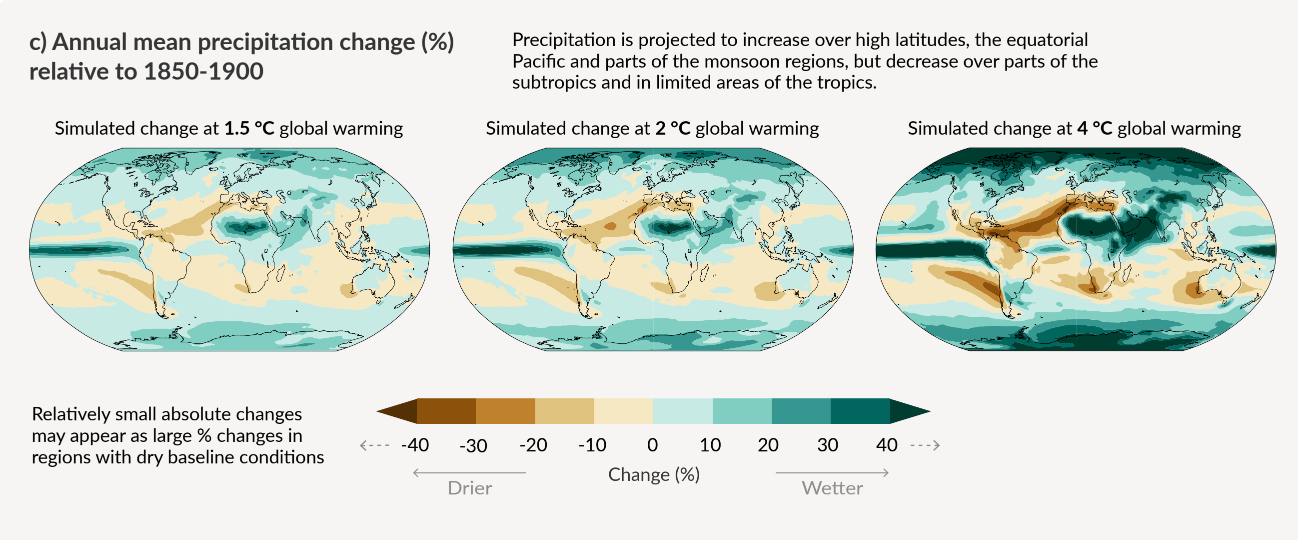
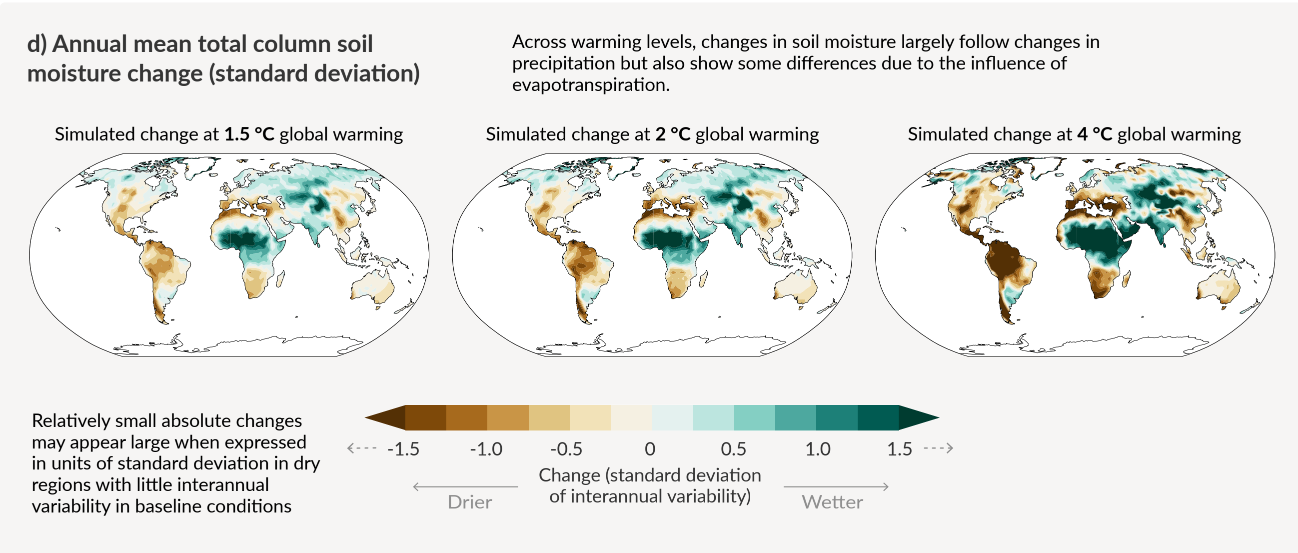


Figure SPM.5: Changes in annual mean surface temperature, precipitation, and soil moisture.

Panel a) Comparison of observed and simulated annual mean surface temperature change. The **left map** shows the observed changes in annual mean surface temperature in the period of 1850–2020 per °C of global warming (°C). The local (i.e., grid point) observed annual mean surface temperature changes are linearly regressed against the global surface temperature in the period 1850–2020. Observed temperature data are from Berkeley Earth, the dataset with the largest coverage and highest horizontal resolution. Linear regression is applied to all years for which data at the corresponding grid point is available. The regression method was used to take into account the complete observational time series and thereby reduce the role of internal variability at the grid point level. White indicates areas where time coverage was 100 years or less and thereby too short to calculate a reliable linear regression. The **right map** is based on model simulations and shows change in annual multi-model mean simulated temperatures at a global warming level of 1°C (20-year mean global surface temperature change relative to 1850–1900). The triangles at each end of the color bar indicate out-of-bound values, that is, values above or below the given limits.

Panel b) Simulated annual mean temperature change (°C), panel c) precipitation change (%), and panel d) total column soil moisture change (standard deviation of interannual variability) at global warming levels of 1.5°C, 2°C and 4°C (20-yr mean global surface temperature change relative to 1850–1900). Simulated changes correspond to CMIP6 multi-model mean change (median change for soil moisture) at the corresponding global warming level, i.e. the same method as for the right map in panel a).





In **panel c),** high positive percentage changes in dry regions may correspond to small absolute changes. In **panel d),** the unit is the standard deviation of interannual variability in soil moisture during 1850–1900. Standard deviation is a widely used metric in characterizing drought severity. A projected reduction in mean soil moisture by one standard deviation corresponds to soil moisture conditions typical of droughts that occurred about once every six years during 1850–1900. In panel d), large changes in dry regions with little interannual variability in the baseline conditions can correspond to small absolute change. The triangles at each end of the color bars indicate out-of-bound values, that is, values above or below the given limits. Results from all models reaching the corresponding warming level in any of the five illustrative scenarios (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5) are averaged. Maps of annual mean temperature and precipitation changes at a global warming level of 3°C are available in Figure 4.31 and Figure 4.32 in Section 4.6.

Corresponding maps of panels b), c) and d) including hatching to indicate the level of model agreement at grid-cell level are found in Figures 4.31, 4.32 and 11.19, respectively; as highlighted in CC-box Atlas.1, grid-cell level hatching is not informative for larger spatial scales (e.g., over AR6 reference regions) where the aggregated signals are less affected by small-scale variability leading to an increase in robustness.

{TS.1.3.2, Figure TS.3, Figure TS.5, Figure 1.14, 4.6.1, Cross-Chapter Box 11.1, Cross-Chapter Box Atlas.1}

Projected changes in extremes are larger in frequency and intensity with every additional increment of global warming

