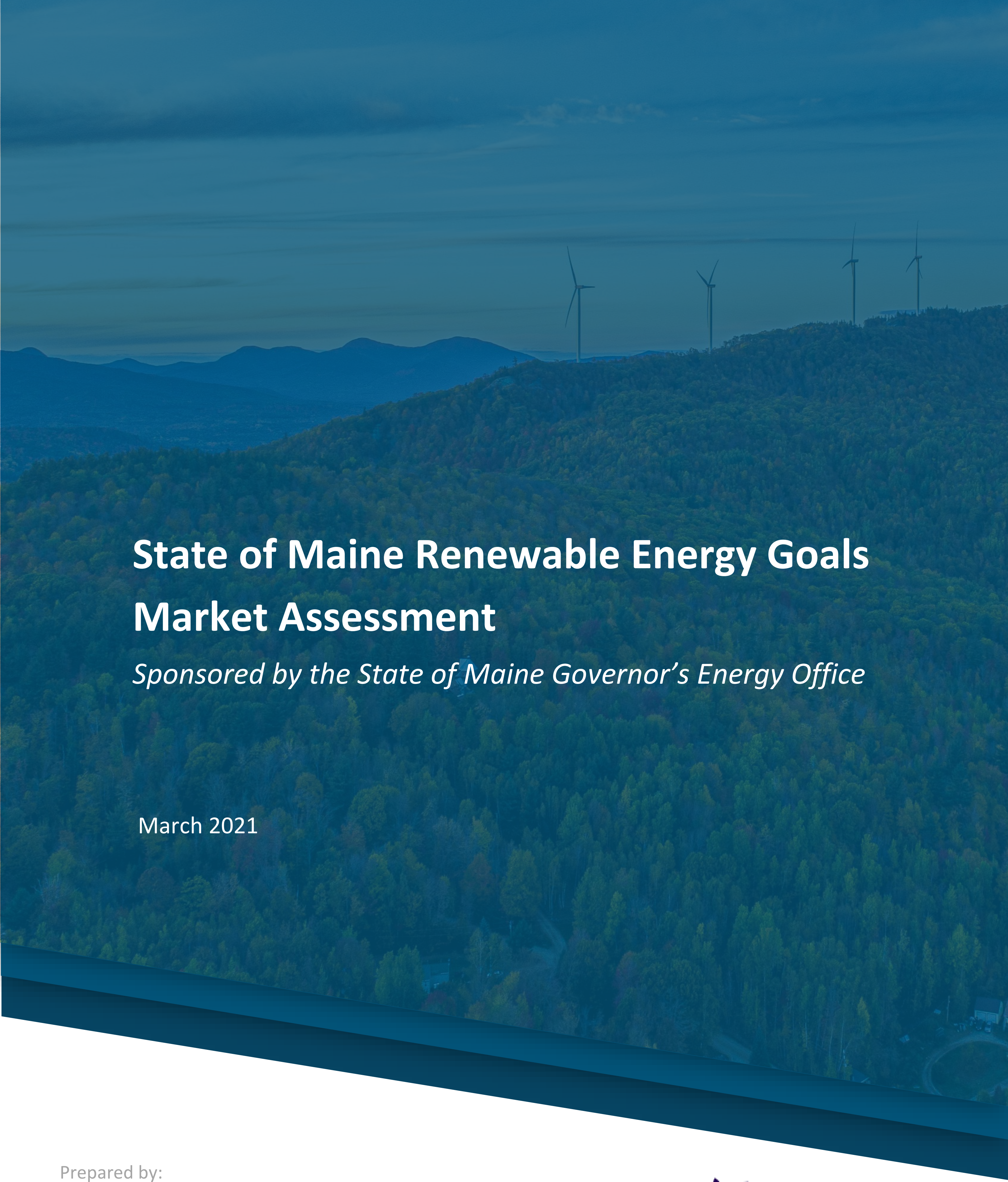

State of Maine Renewable Energy Goals Market Assessment

Sponsored by the State of Maine Governor's Energy Office

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Prepared by:

Energy+Environmental Economics

Applied Economics Clinic
Economic and Policy Analysis of Energy, Environment and Equity

Project Team

This report was produced in a collaboration between Energy and Environmental Economics, Inc. (E3) and The Applied Economics Clinic (AEC) and sponsored by the Maine Governor's Energy Office (GEO). While the GEO and other Maine market participants provided input and perspectives regarding the study scope and analysis, all decisions regarding the analysis were made by E3 and AEC. Thus, this report solely reflects the research, analysis, and conclusions of the E3 and AEC study authors.

E3 is a leading economic consultancy focused on the clean energy transition. E3's analysis of clean energy issues and the electric power sector is utilized extensively by utilities, regulators, developers, and government agencies in leading-edge jurisdictions such as California, New York, and Hawaii. E3 has offices in Boston, New York, San Francisco, Calgary, and Raleigh.

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AEC is a nonprofit consulting group offering low-cost expert services from seasoned professionals while providing on-the-job training to the next generation of technical experts. AEC makes its expertise available to public service organizations working on topics related to the environment, consumer rights, the energy sector, and community equity.

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Abbreviations

ACP	**Alternative Compliance Payment**
AEO	Annual Energy Outlook
AMP	Maine’s Arrearage Management Program
AS	Ancillary Services
ATB	Annual Technology Baseline
BAU	Business As Usual
BYOD	Bring Your Own Device
CES	Clean Energy Standard
CF	Capacity Factor (CF)
CMP	Central Maine Power
COVID-19	Coronavirus Disease 2019
CREZ	Competitive Renewable Energy Zone
EIA	Energy Information Agency
ELCC	Effective Load-Carrying Capacity
ERCOT	Energy Reliability Council of Texas
EV	Electric Vehicle
FCA	Forward Capacity Auction
GEO	Maine Governor’s Energy Office
GHG	Greenhouse Gas
HDV	Heavy-Duty Vehicle
IC	Interconnection
ISO-NE	ISO New England, Inc.
LCOE	Levelized Cost of Energy
LDV	Light-Duty Vehicle
MCC	Maine Climate Council
MEOPA	Maine Office of the Public Advocate
MPUC	Maine Public Utilities Commission
MRIS	Maine Resource Integration Studies
NEADA	National Energy Assistance Directors Association
NEB	Net Energy Billing
NECEC	New England Clean Energy Connect
NESCOE	New England States Committee on Electricity
Net CONE	Net Cost of New Entry
NMISA	Northern Maine Independent System Administrator

NQC	Net Qualifying Capacity
NREL	National Renewable Energy Laboratory
NSRDB	National Solar Radiation Database
PPA	Power Purchase Agreement
PPR	Public Policy Requirements
PPTS	Public Policy Transmission Study
PPTU	Policy Transmission Upgrade
PUCT	Public Utilities Commission of Texas
PV	Photovoltaic
REC	Renewable Energy Credit
ReEDS	Regional Energy Deployment System
REGMA	Renewable Energy Goals Market Assessment
RETI	Renewable Energy Transmission Initiative
RFP	Request for Proposal
RNS	Renewable Net Short (in this study)
RPS	Renewable Portfolio Standard
RTO	Regional Transmission Organization
SVI	Social Vulnerability Index
VMT	Vehicle Miles Travelled
WtE	Waste to Energy
WTK	Wind Toolkit

Executive Summary

In 2019, Governor Mills signed LD 1494, "An Act to Reform Maine's Renewable Portfolio Standard (RPS)," which sets ambitious renewable energy targets for the state. The act requires 80% of Maine's electricity to come from renewable resources by 2030 and sets a goal of having 100% of Maine's electricity served by renewables by 2050. In addition, the electric sector is expected to support rapid load growth due to electrification of end uses, especially in the transportation and building sectors, to help meet the state's greenhouse gas (GHG) reduction goals.

Maine, like much of New England, has these dual goals to achieve – 1) serving growing and likely more dynamic load due to electrification, and 2) increasing the share of renewables serving the state's electricity needs. Maine has an abundance of high-quality renewable resources available for development that positions the state well to achieve both these goals. At the same time, Maine's current resource mix, geography, and population distribution pose unique considerations that need to be addressed through intentional action and thoughtful policy support to the market to ensure that the renewable transition is effective, affordable, and equitable.

This study, sponsored by the Maine Governor's Energy Office (GEO) and conducted by Energy & Environmental Economics (E3) and Applied Economics Clinic (AEC), fulfills the requirements of LD 1494, which called for a Renewable Energy Goals Market Assessment (REGMA) to assess options for how to meet the renewable transition in Maine over the next decade. It is meant to support policy discussions and decision-making to achieve the state's RPS. The analysis in this study is meant to complement the work of the Maine Climate Council (MCC) in studying and supporting pathways to meeting Maine's clean energy and GHG reduction requirements.

The REGMA analyzes six future scenarios to explore plausible renewable portfolios that would enable Maine to meet its 2030 RPS target. The scenarios were informed by stakeholder feedback and are meant to reflect the characteristics that are unique to Maine – onshore resource potential, land use considerations, transmission availability, offshore wind potential, and coordination with the rest of New England. Comparing the resource portfolios, costs, and equity impacts across the scenarios provides insight into the possible effects of each of these unique characteristics on Maine's electric sector and population. Taken together, these individual effects paint a larger picture of the opportunities and challenges that Maine may face as it works towards achieving the RPS. As such, ***the scenarios and their results are not meant to be prescriptive*** and are instead intended to highlight the considerations to support policy discussions and decisions related to the RPS.

Key findings from the study that provide insight into how Maine may achieve its RPS target in the next decade are found below.

- ***Maine is on track to meeting its RPS until 2026, but new resources will be needed to meet increasing goals thereafter***. A combination of existing generation and resources procured previously and through LD 1494 and LD 1711, "An Act To Promote Solar Energy Projects and Distributed Generation Resources in Maine," will be sufficient to meet the need for renewable energy credits (RECs) until 2026. Beyond this point, new resources will be needed to meet increasing goals. Scenario analysis indicates a range of new builds between 800 and 900 MW by 2030 will be needed. This need can be satisfied by a number of resources, though each requires the consideration of tradeoffs: Maine's high-quality onshore wind potential is largely inaccessible absent investments in transmission; small-scale solar may be developed in proximity to loads and provides resiliency, but significant transmission and distribution upgrades are likely needed to interconnect large amounts of these systems; and offshore wind is still in the nascent stages of technological development but could emerge as a competitive source of renewable supply. Given the challenges facing renewable development in the state – particularly with respect to transmission – there is need for action well before 2026 so that the intervening years are used to develop and implement plans to ensure enough new renewable generation is online and operational by 2026. Further, given federal tax incentive expiration, there are cost savings to advancing development to before 2026.

+ ***Transmission will be a key driver of renewable development***. Building new transmission is difficult in New England and can be challenging in Maine. At the same time, the report required by LD 1401[1] and subsequent findings show that key transmission pathways in Maine are severely congested and constrained. This study highlights that many lower-cost pathways to meet Maine's RPS requirements in the next decade are achievable through the development of high-quality wind resources in western and northern Maine, which in turn require new transmission investments. The scale of these transmission investments, along with the longer development timelines as compared to renewable projects, will make it difficult for any single wind project to shoulder the development burden of these transmission projects. Limited transmission availability will present similar challenges for the development of other generation sources, such as solar. A state-sponsored anticipatory transmission planning process could help address this issue by identifying the transmission needed to meet the RPS in advance of renewable development. Maine could look to states like Texas (Competitive Renewable Energy Zone, or CREZ, process) or California (Renewable Energy Transmission Initiative, or RETI) to see how other states in similar situations have successfully approached this challenge.

+ ***A technologically diverse portfolio helps lower risk***. Each resource type has its own set of challenges that introduce risk into the resource portfolio. Onshore resources in western and northern Maine require transmission upgrades and could face siting challenges. Floating offshore wind is not yet deployed at scale and thus has a higher initial cost, which may decrease with increasing penetration. Large penetrations of distributed generation, which are expected by 2025 (500 MW), will likely require distribution and transmission upgrades. There is also uncertainty associated with the resource costs, as technologies are continuing to evolve. Pursuing a diverse portfolio serves as a hedge against several uncertainties, including slower-than-expected cost declines and the development of new transmission. This study explores one such diverse portfolio, but the appropriate mix will be ultimately decided to meet multiple policy objectives.

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[1] *"Resolve, To Study Transmission Solutions to Enable Renewable Energy Investment in the State Final Report," 2020.*

- ***Regional coordination can help lower the costs of meeting Maine's RPS***. In addition to having a large amount of land for renewable development, Maine has some of the highest-quality wind resources available in New England. If developed, these resources can help to meet both Maine and the broader region's clean energy goals. New transmission is required to access these resources, however, due to their remote location. The study results show that coordination of Maine with neighboring states can mitigate the "lumpiness" challenge of new transmission investment—that transmission projects are generally large in size, are expensive, and the full project has to be developed before any benefits can be realized—so that Maine's customers do not bear the full cost of transmission to access high-quality wind resources in the northern and western parts of the state.
- ***Storage paired with solar resources can provide value***. Storage paired with solar was found to be chosen economically alongside onshore wind. Maine's winter peak is projected to increase with heating electrification. Pairing solar with storage improves the combined generation profile of these hybrid resources, enabling them to generate during evening peak demand, increasing their value to the system. Storage has additional benefits, such as transmission and distribution deferral value, resiliency, and ancillary services provision, which are not captured in this RPS-focused study. Including these value streams is likely to further improve the economics of storage.
- ***Energy equity challenges cut across four dimensions: resource diversity, customer-sited resources, geographic resource distribution, and cost.*** Successfully achieving Maine's renewable energy goals may result in at least three benefits for its vulnerable communities: 1) reductions in emissions resulting in corresponding improvements in air quality and human health, 2) renewable resources increasing the energy supply's resiliency, and 3) clean energy development creating employment and community investment. Ensuring equity considerations are prioritized during Maine's clean energy transition requires careful attention to resource diversity, customer-sited resources, geographic resource distribution, and the cost impacts experienced by vulnerable communities. Thoughtful selection of a resource mix should be complemented with periodic review and modifications to rate structure to ensure Maine's vulnerable communities are not adversely impacted. Investment in programs that provide resources to vulnerable communities should also continue to be supported. Furthermore, siting of new resources should consider and seek to minimize impacts to existing industries, stakeholders, communities, and natural resources.

This study finds that Maine has several economical pathways to meet its renewable goals. Each resource option has its own set of challenges to overcome, with the primary challenge being building transmission to access high-quality renewables in the state and the associated siting, permitting, and environmental concerns. This study outlines potential policy implications of the renewable transition and is meant to support policy considerations as the state charts its way to a high renewable future.

1 Introduction

1.1 Study motivation

The State of Maine has been a leader in both recognizing the potential impacts of climate change on the state and in enacting policy to mitigate and prepare for the risks associated with climate change impacts. In 2019, Governor Janet Mills signed landmark bipartisan legislation establishing the Maine Climate Council and mandating that Maine reduce GHG emissions 45% below 1990 levels by 2030 and 80% by 2050. This was followed by an Executive Order committing the state to a carbon-neutral target by 2045. In support of those targets, Governor Mills also signed LD 1494, “An Act to Reform Maine’s Renewable Portfolio Standard (RPS),” which sets ambitious renewable energy targets for the state through 2050. The act requires that 80% of Maine’s electricity come from renewable resources by 2030 and sets a goal of a 100% RPS by 2050. The law also calls for a 10-year Renewable Energy Goals Market Assessment (REGMA).

This study fulfills the market assessment requirement by evaluating the current renewable market in Maine, assessing the need for Renewable Energy Credits (RECs) until 2030 (based on the RPS targets established by LD 1494), and estimating the costs of multiple renewable resource portfolios that meet the 2030 RPS targets, along with additional equity considerations.

In addition to modeling renewable resource portfolios, this study also identifies areas that may require policy actions to meet the state’s RPS requirements and discusses options available to the state to enable a smooth and equitable transition to a high renewable future, while ensuring affordable and reliable electricity for the state’s ratepayers. The aim of this study is not to be prescriptive in determining the exact mix of resources that Maine must procure, but rather – through the modeling and analysis of example portfolios -- extract general themes of benefits, challenges, and barriers to renewable development in the state. As such, the analysis and policy options discussed in this study are intended to support policy discussions and decision-making to achieve the state’s RPS.

1.2 GEO’s role in effort

The GEO is the sponsor of this study and selected E3 and the AEC to conduct this work. GEO worked with the consultants in designing the study, conducting public comment processes, facilitating, and participating in meetings between stakeholders and consultants, and preparing this report.

1.3 Public comment process

As part of this study, GEO, E3, and AEC conducted a public comment process in which stakeholders were invited to participate in two webinars. In the first webinar, conducted on November 6, 2020, E3 presented the initial study design and solicited feedback from stakeholders. This feedback was then used to modify the study design and the scenarios modeled. Follow-up meetings to gather more data were scheduled as needed. A summary of the received feedback can be found in the Appendix.

The second webinar was conducted on February 17, 2021 and presented the final scenario analysis results and key findings provided in this report. Stakeholders were invited to provide comments on the final report following this webinar, the summary of which of will be posted online.

1.4 Objectives of this study

The key objectives of this study are to:

- ***Assess Maine's existing renewables*** to help quantify RECs expected to be generated and used to meet Maine's RPS through 2030 from existing resources.
- ***Establish the need for RECs through 2030***. Establish the need for incremental RECs through 2030, after accounting for RECs from Maine's existing resources.
- ***Explore resource portfolios that help the state meet its renewable targets through 2030.*** Determine portfolios of resources that can economically meet the incremental REC need through 2030 and determine the costs of such portfolios.
- ***Explore the implications of regional coordination.*** Identify impacts of regional coordination strategies on the achievement of the state's RPS.
- ***Consider the equity implications of renewable development*** on Maine's population.
- ***Explore policy options to support achieving Maine's RPS by 2030*** by reviewing analysis results and stakeholder feedback.

1.5 Report contents

The remainder of the report is organized as follows:

- Section 2 provides background and study context, including an overview of Maine's RPS and GHG mandates and targets, and the relevant policy considerations assessed through the scenario analysis. This section also identifies Maine's socially vulnerable communities, which helps contextualize the equity impacts of the results of this study (presented in Section 4).
- Section 3 provides an overview of the modeling approach, scenarios modeled, and key assumptions utilized in the scenario analysis.
- Section 4 presents results from the scenario analysis and discusses the drivers of the results.
- Section 5 describes the policy implications of the scenario analysis performed and includes a discussion of the options to reduce challenges and barriers to renewable development in the state.
- Section 6 summarizes the anticipated energy equity benefits and challenges of Maine's transition to a high renewable state on Maine's most vulnerable populations.
- Section 7 summarizes the key takeaways from the study.
- Section 8 is an Appendix that provides a summary of stakeholder feedback collected as part of this study and contains other supplemental material.

2 Background and Context

This section provides background on the current energy policy, resource mix, and equity context under which this study is conducted.

2.1 Maine's renewable energy and climate goals

The State of Maine has set some of the most ambitious decarbonization policies in the country, aimed at mitigating the worst impacts of climate change on the state and catalyzing the development of Maine's clean energy economy. Three important pieces of bipartisan legislation, signed by Governor Mills in 2019, are central to the state's decarbonization policy agenda:

- ***LD 1679 (An Act To Promote Clean Energy Jobs and To Establish the Maine Climate Council):*** This act established the Maine Climate Council, which is tasked with advising on strategies for Maine to meet economy-wide emission reductions of at least 45% below 1990 levels by 2030 and 80% below by 2050. These targets are based on 38 M.R.S.A. § 576. Since the signing of this legislation, Governor Mills has also issued an Executive Order aimed at achieving economy-wide carbon neutrality by 2045.
- ***LD 1494 (An Act To Reform Maine's Renewable Portfolio Standard):*** This act increased the share of the state's electricity coming from renewable resources to a total of 80% by 2030 and a goal of 100% by 2050. This law also requires the Maine Public Utilities Commission (MPUC) to procure long-term clean energy generation contracts totaling 14% of Maine's 2018 retail sales in two rounds of procurement in 2020 and 2021. This act also provides the basis for the renewable energy assessment developed in this study.
- ***LD 1711 (An Act To Promote Solar Energy Projects and Distributed Generation Resources in Maine):*** The policy levers within this bill are aimed at encouraging broader participation in the renewable energy market. This act issues procurement orders for a total of 375 MW of distributed generation, primarily expected to be small solar photovoltaic (PV) projects, by 2024, and creates incentives for commercial, institutional, and community projects. The bill also removes caps on Net Energy Billing (NEB), increases the eligible project size to 5 MW, and requires that community projects support low- and moderate-income customers. As of the time of writing of this report, Block 1 of the 375 MW distributed generation procurement was deemed not competitive by the MPUC. Under current law, a new competitive procurement for Block 1 is required to occur by July 2021.[2]

These laws, and others, provide complementary policy support for economy-wide decarbonization. In December 2020, the Maine Climate Council released its four-year climate action plan, *Maine Won't Wait*, to set the state on a path to achieve the ambitious economy-wide decarbonization targets outlined in LD 1679. The plan requires action across all emitting sectors of the economy, including transportation,

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[2] *"Report on Renewable Distributed Generation Solicitation" (Maine Public Utilities Commission, 2020).*

buildings, industry, and power. In the action plan, low-carbon power generation plays a critical role: reducing overall power sector emissions, while enabling beneficial electrification of transportation and buildings. Thus, achieving the requirements of LD 1494 are not only essential for compliance with the law – but will also ensure that overall economy-wide decarbonization is achieved.

The LD 1494 RPS targets give Maine one of the most ambitious RPS targets in the country. It is designed to spur investment in new renewables while also incentivizing existing resources to generate and contribute RECs to meeting the state's RPS.

2.2 Regional context

The majority of Maine's electric grid is operated by ISO-NE,[3] an independent, non-profit Regional Transmission Organization (RTO) that operates a regional wholesale power market. In 2020, Maine's share of ISO-NE's annual load, which includes all six New England states, was 10%.[4] Maine's participation in this market provides opportunities for coordinated decarbonization activities across the region that could lower costs and provide benefits to Maine ratepayers. Similar to Maine, the other five New England states—Massachusetts, Connecticut, New Hampshire, Rhode Island, and Vermont—are pursuing a range of policies to dramatically reduce GHG emissions and increase renewable energy deployment. These include RPS, Clean Energy Standards (CES), technology-specific deployment targets, and economy-wide emissions reduction targets. Each state's key policies and share of regional load are summarized below:

- ***Massachusetts (MA)***:
    - **RPS:** MA passed a mandate in 1997 for 35% Class 1 RECs by 2030, with an additional 1% each year thereafter; results in 55% by 2050. Class 1 RECs are generated by eligible new renewable resources (those developed after 1997).
    - **CES:** in 2018, MA also passed a CES, which initially required 16% clean energy in 2018, increasing 2% each year to 80% in 2050. While similar to the RPS, CES compliance can be achieved with a wider range of technologies, including nuclear, large hydro imports, and fossil generators with carbon capture and sequestration.
    - **Technology Specific:** MA has mandated that 3,200 MW of offshore wind are procured by 2035.
    - **Emissions:** The Global Warming Solutions Act of 2008 requires the state to set a target of at least an 80% reduction in economy-wide emissions by 2050, relative to 1990 levels. In April 2020, this target was increased to net-zero GHG emissions by 2050, including at least 85% direct emissions reductions.

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[3] *About 5% of Maine's load is in the Northern Maine Independent System Administrator (NMISA). NMISA is connected to the rest of Maine indirectly through Canada.*

[4] *"ISO New England - Energy, Load, and Demand Reports," accessed January 19, 2021, https://www.iso-ne.com/isoexpress/web/reports/load-and-demand/-/tree/zone-info.*

  - **Percentage of Regional Load**[5]: *45%*

- ***Connecticut (CT):***
  - **RPS:** CT passed an RPS mandate in 1998 for 40% Class I RECs by 2030, with an additional 4% from either Class I or Class II resources.
  - **Technology Specific:** CT has mandated that 2,000 MW of offshore wind are procured by 2030.
  - **Emissions:** The Act Concerning Connecticut Global Warming Solutions requires the state to achieve an 80% reduction in emissions relative to 2001 levels by 2050.
  - **Percentage of Regional Load:** *24%*
- ***New Hampshire (NH):***
  - **RPS:** NH passed an RPS mandate in 2007 for 25.2% REC procurement by 2030. This is an aggregate target across renewable resource classes.
  - **Emissions:** The state's Climate Action Plan outlines a recommended goal of an 80% reduction in GHG emissions below 1990 levels by 2050.
  - **Percentage of Regional Load:** *10%*
- ***Rhode Island (RI):***
  - **RPS:** RI passed an RPS mandate in 2004, which escalates from 3% in 2007 to 38.5% in 2035.
  - **Emissions:** The Resilient Rhode Island Act of 2014 set an economy-wide target of 80% GHG reductions relative to 1990 levels by 2050.
  - **Percentage of Regional Load:** *7%*
- ***Vermont (VT):***
  - **RPS:** VT passed an RPS mandate in 2015 for 75% by 2032.
  - **Emissions:** The state's Comprehensive Energy Plan establishes a goal of 80% to 95% GHG reduction below 1990 levels by 2050.
  - **Percentage of Regional Load:** *4%*

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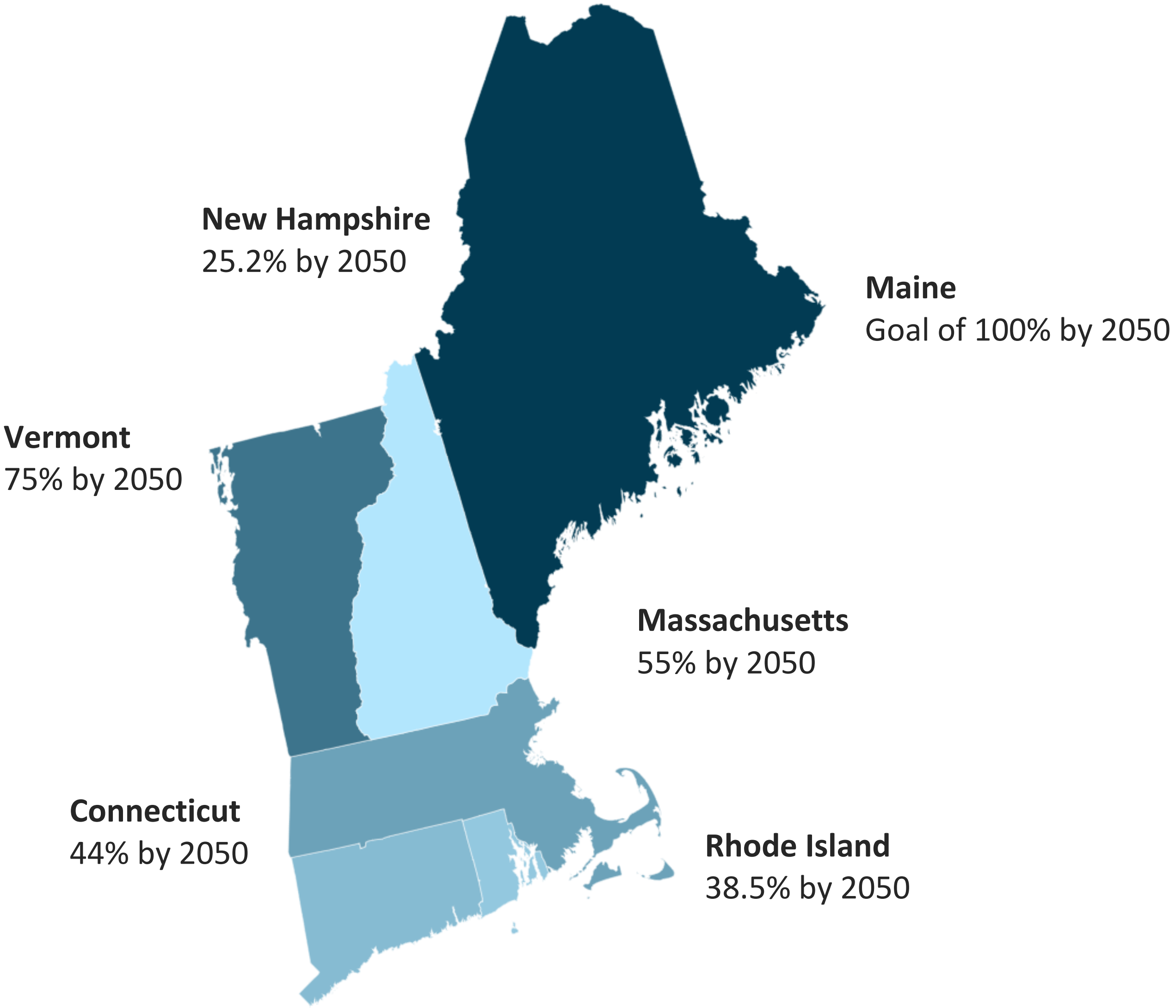
[5] *"ISO New England - Energy, Load, and Demand Reports."*

Figure 1. *New England States' Renewable Portfolio Standards in 2050*



2.3 Historical renewable development and electricity mix in Maine

As of 2018, Maine had an installed capacity of 4,864 MW[6], as shown in Figure 2. Half of this capacity was fossil fuel based (natural gas and petroleum) and the other half was made up of RPS-eligible resources such as wind, biomass, wood-fired, solar, and hydroelectric facilities.

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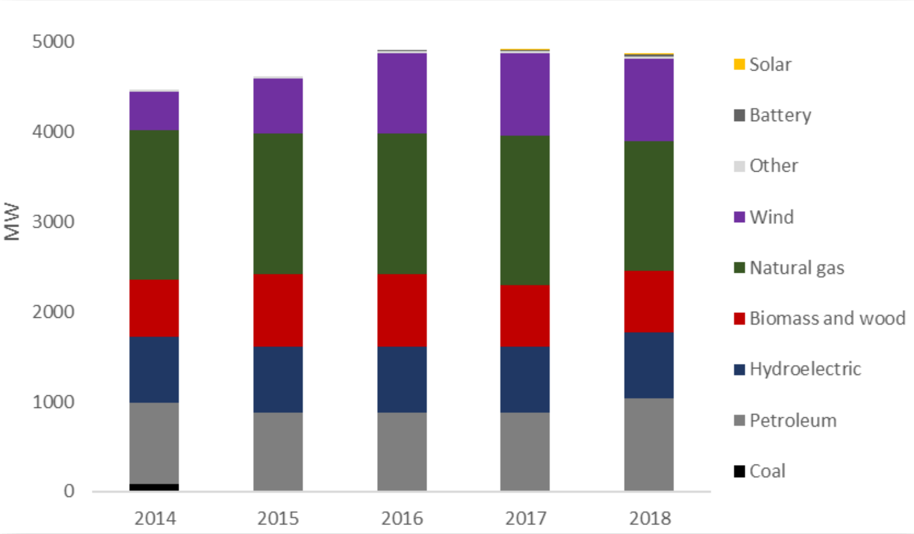
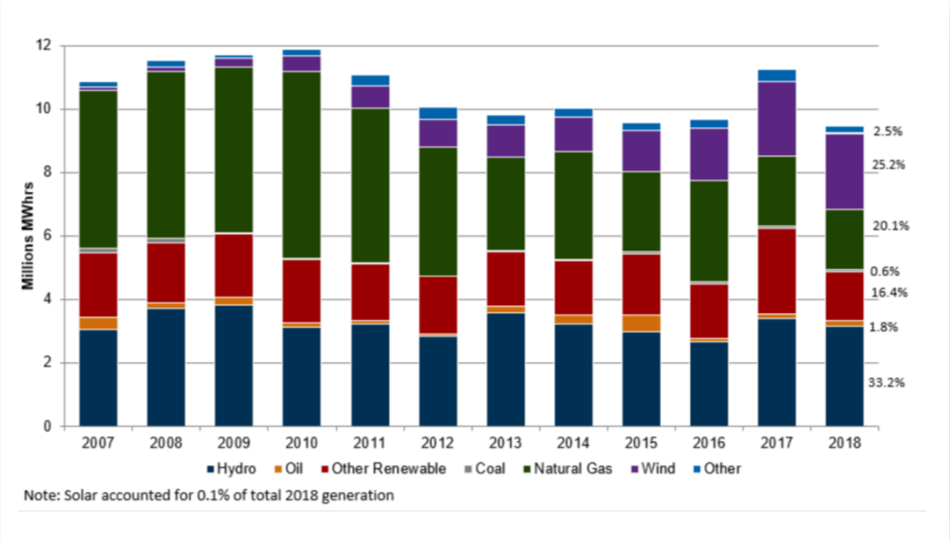
[6] *"Maine - State Energy Profile Overview - U.S. Energy Information Administration (EIA)," accessed December 23, 2020, https://www.eia.gov/state/?sid=ME.*

Figure 2. *Maine's installed capacity from 2014-2018*



Though half of the state's installed capacity is fossil based, 75% of Maine's electricity generation was obtained from renewable sources, as shown in Figure 3. The four largest sources of electricity generation in Maine are hydroelectric (33%), wind (25%), natural gas (20%), and wood/biomass (16%). Together, these supply 94% of Maine's electricity.[7] The rest is supplied by relatively small amounts of petroleum, solar, coal, and storage.