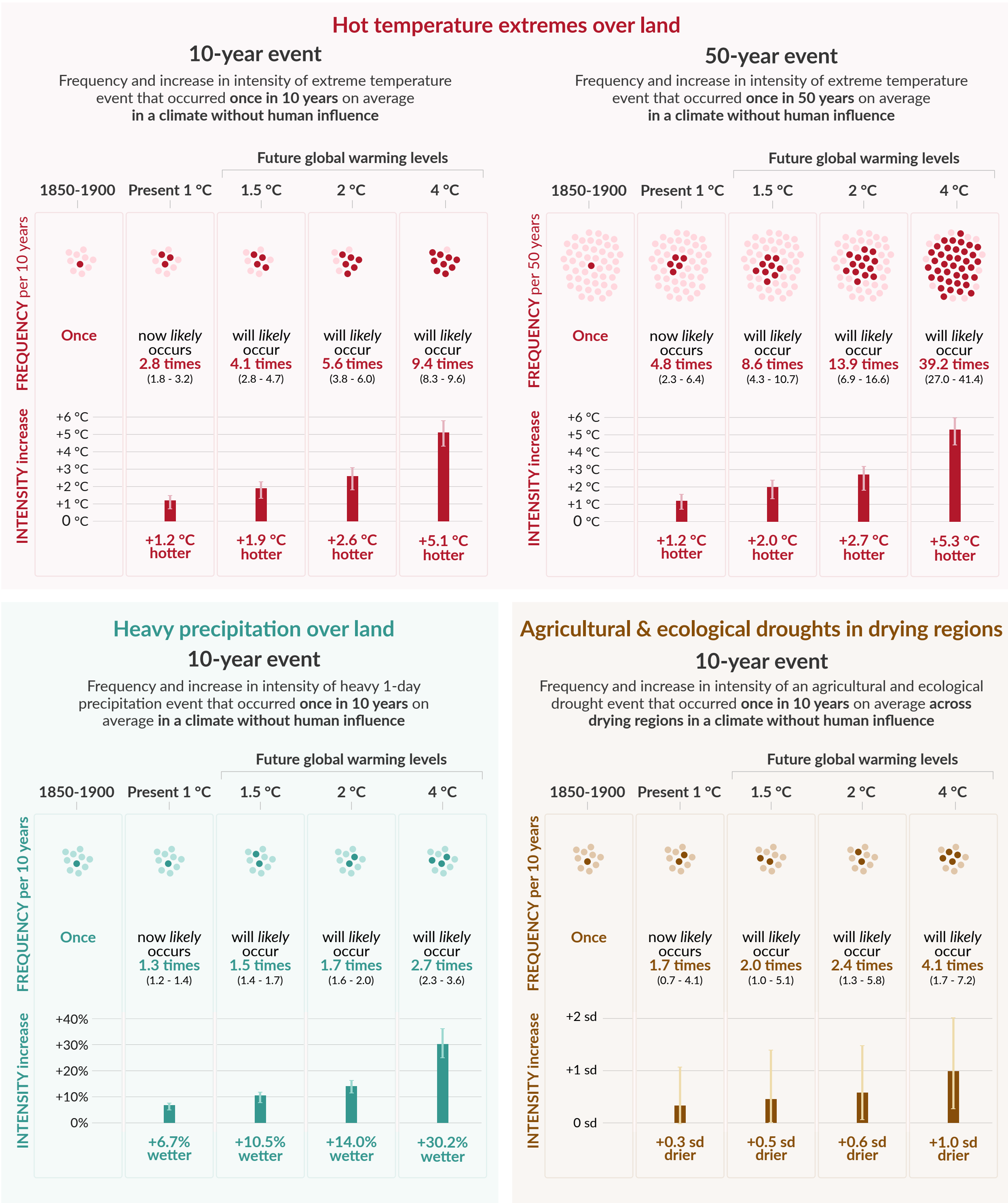


Figure SPM.6: Projected changes in the intensity and frequency of hot temperature extremes over land, extreme precipitation over land, and agricultural and ecological droughts in drying regions.

Projected changes are shown at global warming levels of 1°C, 1.5°C, 2°C, and 4°C and are relative to 1850-1900[9] representing a climate without human influence. The figure depicts frequencies and increases in intensity of 10- or 50-year extreme events from the base period (1850-1900) under different global warming levels.
Hot temperature extremes are defined as the daily maximum temperatures over land that were exceeded on average once in a decade (10-year event) or once in 50 years (50-year event) during the 1850–1900 reference period. **Extreme precipitation events** are defined as the daily precipitation amount over land that was exceeded on average once in a decade during the 1850–1900 reference period. **Agricultural and ecological drought events** are defined as the annual average of total column soil moisture below the 10th percentile of the 1850–1900 base period. These extremes are defined on model grid box scale. For hot temperature extremes and extreme precipitation, results are shown for the global land. For agricultural and ecological drought, results are shown for drying regions only, which correspond to the AR6 regions in which there is at least *medium confidence* in a projected increase in agricultural/ecological drought at the 2°C warming level compared to the 1850–1900 base period in CMIP6. These regions include W. North-America, C. North-America, N. Central-America, S. Central-America, Caribbean, N. South-America, N.E. South-America, South-American-Monsoon, S.W. South-America, S. South-America, West & Central-Europe, Mediterranean, W. Southern-Africa, E. Southern-Africa, Madagascar, E. Australia, S. Australia (Caribbean is not included in the calculation of the figure because of the too small number of full land grid cells). The non-drying regions do not show an overall increase or decrease in drought severity. Projections of changes in agricultural and ecological droughts in the CMIP5 multi-model ensemble differ from those in CMIP6 in some regions, including in part of Africa and Asia. Assessments on projected changes in meteorological and hydrological droughts are provided in Chapter 11. {11.6, 11.9}

In the **'frequency' section,** each year is represented by a dot. The dark dots indicate years in which the extreme threshold is exceeded, while light dots are years when the threshold is not exceeded. Values correspond to the medians (in bold) and their respective 5–95% range based on the multi-model ensemble from simulations of CMIP6 under different SSP scenarios. For consistency, the number of dark dots is based on the rounded-up median. In the **'intensity' section,** medians and their 5–95% range, also based on the multi-model ensemble from simulations of CMIP6, are displayed as dark and light bars, respectively. Changes in the intensity of hot temperature extremes and extreme precipitations are expressed as degree Celsius and percentage. As for agricultural and ecological drought, intensity changes are expressed as fractions of standard deviation of annual soil moisture.

{11.1, 11.3, 11.4, 11.6, Figure 11.12, Figure 11.15, Figure 11.6, Figure 11.7, Figure 11.18}

B.3 Continued global warming is projected to further intensify the global water cycle, including its variability, global monsoon precipitation and the severity of wet and dry events.

{4.3, 4.4, 4.5, 4.6, 8.2, 8.3, 8.4, 8.5, Box 8.2, 11.4, 11.6, 11.9, 12.4, Atlas.3} **(Figure SPM.5, Figure SPM.6)**

B.3.1 There is strengthened evidence since AR5 that the global water cycle will continue to intensify as global temperatures rise (*high confidence*), with precipitation and surface water flows projected to become more variable over most land regions within seasons (*high confidence*) and from year to year (*medium confidence*). The average annual global land precipitation is projected to increase by 0–5% under the very low GHG emissions scenario (SSP1-1.9), 1.5-8% for the intermediate GHG emissions scenario (SSP2-4.5) and 1–13% under the very high GHG emissions scenario (SSP5-8.5) by 2081–2100 relative to 1995-2014 (*likely* ranges). Precipitation is projected to increase over high latitudes, the equatorial Pacific and parts of the monsoon regions, but decrease over parts of the subtropics and limited areas in the tropics in SSP2-4.5, SSP3-7.0 and SSP5-8.5 (*very likely*). The portion of the global land experiencing detectable increases or decreases in seasonal mean precipitation is projected to increase (*medium confidence*). There is *high confidence* in an earlier onset of spring snowmelt, with higher peak flows at the expense of summer flows in snow-dominated regions globally.
{4.3, 4.5, 4.6, 8.2, 8.4, Atlas.3, TS.2.6, Box TS.6, TS.4.3} **(Figure SPM.5)**

B.3.2 A warmer climate will intensify very wet and very dry weather and climate events and seasons, with implications for flooding or drought (*high confidence*), but the location and frequency of these events depend on projected changes in regional atmospheric circulation, including monsoons and mid-latitude storm tracks. It is *very likely* that rainfall variability related to the El Niño–Southern Oscillation is projected to be amplified by the second half of the 21st century in the SSP2-4.5, SSP3-7.0 and SSP5-8.5 scenarios.
{4.3, 4.5, 4.6, 8.2, 8.4, 8.5, 11.4, 11.6, 11.9, 12.4, TS.2.6, TS.4.2, Box TS.6} **(Figure SPM.5, Figure SPM.6)**

B.3.3 Monsoon precipitation is projected to increase in the mid- to long term at global scale, particularly over South and Southeast Asia, East Asia and West Africa apart from the far west Sahel (*high confidence*). The monsoon season is projected to have a delayed onset over North and South America and West Africa (*high confidence*) and a delayed retreat over West Africa (*medium confidence*).
{4.4, 4.5, 8.2, 8.3, 8.4, Box 8.2, Box TS.13}

B.3.4 A projected southward shift and intensification of Southern Hemisphere summer mid-latitude storm tracks and associated precipitation is *likely* in the long term under high GHG emissions scenarios (SSP3-7.0, SSP5-8.5), but in the near term the effect of stratospheric ozone recovery counteracts these changes (*high confidence*). There is *medium confidence* in a continued poleward shift of storms and their precipitation in the North Pacific, while there is *low confidence* in projected changes in the North Atlantic storm tracks.
{TS.4.2, 4.4, 4.5, 8.4, TS.2.3}

B.4 Under scenarios with increasing CO_2 emissions, the ocean and land carbon sinks are projected to be less effective at slowing the accumulation of CO_2 in the atmosphere.

{4.3, 5.2, 5.4, 5.5, 5.6} **(Figure SPM.7)**

B.4.1 While natural land and ocean carbon sinks are projected to take up, in absolute terms, a progressively larger amount of CO_2 under higher compared to lower CO_2 emissions scenarios, they become less effective, that is, the proportion of emissions taken up by land and ocean decrease with increasing cumulative CO_2 emissions. This is projected to result in a higher proportion of emitted CO_2 remaining in the atmosphere (*high confidence*).
{5.2, 5.4, Box TS.5} **(Figure SPM.7)**

B.4.2 Based on model projections, under the intermediate scenario that stabilizes atmospheric CO_2 concentrations this century (SSP2-4.5), the rates of CO_2 taken up by the land and oceans are projected to decrease in the second half of the 21st century (*high confidence*). Under the very low and low GHG emissions scenarios (SSP1-1.9, SSP1-2.6), where CO_2 concentrations peak and decline during the 21st century, land and oceans begin to take up less carbon in response to declining atmospheric CO_2 concentrations (*high confidence*) and turn into a weak net source by 2100 under SSP1-1.9 (*medium confidence*). It is *very unlikely* that the combined global land and ocean sink will turn into a source by 2100 under scenarios without net negative emissions[32] (SSP2-4.5, SSP3-7.0, SSP5-8.5).
{4.3, 5.4, 5.5, 5.6, Box TS.5, TS.3.3}

B.4.3 The magnitude of feedbacks between climate change and the carbon cycle becomes larger but also more uncertain in high CO_2 emissions scenarios (*very high confidence*). However, climate model projections show that the uncertainties in atmospheric CO_2 concentrations by 2100 are dominated by the differences between emissions scenarios (*high confidence*). Additional ecosystem responses to warming not yet fully included in climate models, such as CO_2 and CH_4 fluxes from wetlands, permafrost thaw and wildfires, would further increase concentrations of these gases in the atmosphere (*high confidence*).
{5.4, Box TS.5, TS.3.2}

[32] These projected adjustments of carbon sinks to stabilization or decline of atmospheric CO_2 are accounted for in calculations of remaining carbon budgets.