Figure 3. *Maine's electric generation mix by fuel*[8]



Note: Solar accounted for 0.1% of total 2018 generation

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[7] *"Maine - State Energy Profile Overview - U.S. Energy Information Administration (EIA)."*

[8] *Maine Public Utilities Commission, "2019 Annual Report," February 1, 2020, https://www.maine.gov/tools/whatsnew/attach.php?id=2074549&an=1.*

The amount of wind in the electricity mix has increased over the years, as seen in both installed capacities and electric generation mix figures. Additionally, the amount of electricity generation from natural gas has significantly decreased. Over 2019 and 2020, the amount of wind has increased further, spurred on by a slew of clean energy bills passed into legislation such as the ones described in Section 2.1, among others. The electric generation mix shown above is not the same as the state's RPS requirements. The RPS is a mechanism that requires compliance to a renewable standard through REC purchases that represent the environmental attributes of electric generation.

2.4 Benefits of renewable energy

Renewable Portfolio Standard (RPS) compliance can offer a variety of benefits to states. A transition away from fossil fuel resources to low- and zero-carbon renewable resources can significantly reduce greenhouse gas emissions, mitigating the impacts of climate change. This reduction in emissions, including of particulate emissions from burning fossil fuels, can offer improvements in public health.[9] The growth of the clean energy sector through policies like the RPS presents economic development opportunities throughout the associated supply chains, and the potential of innovative solutions to create additional products and services for the state, regional, and even global markets. The development of clean energy projects can provide various community benefits, from financial benefits in the form of property or income taxes, community benefits agreements, and workforce opportunities.[10] As the growth progresses, the associated job creation presents workforce opportunities across a broad range of positions with varying education and experience requirements. Jobs in the clean energy sector tend to be higher paying for relatively lower educational requirements – though often requiring training credentials – and are more likely to offer health care and retirement benefits than the rest of the private sector.[11] While not an inclusive analysis of associated benefits, this overview is illustrative of the types of benefits associated with growing the clean energy sector through policies like RPS.

Fossil fuels often experience price volatility that is influenced by a global market. In contrast, renewable energy generation can provide price stability through its ability to utilize existing non-purchase fuels such as solar, wind, water, and geothermal after development. The overall costs of building and generating electricity from renewable sources have shown to be stable or decreasing over time, compared to the fluctuating costs of fossil fuels. Not only can in-state generation resources provide more stable energy costs, but the economic benefits and payments for purchase of these sources of energy can stay within the state, rather than going to out-of-state fossil fuel providers.[12] In 2018, Maine spent $4.4 billion on out-of-state fossil fuels, with the majority of that spending going to out-of-state fossil fuel providers.[13] As the state

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[9] *United States Environmental Protection Agency, State and Local Energy and Environment Program. Public Health Benefits per kWh of Energy Efficiency and Renewable Energy in the United States: A Technical Report. July 2019. Retrieved from https://www.epa.gov/sites/production/files/2019-07/documents/bpk-report-final-508.pdf*

[10] *Maine Governor's Energy Office. Strengthening Maine's Clean Energy Economy. https://www.maine.gov/energy/sites/maine.gov.energy/files/inline-files/StrengtheningMainesCleanEnergyEconomy_Nov92020.pdf*

[11] *https://e2.org/reports/clean-jobs-better-jobs/*

[12] *Dan Lieberman and Siobhan Doherty. Commission for Environmental Cooperation. Renewable Energy as a Hedge Against Fuel Price Fluctuation. 2008. http://www3.cec.org/islandora/fr/item/2360-renewable-energy-hedge-against-fuel-price-fluctuation-en.pdf*

[13] *"U.S. Energy Information Administration - EIA - Independent Statistics and Analysis," accessed February 3, 2021, https://www.eia.gov/state/seds/.*

moves to beneficial electrification and biofuels developed from resources in Maine, these energy dollars can stay within Maine's economy.

2.5 Maine's energy equity context

As Maine transitions to decarbonizing its grid, the state is working to ensure that this transition is equitable and that it brings benefits to Maine's most vulnerable communities. To help understand the equity implications of the renewable portfolios considered in this study's analysis, AEC conducted an energy equity assessment alongside the renewable modeling to identify the equity benefits that people in Maine are likely to gain from the renewable transition and the corresponding equity challenges that need to be preemptively avoided through careful policy action. AEC developed a Social Vulnerability Index (SVI) for Maine – an index to identify the state's most socially vulnerable populations – which provides an equity lens through which to interpret the analysis results presented in Section 4. It is also useful to contextualize the equity benefits and challenges that Maine is likely to face during the renewable transition and the corresponding policy implications, which are discussed in Section 6. This section explains the SVI and the key takeaway from the SVI analysis as applied to Maine's current population. The full development of the SVI can be found in the Appendix.

Vulnerable communities are those that contain populations that are disproportionately burdened by existing inequities—for example, people of color experience more pollution from fossil fuel generation than their white counterparts across the United States[14]—and/or lack the capacity to withstand new or worsening burdens. AEC calculated an SVI for Maine[15] that combines values from six categories of vulnerability, each expressed as a share of population: children (17 and younger), limited English-speaking households, older adults (65 and older), people of color, people with disabilities, and low-to-no income individuals.[16]

Population shares for the six vulnerable groups are combined into a single measure of vulnerability in each local area (by counties and "census tracts"[17]). A higher SVI score (darker color) indicates a greater degree of vulnerability (see Figure 4). The key takeaway for Maine's population is:

+ ***Vulnerability is not evenly distributed across Maine and the three most socially vulnerable counties are located in the northern and eastern parts of Maine***. Piscataquis and Aroostook counties in the north, and Washington County in the east (see Figure 4) are the three most socially vulnerable counties in the state. Large portions of Piscataquis and Aroostook counties are served by the Northern Maine Independent System Administrator (NMISA) and utilizes electricity

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[14] *C.W. Tessum,* Inequity in Consumption of Goods and Services Adds to Racial–Ethnic Disparities in Air Pollution Exposure*, vol. 116 (Proceedings of the National Academy of Sciences of the United State of America (PNAS, 2019), https://www.pnas.org/content/116/13/6001.*

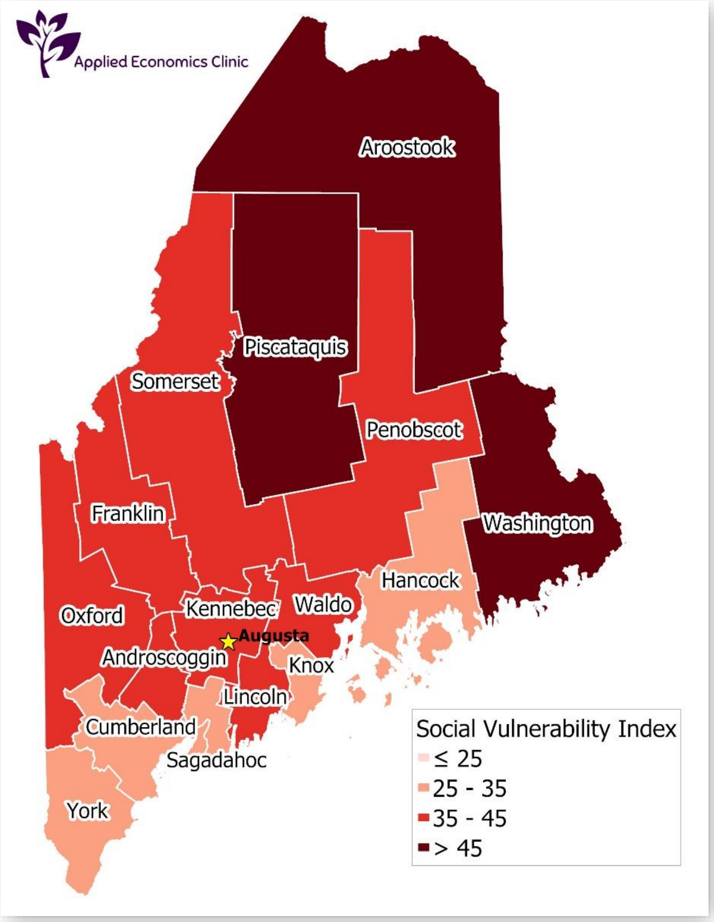
[15] *Note that while the criteria used to calculate Maine's SVI are widely used in development of similar vulnerable indices, the numerical values of the SVI calculated in this study are for internal comparison among Maine jurisdictions and are not meant to be compared to ones calculated for other jurisdictions.*

[16] *Defined as income that is 150 percent of the federal poverty level or less.*

[17] *Census tracts are small statistical subdivisions of a county that are updated prior to each decennial census, and typically have a population size between 1,200 and 8,000 people, see: U.S.Census Bureau n.d,* Glossary, *n.d., https://www.census.gov/programs-surveys/geography/about/glossary.html#par_textimage_13.*

predominantly from New Brunswick rather than Maine. Washington County is served by Eastern Maine Electric Cooperative and Versant Power.

Figure 4. *Maine Social Vulnerability Index*[18]



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[18] *U.S. Census Bureau, 2019 American Community Survey 1-Year Estimates. "Earnings in the Past 12 Months" (Table S2001), "Limited English Households" (Table S1602), "Disability Characteristics" (Table S1810), "Age and Sex" (Table S0101), "Race and Population (Table B02001).*

3 Modeling and Scenario Analysis Approach

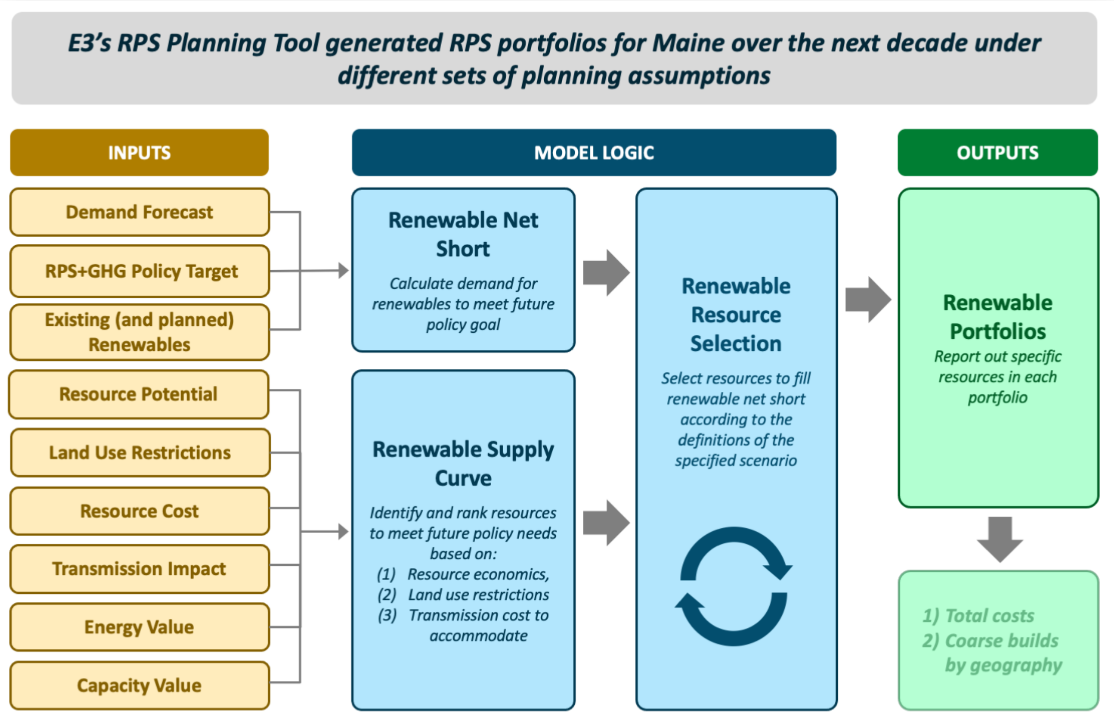
This study's analysis identifies potential least-cost renewable resource portfolios under a range of assumptions regarding policy and market conditions. This section describes the modeling approach used in this study, the scenarios evaluated, and key modeling assumptions.

3.1 Modeling approach

The model used in this study is a spreadsheet tool that aims to extract portfolios that meet Maine's REC needs over the next decade. The model is not meant to be a power-flow tool that analyzes the operational reliability of the resultant portfolios. The focus is, rather, on defining multiple scenarios, determining portfolios that are policy compliant across those scenarios, and understanding the economic and policy implications of such portfolios.

The goals of the modeling approach are: 1) to identify the need for renewables to meet future policy goals (referred to as the Renewable Net Short (RNS) in this study); 2) to curate a set of candidate renewable resources to fill the identified need (the "Renewable Supply Curve"); and 3) to select the least-cost portfolio from the renewable supply curve to fill the identified need. This approach is illustrated in the 'Model Logic' portion of the model schematic shown in Figure 5. A variety of inputs are needed to develop both the RNS and the Renewable Supply Curves. Key inputs are shown in the 'Inputs' section of the schematic. In particular, a demand forecast, an RPS target, and existing renewables all go into establishing the RNS.

Figure 5. *Model Schematic*



The model calculates the "net cost" for each candidate resource, taking the following factors into account:

- Cost of the resource;
- An estimate of the transmission upgrades (if any) needed to interconnect and deliver the resource;
- Energy value of the resource; and
- Capacity value of the resource.

Once the net cost has been calculated for each resource, the model fills in the RNS with a portfolio of resources[19] that, together, have the lowest total cost to the system while meeting the RPS policy goals and scenario parameters. More details of the assumptions of the model are given in Section 3.3.

3.2 Scenarios

The analysis studied six scenarios: 1) a base scenario that assumed current market trends through 2030 and 2) five scenarios that varied key input assumptions from the base scenario to explore how renewable resource portfolios and their costs change under plausible future conditions. The list of scenarios considered in this analysis is shown in Table 1; each is described in further detail below. The input assumptions for these scenarios were derived from discussions with stakeholders and publicly available data sets.

Table 1. *Scenarios studied in this report*

Scenarios	
1. Base Case	Policy-compliant Business-As-Usual (BAU) case; uses current trends through 2025 and then meets need with least cost resources after including land use restrictions; lower loads tested as a sensitivity
2. Unconstrained Land Use	Similar to Base Case without additional land-use restrictions imposed
3. High Offshore Wind	Assumes the addition of up to 1 gigawatt (GW) of offshore wind by 2030
4. Existing Transmission	Assumes only existing onshore transmission can be used to deliver resources to meet the RPS
5. Regional Coordination	Scenario where Maine coordinates with the broader New England region through the use of out-of-state RECs and shared onshore transmission costs
6. Diverse Portfolio	A diverse portfolio consisting of onshore wind, offshore wind, utility solar paired with storage, distributed generation resources, out-of-state RECs, and mechanisms for cost-sharing of onshore transmission by 2030

All scenarios are consistent with existing clean energy and decarbonization policy in Maine and include load growth from building and vehicle electrification likely needed to achieve Maine's economy-wide GHG

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[19] *In addition to in-state resources, in some scenarios, out of state RECs are also eligible to meet the RNS. Out of state RECs that are currently meeting a portion of Maine's REC requirements are assumed to continue doing so through the study horizon.*

emissions targets.[20] In addition, the scenarios assume that some existing hydroelectric facilities,[21] planned procurements of Class IA resources,[22] and a percentage of distributed resources procured per Maine law or in executed NEB agreements with Central Maine Power (CMP) or Versant Power will all qualify for and contribute to the state's RPS targets.[23] Any remaining Class I/IA REC need is assumed to be met from either new in-state generation or out-of-state RECs[24]. Identifying these new resources is the focus of this study. For the purposes of this study, Class II RECs are assumed to continue to be available to Maine and are not expected to drive significant investment in new renewables in the short term. An overview of each scenario is provided in Sections 3.2.1 through 3.2.6 that follow.

3.2.1 Base Case

This scenario represents a future in which Maine meets its RPS targets through least-cost resources, based on current market trends and policy implemented in Maine and the broader New England region. This scenario allows the development of onshore resources as well as offshore wind resources to the extent they are cost effective during the 2020-2030 window.

To construct realistic estimates of potential renewable availability within Maine, this analysis starts with the solar and wind technical potential values available from the National Renewable Energy Laboratory's (NREL's) Regional Energy Development System (ReEDS) model, which represents all potential resources available for development after land-use screens that remove land area that is either protected or already developed (e.g., national parks or cities).[25] However, NREL's total resource potential likely still far exceeds what can feasibly be developed in the state. Thus, this analysis adds additional land use constraints to reflect the practical challenges around land use for renewable development and the impact this would have in reducing the resource potentials of renewable resources. This scenario layers on restrictions that limit onshore wind technical potential to 2% farmland and 2% forest,[26] and utility-scale solar to 4% of

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[20] *Jamie Hall et al., "Volume 3: Maine Emissions Analysis Consolidated Energy Sectors Modeling Results," https://www.maine.gov/future/sites/maine.gov.future/files/inline-files/ERG_MCC_Vol3_MaineEmissionsAnalysisSynapse_11-9-2020.pdf.*

[21] *"MRS Title 35-A, Section 3210. Renewable Resources," n.d., https://mainelegislature.org/legis/statutes/35-A/title35-Asec3210.html.*

[22] *"S.P. 457 - L.D. 1494: An Act to Reform Maine's Renewable Portfolio Standard," 2019.*

23 *"CMP Response to Docket No. 2020-00199" (Central Maine Power, 2020), https://mpuc-cms.maine.gov/CQM.Public.WebUI/MatterManagement/MatterFilingItem.aspx?FilingSeq=109306&CaseNumber=2020-00199; "Versant Response to Docket No. 2020-00199" (Versant Power, 2020), https://mpuc-cms.maine.gov/CQM.Public.WebUI/MatterManagement/MatterFilingItem.aspx?FilingSeq=109323&CaseNumber=2020-00199.*

[24] *Depending on scenario definitions. See sections 3.2.1 - 3.2.6 for more detail.*

[25] *The resource potential within NREL ReEDS for solar includes land located on large parcels outside urban boundaries, excluding federally protected lands, inventoried "roadless" areas, U.S. Bureau of Land Management areas of critical environmental concern, and areas with slope greater than 5%. For onshore wind, the resource potential excludes areas considered unlikely to be developed for environmental or technical reasons: federal and state protected areas (e.g., parks, wilderness areas, and wildlife sanctuaries), areas covered by water, urban areas, wetlands, airports, and rough terrain. Areas classified as non-ridge-crest forest, U.S. Forest Service and U.S. Department of Defense lands, and state forests are 50% excluded.*

[26] *2% of farmland corresponds to 26,000 acres and 2% of forest land corresponds to 403,000 acres.*

farmland.[27,28] This report is not suggesting the implementation of these specific land-use screens but is including these screens to better understand land use restrictions' overall impact on development opportunities.

Currently, the standard load assumptions represent high levels of beneficial electrification consistent with Maine achieving its GHG emissions goals. However, it may be possible for Maine to achieve these goals with lower load growth through strategies such as more aggressive building weatherization, reduced vehicle miles traveled (VMT), grid flexibility or demand management. To test such a future, a Low Load sensitivity on the Base Case was evaluated to investigate the influence of different load trajectories on the resource and transmission build and costs.

3.2.2 Unconstrained Land Use

This scenario investigates the impact of removing the additional land use restrictions on utility-scale renewables, particularly onshore wind and utility-scale solar construction. This is meant as a mechanism to better understand what additional constraints are binding if these additional land use restrictions are removed.

3.2.3 High Offshore Wind

The Gulf of Maine is characterized by its vast offshore wind resource, and up to 5 GW of offshore wind development have been contemplated by 2030.[29] The high offshore wind scenario studies the impact of including up to 1 GW of offshore wind in Maine's resource portfolio to meet the 2030 RPS. This includes up to 144 MW from the State of Maine-proposed floating offshore wind research array beginning in 2025.[30] Offshore wind costs are projected to drop, especially beyond 2030 as technology advances (see Section 3.3.2 for more details). As a result, offshore wind is expected to play a greater role in the 2030 and beyond timeline.

3.2.4 Existing Transmission

Transmission was overwhelmingly identified by stakeholders in this study's public comment process as a key obstacle to renewable energy development in Maine. At the same time, transmission projects regularly face a number of siting, permitting, land-use, legal, and environmental challenges. This scenario is meant to simulate an extreme scenario where no onshore transmission is built in the state. The resultant portfolio will point to an alternative mix of resources that could be used to meet the state's RPS requirements in

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[27] *These indicative numbers were previously used in another New England renewable transition study and those numbers in turn are loosely derived by back-calculating the total percentage of available land that would be used for renewable development in California that would enable the state to reach its 100% by 2045 clean-energy goal (https://www.ethree.com/wp-content/uploads/2019/06/E3_Long_Run_Resource_Adequacy_CA_Deep-Decarbonization_Final.pdf)*

[28] *"Net-Zero New England: Ensuring Electric Reliability in a Low-Carbon Future" (Energy and Environmental Economics, Inc., 2020), https://www.ethree.com/wp-content/uploads/2020/11/E3-EFI_Report-New-England-Reliability-Under-Deep-Decarbonization_Full-Report_November_2020.pdf.*

[29] *"Final Report of the Ocean Energy Task Force," 2009, https://umaine.edu/offshorewindtestsite/wp-content/uploads/sites/303/2017/02/OETF_FinalReportAppendices.pdf.*

[30] *"Gulf of Maine Floating Offshore Wind Research Array | Governor's Energy Office," accessed January 5, 2021, https://www.maine.gov/energy/initiatives/offshorewind/researcharray.*

such an extreme scenario. The Base Case and this scenario are meant to represent two extreme transmission futures – one where onshore transmission face no significant hurdles and another where it is extremely challenging to build more onshore transmission.

3.2.5 Regional Coordination

As noted above, stakeholders have identified that transmission can be a key component of renewable energy development, particularly in Maine, where the transmission system experiences significant congestion and constraints that impact the ability and cost of building new generation in the state. In this scenario, building new transmission can be facilitated by sharing costs between Maine and out-of-state entities, such as other New England states. Such cost sharing is motivated by the fact that Maine is currently already a net exporter of energy[31] and its existing solar and wind resources sell their RECs out-of-state.[32] Given the role today of Maine's current renewable generation in supporting other New England states' RPS requirements and energy needs, there is continued potential for Maine's in-state resources to support not only its own but also New England's renewable energy requirements, facilitated by sharing the costs of transmission upgrades in Maine between Maine itself and the rest of New England. This type of approach has the potential to offer lower-cost options to meet Maine's goals, as well as additional economic, community, and workforce benefits for Maine communities.

Further, Maine currently partially relies on RECs produced by out-of-state biomass generators to meet its REC needs.[33] Throughout the study period, Connecticut is planning to reduce the number of biomass generators that can qualify for its Class I requirement.[34] This creates the possibility that Maine could purchase additional Class I RECs on top of those it acquires today, instead of building new generation in-state to meet its renewable goals.

In this scenario, the effect of two elements of regional coordination on Maine's compliance with its renewable energy requirements are modeled: 1) cost-sharing of transmission upgrades with the rest of New England, and 2) the potential availability of additional out-of-state RECs for purchase by Maine (in addition to those available today).

3.2.6 Diverse Portfolio

Informed by the results of the five previous scenarios, a hand-crafted diverse portfolio is modeled. This portfolio consists of onshore wind, offshore wind, utility solar paired with storage, distributed generation resources, out-of-state RECs, and mechanisms for cost sharing of onshore transmission. While this is not a suggestion of the ideal resource mix, it provides insight into the downstream portfolio and cost impacts of a mixed resource scenario.

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[31] *"Maine - State Energy Profile Overview - U.S. Energy Information Administration (EIA)."*

[32] *"Annual Report on New Renewable Resource Portfolio Requirement: Report for 2017 Activity" (Maine Public Utilities Commission, 2019).*

[33] *"Annual Report on New Renewable Resource Portfolio Requirement: Report for 2017 Activity."*

[34] *"Connecticut to Phase down Value of Biomass, Landfill Gas RECs | Biomassmagazine.Com," accessed January 6, 2021, http://biomassmagazine.com/articles/15065/connecticut-to-phase-down-value-of-biomass-landfill-gas-recs.*

3.3 Key assumptions

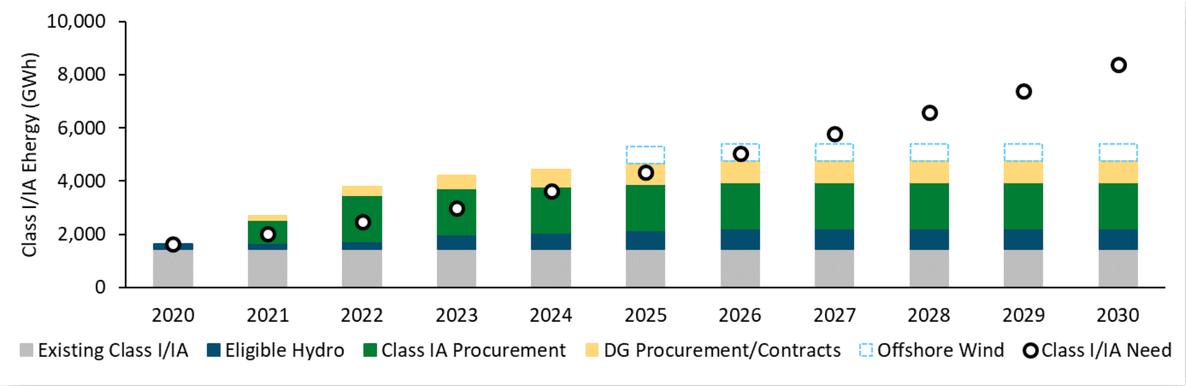
This section provides details on the key assumptions utilized in the analysis. This section describes key assumptions in and the methodology behind establishing Class I/IA REC need and then the resources needed to fill in that need.

3.3.1 Renewable Net Short

The RNS, as calculated in this study, is Maine's REC need in every modeled year, after accounting for the RECs that are available to the state from existing and planned resources. To determine Maine's RNS required to meet Maine's 2030 RPS target, several pieces of information are required: 1) a forecast of future energy demands, 2) the state's future RPS requirements, and 3) the availability of existing and planned renewable generation to meet Maine's RPS needs. The first two pieces of information determine the gross REC need (shown by the blue line in Figure 9), while the third piece provides information on RECs that are available from existing and planned generation. RECs from existing generation physically located both in and out of state have been used to meet Maine's RPS needs historically.

While the gross REC need includes REC need from all classes (Classes I, IA, and II), the focus of this study is primarily on Class I/IA need,[35] as this is expected to drive most of the new renewable investment in the state over the coming decade. This I/IA need is shown in Figure 6 and is indicated by the black circle. RECs from existing and planned procurements are also shown. Maine is projected to have a sufficient supply of I/IA RECs through 2026, and new REC-generating resources are required by 2026 for most scenarios and by 2027 for the Offshore Wind and Diverse Portfolio scenarios. While the exact mixture of REC sources used to satisfy Maine's RPS may not be precisely what is shown in Figure 6, it is anticipated that as Class I/IA REC need increases in Maine, their price will also increase, in turn driving the sale of RECs to Maine.

Figure 6. *Class I/IA REC need through 2030*



Specific data and assumptions used to determine the RNS are listed below.

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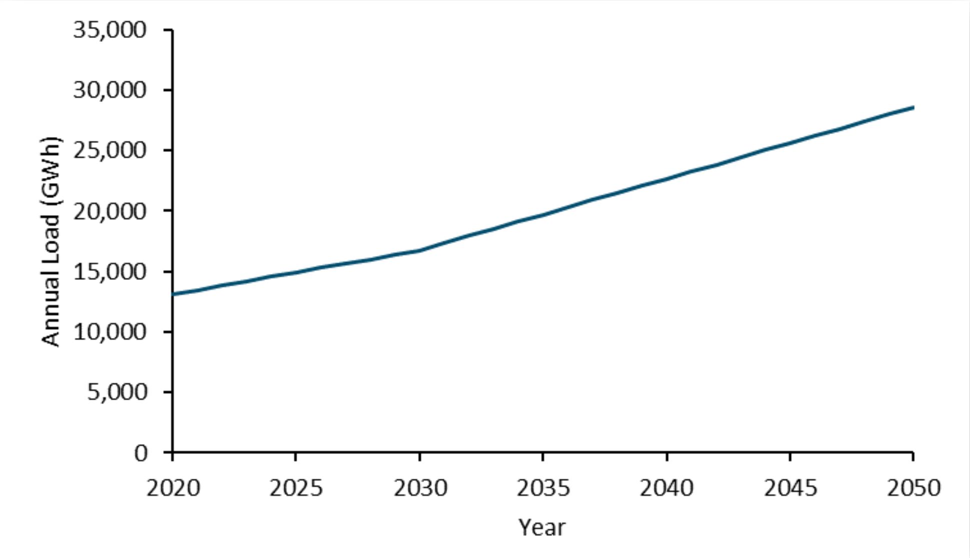
[35] *It is assumed in this study that Class II RECs are in sufficient supply to meet Class II need through 2030. Current low Class II REC prices as well as the relatively large hydro portfolio that qualifies for Class II RECs support this assumption.*

3.3.1.1 Load Forecast

The primary load forecast used in this study was developed for the MCC's Electric Sector study. The MCC study showed that this load forecast (called T4/H4 forecast in the study) would meet Maine's 2030 GHG reduction targets. Specifically, it incorporates aggressive levels of transportation and heating electrification; 85% of new Light-Duty Vehicles (LDV) sales by 2030 are assumed to be electric, while 55% of Heavy-Duty Vehicles (HDV) are assumed to be zero-emission vehicles. LDV and HDV VMT are also assumed to decline by 20% and 4% by 2030, respectively.[36] Fuel efficiency is assumed to reach 42 MPG for new cars and 30 MPG for new light trucks by 2050. A portion of electric vehicle (EV) charging is also assumed to be managed. The forecast also assumes a 1.5% cumulative residential space heat energy reduction by 2030 through weatherization. Furthermore, 90% of all residential and commercial heating systems that burn out are assumed to be replaced with heat pumps by 2030.[37] See Figure 7.

Figure 7. *Load forecast used in this study*



The load for intermediate study years was linearly interpolated between the Energy Information Agency's (EIA's) 2018 net load[38] in Maine and the 2030 H4/T4 projection.

3.3.1.2 Policy Requirements

LD 1494 established a requirement of 80% RPS by 2030 and a target of 100% by 2050. A breakdown of these requirements and goals as percentages of retail sales is shown in Figure 8. Ten percent of retail sales are required to be met by Class I resources, 30% from Class II resources, and the remaining is to be met from Class IA resources.

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[36] *Hall et al., "Volume 3: Maine Emissions Analysis Consolidated Energy Sectors Modeling Results."*

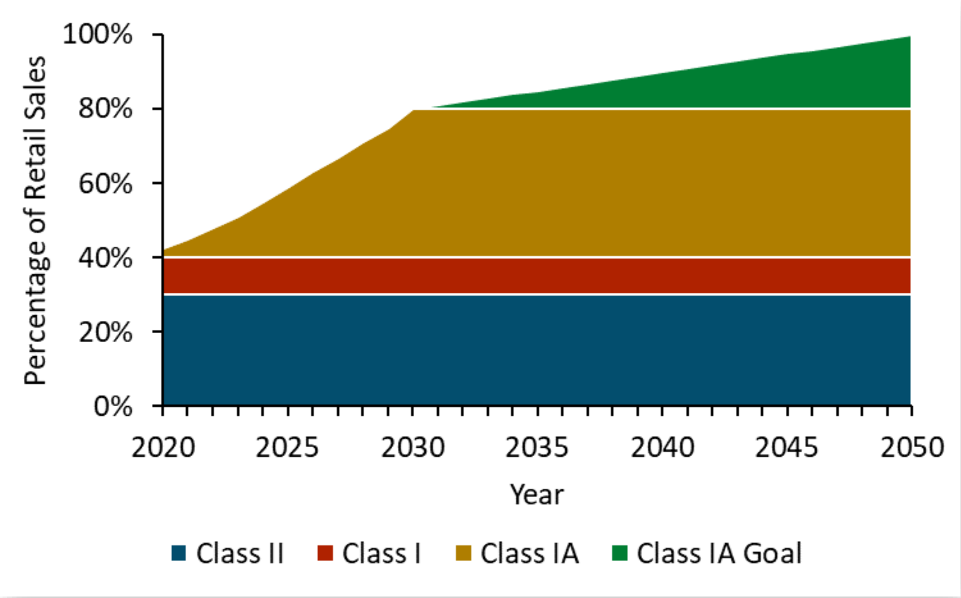
[37] *Hall et al.*

[38] *"Maine - State Energy Profile Overview - U.S. Energy Information Administration (EIA)."*

Class I and IA resources represent most of the growth in Maine's RPS. These "new" renewable resources can be any capacity when powered by wind or solar energy and cannot exceed 100 MW in capacity if powered in some part by any of fuel cells, tidal power, geothermal, hydro, or biomass.

Class II resources are pre-existing resources (with an in-service date prior to September 1, 2005 and not refurbished) that have capacities that do not exceed 100 MW and either have thermal efficiencies greater than 60% or are powered by fuel cells, tidal power, solar arrays, wind, geothermal, hydro, biomass, or municipal solid waste.[39]

Figure 8. *Maine RPS targets as percentage of retail sales*



The focus of this study is the Class IA requirement that is expected to drive the need for new renewables in Maine. Class II RECs are assumed to continue to be available to Maine and are not expected to drive significant investment in new renewables in the short-term. In 2017, Class II REC prices ranged from $0/MWh to $2/MWh, signaling a significant oversupply of Class II-eligible resources relative to Class II REC need.[40] This oversupply likely comes from some hydroelectric resources, which qualify as Class II resources in Maine alone. Given this historic oversupply and commentary from stakeholders, it is envisioned that these resources will continue to be sufficiently available through the study period. As a result, it is assumed that the Class II requirement will be met by existing resources and that any REC need will arise from Class I/IA deficits.

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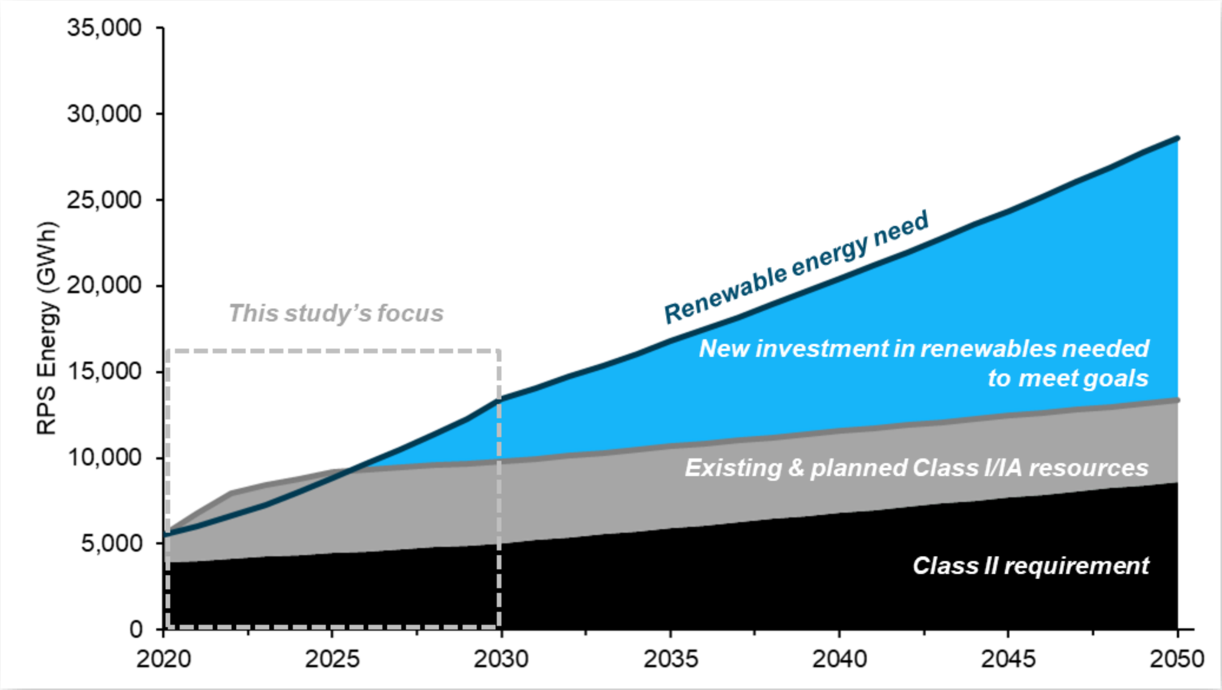
[39] *A detailed description of these classes is available on the Maine Public Utilities Commission's website."RPSMain," accessed January 6, 2021, https://www.maine.gov/mpuc/electricity/RPSMain.htm.*

[40] *"Annual Report on New Renewable Resource Portfolio Requirement: Report for 2017 Activity."*

__Figure 9.__ Renewable energy need (dark blue line) and assumed baseline RECs provided by existing and planned Class I/IA resources (gray band, excludes offshore wind) and existing Class II resources (black band)



3.3.1.3 Existing REC Resources

Existing REC resources will meet a portion of the state's needs. These include a combination of Class I and Class II resources. As mentioned above, this study focuses on REC needs driven by Class I/IA requirements. To this end, existing and planned Class I/IA resources are listed below. These resources are assumed to meet some of the REC need and the remaining need will drive renewable investment and is the focus of this study.

Class I/IA Resources

The baseline of Class I/IA RECs are assumed to come from a variety of sources:

- ***Existing generation.*** Historically, Maine Class I requirements have been met by a mixture of RECs generated by in-state and out-of-state resources, most of which are fueled by biomass, as shown in Figure 10.[41]

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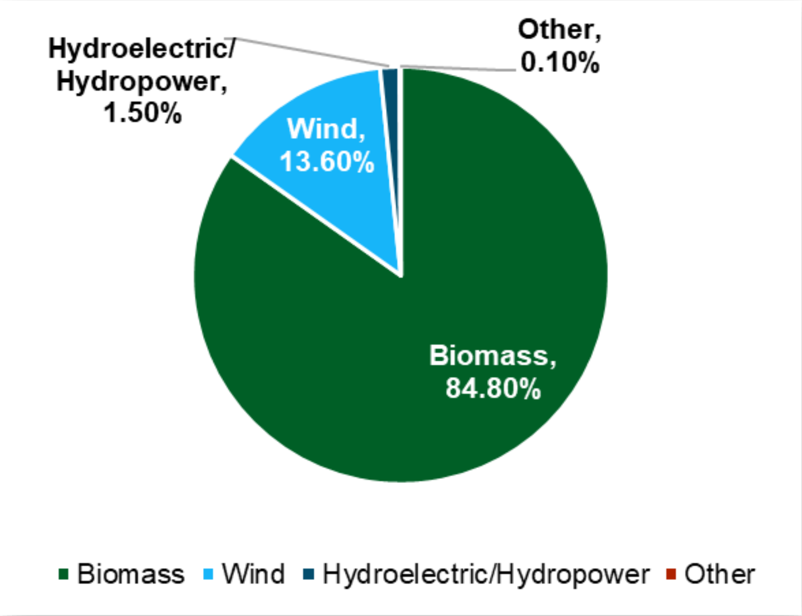
[41] *Maine Public Utilities Commission, "2019 Annual Report."*

Figure 10. *Class I REC mix used to meet requirements in 2018*[42]



Class I REC prices ranged from $1.15/MWh to $33/MWh in 2017, significantly below the alternative compliance payment of $67.71/MWh in that same year.[43] More recently, Maine's Class I REC prices have been lower than REC I prices of other New England states, signaling some oversupply of Class I RECs (see Figure 11). Keeping the current oversupply of Class I Maine RECs and the lower prices, for this study, it is assumed that resources that have historically met a portion of Maine's REC I requirements continue to do so.

Baseline resources include all projects that have achieved commercial operation through the end of Q3 of 2020. Procurements through LD 1494 and LD 1711 are also accounted for (see below). To the extent new resources have been contracted for and are not currently operational, they will help meet some of the REC need that is projected in 2026 once they become operational.

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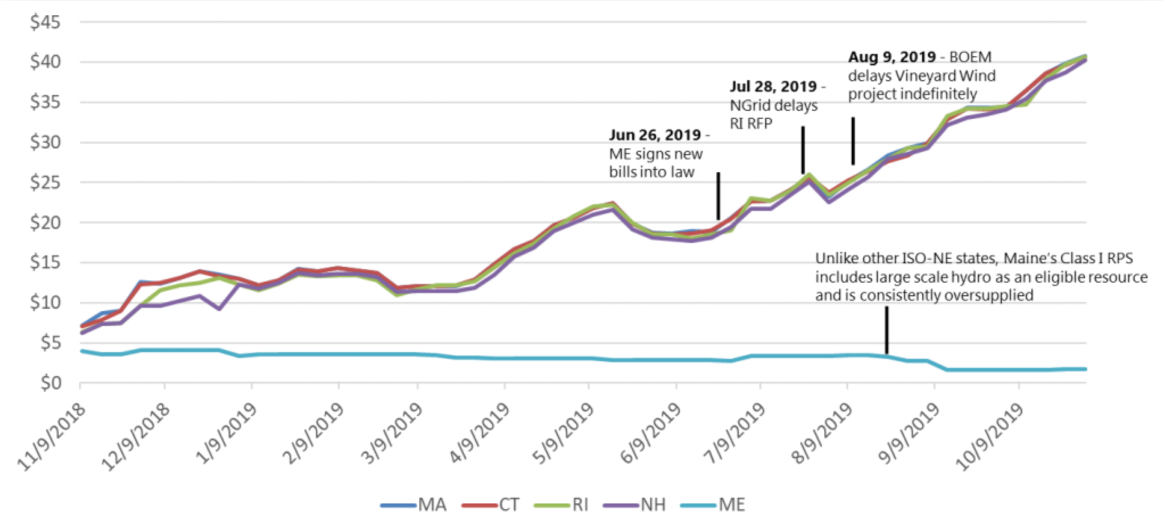
[42] *Maine Public Utilities Commission.*

[43] *"Annual Report on New Renewable Resource Portfolio Requirement: Report for 2017 Activity."*

Figure 11. *New England States' REC I prices*[44]



- ***Qualified hydro.*** The second source of baseline Class I/IA RECs are older hydroelectric plants with capacities greater than 25 MW but less than 100 MW, also known as "qualified" hydro.[45] This qualification corresponds to approximately 150 MW of hydroelectric generators statewide.[46] Maine recently allowed these generators to bid an escalating percentage of their annual generation into the Class IA REC market, capped at 200 GWh in 2020, 250 GWh in 2021, and 300 GWh in 2023. It is assumed that these generators will supply the legal maximum of their generation to meet Class I/IA requirements.
- ***Recent Class IA procurements.*** As mandated by LD 1494, the MPUC is in the process of conducting two rounds of procuring energy from Class IA eligible resources. The first procurement tranche consisted of a minimum of 7% (and no more than 10%) of Maine's retail electricity sales in 2018. The second tranche is for the remaining amount, totaling 14% of Maine's retail electricity sales in 2018 in combination.[47] The most recent round of procurements secured 546 MW of capacity with contract prices in the range of $20-$50/MWh.[48] It is assumed that RECs from these resources will go towards Maine's RPS compliance throughout the study period.
- ***New distributed generation.*** There has been significant interest in developing distributed generation resources, including the 375 MW solar procurement mandated by LD 1711[49] and about

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[44] *Carson Robers, "New England Class I REC Market Update | Power Advisory LLC," accessed January 5, 2021, https://poweradvisoryllc.com/new-england-class-i-rec-market-update/.*

[45] *"MRS Title 35-A, Section 3210. Renewable Resources."*

[46] *"Maine RPS Study | Synapse Energy," accessed December 23, 2020, https://www.synapse-energy.com/project/maine-rps-study.*

[47] *"S.P. 457 - L.D. 1494: An Act to Reform Maine's Renewable Portfolio Standard."*

[48] *"MPUC: 2020 Request for Proposals for the Sale of Energy or Renewable Energy Credits from Qualifying Renewable Resources," accessed January 19, 2021, https://www.maine.gov/mpuc/electricity/rfps/class1a2020/index.shtml.*

[49] *"S.P. 595 - L.D. 1711: An Act to Promote Solar Energy Projects and Distributed Generation Resources in Maine," 2019.*

1,100 MW of executed NEB agreements for Central Maine Power and Versant Power, as of late 2020.[50] Given the MPUC's recent ruling on the first round of the 375 MW distributed generation procurement[51] and the uncertainty of attrition of executed agreements, a total of 500 MW of distributed generation is assumed in the baseline. These projects are assumed to be fully operational by 2025.

+ ***Planned offshore wind.*** Maine currently has plans to develop a floating offshore wind research array of up to twelve turbines. While the specific MW have not been determined at this stage in the project, for purposes of the study, the total capacity of this array is assumed to be 144 MW in 2025 and will provide RECs to Maine for the remainder of the study period. This resource is included only in the High Offshore Wind and Diverse Portfolio scenarios.

By 2025, these resources are assumed to provide nearly 6,000 GWh of Class I/IA RECs towards Maine's RPS requirements. Any residual needs for Class I/IA resources must be met by additional new resources.

3.3.2 Renewable supply curve

3.3.2.1 Renewable Cost and Potential

Various technologies are deemed eligible in Maine's legislation to meet the state's RPS including hydro generation, biomass, and waste to energy (WtE). These types of generators are already abundant in Maine and enable the state to be well on the way to meeting the ambitious 80% by 2030 target. This section summarizes the assumptions for cost and potential for each of the technologies considered in this study.

Onshore Wind

The potential for onshore wind development in Maine is significant: a recent geospatial analysis completed by NREL indicates up to 50 GW of technical potential exists within the state. While a substantial fraction of this potential is low quality and would not likely be commercially developed, the technical potential for higher-quality resources (30%+ capacity factor) nonetheless exceeds 10 GW. This is still far in excess of what could be realistically developed in the state over the next 10-20 years. Hence, in this study, onshore wind was restricted to be built on 2% of Maine's forest and 2% of its farmland, further restricting the viable potential to 5 GW.[52] Such a restriction filters out all but the highest-quality wind (shown in dark blue in Figure 12).

Despite the challenge of needing transmission upgrades to interconnect these wind resources, especially in the West and North, the development of new onshore wind may be an attractive option for meeting Maine's future RPS needs. Technological innovation has driven costs lower while improving performance, and the cost of developing new wind is currently historically low. To characterize the present and future cost of wind resources, this study relies on NREL's Annual Technologies Baseline. The derivative levelized

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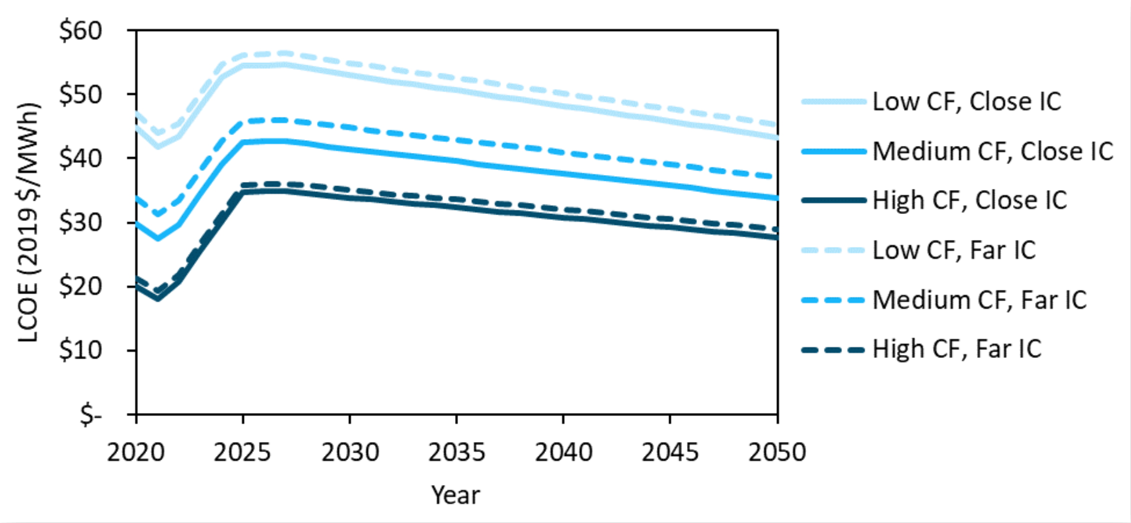
[50] *"CMP Response to Docket No. 2020-00199"; "Versant Response to Docket No. 2020-00199."*

[51] *"Report on Renewable Distributed Generation Solicitation."*

[52] *See Section 3.2.1.*

cost of energy for wind resources with different levels of performance is shown in Figure 12. Note that the increase in cost arises from the retirement of the wind Production Tax Credit (PTC) between 2020 and 2025.

Figure 12. *Projected levelized cost of energy (LCOE) as functions of distance to interconnection (IC) and capacity factor (CF) for new onshore wind resources*



Offshore Wind

The potential for offshore wind development is similarly significant. The University of Maine has estimated that there is about 156 GW of offshore wind technical potential off the coast of Maine.[53] Moreover, offshore wind is higher quality in comparison to onshore wind, with a capacity factor of more than 50%. This is primarily due to higher and more consistent wind speeds. NREL maps[54] of Maine's onshore and offshore wind speeds are shown in Figure 13.

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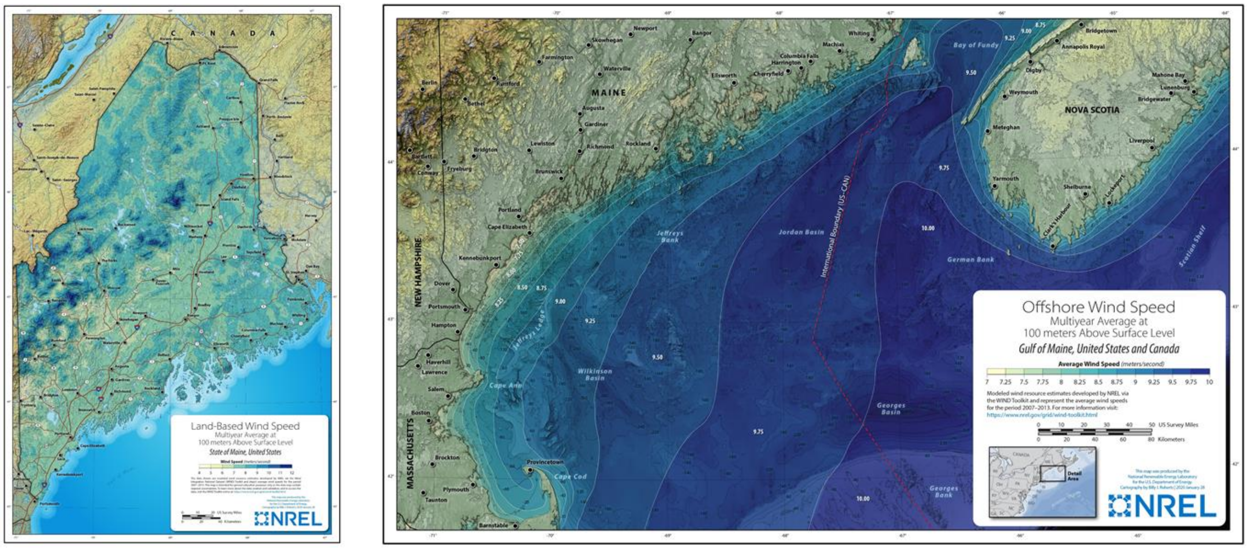
[53] *"Floating Offshore Wind in Maine - Advanced Structures & Composites Center - University of Maine," Advanced Structures & Composites Center, accessed January 1, 2021, https://composites.umaine.edu/offshorewind/.*

[54] *"WINDExchange: Gulf of Maine Offshore Wind Speed at 100 Meters," accessed January 19, 2021, https://windexchange.energy.gov/maps-data/337.*

Figure 13. *Onshore (left) and Offshore wind (right) speeds in Maine (Note that the color scales are different for the two maps)*



Analysis shows that 89% of Maine's offshore wind potential is in deep waters, necessitating floating wind turbine technology (as opposed to southern New England's offshore wind, which is in relatively shallow waters and is fixed-bottom technology). Despite the comparative nascency of floating offshore wind technology, it is well poised to meet Maine's future RPS needs. This is driven in part by the state-of-the-art research on floating turbine technology that is being led by University of Maine, but also by projected rapid declines[55] in technology costs, especially beyond 2030. Shown in Figure 14 are those costs until 2050. Note that the increased costs in 2025 are due to the federal tax credit expiration.

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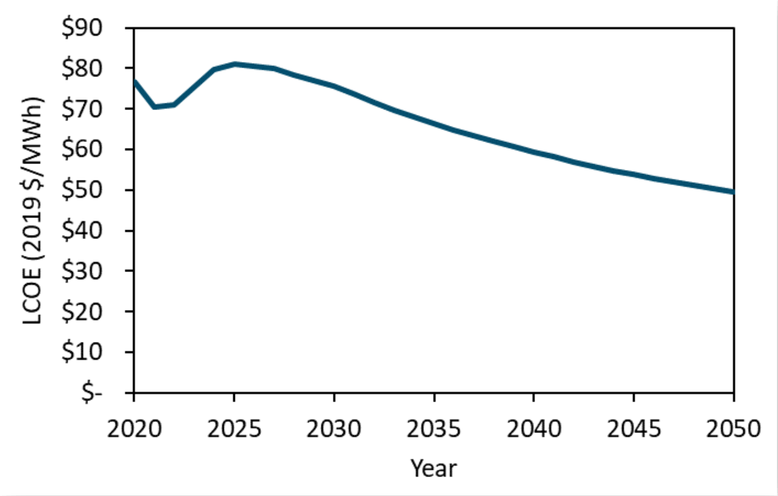
[55] *Walter Musial, Philipp Beiter, and Jake Nunemaker, "Cost of Floating Offshore Wind Energy Using New England Aqua Ventus Concrete Semisubmersible Technology,"* Renewable Energy, *2020, 43.*

***Figure 14.** Projected LCOEs for new floating offshore wind resources*



One of the outstanding questions not being addressed by this study is what supporting onshore transmission infrastructure would be needed to integrate large quantities of offshore wind, such as those considered here. A 2012 University of Maine study found that 200-300 MW of offshore wind could likely be interconnected without the need for any additional onshore transmission upgrades.[56] Since then, there have been no new studies addressing this issue. As a result, it is possible that new transmission upgrades may be required to interconnect beyond 300 MW of offshore wind. In this study though, it is assumed that Maine offshore wind can be interconnected without significant onshore transmission upgrades. This is in line with a recent ISO-NE study[57] that identified interconnection points for ~8 GW of offshore wind in southern New England. In the absence of Maine-specific data, this study assumes a similar situation in Maine, where the existing interconnection is allocated to offshore wind at retired or existing conventional generation sites or at available high-voltage lines nearshore, which are limited in Maine.

Utility-Scale Solar

In Maine, stand-alone utility-scale solar, on average, tends to have a lower capacity factor (capacity factor of 16%[58]) than that in much of the United States (average capacity factor of 24%[59]),[60] making it more expensive in comparison to high-capacity-factor onshore wind on an LCOE basis. By pairing solar arrays

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[56] *"Maine Deepwater Offshore Wind Report" (University of Maine, 2012), https://tethys.pnnl.gov/publications/maine-deepwater-offshore-wind-report.*

[57] *Patrick Boughan, "NESCOE 2019 Economic Study - 8,000 MW Offshore Wind Results," https://www.iso-ne.com/static-assets/documents/2020/02/a6_nescoe_2019_Econ_8000.pdf.*

[58] *"ATB | NREL," accessed December 31, 2020, https://atb.nrel.gov/.. Available at: "https://atb.nrel.gov/"*

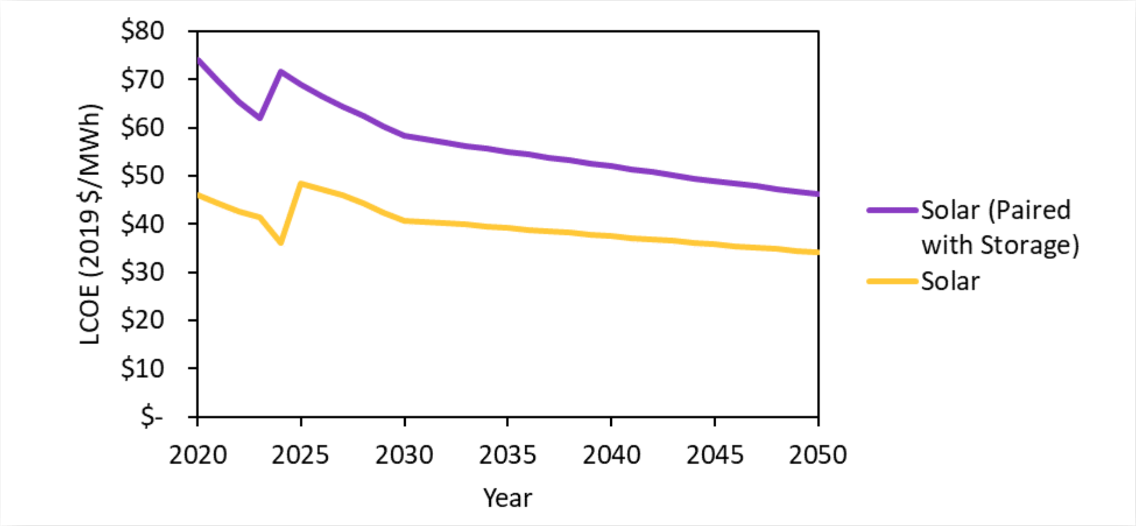
[59] *"Electric Power Monthly - U.S. Energy Information Administration (EIA)," accessed January 6, 2021, https://www.eia.gov/electricity/monthly/epm_table_grapher.php.*

[60] *This is primarily due to differences in solar insolation, which is a measure of solar energy that is incident on a specified area over a set period. Additionally, differences in cloud cover patterns also affect the capacity factors. The North America Land Data Assimilation System (NLDAS) Daily Sunlight (Insolation) database gives this measure by geographic area. Available at: https://wonder.cdc.gov/wonder/help/Insolation.html*

with battery storage (a hybrid array in this study includes 1 MW of solar PV with 0.5 MW of 4-hour lithium ion storage), the capacity factor increases to nearly 40%.[61]

While solar constituted the majority of the first round of Class IA procurement mandated by LD 1494, the selected projects likely do not require major transmission upgrades and are a representation of headroom on existing transmission. Given that this headroom is limited, large quantities of utility-scale PV in the future are unlikely to connect without transmission upgrades. A total of 7 GW of potential (based on the NREL database and the additional land-screens mentioned above) was made available for the model to choose from in this study.

Figure 15. *Utility-scale solar costs*[62]



Nevertheless, utility-scale solar can serve as a means for Maine to achieve its RPS requirements. The costs of solar and solar paired with batteries, drawn from NREL's ATB, is shown in Figure 15.

Distributed Solar

There has been significant interest in developing distributed generation resources in Maine. Distributed generation resources are those in Maine that have capacities of 5 MW or less and are interconnected at the distribution system level. Distributed generation can come from any generator meeting these requirements. However, in practice, distributed solar generation is the primary distributed generation resource in the NEB interconnection queues for Central Maine Power and Versant Power[63]. As a result, distributed solar is focused on in this study and both "distributed solar" and "distributed generation" will be used interchangeably in this report.

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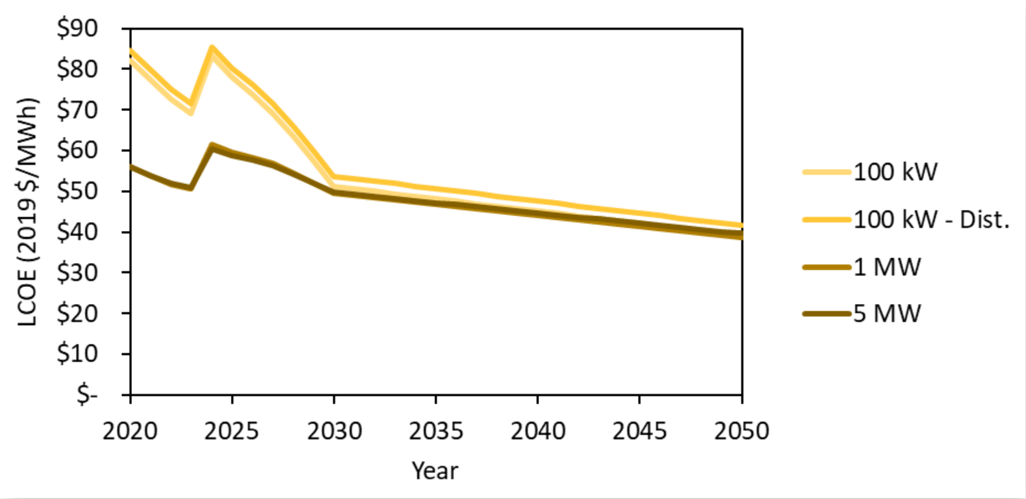
[61] *This is taken from the AURORA modeling software database.*

[62] *This figure was updated in March 2021. See corresponding release notes.*

[63] *"CMP Response to Docket No. 2020-00199"; "Versant Response to Docket No. 2020-00199."*

Distributed resources totaling over 1,100 MW have NEB contracts executed through Central Maine Power's and Versant Power's NEB program, and 375 MW are required to be procured as mandated in LD 1711. However, there are challenges and uncertainties regarding the cost and magnitude of distribution and transmission system upgrades associated with integrating distributed solar generation, likely leading to significant near- and mid-term attrition of planned distributed solar build in Maine.

Figure 16. *Distributed solar costs as function of size of array*



Regardless, distributed solar may be an economical way for Maine to meet its RPS requirements by 2030, while potentially avoiding or deferring transmission upgrades needed to interconnect distant onshore wind resources in western and northern Maine. The current resource cost, distribution system upgrade costs, and overall cost declines of distributed solar vary by the size of the project themselves, ranging from solar arrays in the 100 kW range up to those near the limit distributed generation limit of 5 MW. In this report, the resource costs of distributed solar arrays are drawn from the 2019 Tracking the Sun report,[64] the anticipated declines followed those in NREL's ATB, and costs from distribution system upgrades were adapted from communications with stakeholders.[65] As shown in Figure 16, it is clear that different array sizes, particularly those in the 100 kW size range, can rapidly decline in overall cost over the study period.