The proportion of CO_2 emissions taken up by land and ocean carbon sinks is smaller in scenarios with higher cumulative CO_2 emissions

Total cumulative CO_2 emissions **taken up by land and oceans** (colours) and remaining in the atmosphere (grey) under the five illustrative scenarios from 1850 to 2100

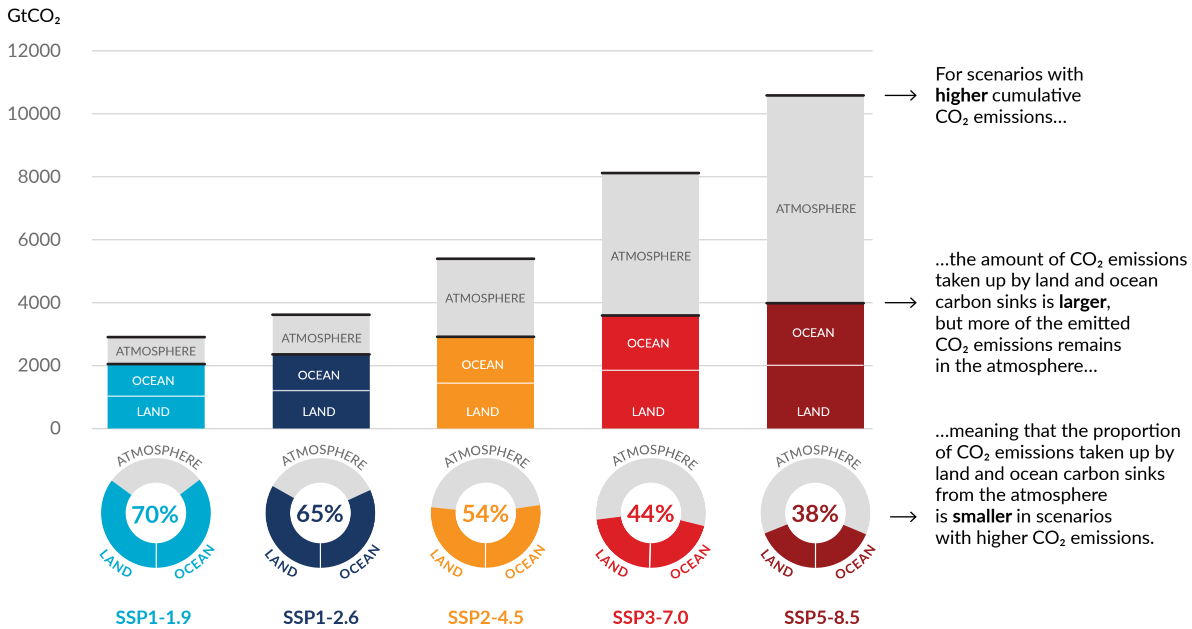


Figure SPM.7: Cumulative anthropogenic CO2 emissions taken up by land and ocean sinks by 2100 under the five illustrative scenarios.

The cumulative anthropogenic (human-caused) carbon dioxide (CO_2) emissions taken up by the land and ocean sinks under the five illustrative scenarios (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5) are simulated from 1850 to 2100 by CMIP6 climate models in the concentration-driven simulations. Land and ocean carbon sinks respond to past, current and future emissions, therefore cumulative sinks from 1850 to 2100 are presented here. During the historical period (1850-2019) the observed land and ocean sink took up 1430 $GtCO_2$ (59% of the emissions).

The **bar chart** illustrates the projected amount of cumulative anthropogenic CO_2 emissions ($GtCO_2$) between 1850 and 2100 remaining in the atmosphere (grey part) and taken up by the land and ocean (coloured part) in the year 2100. The **doughnut chart** illustrates the proportion of the cumulative anthropogenic CO_2 emissions taken up by the land and ocean sinks and remaining in the atmosphere in the year 2100. Values in % indicate the proportion of the cumulative anthropogenic CO_2 emissions taken up by the combined land and ocean sinks in the year 2100. The overall anthropogenic carbon emissions are calculated by adding the net global land use emissions from CMIP6 scenario database to the other sectoral emissions calculated from climate model runs with prescribed CO_2 concentrations[33]. Land and ocean CO_2 uptake since 1850 is calculated from the net biome productivity on land, corrected for CO_2 losses due to land-use change by adding the land-use change emissions, and net ocean CO_2 flux.

{Box TS.5, Box TS.5, Figure 1, 5.2.1, Table 5.1, 5.4.5, Figure 5.25}

[33] The other sectoral emissions are calculated as the residual of the net land and ocean CO_2 uptake and the prescribed atmospheric CO_2 concentration changes in the CMIP6 simulations. These calculated emissions are net emissions and do not separate gross anthropogenic emissions from removals, which are included implicitly.

B.5 Many changes due to past and future greenhouse gas emissions are irreversible for centuries to millennia, especially changes in the ocean, ice sheets and global sea level.
{Cross-Chapter Box 2.4, 2.3, 4.3, 4.5, 4.7, 5.3, 9.2, 9.4, 9.5, 9.6, Box 9.4} **(Figure SPM.8)**

B.5.1 Past GHG emissions since 1750 have committed the global ocean to future warming (*high confidence*). Over the rest of the 21st century, *likely* ocean warming ranges from 2–4 (SSP1-2.6) to 4–8 times (SSP5-8.5) the 1971–2018 change. Based on multiple lines of evidence, upper ocean stratification (*virtually certain*), ocean acidification (*virtually certain*) and ocean deoxygenation (*high confidence*) will continue to increase in the 21st century, at rates dependent on future emissions. Changes are irreversible on centennial to millennial time scales in global ocean temperature (*very high confidence*), deep ocean acidification (*very high confidence*) and deoxygenation (*medium confidence*).
{4.3, 4.5, 4.7, 5.3, 9.2, TS.2.4} **(Figure SPM.8)**

B.5.2 Mountain and polar glaciers are committed to continue melting for decades or centuries (*very high confidence*). Loss of permafrost carbon following permafrost thaw is irreversible at centennial timescales (*high confidence*). Continued ice loss over the 21st century is *virtually certain* for the Greenland Ice Sheet and *likely* for the Antarctic Ice Sheet. There is *high confidence* that total ice loss from the Greenland Ice Sheet will increase with cumulative emissions. There is *limited evidence* for low-likelihood, high-impact outcomes (resulting from ice sheet instability processes characterized by deep uncertainty and in some cases involving tipping points) that would strongly increase ice loss from the Antarctic Ice Sheet for centuries under high GHG emissions scenarios[34]. {4.3, 4.7, 5.4, 9.4, 9.5, Box 9.4, Box TS.1, TS.2.5}

B.5.3 It is *virtually certain* that global mean sea level will continue to rise over the 21st century. Relative to 1995-2014, the *likely* global mean sea level rise by 2100 is 0.28-0.55 m under the very low GHG emissions scenario (SSP1-1.9), 0.32-0.62 m under the low GHG emissions scenario (SSP1-2.6), 0.44-0.76 m under the intermediate GHG emissions scenario (SSP2-4.5), and 0.63-1.01 m under the very high GHG emissions scenario (SSP5-8.5), and by 2150 is 0.37-0.86 m under the very low scenario (SSP1-1.9), 0.46-0.99 m under the low scenario (SSP1-2.6), 0.66-1.33 m under the intermediate scenario (SSP2-4.5), and 0.98-1.88 m under the very high scenario (SSP5-8.5) (*medium confidence*)[35]. Global mean sea level rise above the *likely* range – approaching 2 m by 2100 and 5 m by 2150 under a very high GHG emissions scenario (SSP5-8.5) (*low confidence*) – cannot be ruled out due to deep uncertainty in ice sheet processes.
{4.3, 9.6, Box 9.4, Box TS.4} **(Figure SPM.8)**

B.5.4 In the longer term, sea level is committed to rise for centuries to millennia due to continuing deep ocean warming and ice sheet melt, and will remain elevated for thousands of years (*high confidence*). Over the next 2000 years, global mean sea level will rise by about 2 to 3 m if warming is limited to 1.5°C, 2 to 6 m if limited to 2°C and 19 to 22 m with 5°C of warming, and it will continue to rise over subsequent millennia (*low confidence*). Projections of multi-millennial global mean sea level rise are consistent with reconstructed levels during past warm climate periods: *likely* 5–10 m higher than today around 125,000 years ago, when global temperatures were *very likely* 0.5°C–1.5°C higher than 1850–1900; and *very likely* 5–25 m higher roughly 3 million years ago, when global temperatures were 2.5°C–4°C higher (*medium confidence*).
{2.3, Cross-Chapter Box 2.4, 9.6, Box TS.2, Box TS.4, Box TS.9}

[34] Low-likelihood, high-impact outcomes are those whose probability of occurrence is low or not well known (as in the context of deep uncertainty) but whose potential impacts on society and ecosystems could be high. A tipping point is a critical threshold beyond which a system reorganizes, often abruptly and/or irreversibly. {Cross-Chapter Box 1.3, 1.4, 4.7}

[35] To compare to the 1986–2005 baseline period used in AR5 and SROCC, add 0.03 m to the global mean sea level rise estimates. To compare to the 1900 baseline period used in Figure SPM.8, add 0.16 m.