It is important to note here that rooftop solar arrays are not explicitly considered in this study (they are considered to be part of the up to 100 kW bucket). While they may represent benefits to the people of Maine, such as reduced electricity bills in the long run, increased jobs in the local economy, and improved grid reliability, they are expected to play a minimal role in helping Maine comply with its RPS given their

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[64] *Galen Barbose and Naim Darghouth, "Tracking the Sun: Pricing and Design Trends for Distributed Photovoltaic Systems in the United States, 2019 Edition" (Lawrence Berkley National Laboratory, 2020), https://eta-publications.lbl.gov/sites/default/files/tracking_the_sun_2019_report.pdf.*

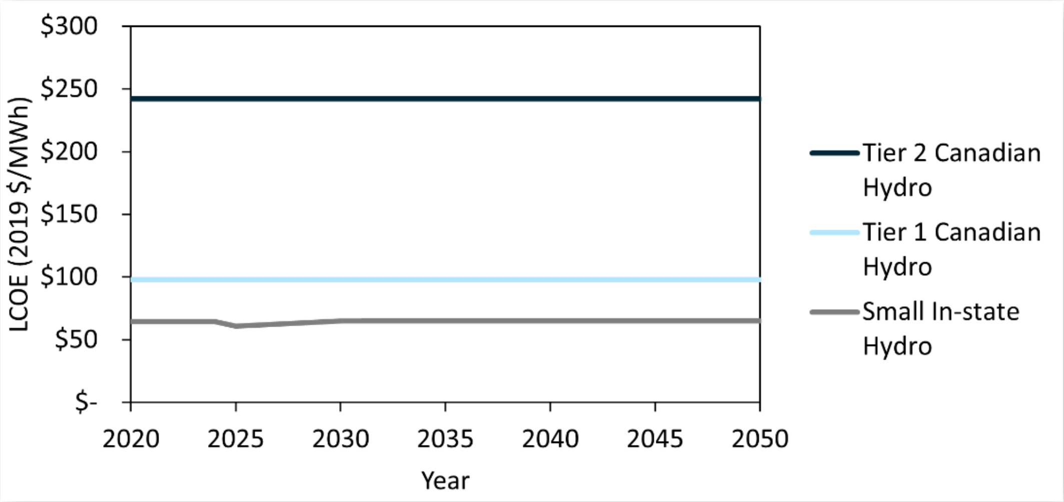
[65] *These were independently verified and benchmarked to standard costing assumptions used in prior work, such as in the recent Net-Zero New England study: https://www.ethree.com/wp-content/uploads/2020/11/E3-EFI_Report-New-England-Reliability-Under-Deep-Decarbonization_Full-Report_November_2020.pdf.*

smaller size. As a result, these are not given as a separate candidate resource for the model to choose from in this study.

Hydroelectric

Hydroelectric generation has been an important resource in Maine's electricity mix, providing 31% of Maine's net electricity generation in 2019.[66] While much of Maine's hydroelectric potential has already been tapped, there is about 56 MW of potential capacity still available and this is given as a candidate resource to the model.[67] A total of 2 GW of Canadian hydro (assumed to be projects under 100 MW) was also made available as a potential candidate resource. Fifty percent of this potential was assumed to be turbine upgrades at existing sites (Tier 1), and the other 50% was assumed to be new projects (Tier 2). [68]

Figure 17. *LCOE of available hydro resources*



Although new in-state hydro is cheaper than Canadian hydro, it is still expensive compared to other in-state resources, such as onshore wind and solar paired with storage, considered in this study. Furthermore, because the technology is relatively mature, the cost remains largely flat over the course of the study period. In combination with hydro's limited potential, these costs suggest that new in-state hydro is unlikely to play a major role in satisfying Maine's RPS requirements. In addition, new Canadian hydro (under 100 MW) can be seen to be the most expensive resource available in this study, due in part to transmission costs. It too is unlikely to play a major role in satisfying Maine's RPS requirements in the near term.

Biomass

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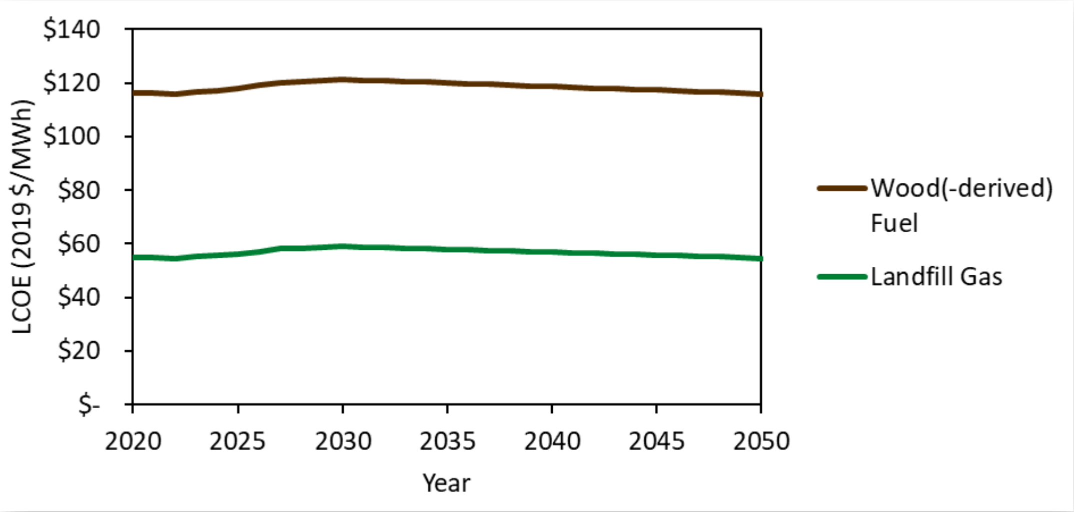
[66] *"Maine - State Energy Profile Overview - U.S. Energy Information Administration (EIA)."*

[67] *"Maine Hydropower Study" (Augusta, Maine: Maine Governor's Energy Office, 2015), https://www.maine.gov/energy/sites/maine.gov.energy/files/inline-files/001-ME-GEO-Rpt-02-04-15.pdf.*

[68] *"Net-Zero New England: Ensuring Electric Reliability in a Low-Carbon Future" (Energy and Environmental Economics, Inc., 2020), https://www.ethree.com/wp-content/uploads/2020/11/E3-EFI_Report-New-England-Reliability-Under-Deep-Decarbonization_Full-Report_November_2020.pdf.*

Like hydroelectric generation, biomass resources, which include generators fueled by wood and wood-derived fuels or landfill gas, have historically been a cornerstone of Maine's generation portfolio. As a result of the extensive utilization of wood-based resources, it was estimated by some stakeholders that there are only approximately 80 MW of new wood-based generation potential remaining in Maine. Further, there are only a few landfills in Maine with appreciable gas flow rates that are not already used in electricity generation, including the Juniper Ridge Landfill, the City of Bath Landfill, and the Aroostook Waste Solutions landfills in Fort Fairfield and Presque Isle. These provide approximately 15 MW of potential in aggregate, according to stakeholder feedback.

Figure 18. *Biomass costs*



In the face of the rapidly declining costs of solar and onshore wind, new standalone biomass generators are unlikely to contribute to Maine's RPS requirements over the next decade without targeted action to support new generation. The costs of these generators, derived from NREL's ATB, EIA technology cost estimates, and communication with stakeholders, are shown in Figure 18. The generating technologies fueled by wood, wood-derived fuel, or landfill gas are quite mature; there are limited cost declines expected over the study period.

Waste-to-Energy

There has been some interest in incorporating greater levels of municipal waste-to-energy generation in Maine's resource portfolio. LD 1494 established that electricity produced by a WtE unit can be multiplied by 300% until January 1, 2025, for the purposes of REC accounting.[69] Despite this, WtE has limited potential

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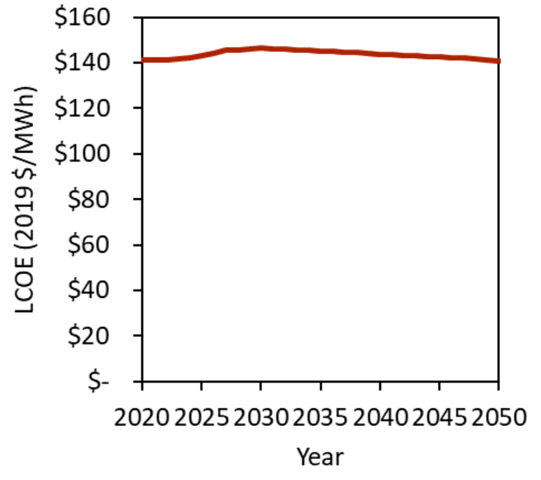
[69] *This provision is currently set to expire in 2025.*

to satisfy Maine's RPS requirements. The costs over the next decade, derived from a survey of NREL's ATB, for these resources are among the highest of those examined in this report (see Figure 19). A Class II REC for a new WtE plant will be priced between $90 to $100/MWh over the course of the study period, after netting energy and capacity value from a WtE plant's LCOE and before accounting for the 300% multiplier placed on energy produced from WtE plants.[70] After accounting for this multiplier, the price for a WtE Class II REC will be in the range of $30-$33/MWh. In either case, given the historically low Class II REC prices, new WtE plants are unlikely to be built to support ME's Class II REC requirement over the next decade.

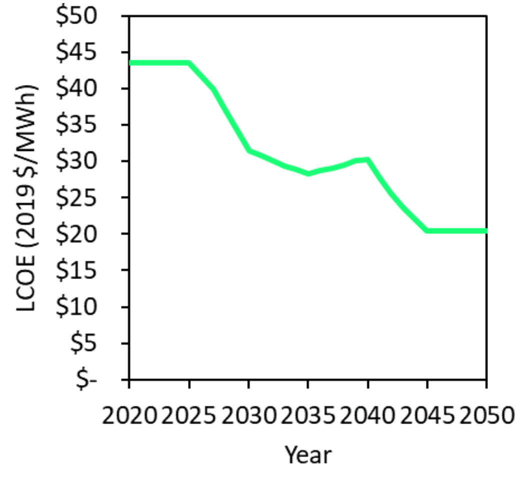
Figure 19. Waste-to-energy costs



Additional out-of-state RECs

Maine currently satisfies a portion of its REC requirements from out-of-state RECs.[71] It is assumed that these RECs will continue to satisfy Maine's REC requirements at the same levels as today. The use of additional out-of-state RECs is an option to satisfy more of Maine's REC requirements and avoid the need to build new renewable generation. Using AURORA capacity expansion and production simulation modeling, the cost of a New England Class I REC was estimated through the study period, shown in Figure 20. Although New England Class I REC prices are expected to decline going forward, they are still expected to remain relatively high when compared to Maine Class I REC prices since the entire region is moving towards deep decarbonization, keeping the demand for New England Class I RECs high.

Figure 20. Out of state REC costs



Supply Curve

Resource costs, in combination with resource quality and availability, dictate which technologies are most economic and are chosen by the model to be built to meet the Maine RPS requirement. Costs used are generated by E3's Pro Forma model and are based on the 2020 NREL ATB. The figure below shows the LCOE of the set of resources considered in the model in 2030. The costs include both the raw resource cost and

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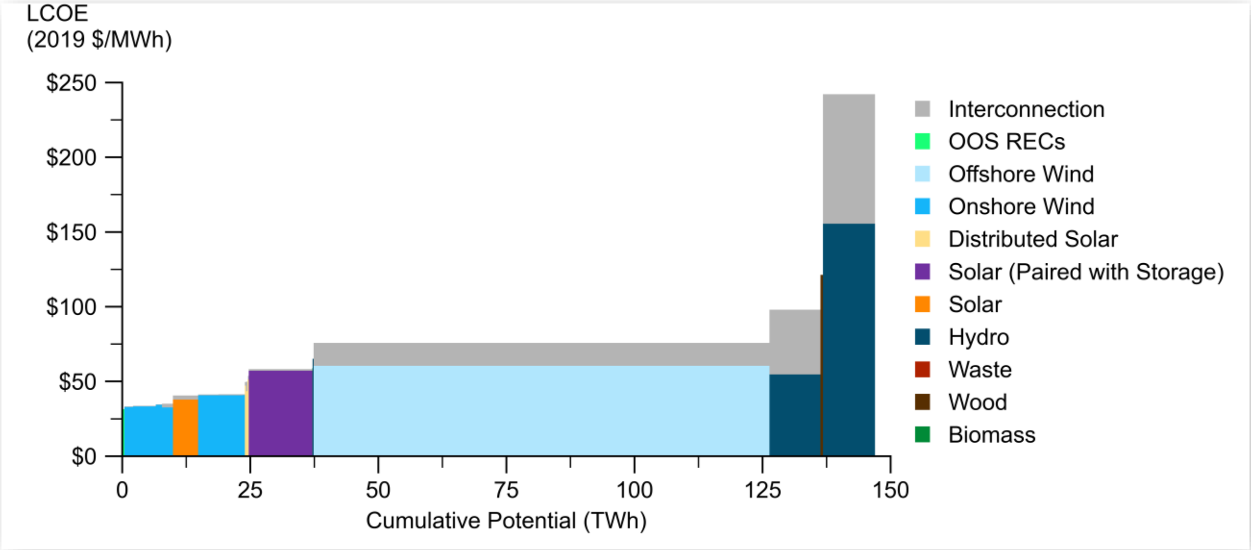
[70] *"MRS Title 35-A, Section 3210. Renewable Resources"; "ATB | NREL."*

[71] *Maine Public Utilities Commission, "2019 Annual Report."*

the cost of a 230 kV line to interconnect to the nearest point in the transmission system. Note that the supply curve does not reflect the amount of available transmission headroom in the system or the cost of transmission upgrades to accommodate interconnection. These are detailed in the following section. The supply curve also does not account for differences in energy or capacity revenues recovered by these resources. Thus, the final, lowest-cost resource mix after transmission costs and constraints are accounted for may not be comprised of the most inexpensive resources in the supply curve shown below.

Figure 21. *Renewable resource supply curve in 2030*[72]



3.3.2.2 Transmission Availability & Cost

A stakeholder study completed in January 2020, as required by LD 1401 (Resolve, To Study Transmission Solutions to Enable Renewable Energy Investment in the State), clearly outlines the state of Maine's electric grid today as well as identifying important congestion corridors and constraints on the system. Insights from this report were used to craft "transmission zones" within Maine for the purposes of this study. Transmission zones in this study are zones associated with the two primary characteristics: headroom on the existing system, and cost and capacity of the transmission upgrades. The first characteristic - headroom on the existing system - is the MW capacity of renewables that can be interconnected and delivered at full capacity on the existing transmission system. Once this headroom is exhausted with new resources, transmission needs to be upgraded to integrate any more resources and these are defined by the second characteristic, cost and capacity of transmission upgrades. There can be multiple tiers of transmission upgrades (relatively cheaper to more expensive). The broad idea is that any resource built in a transmission zone will take up headroom on the existing transmission system (also referred to as existing headroom in this report) and any interconnection needed after the existing headroom has been used up (to deliver

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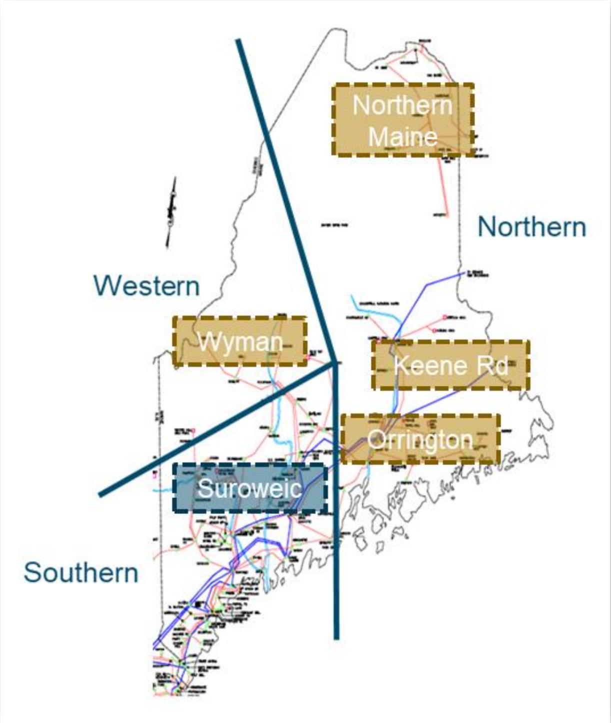
[72] *This figure was updated in March 2021. See corresponding release notes.*

electricity to Maine load centers) will trigger a transmission upgrade if the model chooses to build such a resource.

Shown in Figure 22 is a transmission map of Maine with constraints identified by the LD 1401 report highlighted in orange or blue boxes. Those in orange boxes are constraints with limited or no headroom for additional resources to be interconnected to them; the blue boxes are those with some headroom. It is clear that large portions of Maine are transmission constrained, leaving potential high-quality resources unable to serve Maine's load or participate in the ISO-NE market. The impacts of the New England Clean Energy Connect (NECEC) on Maine's grid and the necessary upgrades needed for NECEC are not considered in this study.

Figure 22. *Major transmission constraints in Maine and zones in this study*



Considering the findings from LD 1401 report, discussions with stakeholders, and the needs of this study, Maine's grid was divided into three transmission zones. Note that these zones are not meant to be representative of any physical or administrative divisions/constraints within the system today. Rather, these are meant to represent the reality of significant transmission limitations preventing interconnection of resources in northern and western Maine. It should be noted that although the northern Maine grid is not directly connected to the rest of Maine's ISO-NE grid, it is a part of the Northern zone in this study. This was done as any renewables developed in northern Maine, such as in Aroostook County, are still expected to face downstream constraints such as Keene Road and Orrington-South.

As shown in Figure 22, the three zones incorporate different transmission constraints. The West contains the Wyman transmission constraint, which limits interconnection of western resources. The North contains the Keene Road and Orrington South constraints. Finally, the South contains the Suroweic-South interface and is assumed to have a 200 MW of headroom[73], after which transmission upgrades must be built. There is some debate about the exact amount of headroom available in the South, especially as this is intertwined with the question of NECEC-related upgrades at Suroweic-South. This is still uncertain, and the actual number may vary; but for the purposes of this study, it is assumed that 200 MW of headroom exists.[74] Although not considered in this study, the available headroom in the South also impacts the amount of renewables that may be developed in the West and North as low available transfer capacity in the South and further down would prevent western and northern wind from being sold out of state. Additional study of the Suroweic-South interface has been committed to by the NECEC, stipulating parties as approved by the MPUC.

The costs and MW capacities of these transmission upgrades differ by zone and by tier and are sourced from publicly available information, where available. For example, the two Maine Resource Integration Studies (MRISs) conducted by ISO-NE were used to inform transmission upgrade costs in the western and northern zones to interconnect resources on an energy-only basis.[75] Due to the lack of publicly available Maine-specific data on transmission upgrades in the southern zone, these were informed by urban transmission costs in other parts of New England.[76] Transmission upgrade costs in the southern zone are higher than those in the western and northern zones on a per-MW basis, reflecting the increased cost of transmission in urban areas. See Table 2 for the costs and capacities assumed for these upgrades.

Table 2. *Transmission upgrades costs and capacities used in this study*

Zone	**Existing Headroom**	**Upgrade 1**		**Upgrade 2**	
	Capacity (MW)	Cost (2019 $ MM)	Cum. Capacity (MW)	Cost (2019 $ MM)	Cum. Capacity (MW)
Northern	0 MW	$779	518	$1,422	1119
Western	0 MW	$303	360	$600	777
Southern	200 MW	$518	360	$1,025	777

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[73] *MPUC Order in Docket 2017-00232 (NECEC).*

[74] *As such, NECEC does not directly impact the assumptions in this study aside from the available headroom in the South.*

[75] *The implication of this assumption is that new resources that are developed behind the transmission upgrades in this study get an energy value and not a capacity value. There is no publicly available data on the costs and magnitudes of possible transmission upgrades to the North and the West that would also allow resources to receive their full capacity value. Nevertheless, the impact of this assumption on the higher-level findings from this study are expected to be minimal as the transmission upgrades to the West and the South and the resource builds in the West and the North are chosen economically by the model in the Base Case. An added capacity value is not expected to change the economics of these lines.*

[76] *"Greater Boston Cost Estimates: Clarifying Questions," https://www.iso-ne.com/static-assets/documents/2014/11/nht_greater_boston_clarifying_questions.pdf.*

The zones mentioned above are used in the study to identify the optimal mix of resources that can meet Maine's annual REC need. For the purposes of this study, renewable development in the West and the North is assumed to be driven by increases in load in the southern zone. As such, all renewable development in the state is assumed to meet state-wide load and not individual zonal load.[77]

3.3.2.3 Energy Value

Seasonal and daily generation patterns are also important to quantify so that generation closely matches up with demand, especially for variable renewable resources like solar and wind. High-demand hours result in higher wholesale energy prices, which would give generators higher revenues. This energy value is one variable in the equation the model considers when deciding which resources to procure to meet the RPS. The energy value of a resource is the product of its generation MWh output and the projected future energy prices for Maine. A description of these two components is given below.

Resource profiles

Solar, distributed solar, wind, and offshore wind profiles were simulated from NREL's National Solar Radiation Database (NSRDB) and Wind Toolkit (WTK). A selection of sites across Maine were sampled for each resource to ensure each profile was representative of the resource. Because utility-scale solar and wind quality differ across Maine, separate profiles were developed for a representative southern Maine resource and a northern Maine resource. State-of-the-art resource characteristics such as single-axis tracking (for solar) and 100-meter hub height (for wind) were used for the profile simulation. For distributed solar, only one profile was developed since distributed resources are deployed near population centers, so the set of sampled sites was in southern Maine, where the majority of people in Maine live. Distributed solar arrays tend to be smaller and in a fixed position, so their capacity factors are less than utility-scale solar. The offshore wind profile was developed using sites off the coast of southern Maine near load centers, given that an advantage of offshore wind is delivering renewable energy into transmission-constrained areas. The solar paired with storage profiles were constructed using the original solar profiles and assuming the nameplate solar capacity is twice the storage capacity it is paired with. Profiles of other resources considered are less variable and do not require a weather-based simulation, so flat historical monthly capacity factors were used from EIA 2018 generation data. The average annual generation for each resource is shown in Figure 23.

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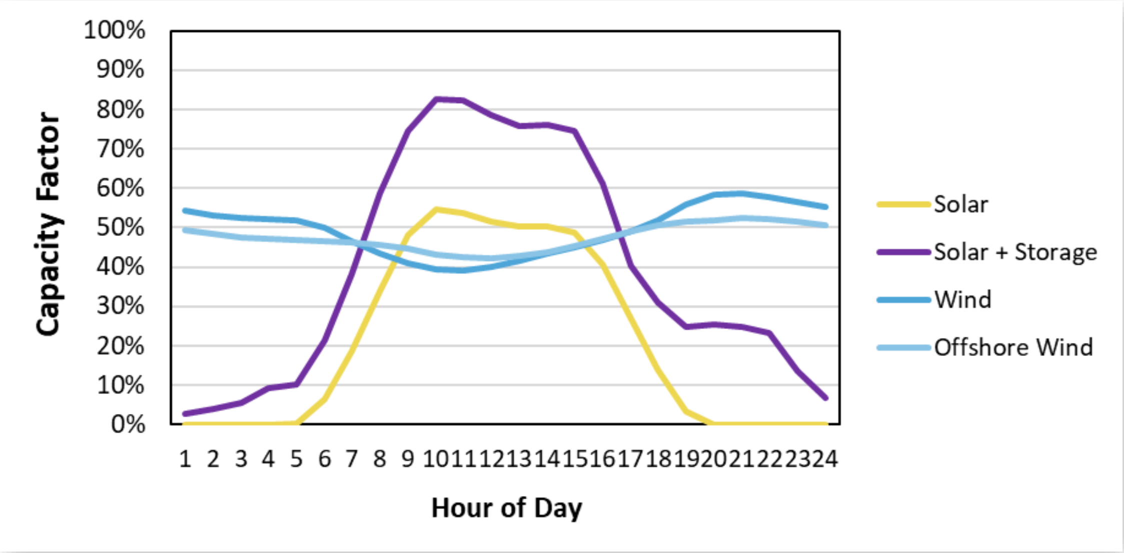
[77] *A detailed power analysis will identify the actual deliverability of developed renewable resources to different demand locations within the state. This is out of the scope of this analysis.*

Figure 23. *Average annual generation for representative resources used in this study*



Projected energy prices

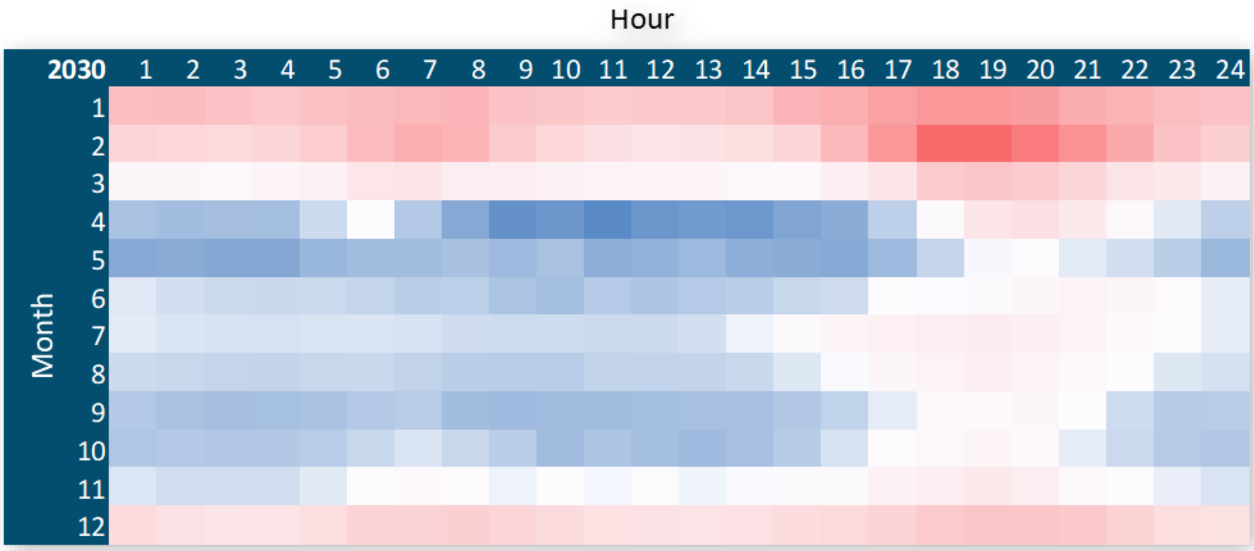
E3 forecasts future energy prices using AURORA to perform both capacity expansion and production simulation. The process for producing the price forecast involves modifying AURORA's default database with E3's assumptions for load, existing generator characteristics, fuel prices, new resource options, and policy assumptions. Key assumptions in E3's price forecast include:

- Forecasts of transportation and building electrification consistent with NREL's 2019 ATB;
- Natural gas price forecasts based on OTC Global Holdings forwards in the near term at each hub, and the EIA's Annual Energy Outlook (AEO) in the long term;
- Updates to plant-level operating characteristics and retirement dates based on public plans and E3's expert knowledge of electricity markets;
- State RPS and other clean energy goals, technology-specific mandates, regional carbon price programs, and federal tax incentives (including the ITC and PTC);
- New resource options, including solar, wind, offshore wind, lithium-ion battery storage, gas combined cycles, and gas combustion turbines, with costs derived from NREL's ATB and E3's pro forma financing model.

Once these changes are incorporated, a three-step process is used to create the price forecast. First, a capacity expansion run in AURORA is done to determine the new resources that will be built to meet future load and policies. Then, a production simulation run in AURORA is done with those new resources incorporated to produce hourly energy prices. Finally, post-processing is done to incorporate historical price volatility that does not show up in the over-optimized result of the production simulation.

The hourly results of the energy price forecast were averaged monthly and used with the generation profile of each resource to determine the energy value. Figure 24 shows E3’s price forecast for ISO-NE in 2030, summarizing the average hourly prices by month; red indicates higher prices and blue shows lower prices. During the winter months, when natural gas demand (and thus prices) is higher across the region, the electricity prices are also highest. Prices throughout the year are generally higher in the evening hours when electricity demand is highest; prices are typically lower overnight, when demand is lowest, and in the middle of the day, when abundant solar depresses prices.

Figure 24. *Heatmap of projected energy prices (2030)*



3.3.2.4 Capacity Value

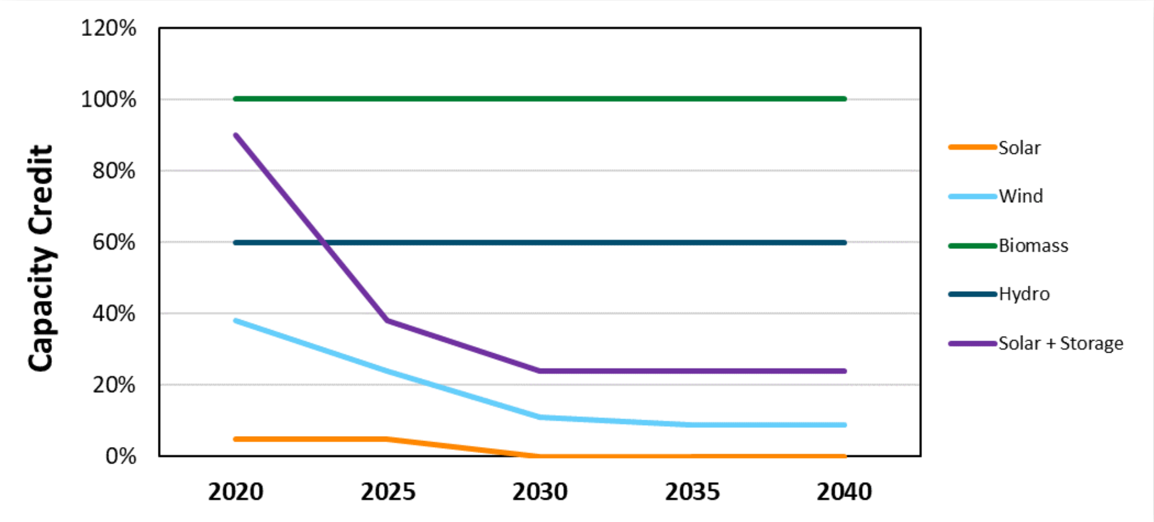
The capacity value of a resource is the value a resource brings to the system by generating energy during times of system peaks. Quantifying the capacity value includes quantifying: 1) the capacity contribution of a resource during system peaks (this is referred to as its Net Qualifying Capacity or Effective Load Carrying Capacity), and 2) the capacity price. Multiplying these two values for a resource gives its total capacity value. Each of these components is described below.

Net Qualifying Capacity (NQC) or Effective Load Carrying Capacity (ELCC)

In practice, both NQC and ELCC, represent the percentage of a resource’s capacity that can be relied upon during the system peak. However, each term is assigned based on resource type – NQC applied to firm resources and ELCC applied to variable resources and storage. These factor into the valuation of a resource since generators get paid for the capability of providing generation when it is needed most. For example, if the system peak is in the evening, a solar resource would have an ELCC of zero while a firm gas generator would receive close to 100% NQC.

The variable-resource ELCCs used were simulated in RECAP, E3's reliability simulation tool, for New England under deep decarbonization,[78] and are displayed in Figure 25. These are assumed to decline over time due to saturation with increasing penetration. Already the system peak is near sundown in the winter; thus, solar receives a very small ELCC in 2020. As more solar is integrated and the peak shifts more into the evening, that ELCC goes to zero. The ELCC of wind resources, including that of both onshore and offshore wind, also declines, but not as significantly – the value starts at 38% and then declines to 11% by 2030 as more wind is built. When solar and storage are paired up, the ELCC starts high but still declines slightly over time. Hydro and biomass, on the other hand, do not have weather-dependent generation limitations like the other resources, and so receive 60% and 100% NQC throughout.

Figure 25. *Capacity credit of variable resources. Onshore and offshore wind are assigned the same capacity credit.*



Assumed capacity price

This is the price the ISO-NE Forward Capacity Auction (FCA) clears at and is the price a resource gets paid for its capacity. A detailed simulation of future capacity auctions for the Maine zones is beyond the scope of this study. As a simple approximation, the capacity price is assumed to be the net cost of new entry (net CONE). This assumes that when there is a shortage of capacity to meet system peak, the clearing price of the auction will be equal to the cost of building a new generator to meet that system peak. The cheapest firm capacity resource that is often built to meet peak load is a combustion turbine, which is $33/kW-yr.