Human activities affect all the major climate system components, with some responding over decades and others over centuries

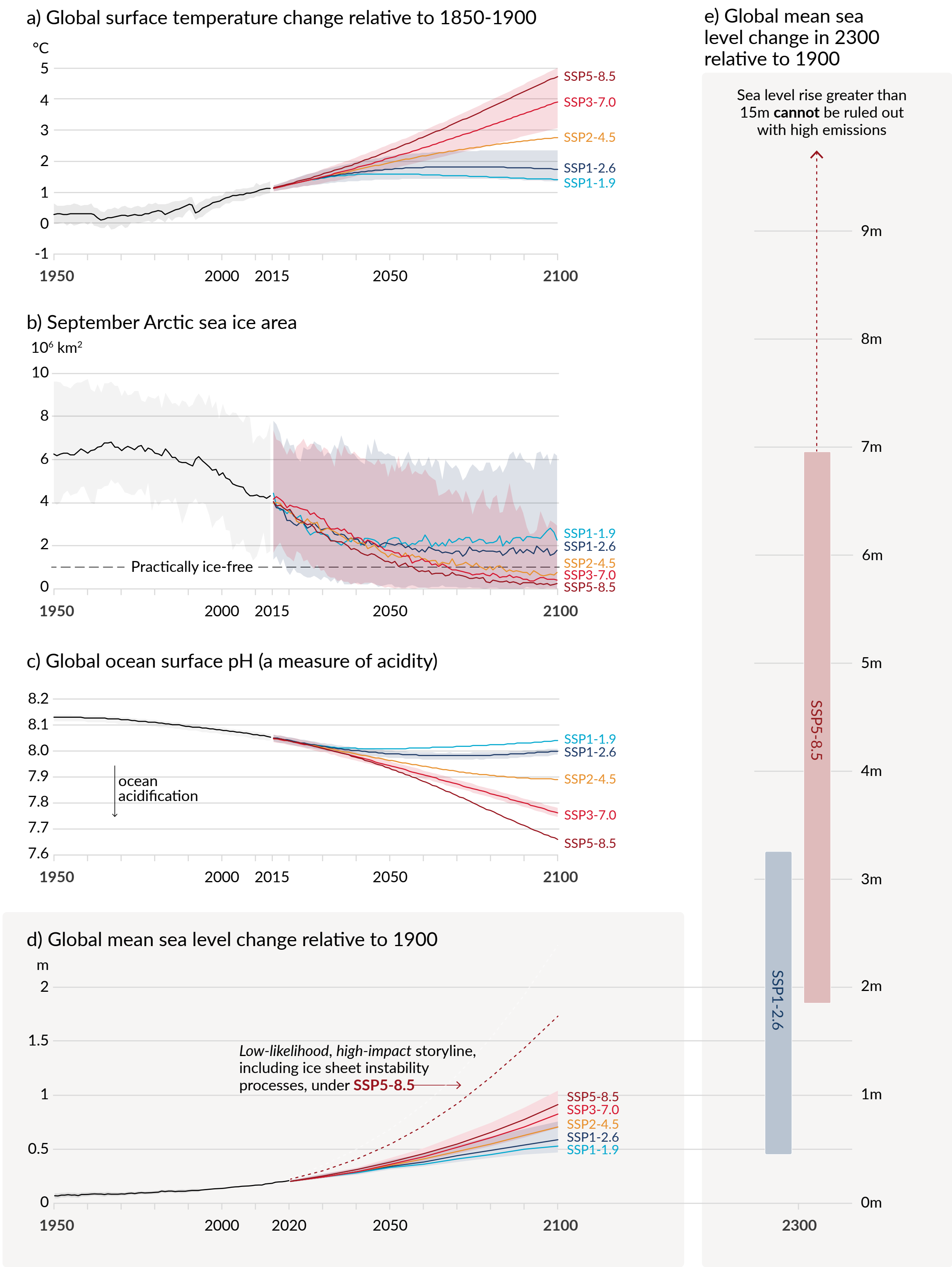


Figure SPM.8: Selected indicators of global climate change under the five illustrative scenarios used in this report.

The projections for each of the five scenarios are shown in colour. Shades represent uncertainty ranges – more detail is provided for each panel below. The black curves represent the historical simulations (panels a, b, c) or the observations (panel d). Historical values are included in all graphs to provide context for the projected future changes.

Panel a) Global surface temperature changes in °C relative to 1850–1900. These changes were obtained by combining CMIP6 model simulations with observational constraints based on past simulated warming, as well as an updated assessment of equilibrium climate sensitivity (see Box SPM.1). Changes relative to 1850–1900 based on 20-year averaging periods are calculated by adding 0.85°C (the observed global surface temperature increase from 1850–1900 to 1995–2014) to simulated changes relative to 1995–2014. *Very likely* ranges are shown for SSP1-2.6 and SSP3-7.0.

Panel b) September Arctic sea ice area in 10^6 km^2 based on CMIP6 model simulations. *Very likely* ranges are shown for SSP1-2.6 and SSP3-7.0. The Arctic is projected to be practically ice-free near mid-century under mid- and high GHG emissions scenarios.

Panel c) Global ocean surface pH (a measure of acidity) based on CMIP6 model simulations. *Very likely* ranges are shown for SSP1-2.6 and SSP3-7.0.

Panel d) Global mean sea level change in meters relative to 1900. The historical changes are observed (from tide gauges before 1992 and altimeters afterwards), and the future changes are assessed consistently with observational constraints based on emulation of CMIP, ice sheet, and glacier models. *Likely* ranges are shown for SSP1-2.6 and SSP3-7.0. Only *likely* ranges are assessed for sea level changes due to difficulties in estimating the distribution of deeply uncertain processes. The dashed curve indicates the potential impact of these deeply uncertain processes. It shows the 83rd percentile of SSP5-8.5 projections that include low-likelihood, high-impact ice sheet processes that cannot be ruled out; because of *low confidence* in projections of these processes, this curve does not constitute part of a *likely* range. Changes relative to 1900 are calculated by adding 0.158 m (observed global mean sea level rise from 1900 to 1995–2014) to simulated and observed changes relative to 1995–2014.

Panel e): Global mean sea level change at 2300 in meters relative to 1900. Only SSP1-2.6 and SSP5-8.5 are projected at 2300, as simulations that extend beyond 2100 for the other scenarios are too few for robust results. The 17th–83rd percentile ranges are shaded. The dashed arrow illustrates the 83rd percentile of SSP5-8.5 projections that include low-likelihood, high-impact ice sheet processes that cannot be ruled out.

Panels b) and c) are based on single simulations from each model, and so include a component of internal variability. Panels a), d) and e) are based on long-term averages, and hence the contributions from internal variability are small.

{Figure TS.8, Figure TS.11, Box TS.4 Figure 1, Box TS.4 Figure 1, 4.3, 9.6, Figure 4.2, Figure 4.8, Figure 4.11, Figure 9.27}

C. Climate Information for Risk Assessment and Regional Adaptation

Physical climate information addresses how the climate system responds to the interplay between human influence, natural drivers and internal variability. Knowledge of the climate response and the range of possible outcomes, including low-likelihood, high impact outcomes, informs climate services – the assessment of climate-related risks and adaptation planning. Physical climate information at global, regional and local scales is developed from multiple lines of evidence, including observational products, climate model outputs and tailored diagnostics.

C.1 Natural drivers and internal variability will modulate human-caused changes, especially at regional scales and in the near term, with little effect on centennial global warming. These modulations are important to consider in planning for the full range of possible changes.

{1.4, 2.2, 3.3, Cross-Chapter Box 3.1, 4.4, 4.6, Cross-Chapter Box 4.1, 4.4, Box 7.2, 8.3, 8.5, 9.2, 10.3, 10.4, 10.6, 11.3, 12.5, Atlas.4, Atlas.5, Atlas.8, Atlas.9, Atlas.10, Cross-Chapter Box Atlas.2, Atlas.11}

C.1.1 The historical global surface temperature record highlights that decadal variability has enhanced and masked underlying human-caused long-term changes, and this variability will continue into the future (*very high confidence*). For example, internal decadal variability and variations in solar and volcanic drivers partially masked human-caused surface global warming during 1998–2012, with pronounced regional and seasonal signatures (*high confidence*). Nonetheless, the heating of the climate system continued during this period, as reflected in both the continued warming of the global ocean (*very high confidence*) and in the continued rise of hot extremes over land (*medium confidence*).
{1.4, 3.3, Cross-Chapter Box 3.1, 4.4, Box 7.2, 9.2, 11.3, Cross-Section Box TS.1} **(Figure SPM.1)**

C.1.2 Projected human caused changes in mean climate and climatic impact-drivers (CIDs)[36], including extremes, will be either amplified or attenuated by internal variability[37] (*high confidence*). Near-term cooling at any particular location with respect to present climate could occur and would be consistent with the global surface temperature increase due to human influence (*high confidence*).
{1.4, 4.4, 4.6, 10.4, 11.3, 12.5, Atlas.5, Atlas.10, Atlas.11, TS.4.2}

C.1.3 Internal variability has largely been responsible for the amplification and attenuation of the observed human-caused decadal-to-multi-decadal mean precipitation changes in many land regions *(high confidence)*. At global and regional scales, near-term changes in monsoons will be dominated by the effects of internal variability (*medium confidence*). In addition to internal variability influence, near-term projected changes in precipitation at global and regional scales are uncertain because of model uncertainty and uncertainty in forcings from natural and anthropogenic aerosols (*medium confidence*).
{1.4, 4.4, 8.3, 8.5, 10.3, 10.4, 10.5, 10.6, Atlas.4, Atlas.8, Atlas.9, Atlas.10, Cross-Chapter Box Atlas.2, Atlas.11, TS.4.2, Box TS.6, Box TS.13}

[36] Climatic impact-drivers (CIDs) are physical climate system conditions (e.g., means, events, extremes) that affect an element of society or ecosystems. Depending on system tolerance, CIDs and their changes can be detrimental, beneficial, neutral, or a mixture of each across interacting system elements and regions. CID types include heat and cold, wet and dry, wind, snow and ice, coastal and open ocean.