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[78] *"Net-Zero New England: Ensuring Electric Reliability in a Low-Carbon Future." Report by E3 and EFI. Available at: https://www.ethree.com/wp-content/uploads/2020/11/E3-EFI_Report-New-England-Reliability-Under-Deep-Decarbonization_Full-Report_November_2020.pdf*

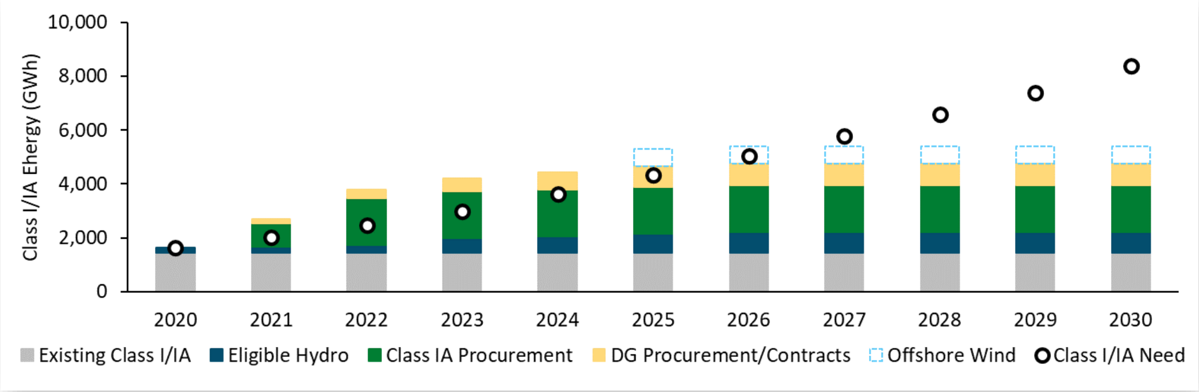
4 Scenario Analysis Results

The results of each scenario are presented below. Each set of scenario results provides resource builds in five-year increments starting in 2030. Though the focus of this study is through 2030, results are presented until 2040 to show the impact of the 2030 mix on the future trajectories of Maine's portfolio. Results presented in this section are not meant to be prescriptive – rather they are meant to illustrate possible pathways to meet the state's RPS requirements cost effectively and better inform policy decision-making (Section 5).

4.1 Individual scenario results

As shown in Section 3.3.1, under the assumptions in this study, Maine starts needing new RECs by 2026 or 2027. This is shown again in Figure 26. The analysis in this study modeled one snapshot year at five-year intervals. Hence the first year modeled is 2020 followed by 2025, 2030, 2035, and 2040. Because no new RECs are expected to be needed by 2025, the first year for which results are shown is 2030. The scenario-specific modeling results that follow are to be considered as showing the amounts of *new* renewables that are needed *by* 2030, 2035, and 2040. Pre-planning and construction need to begin ahead of time, so that these resources are operational and generating RECs starting in 2026 or 2027 and by the years shown in the figures below.

Figure 26. *Class I/IA REC need through 2030*

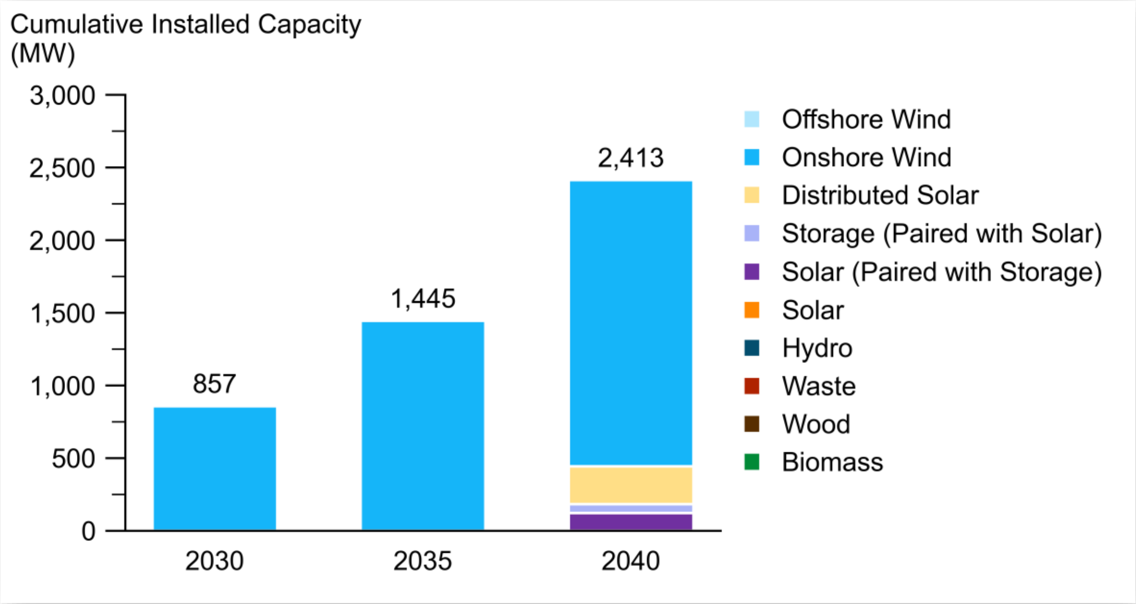


4.1.1 Base Case

The Base Case selects a least-cost portfolio to meet Maine's REC needs. As shown in Figure 27, this portfolio relies on onshore wind to meet needs through 2030 and a mix of onshore wind, solar paired with storage, and distributed solar through 2040. Figure 28 shows where these resources are built, and which transmission upgrades are required to support the resource portfolio. Finally, Figure 30 shows the sources of all RECs in the Base Case, including those arising from existing and planned resources.

In 2030, onshore wind resources are chosen because of their higher capacity factors (which allows more effective utilization of requisite transmission upgrades in the West and North). Beyond 2030, solar paired with storage[79] is chosen because the highest quality wind resources are exhausted in the West. Finally, distributed solar is chosen to avoid expensive transmission upgrades in southern Maine.

Figure 27. *Renewable build in Maine in Base Case*[80]



Transmission upgrades in the West and North are selected to accommodate high-quality onshore wind in 2030. After 2030, a second set of transmission upgrades in the West and North are built to connect onshore wind (North) or a mix of onshore wind and solar paired with storage (West). The remaining need is satisfied by filling existing headroom in the South with onshore wind and building 260 MW of distributed solar generation.[81] These facilities are estimated to be approximately 1 – 5 MW in size and can be located next to commercial, industrial, and small community loads.

Onshore wind and associated transmission development in the West and in the North are found to be economical. This is partly driven by the high quality of wind in these areas but also by comparatively high southern transmission costs, which are assumed to be urban and hence more expensive than the North and the West.

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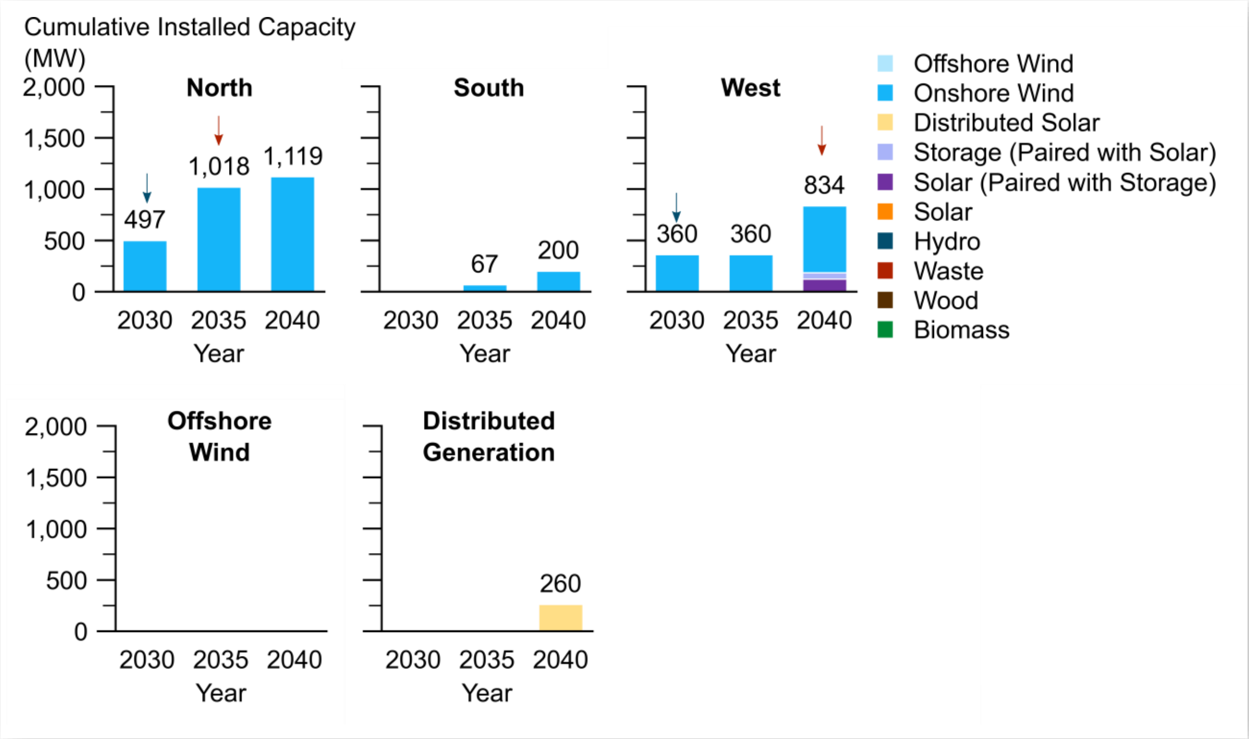
[79] *In the figures, "Solar Paired with Storage" indicates the solar component of the project while "Storage Paired with Solar" points to the storage portion of the project. In this study, the storage component of hybrid solar projects is assumed to be 50% of the nameplate capacity of the solar component.*

[80] *This figure was updated in March 2021. See corresponding release notes.*

[81] *Note that a total of 500 MW of new Distributed Generation is already included in the baseline and is expected to be online by 2025. This 75 MW is in addition to that 500 MW bringing the total new Distributed Generation in Maine to 575 MW.*

Figure 28. *Regional builds in Base Case. The year where the first or second transmission upgrades are needed in each region is indicated by a blue or red arrow, respectively*[82]



As a final overview of the Base Case, Figure 29 shows all REC sources in the Base Case, including baseline resources arising from planned and existing sources. As discussed, new resources must be producing RECs by 2030, even though baseline resources contribute many RECs to support Maine's RPS. From this perspective, it should be noted that, in the case that some baseline RECs fail to materialize as anticipated (such as planned resources not being built or existing resources shutting down earlier than anticipated), new resources must be built in addition to those chosen in the Base Case. In all instances, it must be emphasized that there must be significant planning and construction for new resources to be built in time to satisfy Maine's RPS in the latter half of the 2020s.

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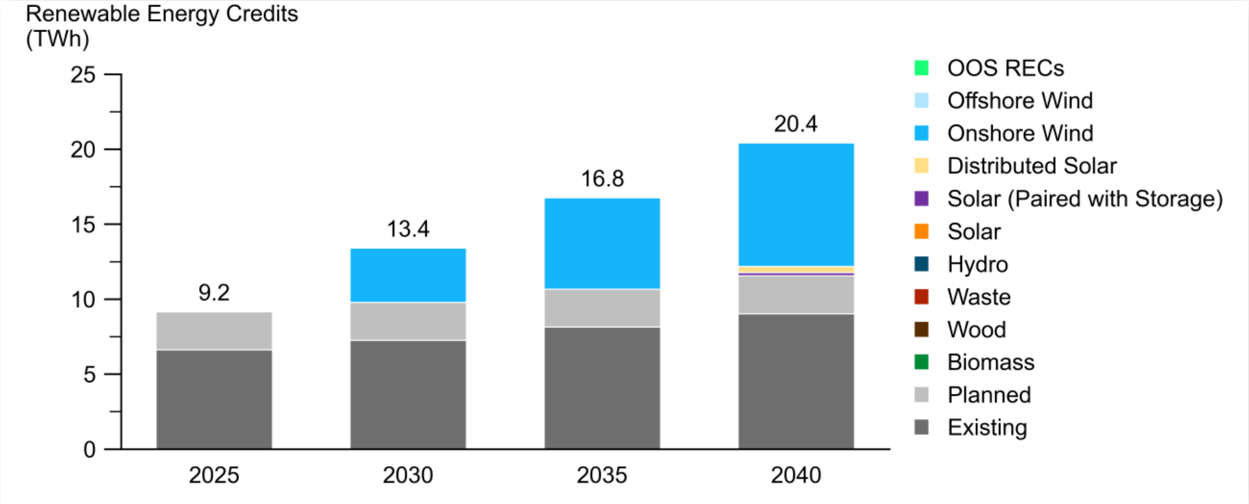
[82] *This figure was updated in March 2021. See corresponding release notes*

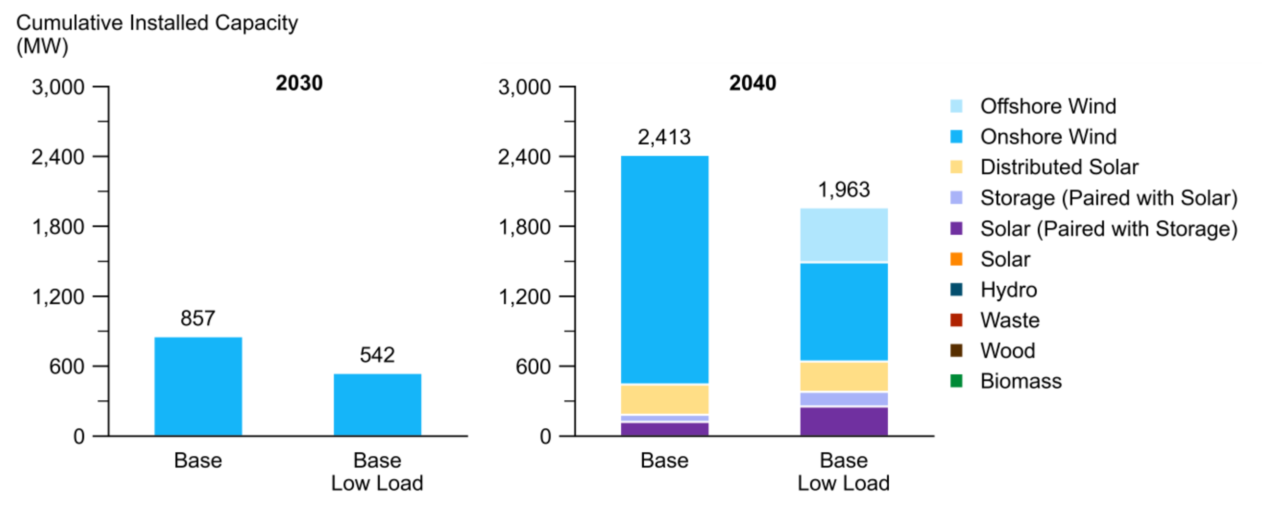
Figure 29. *All REC sources in the Base Case*[83]



4.1.1.1 Base Low Load Sensitivity

Load growth in Maine may be offset with more aggressive demand-side measures such as energy efficiency, weatherization, or load flexibility while still maintaining high levels of beneficial electrification consistent with Maine achieving its GHG emissions requirements. In this sensitivity of the Base Case, the effect of reduced load growth on resource build and costs over the study period was investigated. Figure 30 shows a comparison between resource builds for both the Base Case and the Base Low Load sensitivity. As expected, there are fewer resources built in the sensitivity, as there are fewer RECs required. At a high level, onshore wind is the first resource chosen between each model in 2030. However, in 2040, more solar paired with storage and offshore wind are chosen in the sensitivity.

Figure 30. *Resource build comparison across Base Case and Base Low Load sensitivity in 2030 and 2040*[83]



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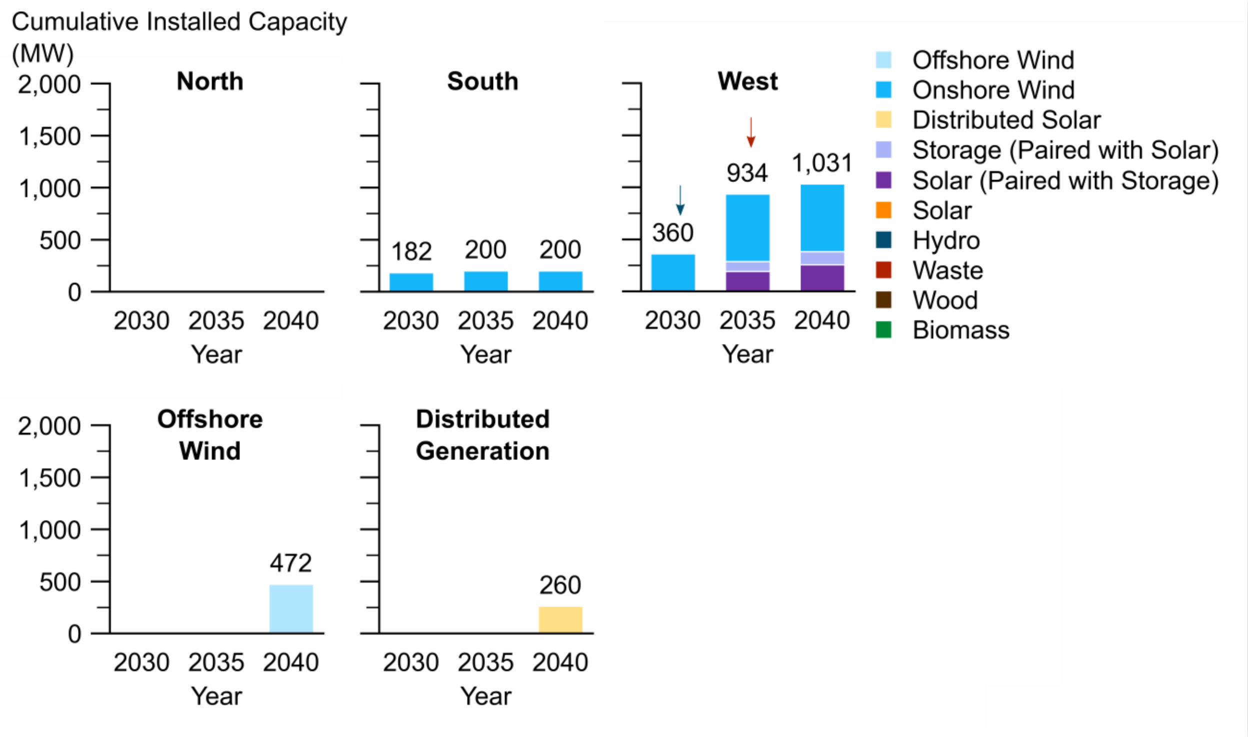
[83] *This figure was updated in March 2021. See corresponding release notes.*

It can be seen why this is the case in Figure 31. As the load profile is sufficiently low, transmission upgrades to the North are not required to meet the lower REC need in 2030. If the full transmission line was built to the North, fewer renewables in comparison to the Base Case would be developed. Due to the low load, this would make the transmission line more expensive on a per MW basis. Hence, instead of building transmission to the North, a combination of distributed generation and offshore wind is built. This is especially driven by offshore wind becoming cheaper in 2035 and 2040. This points to another common challenge around transmission building. Transmission upgrades are lumpy, i.e., a full transmission upgrade needs to be built to access renewables in a zone. There are important policy and equity implications of this challenge; Sections 5 and 6 examine these in greater detail, respectively.

Figure 31. *Regional builds for Base Low Load sensitivity. The year where the first or second transmission upgrades are needed in each region is indicated by a blue or red arrow, respectively*[84]*.*



As a preview to the cost comparisons in Section 4.2, the net present values of the costs from 2025 to 2045 of the Base Case and the Base Low Load sensitivity are presented in Figure 32 below. The Base Low Load sensitivity is cheaper than the Base Case, owing to the lower load and savings from avoided transmission and resource builds in the North.

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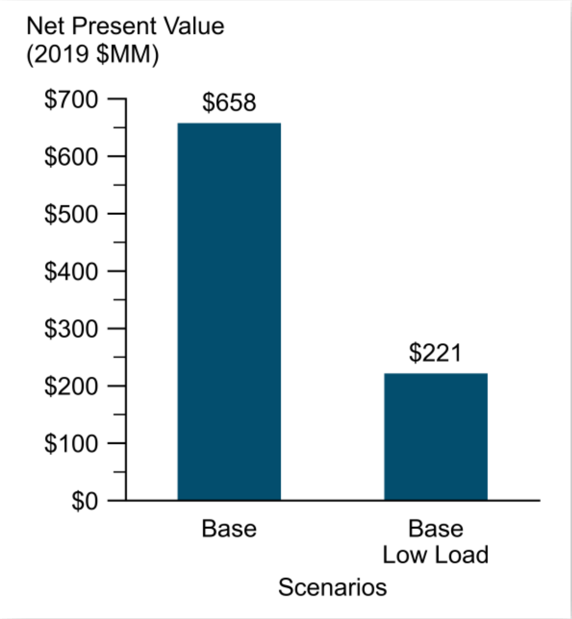
[84] *This figure was updated in March 2021. See corresponding release notes.*

Figure 32. *Net Present Value (NPV) of Base Case and Base Low Load sensitivity costs. Note that different levels of load are being met in these scenarios*[84]*.*



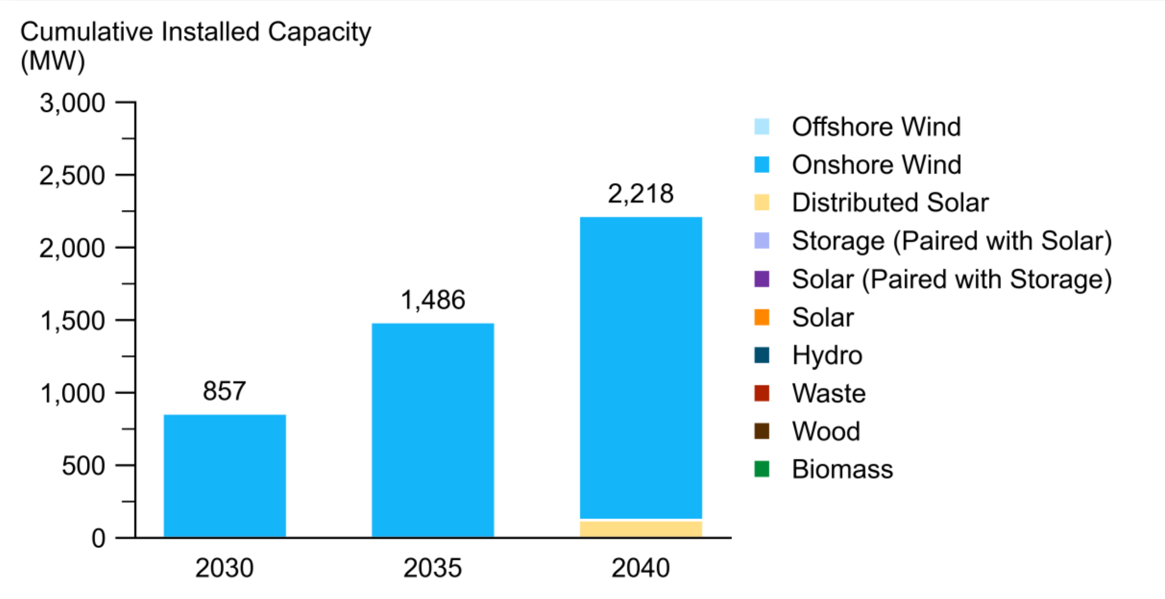
In short, this sensitivity shows the mixture and geographic location of renewable resource builds are highly sensitive to assumptions about future load growth. It suggests that offshore wind and distributed generation be considered for development in the chance that Maine's load growth is lower than anticipated, as they may aid in avoiding expensive transmission build.

4.1.2 Unconstrained Land Use

The Unconstrained Land Use scenario removes the additional restrictions on land use imposed in this study (described in Section 3.2.1) for onshore wind and utility solar resource development to test how those constraints may change how Maine meets its 2030 RPS targets. In the Base Case, these land use constraints screened the most expensive resources, such as the most distant and lowest-capacity factor wind resources. By removing those constraints, those resources were made available to be chosen. The removal of these additional land-use constraints is not to be construed as a suggestion for energy policymaking in Maine. Rather, this is a computational mechanism to reveal other constraints that might be important for Maine to achieve its renewable energy requirements.

The results from this scenario (Figure 33) are similar to those of the Base Case. Removing the land screens allows for a small amount of Western onshore wind to be selected in place of some distributed generation and solar plus storage in the Western zone in the Base Case in 2035. While land screens may impact resource economics within zones, transmission is the limiting factor for renewable resource development across the state as demonstrated by the resource builds in the Southern and Northern zones. These resource builds remain the same across the Unconstrained Land Use scenario and the Base Case, suggesting that even through a greater amount of renewables are available in these zones when land screens are removed, the resource economics within these zones are determined by their respective transmission upgrade costs.

Figure 33. *Renewable build in Unconstrained Land Use case*[85]



4.1.3 High Offshore Wind

In the High Offshore Wind scenario, up to 1 GW of offshore wind is built before other resources by 2030 to fulfill REC need. An additional 500 MW is eligible to be built between 2030 and 2040, bringing the total offshore wind capacity to 1.5 GW. Included in the baseline for this scenario is the 144 MW research array assumed to be built in 2025, whose RECs could be used to supply Class IA RECs. Figure 34 shows the build chosen by the model, excluding the research array. Offshore wind is used to satisfy all of Maine's incremental REC needs in 2030, while a mix of onshore and offshore wind is built to supply growing needs in later years. Figure 35 breaks down the resource build by region, showing that a small amount of onshore wind is built in the existing headroom in the South in 2035 and 2040 and that the first upgrade to the West is filled with onshore wind in 2040. Finally, all REC sources for the High Offshore Wind scenario are shown in Figure 36. As was the case for the Base Case, most RECs are sourced from existing and planned renewables. It again should be noted that additional new resources should be planned and built, in the case that RECs from existing and planned resources do not materialize as expected.

As mentioned in the Key Assumptions section, offshore wind is assumed to be connecting at existing or retired units' interconnection points close to load centers and hence does not incur significant onshore transmission costs. This is an assumption that underpins all offshore wind results in this study. Although this assumption is in line with ISO-NE's study[86] that identified the potential for 8 GW of offshore wind interconnecting at similar interconnection points in Massachusetts, Maine-specific analysis is required to accurately estimate offshore wind's implications on Maine's transmission system.

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[85] *This figure was updated in March 2021. See corresponding release notes.*

[86] *Boughan, "NESCOE 2019 Economic Study - 8,000 MW Offshore Wind Results."*

Figure 34. *Renewable build in High Offshore Wind case*

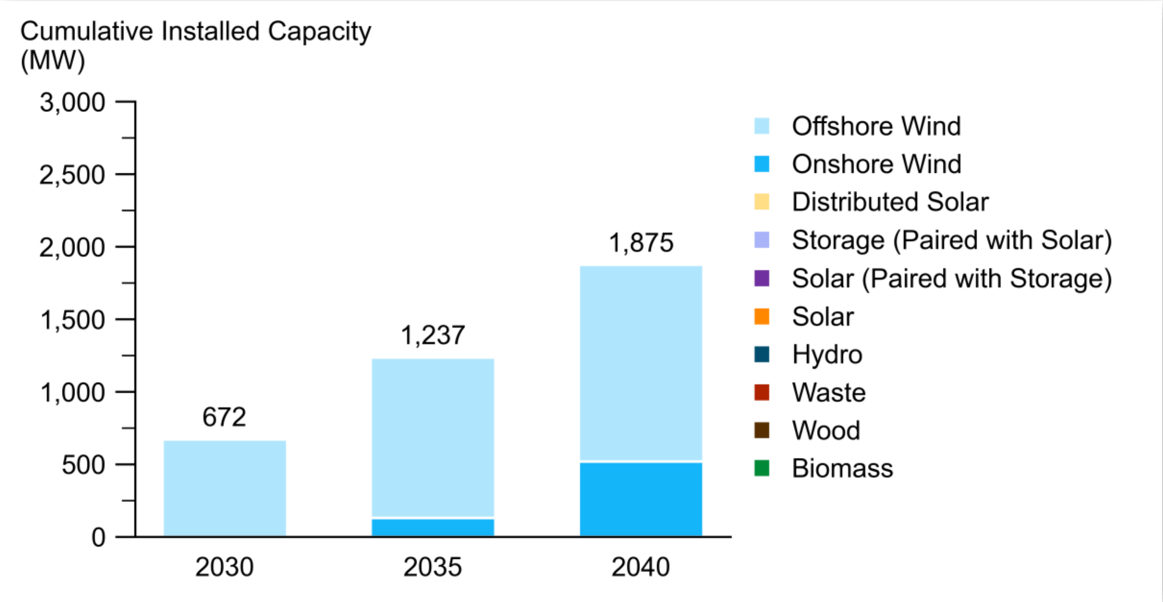


Figure 35. *Regional build for the High Offshore Wind scenario. The year where the first or second transmission upgrades are needed in each region is indicated by a blue or red arrow, respectively.*

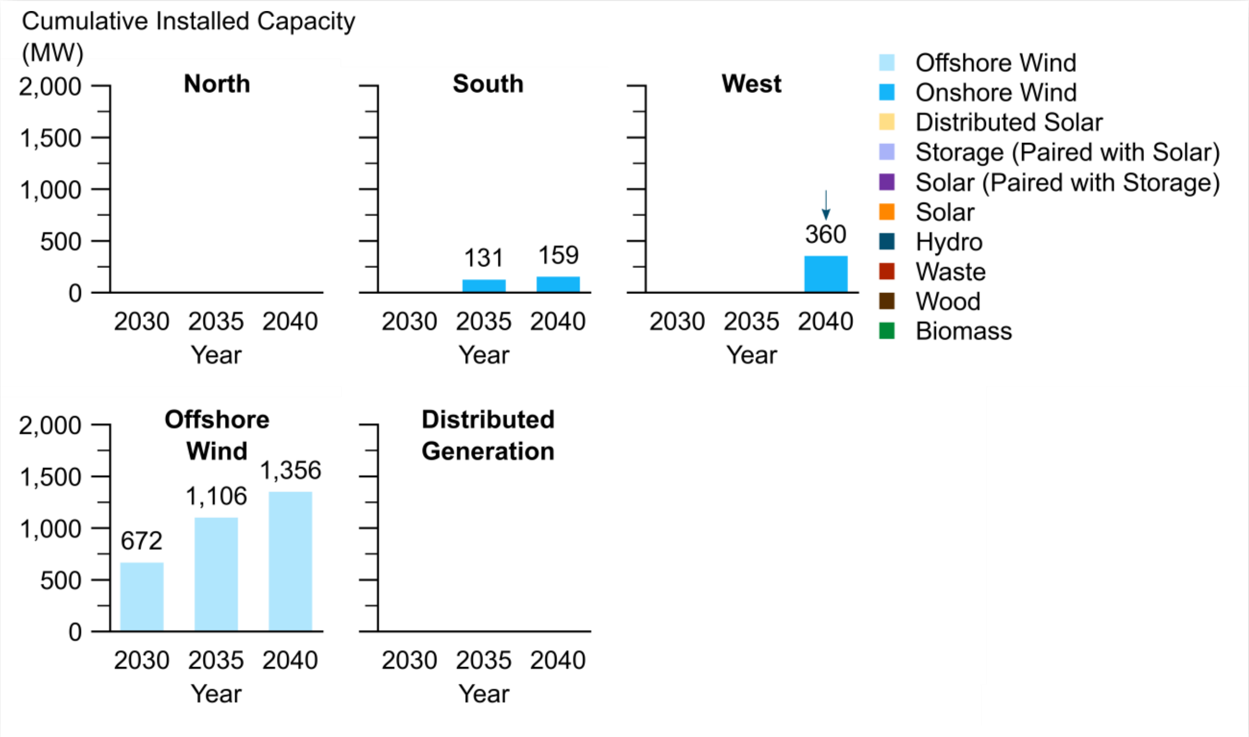
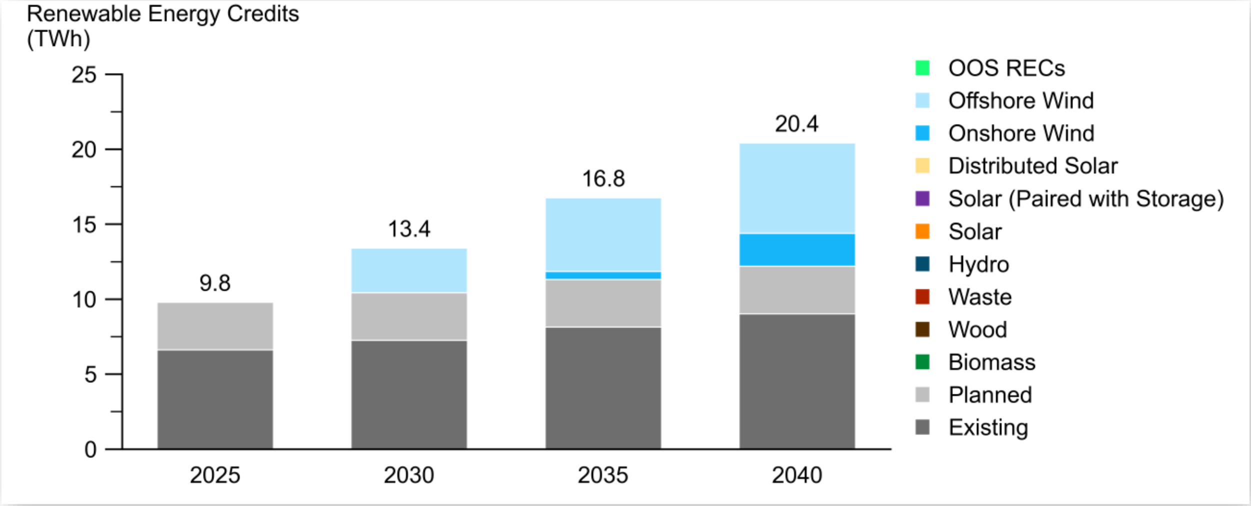


Figure 36. All REC sources for the High Offshore Wind scenario.