[37] The main internal variability phenomena include El Niño–Southern Oscillation, Pacific Decadal variability and Atlantic Multi-decadal variability through their regional influence.

C.1.4 Based on paleoclimate and historical evidence, it is *likely* that at least one large explosive volcanic eruption would occur during the 21st century[38]. Such an eruption would reduce global surface temperature and precipitation, especially over land, for one to three years, alter the global monsoon circulation, modify extreme precipitation and change many CIDs (*medium confidence*). If such an eruption occurs, this would therefore temporarily and partially mask human-caused climate change.
{4.4, Cross-Chapter Box 4.1, 2.2, 8.5, TS.2.1}

C.2 With further global warming, every region is projected to increasingly experience concurrent and multiple changes in climatic impact-drivers. Changes in several climatic impact-drivers would be more widespread at 2°C compared to 1.5°C global warming and even more widespread and/or pronounced for higher warming levels.
{8.2, 9.3, 9.5, 9.6, Box 10.3, Box 11.3, Box 11.4, 11.3, 11.4, 11.5, 11.6, 11.7, 11.9, 12.2, 12.3, 12.4, 12.5, Atlas.4, Atlas.5, Atlas.6, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11, Cross-Chapter Box 11.1, Cross-Chapter Box 12.1} **(Table SPM.1, Figure SPM.9)**

C.2.1 All regions[39] are projected to experience further increases in hot climatic impact-drivers (CIDs) and decreases in cold CIDs (*high confidence*). Further decreases are projected in permafrost, snow, glaciers and ice sheets, lake and Arctic sea ice (*medium* to *high confidence*)[40]. These changes would be larger at 2°C global warming or above than at 1.5°C (*high confidence*). For example, extreme heat thresholds relevant to agriculture and health are projected to be exceeded more frequently at higher global warming levels (*high confidence*).
{9.3, 9.5, 11.3, 11.9, 12.3, 12.4, 12.5, Atlas.4, Atlas.5, Atlas.6, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11, TS.4.3, Cross-Chapter Box 11.1, Cross-Chapter Box 12.1} **(Table SPM.1, Figure SPM.9)**

C.2.2 At 1.5°C global warming, heavy precipitation and associated flooding are projected to intensify and be more frequent in most regions in Africa and Asia (*high confidence*), North America (*medium* to *high confidence*)[40] and Europe (*medium confidence*). Also**,** more frequent and/or severe agricultural and ecological droughts are projected in a few regions in all continents except Asia compared to 1850–1900 (*medium confidence*); increases in meteorological droughts are also projected in a few regions (*medium confidence*). A small number of regions are projected to experience increases or decreases in mean precipitation (*medium confidence*).
{11.4, 11.5, 11.6, 11.9, Atlas.4, Atlas.5, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11, TS.4.3} **(Table SPM.1)**

[38] Based on 2,500 year reconstructions, eruptions more negative than -1 W m^{-2} occur on average twice per century.

[39] Regions here refer to the AR6 WGI reference regions used in this Report to summarize information in sub-continental and oceanic regions. Changes are compared to averages over the last 20–40 years unless otherwise specified. {1.4, 12.4, Atlas.1, Interactive Atlas}.

[40] The specific level of confidence or likelihood depends on the region considered. Details can be found in the Technical Summary and the underlying Report.

C.2.3 At 2°C global warming and above, the level of confidence in and the magnitude of the change in droughts and heavy and mean precipitation increase compared to those at 1.5°C. Heavy precipitation and associated flooding events are projected to become more intense and frequent in the Pacific Islands and across many regions of North America and Europe (*medium* to *high confidence*)[40]. These changes are also seen in some regions in Australasia and Central and South America (*medium confidence*). Several regions in Africa, South America and Europe are projected to experience an increase in frequency and/or severity of agricultural and ecological droughts with *medium* to *high confidence*[40]; increases are also projected in Australasia, Central and North America, and the Caribbean with *medium confidence*. A small number of regions in Africa, Australasia, Europe and North America are also projected to be affected by increases in hydrological droughts, and several regions are projected to be affected by increases or decreases in meteorological droughts with more regions displaying an increase (*medium confidence*). Mean precipitation is projected to increase in all polar, northern European and northern North American regions, most Asian regions and two regions of South America (*high confidence*).
{11.4, 11.6, 11.9, 12.4, 12.5, Atlas.5, Atlas.7, Atlas.8, Atlas.9, Atlas.11, TS.4.3, Cross-Chapter Box 11.1, Cross-Chapter Box 12.1} **(Table SPM.1, Figure SPM.5, Figure SPM.6, Figure SPM.9)**

C.2.4 More CIDs across more regions are projected to change at 2°C and above compared to 1.5°C global warming (*high confidence*). Region-specific changes include intensification of tropical cyclones and/or extratropical storms (*medium confidence*), increases in river floods (*medium* to *high confidence*)[40], reductions in mean precipitation and increases in aridity (*medium* to *high confidence*)[40], and increases in fire weather (*medium* to *high confidence*)[40]. There is *low confidence* in most regions in potential future changes in other CIDs, such as hail, ice storms, severe storms, dust storms, heavy snowfall, and landslides.
{11.7, 11.9, 12.4, 12.5, Atlas.4, Atlas.6, Atlas.7, Atlas.8, Atlas.10, TS.4.3.1, TS.4.3.2, TS.5, Cross-Chapter Box, 11.1, Cross-Chapter Box 12.1} **(Table SPM.1, Figure SPM.9)**

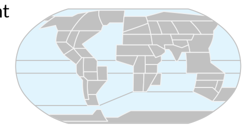
C.2.5 It is *very likely* to *virtually certain*[40] that regional mean relative sea level rise will continue throughout the 21st century, except in a few regions with substantial geologic land uplift rates. Approximately two-thirds of the global coastline has a projected regional relative sea level rise within ±20% of the global mean increase (*medium confidence*). Due to relative sea level rise, extreme sea level events that occurred once per century in the recent past are projected to occur at least annually at more than half of all tide gauge locations by 2100 (*high confidence*). Relative sea level rise contributes to increases in the frequency and severity of coastal flooding in low-lying areas and to coastal erosion along most sandy coasts (*high confidence*).
{9.6, 12.4, 12.5, Box TS.4, TS.4.3, Cross-Chapter Box 12.1} **(Figure SPM.9)**

C.2.6 Cities intensify human-induced warming locally, and further urbanization together with more frequent hot extremes will increase the severity of heatwaves (*very high confidence*). Urbanization also increases mean and heavy precipitation over and/or downwind of cities (*medium confidence*) and resulting runoff intensity (*high confidence*). In coastal cities, the combination of more frequent extreme sea level events (due to sea level rise and storm surge) and extreme rainfall/riverflow events will make flooding more probable (*high confidence*).
{8.2, Box 10.3, 11.3, 12.4, Box TS.14}

C.2.7 Many regions are projected to experience an increase in the probability of compound events with higher global warming (*high confidence*). In particular, concurrent heatwaves and droughts are *likely* to become more frequent. Concurrent extremes at multiple locations become more frequent, including in crop-producing areas, at 2°C and above compared to 1.5°C global warming (*high confidence*).
{11.8, Box 11.3, Box 11.4, 12.3, 12.4, TS.4.3, Cross-Chapter Box 12.1} **(Table SPM.1)**

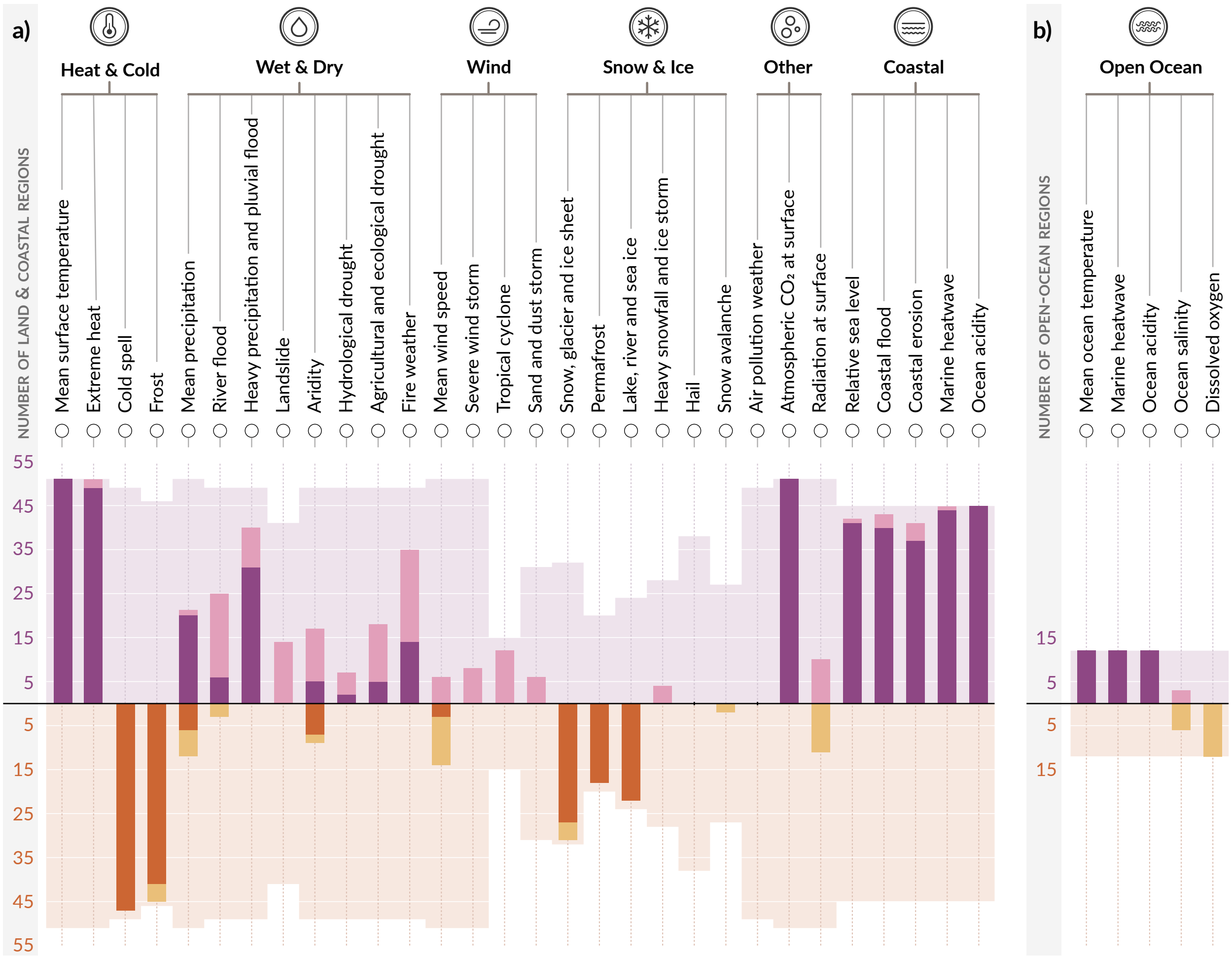
Multiple climatic impact-drivers are projected to change in all regions of the world

Climatic impact-drivers (CIDs) are physical climate system conditions (e.g., means, events, extremes) that affect an element of society or ecosystems. Depending on system tolerance, CIDs and their changes can be detrimental, beneficial, neutral, or a mixture of each across interacting system elements and regions. The CIDs are grouped into seven types, which are summarized under the icons in the figure. All regions are projected to experience changes in at least 5 CIDs. Almost all (96%) are projected to experience changes in at least 10 CIDs and half in at least 15 CIDs. For many CIDs there is wide geographical variation in where they change and so each region are projected to experience a specific set of CID changes. Each bar in the chart represents a specific geographical set of changes that can be explored in the WGI Interactive Atlas.



interactive-atlas.ipcc.ch

Number of land & coastal regions (a) and **open-ocean regions** (b) where each **climatic impact-driver** (CID) is projected to **increase** or **decrease** with ***high** confidence* (dark shade) or ***medium** confidence* (light shade)



BAR CHART LEGEND

- Regions with ***high** confidence* **increase**
- Regions with ***medium** confidence* **increase**
- Regions with ***high** confidence* **decrease**
- Regions with ***medium** confidence* **decrease**

LIGHTER-SHADED 'ENVELOPE' LEGEND

The height of the lighter shaded 'envelope' behind each bar represents the maximum number of regions for which each CID is relevant. The envelope is symmetrical about the x-axis showing the maximum possible number of relevant regions for CID increase (upper part) or decrease (lower part).

ASSESSED FUTURE CHANGES

Changes refer to a 20–30 year period centred around 2050 and/or consistent with 2°C global warming compared to a similar period within 1960-2014 or 1850-1900.

Figure SPM.9: Synthesis of the number of AR6 WGI reference regions where climatic impact-drivers are projected to change.

A total of 35 climatic impact-drivers (CIDs) grouped into seven types are shown: heat and cold, wet and dry, wind, snow and ice, coastal, open ocean and other. For each CID, the bar in the graph below displays the number of AR6 WGI reference regions where it is projected to change. The **colours** represent the direction of change and the level of confidence in the change: purple indicates an increase while brown indicates a decrease; darker and lighter shades refer to *high* and *medium confidence*, respectively. Lighter background colours represent the maximum number of regions for which each CID is broadly relevant.

Panel a) shows the 30 CIDs relevant to the **land and coastal regions** while **panel b)** shows the 5 CIDs relevant to the **open ocean regions.** Marine heatwaves and ocean acidity are assessed for coastal ocean regions in panel a) and for open ocean regions in panel b). Changes refer to a 20–30 year period centred around 2050 and/or consistent with 2°C global warming compared to a similar period within 1960-2014, except for hydrological drought and agricultural and ecological drought which is compared to 1850-1900. Definitions of the regions are provided in Atlas.1 and the Interactive Atlas (see *interactive-atlas.ipcc.ch*).

{Table TS.5, Figure TS.22, Figure TS.25, 11.9, 12.2, 12.4, Atlas.1} **(Table SPM.1)**

C.3 Low-likelihood outcomes, such as ice sheet collapse, abrupt ocean circulation changes, some compound extreme events and warming substantially larger than the assessed *very likely* range of future warming cannot be ruled out and are part of risk assessment.

{1.4, Cross-Chapter Box 1.3, Cross-Chapter Box 4.1, 4.3, 4.4, 4.8, 8.6, 9.2, Box 9.4, Box 11.2, 11.8, Cross-Chapter Box 12.1} **(Table SPM.1)**

C.3.1 If global warming exceeds the assessed *very likely* range for a given GHG emissions scenario, including low GHG emissions scenarios, global and regional changes in many aspects of the climate system, such as regional precipitation and other CIDs, would also exceed their assessed *very likely* ranges (*high confidence*). Such low-likelihood high-warming outcomes are associated with potentially very large impacts, such as through more intense and more frequent heatwaves and heavy precipitation, and high risks for human and ecological systems particularly for high GHG emissions scenarios.
{Cross-Chapter Box 1.3, 4.3, 4.4, 4.8, Box 9.4, Box 11.2, Cross-Chapter Box 12.1, TS.1.4, Box TS.3, Box TS.4} **(Table SPM.1)**

C.3.2 Low-likelihood, high-impact outcomes[34] could occur at global and regional scales even for global warming within the *very likely* range for a given GHG emissions scenario. The probability of low-likelihood, high impact outcomes increases with higher global warming levels (*high confidence*). Abrupt responses and tipping points of the climate system, such as strongly increased Antarctic ice sheet melt and forest dieback, cannot be ruled out (*high confidence*).
{1.4, 4.3, 4.4, 4.8, 5.4, 8.6, Box 9.4, Cross-Chapter Box 12.1, TS.1.4, TS.2.5, Box TS.3, Box TS.4, Box TS.9} **(Table SPM.1)**

C.3.3 If global warming increases, some compound extreme events[18] with low likelihood in past and current climate will become more frequent, and there will be a higher likelihood that events with increased intensities, durations and/or spatial extents unprecedented in the observational record will occur (*high confidence*).
{11.8, Box 11.2, Cross-Chapter Box 12.1, Box TS.3, Box TS.9}

C.3.4 The Atlantic Meridional Overturning Circulation is *very likely* to weaken over the 21st century for all emission scenarios. While there is *high confidence* in the 21st century decline, there is only *low confidence* in the magnitude of the trend. There is *medium confidence* that there will not be an abrupt collapse before 2100. If such a collapse were to occur, it would *very likely* cause abrupt shifts in regional weather patterns and water cycle, such as a southward shift in the tropical rain belt, weakening of the African and Asian monsoons and strengthening of Southern Hemisphere monsoons, and drying in Europe. {4.3, 8.6, 9.2, TS2.4, Box TS.3}

C.3.5 Unpredictable and rare natural events not related to human influence on climate may lead to low-likelihood, high impact outcomes. For example, a sequence of large explosive volcanic eruptions within decades has occurred in the past, causing substantial global and regional climate perturbations over several decades. Such events cannot be ruled out in the future, but due to their inherent unpredictability they are not included in the illustrative set of scenarios referred to in this Report. {2.2, Cross-Chapter Box 4.1, Box TS.3} **(Box SPM.1)**

D. Limiting Future Climate Change

Since AR5, estimates of remaining carbon budgets have been improved by a new methodology first presented in SR1.5, updated evidence, and the integration of results from multiple lines of evidence. A comprehensive range of possible future air pollution controls in scenarios is used to consistently assess the effects of various assumptions on projections of climate and air pollution. A novel development is the ability to ascertain when climate responses to emissions reductions would become discernible above natural climate variability, including internal variability and responses to natural drivers.