4.1.4 Existing Transmission scenario

Stakeholders have emphasized during this study that building new transmission to interconnect renewable resources is believed to be a key factor in helping Maine achieve its renewable energy requirements. To investigate how Maine might comply with its RPS requirement while reflecting the difficulty of building new transmission, the Existing Transmission scenario was developed. This scenario eliminated all possible transmission upgrades, requiring only those resources that could be built without any associated transmission upgrades, including offshore wind, some distributed generation, and utility-scale land-based resources in the existing headroom in the South. The goal is to understand the resultant portfolio that is RPS compliant when transmission build in Maine is delayed.

It can be seen in Figure 37 and Figure 38 that about 500 MW of offshore wind, 260 MW of distributed generation, and 200 MW of onshore wind in the South were built in 2030. Beyond that, the only resource that could be built without triggering transmission upgrades was offshore wind. Because of the uncertainty of how much offshore wind can be interconnected without onshore transmission upgrades, it may be likely that the levels of offshore wind shown in these figures may not be possible unless onshore transmission upgrades are built. Finally, all REC sources for the Existing Transmission scenario are shown in Figure 39. As was the case for the Base Case, most RECs are sourced from existing and planned renewables. It again should be noted that additional new resources should be planned and built, in the case that RECs from existing and planned resources do not materialize as expected.

Figure 37. *Renewable Build in the Existing Transmission Case*

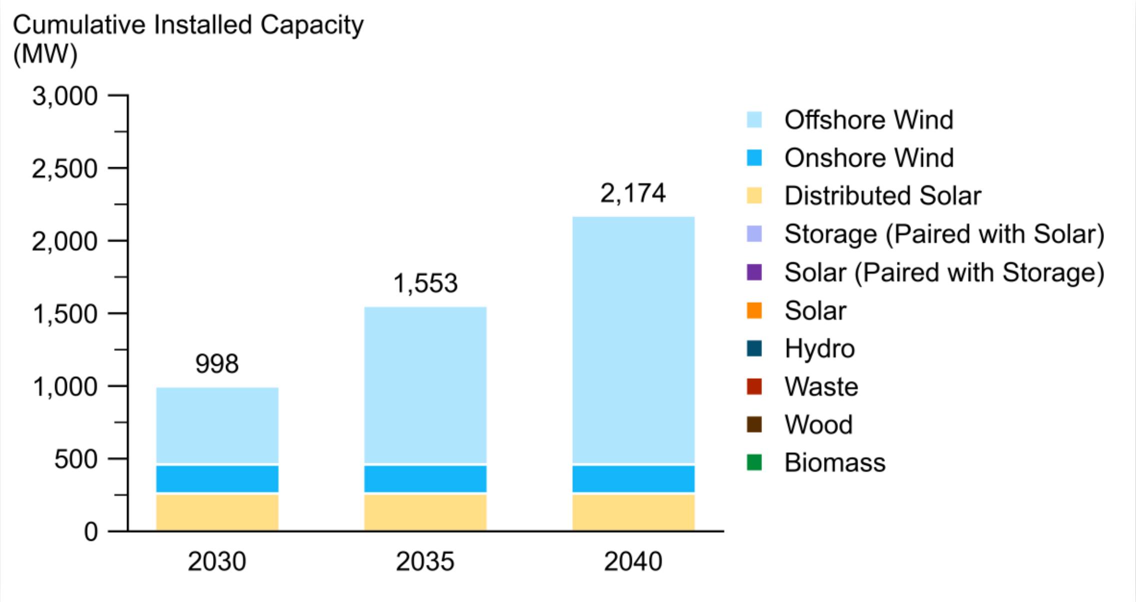


Figure 38. *Regional build in the Existing Transmission case. The year where the first or second transmission upgrades are needed in each region is indicated by a blue or red arrow, respectively.*

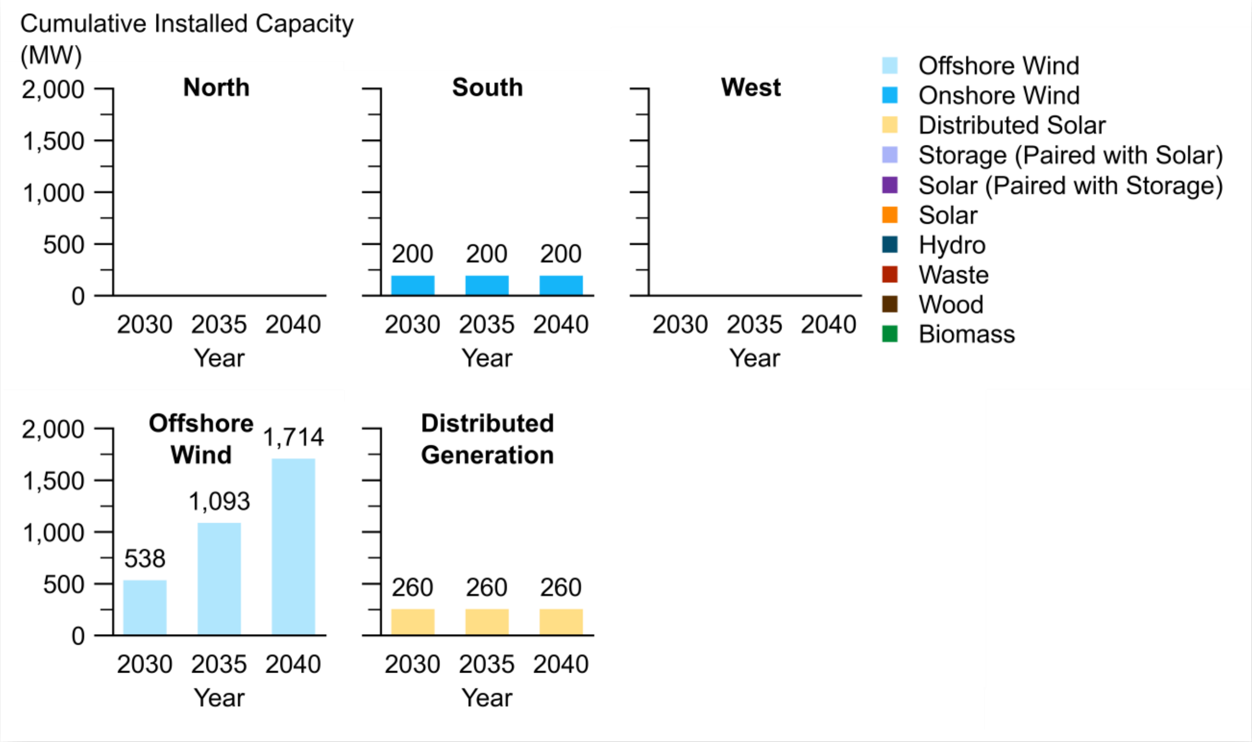
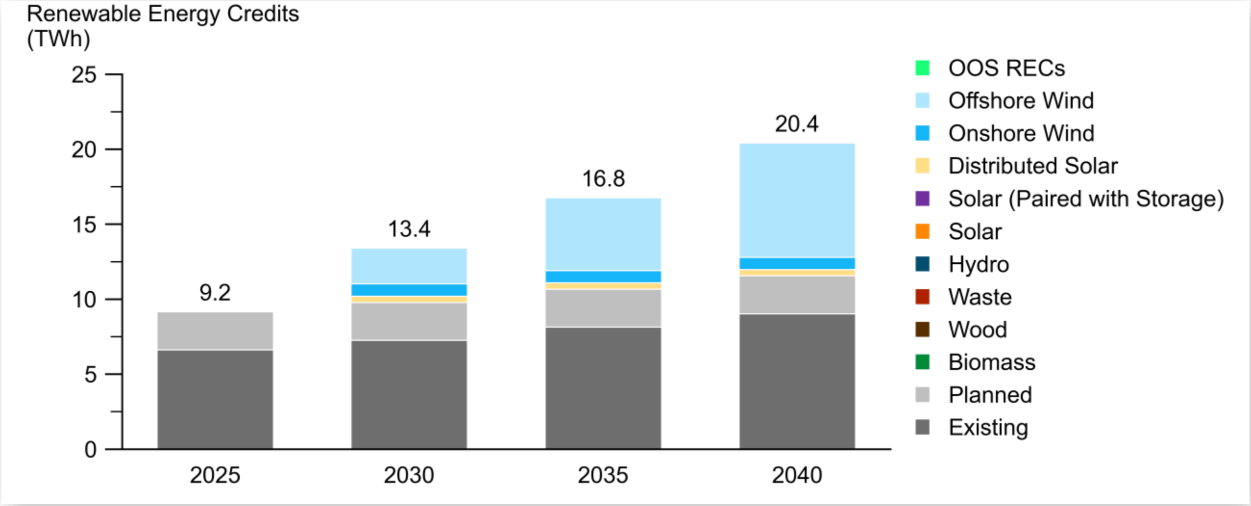


Figure 39. All REC sources for the Existing Transmission scenario.



4.1.5 Regional Coordination

The Regional Coordination scenario consists of two regional components. First, beyond those in the baseline, *additional* out-of-state RECs are made available to be economically chosen, the amount of which is equal to 20% of Maine's RNS in 2030. Second, Maine is assumed to coordinate with other states/regional entities[87] and share the cost of transmission upgrades to the North and the West with Maine's share equaling 50%. In exchange, 50% of the headroom brought online by these transmission upgrades are used to build resources to support the clean energy goals of other entities other than Maine, reducing the amount of the resources the model can pick by 50% to fill a given upgrade. This has the effect of reducing the lumpiness issue that commonly poses a challenge to new transmission development and was seen previously in the Base Low Load sensitivity results.

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[87] *For the purposes of this study, the cost-sharing entity can be either a state, a group of states, or other transmission development entities*

__Figure 40.__ Renewable builds in Regional Coordination case

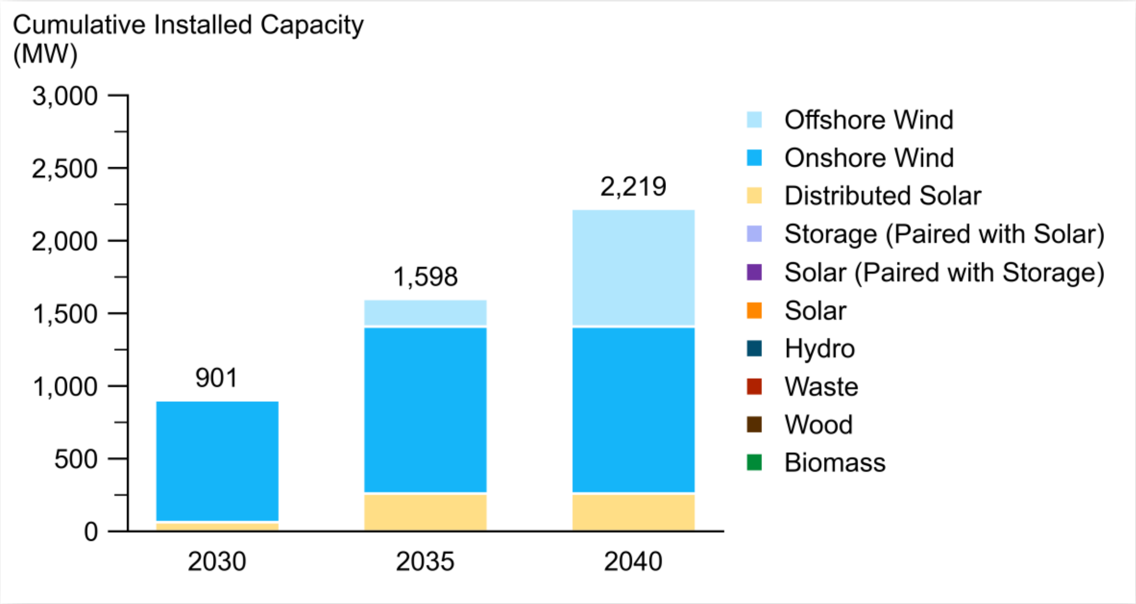


Figure 40 shows the resource build for the Regional Coordination scenario. Although available, no additional out-of-state RECs were chosen in this scenario, as the net cost of the marginal resource within Maine is less than the assumed cost of an out-of-state REC. The assumptions behind out-of-state REC prices used in this study account for the aggressive RPS targets of other New England states. As shown in this scenario, with most New England states competing for RECs, their price is projected to remain high enough that building in-state resources is a more economical way for Maine to meet its REC need.

Onshore wind and a small amount of additional distributed solar were used to satisfy Maine’s REC needs in 2030, after which offshore wind, and more onshore wind and distributed solar were built. In Figure 41, all upgrades are built in the North and West by 2035. It should be noted that resources built along with each transmission upgrade only fill half of the upgrade’s headroom, while the other half is used by other states. As a result, additional onshore wind and distributed generation is built to help satisfy the RPS. Finally, only the existing headroom in southern Maine is filled with onshore wind given the expensive cost of transmission upgrades there.

Finally, all REC sources for the Regional Coordination scenario are shown in Figure 42. As was the case for the Base Case, most RECs are sourced from existing and planned renewables. It again should be noted that additional new resources should be planned and built, in the case that RECs from existing and planned resources do not materialize as expected.

Figure 41. *Build breakdown in Regional Coordination scenario. The year where the first or second transmission upgrades are needed in each region is indicated by a blue or red arrow, respectively.*

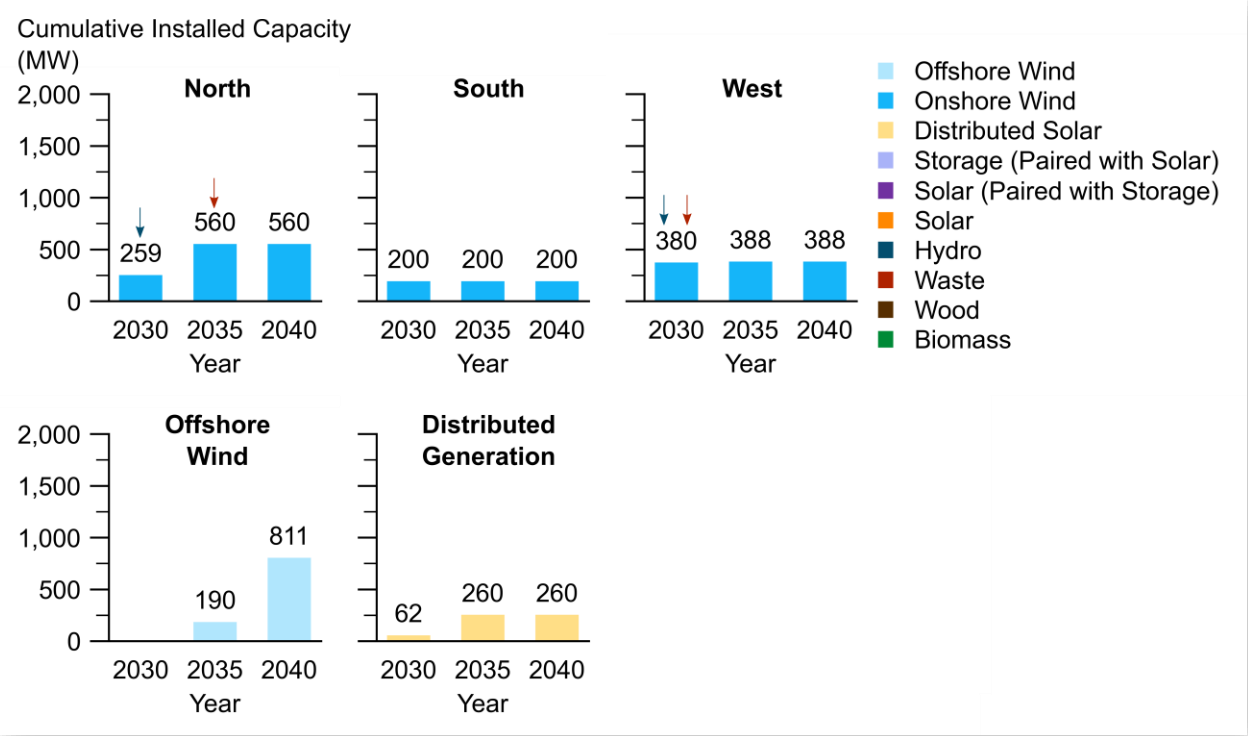
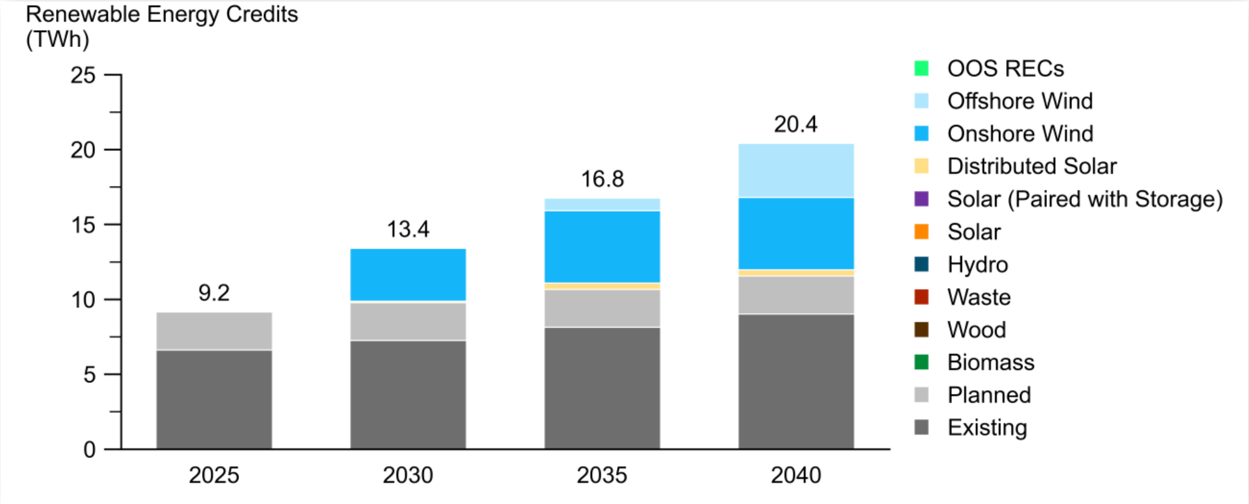


Figure 42. *RECs for Regional Coordination scenario.*



4.1.6 Diverse Portfolio scenario

The Diverse Portfolio scenario was designed to incorporate the lessons learned from all previous scenarios. These include the following observations:

- Onshore wind is among the most economical resources in Maine with its wide availability and high-capacity factors.
- Solar paired with storage can provide resource diversity and is relatively low cost.
- While transmission builds to the West and North are economical, a combination of distributed generation and offshore wind can be used to avoid building Southern transmission upgrades, which are more expensive owing to their proximity to urban centers.
- Coordinating transmission planning and sharing upgrade costs and transmission capacities circumvents its lumpiness and the overall cost borne by Maine ratepayers to meet Maine's RPS requirement.

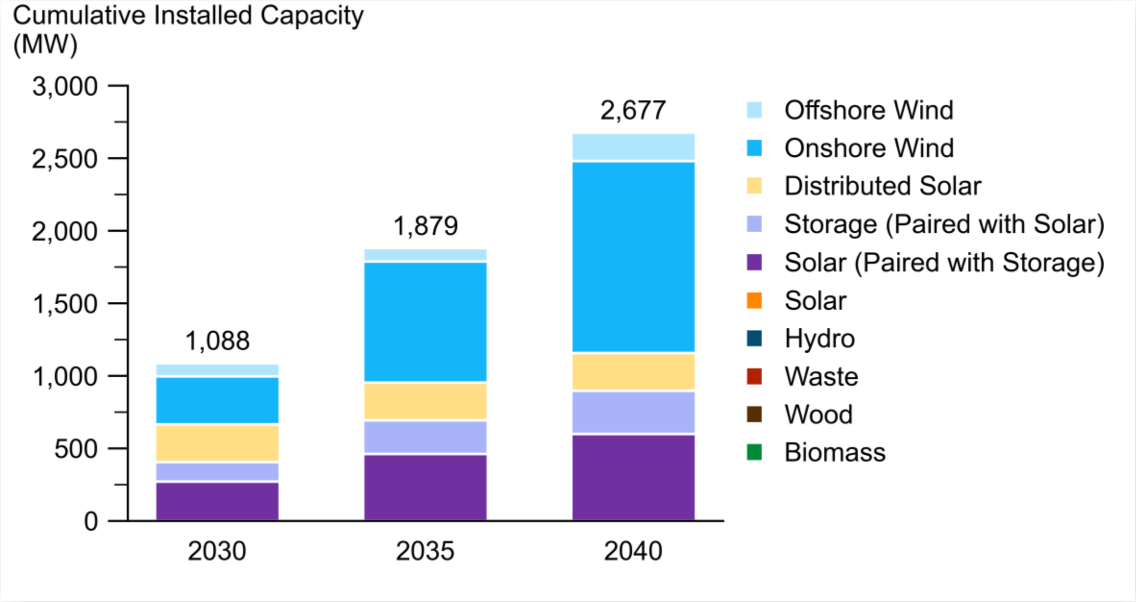
Table 3. *Diverse Portfolio Scenario assumptions*

Resource/Parameter	Assumption
Baseline	+ RECs from planned and existing generators assumed in all other cases + 144 MW offshore wind research array
Onshore Wind	+ 1.4 TWh in 2030
Solar Paired with Storage	+ 0.5 TWh in 2030
Additional Offshore Wind	+ 0.4 TWh in 2030
Distributed Generation	+ 0.3 TWh residential in 2030 + 0.1 TWh commercial in 2030
Additional out-of-state RECs	+ 0.3 TWh in 2030
Transmission	+ Southern existing headroom for solar paired with storage in 2030 + Remaining southern headroom and first western upgrade for onshore wind in 2030 + 75% of costs and headroom shouldered by Maine for all study years

The portfolio in 2030 for the Diverse Portfolio scenario was handcrafted to include a mixture of onshore wind, solar paired with storage, offshore wind, and distributed generation. Further, existing headroom in the South was used to accommodate solar paired with storage and transmission upgrades to the West (with costs and headroom shared with out-of-state entities as in the Regional Coordination scenario) were assumed to accommodate onshore wind. Finally, the 144 MW offshore wind research array was included in the REC baseline (as assumed in the Offshore Wind scenario) and additional out-of-state RECs were assumed to supply 20% of the RNS in 2030. Beyond 2030, transmission upgrades and resource builds are chosen based on the least-cost methodology used in most of the other scenarios. The specific assumptions for this scenario are shown in Table 3.

It should be noted that this scenario is not a prescription for resource mix nor for the location of such resources, what transmission should be built, or to what extent Maine should rely on out-of-state coordination to meet its RPS. Instead, it should be viewed as a demonstration that resource planning, informed by reasonable estimates of transmission and resource costs – and coupled with some cooperation with out-of-state entities – can achieve Maine's renewable energy requirements while remaining relatively low cost (See Figure 50).

Figure 43. *Renewable build in Diverse Portfolio scenario*[88]



The resource build for the Diverse Portfolio scenario can be seen in Figure 43. As described in Table 3, the portfolio consists of a mixture of distributed generation, onshore wind, solar paired with storage, and offshore wind in 2030. Beyond 2030, the RPS is incrementally met mostly by new onshore wind, with some solar paired with storage and offshore wind filling in the remaining need. It can be seen in Figure 44 that a mixture of onshore wind and solar paired with storage fills up both upgrades in the North and the West by 2040, necessitating additional offshore wind generating RECs in 2040. Finally, all REC sources for the Diverse Portfolio scenario are shown in Figure 45. As was the case for the Base Case, most RECs are sourced from existing and planned renewables. It again should be noted that additional new resources should be planned and built (or additional out-of-state RECs should be purchased if available), in the case that RECs from existing and planned resources do not materialize as expected.

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[88] *This figure was updated in March 2021. See corresponding release notes.*

Figure 44. *Regional build for Diverse Portfolio case. The year where the first or second transmission upgrades are needed in each region is indicated by a blue or red arrow, respectively*[88].

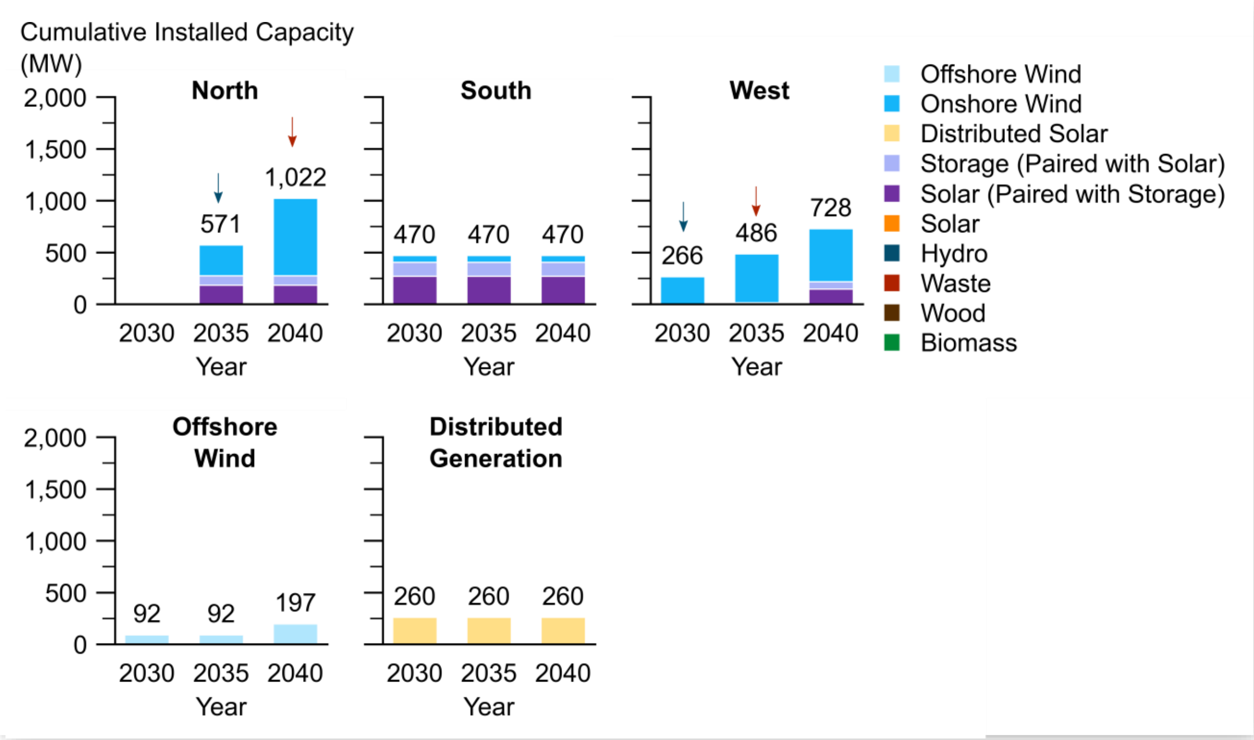
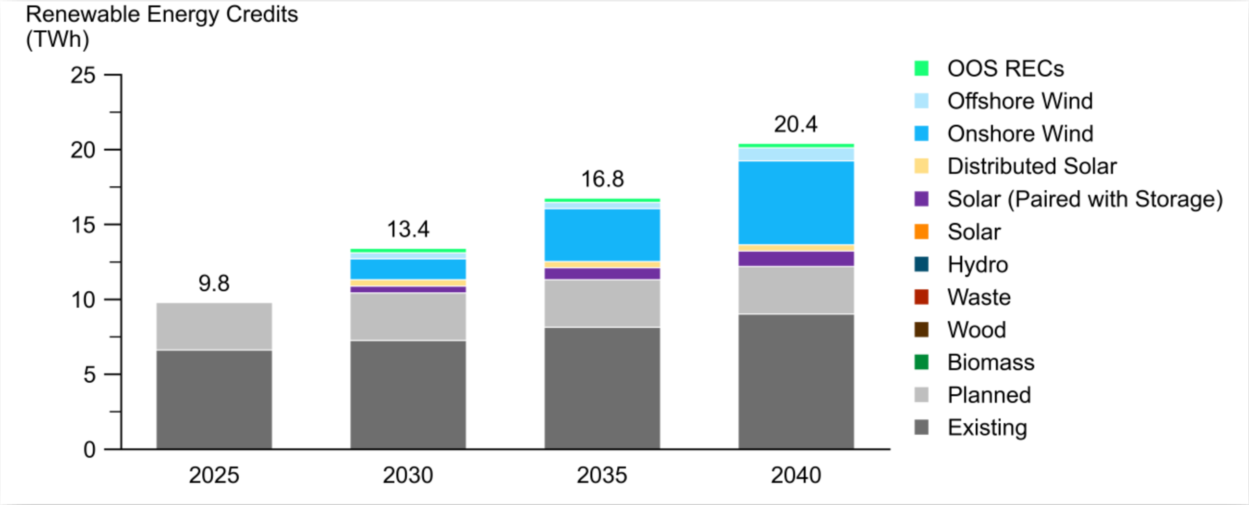


Figure 45. *RECs for Diverse Portfolio scenario*[88].



4.2 Scenario comparisons

4.2.1 Portfolio composition

Figure 46 and Figure 48 show a comparison of the new renewable resource portfolios across all scenarios in 2030 and 2040, respectively. In 2030, it is clear that onshore wind can play a critical role in helping Maine meet its RPS. It is the largest resource in four of the six scenarios and is part of the portfolio in five out of six scenarios, due to its low cost and high-capacity factor. Building onshore wind to the capacities seen in most scenarios needs transmission to be developed. The results also indicate that offshore wind, distributed generation, and pairing solar with storage will likely play an important role in meeting the near-term RPS requirement. As a final comparison, a comparison of all REC sources for each scenario in 2030 are shown in Figure 47. As noted, most RECs are sourced from baseline resources, which is the sum of existing and planned renewables. It again should be noted that additional new resources should be planned and built, in the case that RECs from existing and planned resources do not materialize as expected.

Figure 46. *Renewable build comparison in 2030 across scenarios*[89]

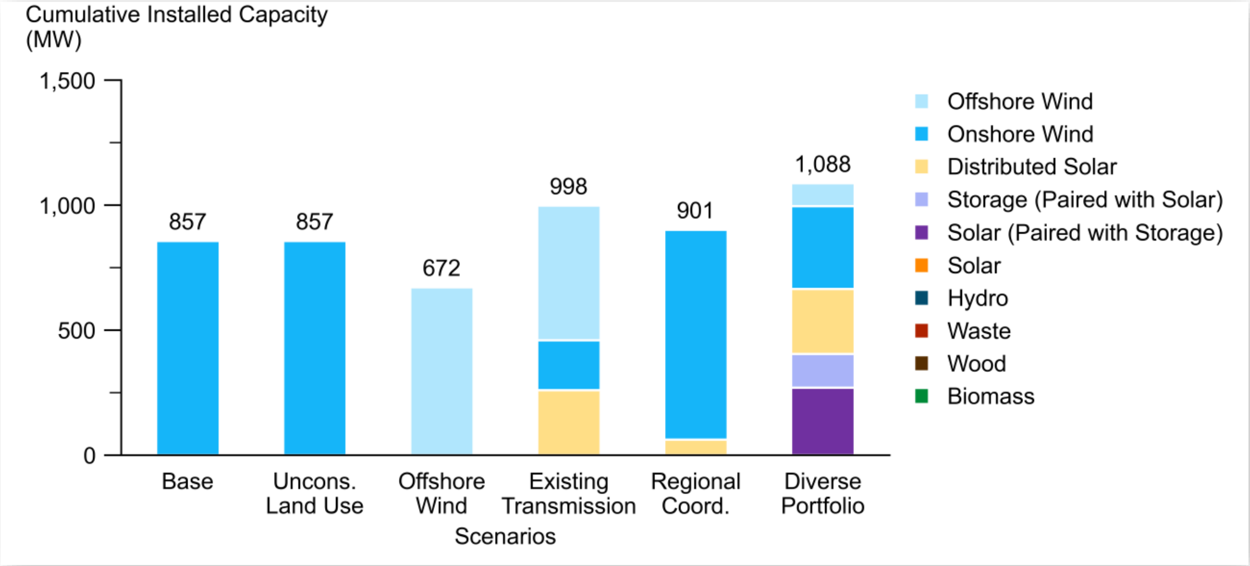


Table 4. *Summary of resource build by type in 2030*[89]*.*

Scenario	Capacity (MW)				
	Offshore Wind	Onshore Wind	Distributed Solar	Storage (Paired with Solar)	Solar (Paired with Storage)
Base Case	0	857	0	0	0

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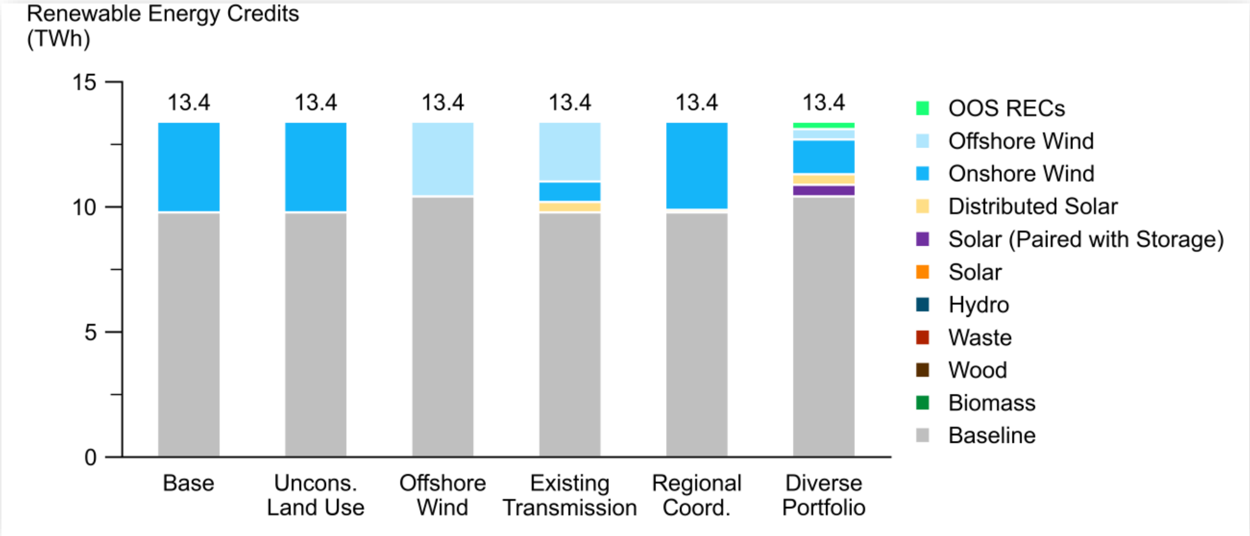
[89] *This figure/chart was updated in March 2021. See corresponding release notes.*

Unconstrained Land Use	0	857	0	0	0
Offshore Wind	672	0	0	0	0
Existing Transmission	538	200	260	0	0
Regional Coordination	0	839	62	0	0
Diverse Portfolio	92	330	260	135	270

Figure 47. *RECs from all sources for all scenarios in 2030*[89].



In 2040, onshore wind still makes up most of the resource portfolio in four of the six scenarios. However, a larger amount of distributed generation and offshore wind may be important, particularly as they help to avoid expensive transmission upgrades in the South. In addition, as the best wind resources are exhausted in the West, solar paired with storage may play a role in supplying the incremental RECs needed for Maine to meet its RPS in 2040. As a final comparison, a comparison of all REC sources for each scenario in 2040 are shown in Figure 49. While most RECs are sourced from baseline resources, they are smaller percentage of total RECs in comparison to 2030. It again should be noted that additional new resources should be planned and built, in the case that RECs from existing and planned resources do not materialize as expected.

Figure 48. Renewable build comparison in 2040 across scenarios[90]

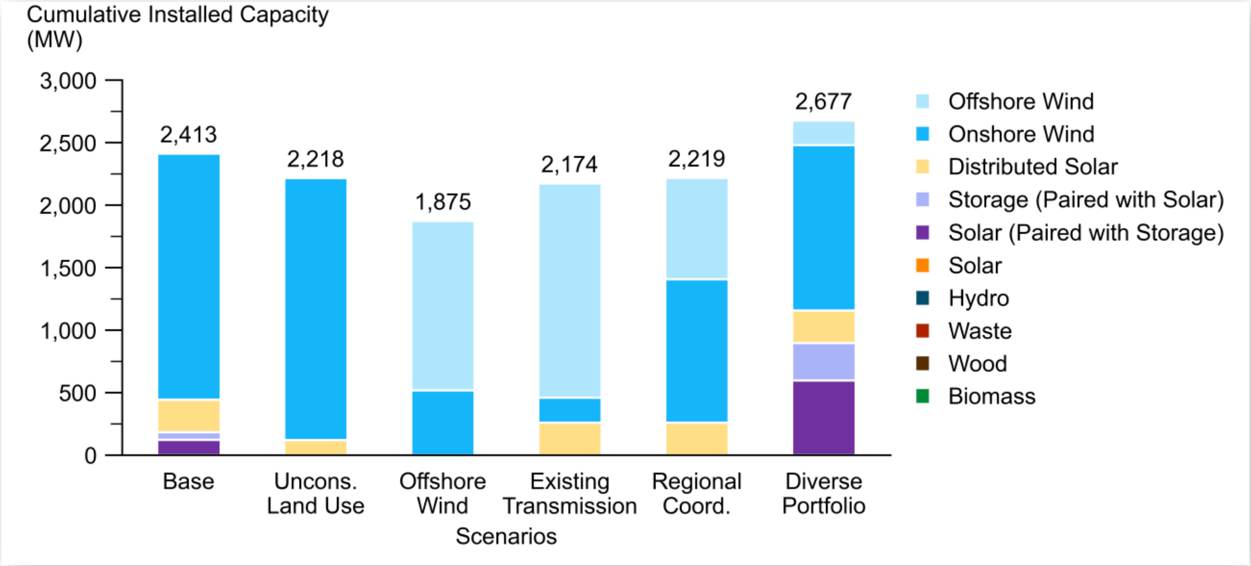


Table 5. Summary of resource build by type in 2040[90]

Scenario	Capacity (MW)				
	Offshore Wind	Onshore Wind	Distributed Solar	Storage (Paired with Solar)	Solar (Paired with Storage)
Base Case	0	1,969	260	61	122
Unconstrained Land Use	0	2,096	122	0	0
Offshore Wind	1,356	519	0	0	0
Existing Transmission	1,714	200	260	0	0
Regional Coordination	811	1,148	260	0	0
Diverse Portfolio	197	1,323	260	299	598

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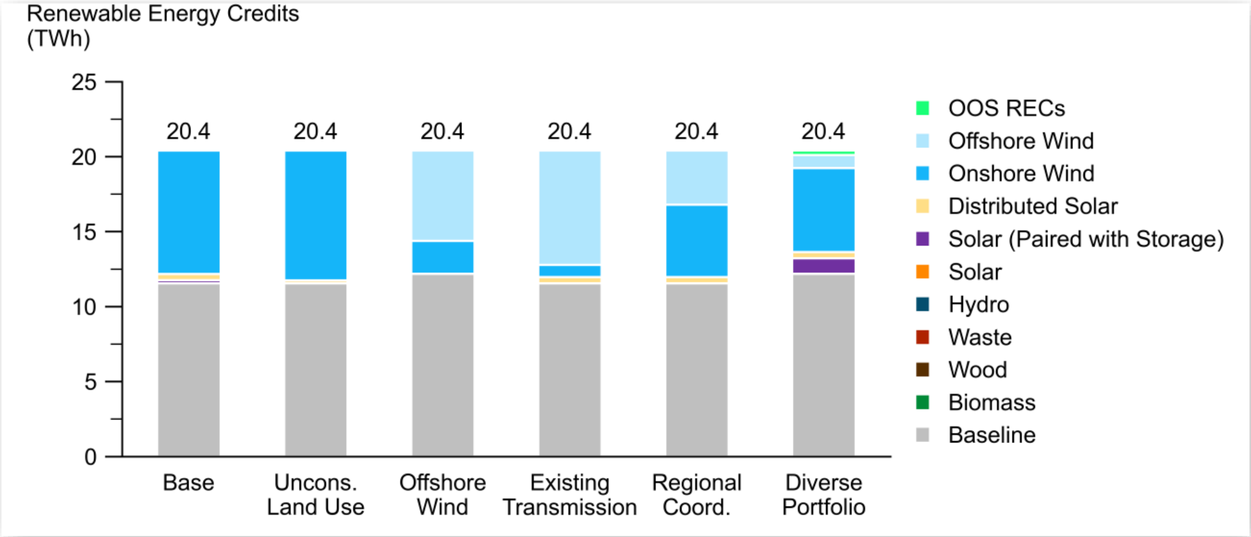
[90] *This figure/chart was updated in March 2021. See corresponding release notes.*

Figure 49. RECs from all sources for all scenarios in 2040[91].



4.2.2 Costs to customers

This study aims to find economical strategies for Maine to meet its RPS requirements. Figure 50 shows the net present value of costs from 2025 to 2045 of each of these strategies.[92] For the modeled scenarios, this is the net present value of the resultant portfolio. As a point of comparison, the cost of using the Alternative Compliance Payment (ACP, assumed to be 2019 $49.02/MWh[93]) to meet the RPS is shown. It is by far the most expensive method to comply with the RPS when compared to costs of the six scenarios analyzed. As noted above, the Base Case and the Unconstrained Land Use scenarios produce similar resource portfolios and costs. The Offshore Wind and Existing Transmission scenarios, both of which heavily rely on offshore wind, have relatively higher costs. This is because offshore wind is more expensive in the short term, despite its cost competitiveness beyond 2035. The Regional Coordination scenario is the most economical scenario. By allowing some resources in Maine to satisfy out-of-Maine RPS needs in exchange for cheaper transmission upgrades, the overall portfolio cost is decreased. This scenario demonstrates the value of coordinating with other states to reduce overall costs to Maine.[94] Finally, the Diverse Portfolio scenario, which curates a portfolio based on the resources selected in the other cases, meets Maine's RPS standard while being moderately more expensive than the Base Case, showing that informed resource planning can be used to acquire a relatively low-cost resource portfolio. It should be noted that because of the uncertainty of the costs of transmission upgrades needed to interconnect extensive amounts of offshore wind, the starred portfolios in Figure 50 may be more expensive than this report may indicate.

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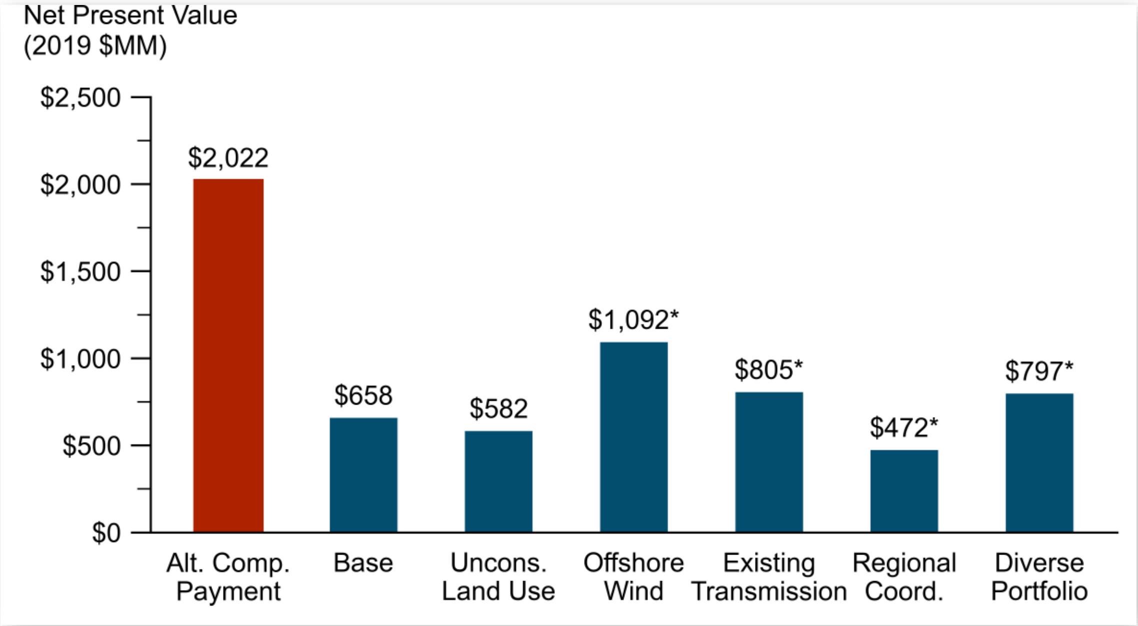
[91] This figure was updated in March 2021. See corresponding release notes.

[92] It was assumed that costs in years not modeled were the same as those costs in the most recently modeled year.

[93] "65-407 Chapter 311" (Maine Public Utilities Commission, n.d.), https://www.maine.gov/sos/cec/rules/65/407/407c311.docx.

[94] Such regional coordination is expected to reduce overall costs to the cooperating states as well.

Figure 50. *NPV of costs of each scenario (2025–2045). Starred bars are those scenarios with high amounts of offshore wind in their portfolio and thus have significant uncertainty in the onshore transmission costs associated with interconnecting offshore wind*[95].



4.2.3 Equity impacts by scenario

Potential equity impacts vary from one RPS-compliant scenario to another across four primary dimensions: resource diversity, customer-sited resources, geographic resource distribution and cost. This study is not a full cost-benefit analysis of each scenario; however, the following narratives should be considered by policy makers.

Resource diversity—different resources entail different equity benefits and challenges, so pursuing a greater mix of resources affords more flexibility. For example, onshore wind and utility-scale solar involve equity challenges as it relates to decisions around land use but can also provide benefits such as increased revenues to local communities. Additionally, when paired with energy storage, these resources offer important reliability and resiliency benefits to the grid—and by extension, equity benefits for households that are most vulnerable to power outages—by being able to avoid or shorten the duration of power outages.[96] Likewise, offshore wind entails potential impacts on existing ocean-dependent people and the communities they support (which can be mitigated by working with stakeholders and increasing scientific understanding of impacts) but also provides important potential benefits: if Maine were to establish itself as a national leader on offshore wind—a burgeoning industry—it could pay dividends greater than the initial investment, dividends in the form of lower long-term costs and benefits to the local economy, which

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[95] *This figure was updated in March 2021. See corresponding release notes.*

[96] *U.S. Department of Energy Office of Technology Transitions. 2019. Solving Challenges in Energy Storage. Available at: https://www.energy.gov/sites/prod/files/2019/07/f64/2018-OTT-Energy-Storage-Spotlight.pdf.*

could be directed at vulnerable communities. Whether it is onshore wind and utility-scale solar or offshore wind, each energy resource has unique benefits and challenges that may benefit or challenge communities in different ways. One of the benefits of diversifying the energy portfolio is a balancing of those benefits and risks.

The scenarios that build the broadest variety of renewable resources are the Diverse Portfolio and High Regional Coordination scenarios. It is worth noting that both these scenarios assume stronger regional coordination on transmission investment than present, indicating that transmission cost-sharing facilitates renewable resource diversity.

Customer-sited resources—customer siting builds household-level energy reliability and resiliency. Customer-sited resources—like rooftop solar—enable households to produce their own energy, making them less reliant on the electric grid and less vulnerable to power outages. When rooftop solar is paired with energy storage (like batteries), it can provide the added benefit of being able to continue delivering energy during an extended power outage. Maine's NEB program also ensures that households and communities with installed distributed solar are compensated for excess energy they provide back to the grid. For the benefits of distributed generation to be equitable, rooftop solar should be developed in areas with adequate technical potential, across all kinds of homeowners and all household income levels.

All scenarios assume 500 MW of distributed generation, and in all but the Offshore Wind scenario, additional distributed generation was selected to be developed. The remaining scenarios (Base Case, Unconstrained Land Use, Existing Transmission Only, Regional Coordination and Diverse Portfolio) entail the potential for equity-related resiliency, reliability, and cost benefits from distributed generation, given equitable access and the development of these resources.

Geographic resource distribution—renewable resource development benefits local communities by, for example, creating jobs. For the purposes of this study, Maine was divided into three zones: North, South and West (see Figure 22). Broadly speaking, the Northern region corresponds to the most socially vulnerable counties in the state (see Figure 4). In four out of six scenarios (Base Case, Unconstrained Land Use, Regional Coordination, and Diverse Portfolio), new renewable resources are developed in all three regions of the state by 2035. These resources represent the most economical combination of resources across all zones. In addition to being cost effective, these portfolios have the ability to bring benefits to the local economies of all zones, including to Maine's vulnerable populations in the North.

Cost—resource mix impacts electric bills. Portfolios from all modeled scenarios show savings compared to RPS compliance through ACP payments (Figure 50). Still, some portfolios are more expensive than others. Scenarios with significant amounts of new wind resources in the Western and Northern parts of the state and more regional coordination on building new transmission (Base Case and Regional Coordination Case) show the greatest total cost savings compared to the ACP case. Resource selection must consider impacts on customer bills and must be complemented by periodic evaluation and changes to electric rate structures and/or additional low-income assistance programs to ensure that Maine's vulnerable communities are not adversely impacted.

5 Policy Implications

The analysis conducted suggests that new renewables need to be operational and delivering RECs to Maine in the 2026-2027 timeframe. This timeline provides some runway for the development of policies and processes to support the achievement of Maine's RPS target. This section discusses the policy implications related to resource additions, transmission, and each of the resources assessed in this study to help inform the policy discussions in Maine.

5.1 Planning & resource additions

The scenario results in Section 4 provide guidance on the timing and amount of resource additions that Maine will need to meet its RPS requirements by 2030. While the state has sufficient resources to meet its RPS needs with existing RECs in the near-term, the study results estimate 3,630 GWh of RECs will need to be procured by 2030, which could equate to 800 MW to 900 MW of new renewable build depending on the mix of resources pursued.[97]

REC Forecasts and Long-term Planning

Though REC need is influenced by multiple factors such as load growth and availability of existing RECs, providing a forecast of potential REC need can provide information on the potential market size and timing of need to renewable developers and interested stakeholders. An example of this could be a report which outlines the REC need and resource additions that are expected over the immediate next three years and a projection of REC need for the remaining seven years of the decade. While immediate resource additions will be driven by the REC need over the next three years, projections for all 10 years can allow for planning and discussions to address any identified challenges in meeting future needs. Given the dynamic nature of the industry and factors influencing REC need, this report can be updated on an annual basis to ensure updates to load growth and behind-the-meter interconnections are captured in the forecasts.

This REC forecast could also be an output of a broader state-wide, long-term planning process to achieve not only the RPS requirements, but the broader GHG goals. States such as California and New York that also have ambitious RPS requirements have long-term planning processes (conducted annually or bi-annually), which help identify resource needs and generally serve as a platform for all state stakeholders to come together to discuss and inform their clean energy transitions.

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[97] *Under current market conditions, the analysis finds that onshore wind and some solar paired with storage are likely to be a cost-effective strategy for resource additions. While likely more expensive in the near term, forecasts for offshore wind technology costs beyond 2035 suggest it becomes cost-competitive with onshore resources and could play an important role in meeting the State's 2035-2050 renewable goals cost-effectively.*

Bid Evaluation

While cost is an important factor in assessing resource bids, there are several non-cost elements that can be important to consider as well. When considering bids to obtain resources to meet the RPS over the next decade, it is prudent for the state to assess costs alongside other factors, such as:

- Status of current project development efforts and timeline for project operation date
- Technology viability
- Benefits to vulnerable communities
- Local job creation
- Local land-use impacts

The modeling, coupled with recent trends in market conditions and technology costs, suggest that resource procurements should be structured to ensure ongoing flexibility to choose resources that provide the highest net value to Maine's ratepayers (including cost and the types of factors listed above). All-source procurements can allow for this type of flexibility by ensuring that all resources compete on a level playing field. They also ease administrative burden by streamlining the procurement process by eliminating the need for resource-specific procurements and the need to determine the exact share of each resource type in the portfolio.

Energy-only, REC-only, and Bundled contracts

Recent MPUC procurements primarily selected energy-only contracts. The REC attribute associated with those contracts could be sold to any qualifying REC market including those outside Maine. The state could evaluate policy that requires renewable energy procurement through bundled contracts – procurement of both energy and RECs. Bundled contracts provide long-term REC price certainty to developers and could be helpful in securing financing to build large-scale renewable energy projects. Such certainty would have the benefit of providing support to renewable development in Maine and could also result in lower-cost power purchase agreements (PPAs) and RPS programs, as developers would not have to shoulder the risk of REC price uncertainty. Another way to ensure such certainty is through procurements of REC-only contracts such those in New York.[98] These are long-term contracts for the REC attribute alone. As the renewable market continues to mature, procurement policy can periodically be revised to gradually balance the risk of procurement between the ratepayers or load-serving entity and developers. This can be done through a combination of bundled and REC-only procurement and gradually reducing the contract length of procurement. Near-term procurements could, for example, take the shape of 20-year bundled contracts while procurements after five years could reduce terms to 15 or 10 years and have a certain percentage be energy-only.

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[98] *"Solicitations for Large-Scale Renewables," NYSERDA, accessed January 26, 2021, https://www.nyserda.ny.gov/All%20Programs/Programs/Clean%20Energy%20Standard/Renewable%20Generators%20and%20Developers/RES%20Tier%20One%20Eligibility/Solicitations%20for%20Long%20term%20Contracts.*

5.2 Transmission

Stakeholders in Maine recognize that existing and future transmission investments will significantly influence renewable development in the state over the coming decade. Existing analysis, detailed in the report required by LD 1401,[99] identified multiple congestion points affecting the pace and location of renewable development. Given existing transmission congestion, the modeling in this study finds that assumptions regarding transmission – including its current and future availability, costs, and transfer capacity – affect where in the state new renewable capacity can be developed.

As described in Section 4, the modeling results demonstrate that transmission enables and directs renewable development in Maine. Across multiple scenarios, onshore wind and associated transmission development in the West and in the North was found to be cost effective. This is partly driven by the high quality of wind in these areas but is also driven by comparatively high transmission costs in the South, which are assumed to be urban and hence more expensive than the North and the West.[100,101] Resources in the South are clearly valuable if major transmission upgrades are not triggered. Policy initiatives that lower transmission costs in the southern part of the state (if possible) may allow onshore wind, PV and storage in these areas to become cost competitive.

For offshore wind, the onshore transmission requirements are less clear, and detailed study is required to evaluate potential interconnection points and associated onshore transmission requirements to support offshore wind capacity greater than 200-300 MW. In this analysis, it is assumed that no major onshore transmission upgrades are needed, analogous to a Massachusetts-focused ISO-NE NESCOE study[102] that identified interconnection points for ~8 GW of offshore wind in southern New England. In the absence of Maine-specific data, the current analysis also assumes existing onshore transmission is allocated to offshore wind at retired or existing conventional generation sites.

These results imply that thoughtful transmission planning may be critical to unlocking renewable potential in the state.[103] In particular, discussed below are two strategies to transmission planning that may drive renewable development, ensure efficient and careful land use, and manage costs to Maine taxpayers.

Anticipatory Transmission Planning

Given the amount and cost of transmission required for renewable development in Maine, state-driven anticipatory transmission development is one possible strategy to ensure that cost-effective, high-quality resources are built in remote locations. This type of approach could help coordinate development across projects and enable cost and risk sharing.

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[99] *"Resolve, To Study Transmission Solutions to Enable Renewable Energy Investment in the State Final Report."*

[100] *In particular, this is given benchmarking costs for urban New England transmission line costs from Southern New Hampshire and Massachusetts were higher relative to western and northern zone transmission costs.*

[101] *"Greater Boston Cost Estimates: Clarifying Questions."*

[102] *Boughan, "NESCOE 2019 Economic Study - 8,000 MW Offshore Wind Results."*

[103] *See Section 5.4 for a discussion on distribution upgrades.*

This approach could be modeled after Texas's CREZ strategy, while recognizing the particular conditions in Maine that may necessitate differences in implementation. In trying to resolve the "chicken and egg" problem that occurs when trying to build transmission or renewables first, the Public Utilities Commission of Texas (PUCT) proposed a CREZ concept that identified high-quality resource areas that required transmission. CREZs were selected based on wind resource quality, developer interest, and preliminary transmission studies. The transmission would be identified to be built prior to the development of individual wind facilities to remove uncertainty of transmission availability for wind developers. The study of the CREZs resulted in the selection of transmission solutions for four CREZs to facilitate wind delivery as well as some common transmission needed to mitigate impacts of the new wind development on the existing system. The costs of these facilities were allocated to transmission utilities based on their contribution to peak load in Texas, effectively socializing the cost of the transmission to all Texas ratepayers. This approach was largely seen as successful as over 20 GW[104] of wind has been developed in the Energy Reliability Council of Texas (ERCOT) to date, with 20% of Texas' electricity coming from wind[105].

A critical result of proactive transmission planning is the certainty to developers that transmission will be available for their projects in designated zones. Uncertainty around transmission availability generally manifests as fewer bids and/or higher-cost bids because developers must cover the risk of the project running into delays due to siting and permitting issues associated with transmission build, as well as potential cost impacts with some costs being shouldered directly by developers. Through proactive transmission planning, some of this uncertainty can be removed, which in turn should result in lower-cost renewable development.

There are several steps Maine can take to make the transmission planning process more proactive. First, similar to other states, Maine can designate identified sites or clusters of sites in the West and in the North as CREZ zones or zones of interest for renewable development. This action would serve as a signal to the market that the state recognizes these zones as important to the renewable transition. This also lays the groundwork for future transmission planning actions by the state. One practical example of such actions is for the state to issue two separate requests for proposal (RFPs) – one for building transmission and one for building resources – for each zone of interest. The transmission rights on transmission facilities/corridors that are built could either be auctioned or allocated to T&D utilities.

While most of the Texas CREZ factors are applicable to Maine, one aspect in which Maine differs significantly from Texas is in barriers to land development. There are significant population and environmental barriers to land development in Maine and any effort that aims to develop transmission should take this factor into account. Any process that aims to designate CREZ zones in Maine should include a fair and consistent approach to incorporating stakeholder concerns (e.g., maintaining protected areas) while supporting new investment. One way to do this is to commission an extension of the LD 1401 study with the purpose of identifying siting, permitting, and environmental challenges to developing transmission in the state. LD 1401 study has already identified the corridors that experience congestion and would likely

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[104] *Warren Lasher, "The Competitive Renewable Energy Zones Process," 2014, 12.*

105 Texas Comptroller of Public Accounts, "Texas' Electricity Resources," accessed December 23, 2020, https://comptroller.texas.gov/economy/fiscal-notes/2020/august/ercot.php.

need upgrades to connect renewables, so this extension study would act as a document to aid stakeholder discussion on overcoming barriers to build transmission in Maine.

Coordination with Canadian provinces and New England states

Coordinating resource and transmission development with neighboring regions may enable RPS compliance at a lower cost for Maine. Specifically, coordinating with Canadian provinces might result in easier development of renewables in Northern Maine because of proximity to existing transmission connectivity to New Brunswick. Maine would then not only increase its own share of renewables but also be able to sell power to Canadian provinces, especially New Brunswick in the winter months.

Coordination among the New England states on transmission planning may enable Maine to share the costs of significant transmission investments with its neighbors, while supporting the efforts of all six states to meet increasingly aggressive clean energy targets. Recent studies[106] demonstrate that significant development of new renewables in New England will be required for states to meet their individual RPS/clean energy goals. Maine's renewable resources, especially wind, is high quality and can potentially be developed to meet both Maine's RPS as well as its neighbors' goals. Transmission planning processes and cost-sharing agreements between Maine and other New England states can help overcome the financing challenge for one or more large transmission infrastructure projects.

Today, the states broadly agree that transmission planning will enable the region to meet its decarbonization goals. Recently, the six New England states released a "Vision Statement" that explicitly called for coordinated transmission planning across the region by ISO-NE.[107] Certain processes already exist for regional transmission planning in New England. In particular, ISO-NE conducts a Policy Transmission Upgrade (PPTU) process every three years to evaluate transmission needs driven by state, federal, or local Public Policy Requirements (PPR). Within this process, any transmission needs driven by federal or state PPRs are communicated by the New England States Committee on Electricity (NESCOE) to ISO-NE.[108] In 2017 and 2020, NESCOE identified no state/federal needs and hence ISO-NE issued a statement saying no Public Policy Transmission Study (PPTS) will be conducted.[109] As detailed on the NESCOE website, there are many issues around cost-allocation and coordination among the different states (especially important for a relatively low-load state such as Maine) that need to be resolved so that NESCOE can recommend future transmission studies to ISO-NE.

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[106] *"Brattle Study: Achieving New England's Ambitious 2050 Greenhouse Gas Reduction Goals Will Require Keeping the Foot on the Clean Energy Deployment Accelerator," accessed December 23, 2020, https://www.brattle.com/news-and-knowledge/news/brattle-study-achieving-new-englands-ambitious-2050-greenhouse-gas-reduction-goals-will-require-keeping-the-foot-on-the-clean-energy-deployment-accelerator; "Maine RPS Study | Synapse Energy"; "Net-Zero New England: Ensuring Electric Reliability in a Low-Carbon Future."*

107 https://newenglandenergyvision.com/

108 "Presentation on Competitive Transmission and Order 1000 Reforms to Platts Conference," NESCOE, accessed December 23, 2020, http://nescoe.com/resource-center/tx1000-platts-may2019/.

109 Brent Oberlin, "2020 Public Policy Transmission Upgrade Process," https://www.iso-ne.com/static-assets/documents/2020/06/a3_public_policy_transmission_upgrade_process_june_2020.pdf.