D.1 From a physical science perspective, limiting human-induced global warming to a specific level requires limiting cumulative CO_2 emissions, reaching at least net zero CO_2 emissions, along with strong reductions in other greenhouse gas emissions. Strong, rapid and sustained reductions in CH_4 emissions would also limit the warming effect resulting from declining aerosol pollution and would improve air quality.

{3.3, 4.6, 5.1, 5.2, 5.4, 5.5, 5.6, Box 5.2, Cross-Chapter Box 5.1, 6.7, 7.6, 9.6} **(Figure SPM.10, Table SPM.2)**

D.1.1 This Report reaffirms with *high confidence* the AR5 finding that there is a near-linear relationship between cumulative anthropogenic CO_2 emissions and the global warming they cause. Each 1000 $GtCO_2$ of cumulative CO_2 emissions is assessed to *likely* cause a 0.27°C to 0.63°C increase in global surface temperature with a best estimate of 0.45°C[41]. This is a narrower range compared to AR5 and SR1.5. This quantity is referred to as the transient climate response to cumulative CO_2 emissions (TCRE). This relationship implies that reaching net zero[42] anthropogenic CO_2 emissions is a requirement to stabilize human-induced global temperature increase at any level, but that limiting global temperature increase to a specific level would imply limiting cumulative CO_2 emissions to within a carbon budget[43]. {5.4, 5.5, TS.1.3, TS.3.3, Box TS.5} **(Figure SPM.10)**

[41] In the literature, units of °C per 1000 PgC are used, and the AR6 reports the TCRE *likely* range as 1.0°C to 2.3°C per 1000 PgC in the underlying report, with a best estimate of 1.65°C.

[42] condition in which anthropogenic carbon dioxide (CO_2) emissions are balanced by anthropogenic CO_2 removals over a specified period.

[43] The term carbon budget refers to the maximum amount of cumulative net global anthropogenic CO_2 emissions that would result in limiting global warming to a given level with a given probability, taking into account the effect of other anthropogenic climate forcers. This is referred to as the total carbon budget when expressed starting from the pre-industrial period, and as the remaining carbon budget when expressed from a recent specified date (see Glossary). Historical cumulative CO_2 emissions determine to a large degree warming to date, while future emissions cause future additional warming. The remaining carbon budget indicates how much CO_2 could still be emitted while keeping warming below a specific temperature level.

Every tonne of CO_2 emissions adds to global warming

Global surface temperature increase since 1850-1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$)

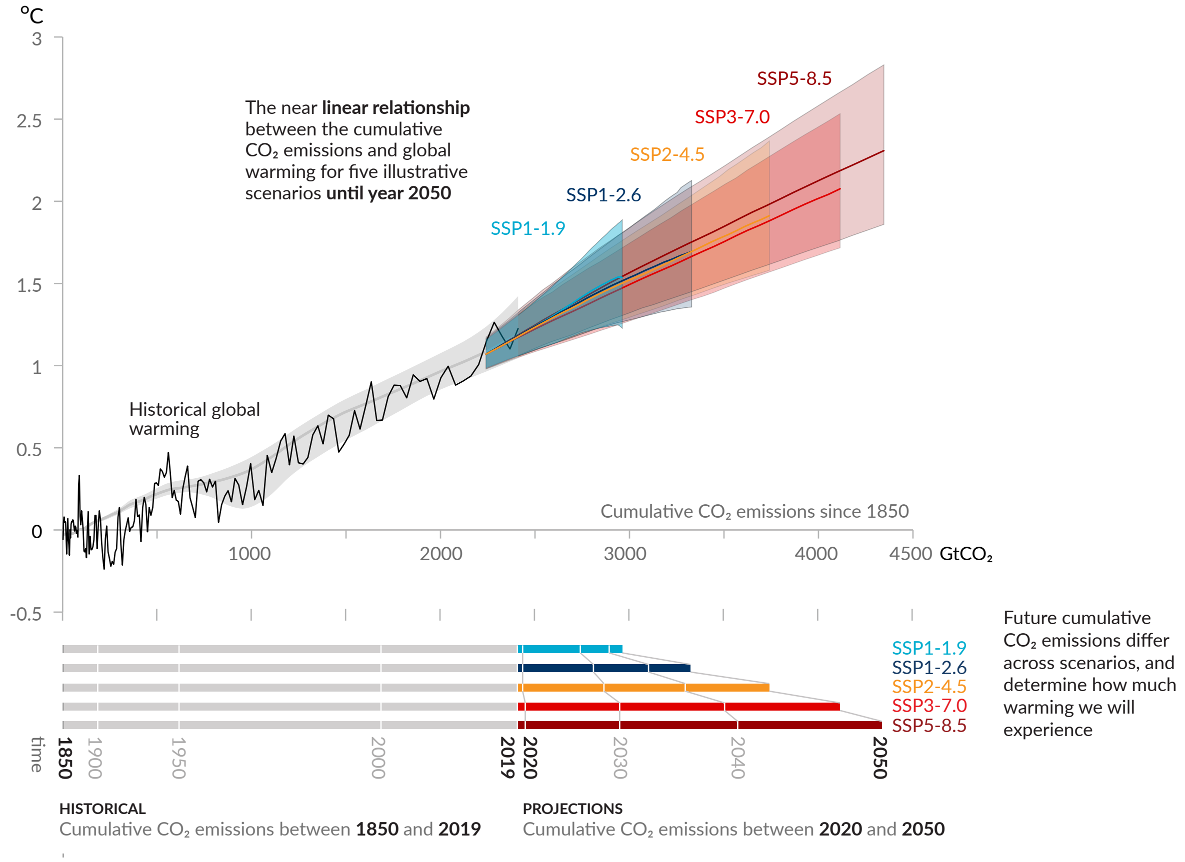


Figure SPM.10: Near-linear relationship between cumulative CO2 emissions and the increase in global surface temperature.

Top panel: Historical data (thin black line) shows observed global surface temperature increase in °C since 1850–1900 as a function of historical cumulative carbon dioxide (CO_2) emissions in $GtCO_2$ from 1850 to 2019. The grey range with its central line shows a corresponding estimate of the historical human-caused surface warming (see Figure SPM.2). Coloured areas show the assessed *very likely* range of global surface temperature projections, and thick coloured central lines show the median estimate as a function of cumulative CO_2 emissions from 2020 until year 2050 for the set of illustrative scenarios (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5, see Figure SPM.4). Projections use the cumulative CO_2 emissions of each respective scenario, and the projected global warming includes the contribution from all anthropogenic forcers. The relationship is illustrated over the domain of cumulative CO_2 emissions for which there is *high confidence* that the transient climate response to cumulative CO_2 emissions (TCRE) remains constant, and for the time period from 1850 to 2050 over which global CO_2 emissions remain net positive under all illustrative scenarios as there is *limited evidence* supporting the quantitative application of TCRE to estimate temperature evolution under net negative CO_2 emissions.

Bottom panel: Historical and projected cumulative CO_2 emissions in $GtCO_2$ for the respective scenarios.

{Figure TS.18, Figure 5.31, Section 5.5}

D.1.2 Over the period 1850–2019, a total of 2390 ± 240 (*likely* range) $GtCO_2$ of anthropogenic CO_2 was emitted. Remaining carbon budgets have been estimated for several global temperature limits and various levels of probability, based on the estimated value of TCRE and its uncertainty, estimates of historical warming, variations in projected warming from non-CO_2 emissions, climate system feedbacks such as emissions from thawing permafrost, and the global surface temperature change after global anthropogenic CO_2 emissions reach net zero.
{5.1, 5.5, Box 5.2, TS.3.3} **(Table SPM.2)**

Table SPM.2: **Estimates of historical CO_2 emissions and remaining carbon budgets.** Estimated remaining carbon budgets are calculated from the beginning of 2020 and extend until global net zero CO_2 emissions are reached. They refer to CO_2 emissions, while accounting for the global warming effect of non-CO_2 emissions. Global warming in this table refers to human-induced global surface temperature increase, which excludes the impact of natural variability on global temperatures in individual years. {Table TS.3, Table 3.1, Table 5.1, Table 5.7, Table 5.8, 5.5.1, 5.5.2, Box 5.2}

Global warming between 1850–1900 and 2010–2019 *(°C)*	Historical cumulative CO_2 emissions from 1850 to 2019 *($GtCO_2$)*
1.07 (0.8–1.3; *likely* range)	2390 (± 240; *likely* range)

Approximate global warming relative to 1850–1900 until temperature limit *(°C)**(1)	Additional global warming relative to 2010–2019 until temperature limit *(°C)*	Estimated remaining carbon budgets from the beginning of 2020 *($GtCO_2$)* *Likelihood of limiting global warming to temperature limit*(2)*					Variations in reductions in non-CO_2 emissions*(3)
		17%	*33%*	*50%*	*67%*	*83%*	
1.5	0.43	900	650	500	400	300	Higher or lower reductions in accompanying non-CO_2 emissions can increase or decrease the values on the left by 220 $GtCO_2$ or more
1.7	0.63	1450	1050	850	700	550	
2.0	0.93	2300	1700	1350	1150	900	

*(1) Values at each 0.1°C increment of warming are available in Tables TS.3 and 5.8.
*(2) This likelihood is based on the uncertainty in transient climate response to cumulative CO_2 emissions (TCRE) and additional Earth system feedbacks, and provides the probability that global warming will not exceed the temperature levels provided in the two left columns. Uncertainties related to historical warming (±550 $GtCO_2$) and non-CO_2 forcing and response (±220 $GtCO_2$) are partially addressed by the assessed uncertainty in TCRE, but uncertainties in recent emissions since 2015 (±20 $GtCO_2$) and the climate response after net zero CO_2 emissions are reached (±420 $GtCO_2$) are separate.
*(3) Remaining carbon budget estimates consider the warming from non-CO_2 drivers as implied by the scenarios assessed in SR1.5. The Working Group III Contribution to AR6 will assess mitigation of non-CO_2 emissions.

D.1.3 Several factors that determine estimates of the remaining carbon budget have been re-assessed, and updates to these factors since SR1.5 are small. When adjusted for emissions since previous reports, estimates of remaining carbon budgets are therefore of similar magnitude compared to SR1.5 but larger compared to AR5 due to methodological improvements[44].
{5.5, Box 5.2, TS.3.3} **(Table SPM.2)**

D.1.4 Anthropogenic CO_2 removal (CDR) has the potential to remove CO_2 from the atmosphere and durably store it in reservoirs (*high confidence*). CDR aims to compensate for residual emissions to reach net zero CO_2 or net zero GHG emissions or, if implemented at a scale where anthropogenic removals exceed anthropogenic emissions, to lower surface temperature. CDR methods can have potentially wide-ranging effects on biogeochemical cycles and climate, which can either weaken or strengthen the potential of these methods to remove CO_2 and reduce warming, and can also influence water availability and quality, food production and biodiversity[45] (*high confidence*).
{5.6, Cross-Chapter Box 5.1, TS.3.3}

D.1.5 Anthropogenic CO_2 removal (CDR) leading to global net negative emissions would lower the atmospheric CO_2 concentration and reverse surface ocean acidification (*high confidence*). Anthropogenic CO_2 removals and emissions are partially compensated by CO_2 release and uptake respectively, from or to land and ocean carbon pools (*very high confidence*). CDR would lower atmospheric CO_2 by an amount approximately equal to the increase from an anthropogenic emission of the same magnitude (*high confidence*). The atmospheric CO_2 decrease from anthropogenic CO_2 removals could be up to 10% less than the atmospheric CO_2 increase from an equal amount of CO_2 emissions, depending on the total amount of CDR (*medium confidence*). {5.3, 5.6, TS.3.3}

D.1.6 If global net negative CO_2 emissions were to be achieved and be sustained, the global CO_2-induced surface temperature increase would be gradually reversed but other climate changes would continue in their current direction for decades to millennia (*high confidence*). For instance, it would take several centuries to millennia for global mean sea level to reverse course even under large net negative CO_2 emissions (*high confidence*).
{4.6, 9.6, TS.3.3}

D.1.7 In the five illustrative scenarios, simultaneous changes in CH_4, aerosol and ozone precursor emissions, that also contribute to air pollution, lead to a net global surface warming in the near and long-term (*high confidence*). In the long term, this net warming is lower in scenarios assuming air pollution controls combined with strong and sustained CH_4 emission reductions (*high confidence*). In the low and very low GHG emissions scenarios, assumed reductions in anthropogenic aerosol emissions lead to a net warming, while reductions in CH_4 and other ozone precursor emissions lead to a net cooling. Because of the short lifetime of both CH_4 and aerosols, these climate effects partially counterbalance each other and reductions in CH_4 emissions also contribute to improved air quality by reducing global surface ozone (*high confidence*).
{6.7, Box TS.7} **(Figure SPM.2, Box SPM.1)**

[44] Compared to AR5, and when taking into account emissions since AR5, estimates in AR6 are about 300–350 $GtCO_2$ larger for the remaining carbon budget consistent with limiting warming to 1.5°C; for 2°C, the difference is about 400–500 $GtCO_2$.

[45] Potential negative and positive effects of CDR for biodiversity, water and food production are methods-specific, and are often highly dependent on local context, management, prior land use, and scale. IPCC Working Groups II and III assess the CDR potential, and ecological and socio-economic effects of CDR methods in their AR6 contributions.

D.1.8 Achieving global net zero CO_2 emissions is a requirement for stabilizing CO_2-induced global surface temperature increase, with anthropogenic CO_2 emissions balanced by anthropogenic removals of CO_2. This is different from achieving net zero GHG emissions, where metric-weighted anthropogenic GHG emissions equal metric-weighted anthropogenic GHG removals. For a given GHG emission pathway, the pathways of individual greenhouse gases determine the resulting climate response[46], whereas the choice of emissions metric[47] used to calculate aggregated emissions and removals of different GHGs affects what point in time the aggregated greenhouse gases are calculated to be net zero. Emissions pathways that reach and sustain net zero GHG emissions defined by the 100-year global warming potential are projected to result in a decline in surface temperature after an earlier peak (*high confidence*).
{4.6, 7.6, Box 7.3, TS.3.3}

D.2 Scenarios with very low or low GHG emissions (SSP1-1.9 and SSP1-2.6) lead within years to discernible effects on greenhouse gas and aerosol concentrations, and air quality, relative to high and very high GHG emissions scenarios (SSP3-7.0 or SSP5-8.5). Under these contrasting scenarios, discernible differences in trends of global surface temperature would begin to emerge from natural variability within around 20 years, and over longer time periods for many other climatic impact-drivers (*high confidence*). {4.6, Cross-Chapter Box 6.1, 6.6, 6.7, 9.6, Cross-Chapter Box 11.1, 11.2, 11.4, 11.5, 11.6, 12.4, 12.5} **(Figure SPM.8, Figure SPM.10)**

D.2.1 Emissions reductions in 2020 associated with measures to reduce the spread of COVID-19 led to temporary but detectible effects on air pollution (*high confidence*), and an associated small, temporary increase in total radiative forcing, primarily due to reductions in cooling caused by aerosols arising from human activities (*medium confidence*). Global and regional climate responses to this temporary forcing are, however, undetectable above natural variability (*high confidence*). Atmospheric CO_2 concentrations continued to rise in 2020, with no detectable decrease in the observed CO_2 growth rate (*medium confidence*)[48].
{Cross-Chapter Box 6.1, TS.3.3}

D.2.2 Reductions in GHG emissions also lead to air quality improvements. However, in the near term[49], even in scenarios with strong reduction of GHGs, as in the low and very low GHG emission scenarios (SSP1-2.6 and SSP1-1.9), these improvements are not sufficient in many polluted regions to achieve air quality guidelines specified by the World Health Organization (*high confidence*). Scenarios with targeted reductions of air pollutant emissions lead to more rapid improvements in air quality within years compared to reductions in GHG emissions only, but from 2040, further improvements are projected in scenarios that combine efforts to reduce air pollutants as well as GHG emissions with the magnitude of the benefit varying between regions (*high confidence*). {6.6, 6.7, Box TS.7}.

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[46] A general term for how the climate system responds to a radiative forcing (see Glossary).

[47] The choice of emissions metric depends on the purposes for which gases or forcing agents are being compared. This report contains updated emission metric values and assesses new approaches to aggregating gases.

[48] For other GHGs, there was insufficient literature available at the time of the assessment to assess detectable changes in their atmospheric growth rate during 2020.

[49] Near term: (2021–2040)

D.2.3 Scenarios with very low or low GHG emissions (SSP1-1.9 and SSP1-2.6) would have rapid and sustained effects to limit human-caused climate change, compared with scenarios with high or very high GHG emissions (SSP3-7.0 or SSP5-8.5), but early responses of the climate system can be masked by natural variability. For global surface temperature, differences in 20-year trends would *likely* emerge during the near term under a very low GHG emission scenario (SSP1-1.9), relative to a high or very high GHG emission scenario (SSP3-7.0 or SSP5-8.5). The response of many other climate variables would emerge from natural variability at different times later in the 21st century (*high confidence*).
{4.6, Cross-Section Box TS.1} **(Figure SPM.8, Figure SPM.10)**

D.2.4 Scenarios with very low and low GHG emissions (SSP1-1.9 and SSP1-2.6) would lead to substantially smaller changes in a range of CIDs[36] beyond 2040 than under high and very high GHG emissions scenarios (SSP3-7.0 and SSP5-8.5). By the end of the century, scenarios with very low and low GHG emissions would strongly limit the change of several CIDs, such as the increase in the frequency of extreme sea level events, heavy precipitation and pluvial flooding, and exceedance of dangerous heat thresholds, while limiting the number of regions where such exceedances occur, relative to higher GHG emissions scenarios (*high confidence*). Changes would also be smaller in very low compared to low emissions scenarios, as well as for intermediate (SSP2-4.5) compared to high or very high emissions scenarios (*high confidence*). {9.6, Cross-Chapter Box 11.1, 11.2, 11.3, 11.4, 11.5, 11.6, 11.9, 12.4, 12.5, TS.4.3}

Actions for Consideration

As the town makes the transition to non-fossil fuel electricity generation it will also need to look at ways to increase the energy efficiency of all of its buildings and to gradually electrify equipment that currently uses fossil fuels. As equipment needs to be replaced electric models should be opted for in most cases, taking into account the savings to the town over the life of the equipment. Examples include:

- Replacing gasoline generators with solar generation
- Constructing microgrids with solar and storage
- Replacing gasoline mowers, weed whackers, blowers and snow blowers with electric models
- Electrification of vehicle fleet
- Installation of heat pumps wherever feasible