Despite the challenges of regional coordination, studies have shown that transmission solutions that come from a joint planning process (as opposed to individual processes) have lower overall costs.[110] Keeping this in mind, NESCOE or New England states may consider first turning to regional third-party organizations or jointly support the independent analysis of transmission solutions that support the states' clean energy goals. The aim of such efforts would be to develop a high-level assessment of the joint benefits and costs of building transmission to interconnect renewables to load centers in two or more states. If a transmission solution is found to be mutually beneficial, NESCOE can then propose it to ISO-NE as part of the PPTU for further analysis.

Maine is poised to play a leadership role in reaching out to other New England states and spurring interstate coordination on transmission. There are high-quality renewable resources in the state that are economically attractive to meet both its own and other New England states' RPS requirements. Developing these resources would ensure economic development within Maine while helping the region meet its clean energy goals.

5.3 Offshore wind

Maine has the potential to not only meet its ambitious RPS requirements using offshore wind, but also to position itself as a policy and research leader in floating offshore wind technology. To this end, on November 20, 2020, Governor Mills announced intent to expand the research and development of offshore wind in the state.[111] This is part of the state's phased approach to offshore wind and one of several steps the state is undertaking to create opportunities in Maine from offshore wind while also working to avoid and minimize potential impacts to existing ocean users, including the fishing industry, which is a critical part of Maine's economy and culture.

Nearly all (89%) of Maine's offshore wind potential is located in deep waters.[112] Deepwater offshore wind turbines are floating, as opposed to fixed-base turbines that can be installed and operated in shallow waters, such as those off the coast of southern New England. While the cost declines for floating offshore wind remain uncertain, Maine is ideally suited to play a leading role in developing floating offshore technology given several factors:

- The abundance of offshore wind potential (estimated at 156 GW)
- A world-class research center such as the University of Maine that already has established partnerships with project developers.
- The 10 MW series pilot Aqua Ventus project, as well as the proposed research array, will yield valuable real-time operational data contributing to a better understanding of the "on the ground"

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[110] *Saamrat Kasina and Benjamin F. Hobbs, "The Value of Cooperation in Interregional Transmission Planning: A Noncooperative Equilibrium Model Approach," European Journal of Operational Research 285, no. 2 (September 1, 2020): 740–52, https://doi.org/10.1016/j.ejor.2020.02.018.*

[111] *"Governor Mills Announces Intent to Expand Research and Development of Floating Offshore Wind in Maine | Office of Governor Janet T. Mills," accessed January 1, 2021, http://www.maine.gov/governor/mills/news/governor-mills-announces-intent-expand-research-and-development-floating-offshore-wind-maine.*

[112] *"Net-Zero New England: Ensuring Electric Reliability in a Low-Carbon Future."*

operational challenges and solutions, which can lead to lower costs in the future and better understanding of other marine interactions.

- Potential to sell clean energy to other New England consumers, which also have ambitious renewable energy requirements.

This study identified that there is currently no recent Maine-specific analysis that explores the onshore transmission implications of significant penetrations of offshore wind. Such a study would provide crucial information to planners and offshore wind developers in the state on locations to interconnect, the amount of offshore wind that can be injected before transmission upgrades are triggered, and once triggered, the cost of onshore transmission builds. The availability of this information would allow the state and developers to accurately gauge the role of offshore wind in helping meet Maine's RPS.

An example of such a study is ISO-NE's analysis[113], which found that 8 GW of southern New England offshore wind may be interconnected in Massachusetts at sites, where conventional units are projected or announced to be retired. Given Maine's transmission constraints and the substantial cost of building onshore transmission to develop renewables, as well as several non-market barriers to onshore transmission development, the state may choose to conduct a similar study for Maine offshore wind.

Maine could also push for broader New England cooperation on offshore wind through joint offshore wind and offshore transmission network development. New England is projected to incorporate 13-22 GW of offshore wind by 2050[114], and the region is potentially a big off taker for offshore wind in the Gulf of Maine. Maine is optimally poised to fill this need, especially if further onshore transmission analysis finds limited costs associated with offshore wind interconnection or there are other coordinated offshore wind solutions that can be considered.

5.4 Distributed generation

Distributed generation, especially rooftop/community-scale solar, has increased dramatically in Maine over the past couple of years. The procurements and amendments to the NEB program in LD 1711 have played and will continue to play crucial roles in spurring this development. The scale of interest and developmental effort is evident in the total capacity of active NEB contracts executed by the two biggest utilities in the state – Central Maine Power and Versant. As of December 2020, CMP has a total of 957 MW in executed NEB contracts with a further 117 MW pending, and Versant has 200 MW in executed contracts and an additional 54 MW pending.[115]

Even while projects are moving forward, the MPUC in Docket 2020-00199[116] specifically requested comments from stakeholders on "how many projects that currently have a NEB agreement or have a NEB agreement in the future are likely to be developed and become operational." In response, stakeholders

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[113] *Boughan, "NESCOE 2019 Economic Study - 8,000 MW Offshore Wind Results."*

[114] *"New Study from E3 and EFI Evaluates Electric Reliability and Innovation Opportunities under Deep Decarbonization Pathways in New England,"* E3 *(blog), November 19, 2020, https://www.ethree.com/new-study-evaluates-deep-decarbonization-pathways-in-new-england/.*

[115] *"CMP Response to Docket No. 2020-00199"; "Versant Response to Docket No. 2020-00199."*

[116] *"MPUC: Net Energy Billing," accessed January 6, 2021, https://www.maine.gov/mpuc/electricity/renewables/neb/index.shtml.*

pointed out that distribution and transmission upgrades are likely necessary to accommodate these projects and indicated that should individual projects be responsible for these upgrades, it would likely make them financially nonviable.[117]

The results show that additional distributed generation can play an important role in some of the scenarios. Significant amounts of distributed generation are chosen in the Regional Coordination and the Existing Transmission scenarios. Crucially, in these scenarios, a significant portion of chosen distributed generation are projects that do not have significant transmission and distribution upgrades associated with them. In the Existing Transmission case, distributed generation is only chosen because other onshore resources cannot be developed due to their lack of transmission and the offshore wind resource alternative is too expensive.

This study finds that distributed generation can help the state meet its REC needs, but the distribution and transmission upgrades associated with these projects require further study. Conversations with stakeholders and responses to MPUC Docket 2020-00199 reveal that some projects currently with executed NEB contracts would not be able to interconnect due to significant costs. To get maximum value from distributed generation projects, the projects should interconnect at locations with available capacity on the existing distribution and transmission system. It is recommended that a thorough study of the locational impacts of distributed generation on Maine's interconnection points be studied and modifications to the NEB program implemented such that new distributed generation builds are incentivized to interconnect in locations with available capacity. One practical approach to accomplish this would be for the state to adopt a value stack[118] approach similar to New York's methodology of evaluating and compensating energy provided by Distributed Energy Resources. The value stack compensates projects based on their location and timing of injection. Some of the value streams that are recognized are:

- Energy value
- Capacity value
- Environmental value
- Demand reduction value
- Locational system relief value

Other value streams for distributed generation are their contributions to system reliability and resiliency. Such a value stack approach could greatly benefit Maine distributed generation projects by incentivizing projects that output energy at the most valuable times in suitable locations. In New York, for example, eligible technologies include solar PV, stand-alone and co-located energy storage, some combined heat and power, anaerobic digesters, wind turbines, small hydro, and fuel cells. This ensures diversity in the

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[117] *Keeping this in view, this study assumes attrition in its assumptions about capacity of distributed generation in the baseline set of resources and assumes only a total of 500 MW of distributed generation to be operational and generating RECs by 2025. Refer to Section 3.3.2.*

[118] *"The Value Stack - Value of Distributed Energy Resources," NYSERDA, accessed January 18, 2021, https://www.nyserda.ny.gov/All-Programs/Programs/NY-Sun/Contractors/Value-of-Distributed-Energy-Resources.*

distribution generation portfolio by compensating resources based on their value to the grid instead of the resource type alone.

5.5 Storage

Storage has the potential to help Maine meet its RPS requirements, though there are a broader set of revenue streams that storage can capture that are not related to the RPS. Because this study is focused on the RPS, it is focused on the energy and capacity value streams. However, several additional value streams are important to consider when fully valuing storage, including:

- Regulation, Spinning, and Supplemental Reserve Value: Ancillary Services (AS) markets dominated by conventional power systems have historically had thermal units as the primary provider of these services. In an electric system with large shares of variable renewable generation, such as solar and wind, storage can play an important role in providing AS.
- Congestion Reduction Value: This is the value provided by energy storage when located in a congested area.
- Deferred Transmission and Distribution Upgrades: This is the value provided by storage when it helps defer transmission and distribution upgrades in a system.
- Avoided Transmission and Distribution Upgrades: This is the value provided by storage when it helps reduce the capacity of transmission and distribution upgrades needed for reliable functioning of the grid.
- Increased Resiliency: By allowing critical facilities to ride through prolonged grid outages, storage adds value to the grid.

Accounting for the above streams could increase the amount of storage that is cost effective to build in each of the scenarios studied. Storage may be particularly valuable given Maine's existing transmission congestion. If enough transmission is not built to the western and northern zones, storage near load centers becomes competitive. Further study is recommended to better understand the value storage can bring to Maine's ratepayers, compensation mechanisms that incentivize storage at suitable locations, and potential areas for policy action. New Hampshire's potential Bring Your Own Device (BYOD) program[119] and Massachusetts State of Charge[120] report are examples of recent initiatives in the region that recognize storage's different value streams and are exploring suitable compensation schemes.

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[119] *David Thill, "New Hampshire Looks for Ways to Pay Battery Owners for Benefits They Provide,"* Energy News Network*, accessed January 26, 2021, https://energynews.us/2020/08/24/northeast/new-hampshire-looks-for-ways-to-pay-battery-owners-for-benefits-they-provide/.*

[120] *"Energy Storage Study | Mass.Gov," accessed January 26, 2021, https://www.mass.gov/service-details/energy-storage-study.*

5.6 Utility-Scale PV and Onshore wind

This analysis showed that utility-scale PV when paired with storage is chosen economically across multiple scenarios. While stand-alone utility PV could generate RECs at low cost, three factors should be considered in Maine:

- Maine's winter evening peak is projected to grow with high electrification, driven by an increase in transportation and heating loads. Stand-alone solar is unable to generate during these times of peak need.
- Maine is congested and since significant utility PV builds would trigger transmission upgrades, they might compete with onshore wind for transmission capacity. Depending on the injection point and the relative quality of the two resources, the best resource should be chosen.
- The onshore alternatives to stand-alone utility PV are onshore wind and distributed generation. Distributed generation that can be interconnected without triggering transmission and distribution upgrades and if transmission upgrades have to be triggered, onshore wind is favored in the modeling.

When utility PV is paired with storage, it is able to shift generation to evening peaks, making the resource economic across multiple scenarios. The amount of battery-paired-solar chosen in this study across the scenarios is likely an under-estimation, given that this study only captures a subset of value streams relevant to storage. Please refer to the 'Storage' section above for more details.

The largest resource selected in most of the scenarios was onshore wind. This is because Maine has some of the highest-capacity factor wind in the country, particularly in the northern and western regions of the state. The analysis in this study shows that onshore wind is an economic way for Maine to meet its REC needs in 2030 and beyond across a variety of possible futures. One of the key reasons is its high-capacity factor and its ability to generate during winter-evening peaks when compared to stand-alone utility-scale solar.

The policy implications for utility PV and onshore wind relate closely to the transmission issues discussed in Section 5.2 and the siting and permitting of onshore renewable projects. An inability (or an extreme delay) to build onshore transmission would mean that the state will likely meet its REC needs from a combination of locally sited distributed generation (which will also reach saturation unless transmission and distribution is upgraded, as mentioned above) and offshore wind. This would not only result in higher costs, as shown in this analysis, but also have equity implications as development in offshore wind or distributed generation alone would bypass Northern Maine as mentioned in Section 4.2.3. This highlights the importance of coordinated generation and transmission planning in the state to ensure cost-effective and equitable renewable portfolio development. Efforts should also be made to ensure that interconnection/permitting timelines are efficient so that these resources can be developed and be operational by the time they are required.

In addition to the transmission-related actions suggested in Section 5.2, the state could lead an exercise to identify potential sites in the South where utility-scale renewables can be connected without triggering major transmission upgrades or could rely on other non-wires alternatives. The results of this study indicate that such resources are economic owing to their ability to contribute to system peak and their proximity to load centers. A state-led effort to assess priority areas for development that are ranked by factors such as resource potential, transmission availability, land use constraints, and environmental impact could also help streamline resource development to areas with the best value to the people of Maine.

6 Equity Benefits and Challenges of Renewable Transition

In this section, the benefits and challenges related to the equity of Maine's transition to a high renewable future are discussed. As Maine looks to fulfill its renewable energy requirements, it will be important for the state to intentionally anticipate and respond to challenges through thoughtful policy support and action.

All six of Maine's RPS-compliant scenarios modeled in this study entail potential energy equity benefits and challenges for Maine's current and future vulnerable and underserved communities, some of which are discussed below. It is important to note that this discussion is not the result of a comprehensive equity analysis and is not intended to present a comprehensive list of potential equity benefits and challenges that may arise. Equity impacts will need to be considered at each step as Maine undertakes its renewable energy transition. That said, the kinds of equity benefits and challenges that may arise include:

- ***Reductions in emissions and corresponding improvements in air quality and human health*** is a benefit to Maine's frontline communities, which suffer from disproportionate levels of pollution exposure. Almost twice the share of Maine households use oil to heat their homes compared to all households in New England.[121] In addition to considerable emissions reduction, electrification of heating will enable Mainers to reap substantial human health benefits by reducing their exposure to pollutants. Replacing fossil fuels like oil and piped gas with renewable energy can also reduce the potential for dangerous events related to fossil fuel infrastructure, such as gas leaks. Gas leaks pose significant climate risks because they release methane—a greenhouse gas with a warming potential 32 times that of carbon dioxide.[122]
- ***Improved energy reliability and resiliency*** is achieved through the addition of renewable energy sources and load flexibility resources like batteries. Distributed generation resources, which are less centralized, make the grid more resilient to shocks and disruptions like extreme weather events.[123] This is a particular benefit for vulnerable communities that face increased risks from power outages, such as hourly employees that lose wages (e.g., those working at restaurants or retailers) and people that depend on nebulizers, oxygen machines and/or refrigerated medicines.
- ***Clean energy employment and community investment*** is the result of renewable energy development that creates jobs when new, clean energy infrastructure is produced, transported, installed, and maintained. According to a report from the Maine Governor's Energy Office, approximately 14,000 people in Maine worked in clean energy fields in 2019, with over 60% of

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[121] U.S. Census Bureau. 2019. "House Heating Fuel" (TableID: B25040). 2019 American Community Survey 1-Year Estimates.

[122] https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

[123] U.S. Department Of Energy, Available at: https://www.energy.gov/eere/femp/distributed-energy-technologies-resilience

those jobs in energy efficiency.[124] The prior and current rounds of MPUC procurement are expected to add more jobs to the state as well. Maine's renewable energy transition will also present new community investment opportunities in the form of taxes, land payments, job training programs, and community ownership structures.

- ***Ensuring affordable electricity.*** Changes to electric rates entail important equity impacts, particularly for low-income households that already spend the greatest share of their income on energy costs. Electric rate structures need to be periodically evaluated to ensure that these households are not adversely impacted. Additionally, strong support is needed in the form of policy and on-the-ground action to alleviate the energy burden of the lowest-income, most energy-burdened households.
- ***Recognizing the equity implications of new transmission.*** The RPS scenarios are sensitive to assumptions about transmission upgrades and coordination with regional entities. This study has demonstrated that there are significant cost savings when scenarios include new transmission in the western and northern parts of the state. Maine's SVI, developed as part of this study, shows that these regions, particularly the North, are characterized by high social vulnerability and would benefit from more renewable development. Benefits include those to the local economy, job creation, and having lower total costs of these pathways relative to other options. Despite these benefits, transmission is difficult to permit and build and, if pursued, may require policy support to enable timely development.
- ***Ensuring equitable distribution of distributed generation benefits.*** While the total amount of distributed generation is important, the type of customers/communities installing distributed generation is also equally important. Efforts are needed to ensure vulnerable communities, such as elderly people in Maine, renters, and low-income households, participate in the benefits of distributed energy such as energy cost savings, property value increases, and—when paired with battery storage—greater energy reliability. While much greater amounts are slated to be developed going forward, today Maine has about 84 MW of distributed solar installed[125]—much of which is located in the southern part of the state, and in the state's least vulnerable counties (York, Cumberland, Sagadahoc, Knox and Hancock).
- ***Minimizing impacts to existing industries, stakeholders, communities, and natural resources.*** The transition to renewable energy brings significant economic opportunity, particularly to vulnerable communities. At the same time, existing industries – both energy-related and non energy-related – may be impacted during this transition and will require consideration. As called for in the Maine Climate Council Action Plan, the state would benefit from working with landowners, developers, fishermen, and other important stakeholders to develop policies and

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[124] *State of Maine Office of Governor Janet T. Mills. November 9, 2020. "Mills Administration Releases Report on Strengthening Maine's Clean Energy Economy." Available at: https://www.maine.gov/governor/mills/news/mills-administration-releases-report-strengthening-maines-clean-energy-economy-2020-11-09.*

[125] *"MPUC: Net Energy Billing."*

siting guidelines that are transparent; seek to minimize impacts to communities, fishing, and the environment; and avoid significant losses of key farmlands.

7 Conclusions

Maine is pursuing a range of ambitious emissions reduction requirements to combat the potential impacts of climate change on the state. Recent work from the Maine Climate Council has highlighted the key role of the electric sector in achieving these goals. The electric sector has to both absorb rapid and deep electrification loads from transportation, buildings, and industries while simultaneously achieving the 80% RPS requirement by 2030. To accomplish this, this study has shown that Maine will need to develop significant quantities of onshore wind, solar, storage, offshore wind, and distributed generation.

The following conclusions, drawn from the analysis conducted in this study, provide insight into the need for resources to meet the RPS through 2030 and the strategies that could be pursued to ensure the RPS is met affordably and equitably.

- ***Maine is on track to meeting its RPS until 2026, but new resources will be needed to meet increasing goals thereafter***. A combination of existing generation and resources procured previously and through LD 1494 and LD 1711, "An Act To Promote Solar Energy Projects and Distributed Generation Resources in Maine," will be sufficient to meet the need for renewable energy credits (RECs) until 2026. Beyond this point, new resources will be needed to meet increasing goals. Scenario analysis indicates a range of new builds between 800 and 900 MW by 2030 will be needed. This need can be satisfied by a number of resources, though each requires the consideration of tradeoffs: Maine's high-quality onshore wind potential is largely inaccessible absent investments in transmission; small-scale solar may be developed in proximity to loads and provides resiliency, but significant transmission and distribution upgrades are likely needed to interconnect large amounts of these systems; and offshore wind is still in the nascent stages of technological development but could emerge as a competitive source of renewable supply. Given the challenges facing renewable development in the state – particularly with respect to transmission – there is need for action well before 2026 so that the intervening years are used to develop and implement plans to ensure enough new renewable generation is online and operational by 2026. Further, given federal tax incentive expiration, there are cost savings to advancing development to before 2026.
- ***Transmission will be a key driver of renewable development***. Building new transmission is difficult in New England and can be challenging in Maine. At the same time, the report required by LD 1401[126] and subsequent findings show that key transmission pathways in Maine are severely congested and constrained. This study highlights that many lower-cost pathways to meet Maine's RPS requirements in the next decade are achievable through the development of high-quality wind resources in western and northern Maine, which in turn require new transmission investments. The scale of these transmission investments, along with the longer development timelines as compared to renewable projects, will make it difficult for any single wind project to shoulder the

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[126] *"Resolve, To Study Transmission Solutions to Enable Renewable Energy Investment in the State Final Report," 2020.*

development burden of these transmission projects. Limited transmission availability will present similar challenges for the development of other generation sources, such as solar. A state-sponsored anticipatory transmission planning process could help address this issue by identifying the transmission needed to meet the RPS in advance of renewable development. Maine could look to states like Texas (Competitive Renewable Energy Zone, or CREZ, process) or California (Renewable Energy Transmission Initiative, or RETI) to see how other states in similar situations have successfully approached this challenge.

- ***A technologically diverse portfolio helps lower risk***. Each resource type has its own set of challenges that introduce risk into the resource portfolio. Onshore resources in western and northern Maine require transmission upgrades and could face siting challenges. Floating offshore wind is not yet deployed at scale and thus has a higher initial cost, which may decrease with increasing penetration. Large penetrations of distributed generation, which are expected by 2025 (500 MW), will likely require distribution and transmission upgrades. There is also uncertainty associated with the resource costs, as technologies are continuing to evolve. Pursuing a diverse portfolio serves as a hedge against several uncertainties, including slower-than-expected cost declines and the development of new transmission. This study explores one such diverse portfolio, but the appropriate mix will be ultimately decided to meet multiple policy objectives.
- ***Regional coordination can help lower the costs of meeting Maine's RPS***. In addition to having a large amount of land for renewable development, Maine has some of the highest-quality wind resources available in New England. If developed, these resources can help to meet both Maine and the broader region's clean energy goals. New transmission is required to access these resources, however, due to their remote location. The study results show that coordination of Maine with neighboring states can mitigate the "lumpiness" challenge of new transmission investment—that transmission projects are generally large in size, are expensive, and the full project has to be developed before any benefits can be realized—so that Maine's customers do not bear the full cost of transmission to access high-quality wind resources in the northern and western parts of the state.
- ***Storage paired with solar resources can provide value***. Storage paired with solar was found to be chosen economically alongside onshore wind. Maine's winter peak is projected to increase with heating electrification. Pairing solar with storage improves the combined generation profile of these hybrid resources, enabling them to generate during evening peak demand, increasing their value to the system. Storage has additional benefits, such as transmission and distribution deferral value, resiliency, and ancillary services provision, which are not captured in this RPS-focused study. Including these value streams is likely to further improve the economics of storage.
- ***Energy equity challenges cut across four dimensions: resource diversity, customer-sited resources, geographic resource distribution, and cost.*** Successfully achieving Maine's renewable energy goals may result in at least three benefits for its vulnerable communities: 1) reductions in emissions resulting in corresponding improvements in air quality and human health, 2) renewable resources increasing the energy supply's resiliency, and 3) clean energy development creating employment and community investment. Ensuring equity considerations are prioritized during

Maine’s clean energy transition requires careful attention to resource diversity, customer-sited resources, geographic resource distribution, and the cost impacts experienced by vulnerable communities. Thoughtful selection of a resource mix should be complemented with periodic review and modifications to rate structure to ensure Maine’s vulnerable communities are not adversely impacted. Investment in programs that provide resources to vulnerable communities should also continue to be supported. Furthermore, siting of new resources should consider and seek to minimize impacts to existing industries, stakeholders, communities, and natural resources.

Appendix

In this Appendix, a summary of stakeholder feedback is presented. This feedback was received after the first webinar (conducted on November 6, 2020) where the initial study design was presented. Stakeholder comments from this process were used to inform the final selection and design of scenarios. Additional equity considerations are also presented in Section 8.2. This section includes a detailed development of the Social Vulnerability Index (SVI) which was presented in Section 2.5 and used to contextualize the scenario specific results in Section 4.

A. Summary of stakeholder feedback

On November 6, 2020, the motivation, methodology, and initial scenarios of the Maine REGMA study were presented in an online seminar to the public and key stakeholders. Stakeholders included, but were not limited to, representatives from Maine's utilities, energy industry trade groups, and environmental groups. To follow up on the online seminar, GEO solicited and collected feedback on the study's structure through an online feedback form. Overall, twenty-one responses were received. Below is a summary of feedback organized by the questions posed to stakeholders. While the study does not address all concerns raised by stakeholders due to its limited scope, much of the feedback was used to inform the analysis, particularly in the design of investigated scenarios. In addition, this feedback informed the recommendations and equity challenges and benefits in Section 6.

POLICY: Are there specific policy options you would like to see considered in planning and procurement related to Maine's RPS?

Stakeholder comments around this question primarily focused on building more transmission to access remote resources (such as those in Aroostook County in Northern Maine), decoupling of transmission and generation planning, and consistent, predictable procurement schedules of resources with bundled RECs and energy. Other comments focused on considering energy storage as standalone units or co-located with renewable generation and avoiding locating generation, transmission, and distribution resources in areas that impact natural resources. Further, some stakeholders suggested establishing a Feed-In-Tariff for projects up to 7 MW nameplate capacity in lieu of NEB.

SCENARIO DESIGN: Do you have any feedback on the list of factors, or are there additional factors that should be considered for designing scenarios?

Some comments focused on the importance of examining the effects of federal policy, such as potential carbon pricing, assumptions on the persistence of the ITC and PTC, and potential infrastructure bills to subsidize transmission. Other stakeholders were interested in modeling the effect of siting and permitting constraints; accounting for energy and capacity value of intermittent resources; quantifying rate effects on consumers; and investigating load flexibility.

SCENARIO DESIGN: Do you have feedback on any of the scenario focus areas or considerations specific to a particular scenario focus area?

Stakeholders were interested in examining a scenario in which onshore wind and solar resources were the primary means by which Maine satisfies its RPS. Some were not sure how load flexibility was defined in the context of the study or wanted explicit consideration of demand-response resources as a load flexibility option. Stakeholders suggested treating Maine as a resource hub to export energy to Canada and New England; examining the deployment of energy storage at various levels; or carefully considering out-of-state RECs, particularly if RECs were not bundled with energy from newly built resources.

TRANSMISSION: Which areas within Maine require new transmission infrastructure to facilitate renewable development?

The overwhelming response from stakeholders was that northern Maine requires transmission to interconnect resources. Part of this interconnection could be accomplished by upgrading key interfaces, such as Orrington-South and Suroweic-South. Stakeholders also suggested policy action to address the burden of transmission and distribution upgrades falling on individual projects in distant, poorly interconnected regions in the state. Finally, responses also suggested considering upgrades of the Maine-New Hampshire interface or transmission in the Portland area within the study.

DATA SOURCES: Are there additional data sources that should be considered?

Key data sources recommended included the interconnection queues and the NEB reports of Central Maine Power and Versant Power and discussions with the transmission experts involved the LD 1401 study. Other data sources included “Caring for the Crown: Taking Stock of the Future and a Renewed Call for Action” or the “Reinventing Fire” report by the Rocky Mountain Institute.

EQUITY: How can Maine pursue a greater share of renewable energy in a just and equitable manner? Do you have any equity or justice concerns related to the renewable scenarios presented today?

Stakeholders identified that Aroostook County needed a higher share of generation, transmission, and distribution development. Further, they requested that the effect of new renewable generation on the equitable distribution of jobs and the influence of a potential reduction in fossil fuel generation on public health should be explored.

B. Additional equity considerations in Maine

As Maine transitions to decarbonizing the grid, the state is working to ensure that this transition is equitable and that it brings benefits to Maine’s most vulnerable communities. Several organizations in Maine offer programs and policies aimed at building equity and justice in the energy sector, including but not limited to the Maine Climate Council, Efficiency Maine Trust, Maine Office of the Public Advocate, and MaineHousing.[127]

To help understand the equity implications of the renewable portfolios considered in this study’s analysis, AEC developed an SVI of Maine’s current population to provide an equity lens through which to interpret

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[127] *Refer to the Appendix for details on the energy equity activities of these organizations.*

the analysis results presented in Section 4. This assessment is not a comprehensive review of the equity considerations. This section provides details on the development of the SVI and the key conclusions from the SVI applied to Maine's current population.

1. Maine's Social Vulnerability Index

Vulnerable communities are those that contain populations that are disproportionately burdened by existing inequities—for example, people of color experience more pollution from fossil fuel generation than their white counterparts across the United States[128]—and/or lack the capacity to withstand new or worsening burdens. AEC calculated an SVI for Maine[129] that combines values from six categories of vulnerability, each expressed as a share of population: Children (17 and younger), limited English-speaking households, older adults (65 and older), people of color, people with disabilities, and low-to-no income individuals (income that is 150 percent of the federal poverty level or less).

Population shares for the six vulnerable groups are combined into a single measure of vulnerability in each local area (by counties and "census tracts"[130]). A higher SVI score (darker color) indicates a greater degree of vulnerability (see Figure 51).

The three most socially vulnerable counties in Maine are Piscataquis and Aroostook counties in the northern part of the state, and Washington County in the eastern part of the state (see Figure 51). Large portions of Piscataquis and Aroostook counties are served by the Canadian grid (New Brunswick) rather than the rest of Maine's New England-connected grid. Washington County is served by Eastern Maine Electric Cooperative and Versant Power.

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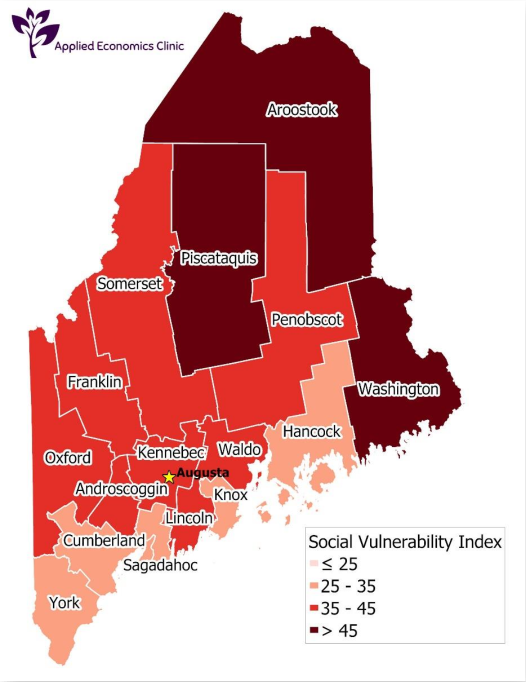
[128] *Tessum,* Inequity in Consumption of Goods and Services Adds to Racial–Ethnic Disparities in Air Pollution Exposure.

[129] *Note that while the criteria used to calculate Maine's SVI are widely used in development of similar vulnerable indices, the numerical values of the SVI calculated in this study are for internal comparison among Maine jurisdictions and are not meant to be compared to ones calculated for other jurisdictions.*

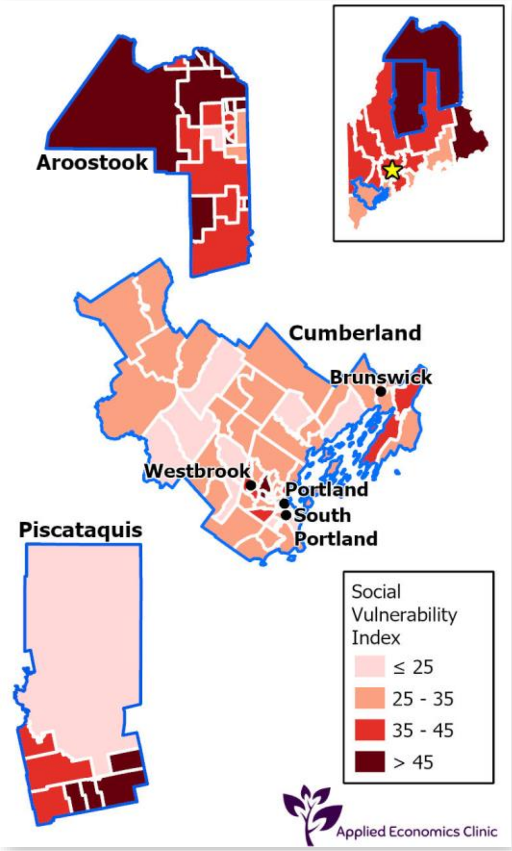
[130] *Census tracts are small statistical subdivisions of a county that are updated prior to each decennial census, and typically have a population size between 1,200 and 8,000 people, see:n.d,* Glossary.

Figure 51. *Maine Social Vulnerability Index*[131]



There is also considerable disparity in the distribution of vulnerability within Maine counties: Figure 52 shows the SVI for the two most vulnerable counties in the state (Piscataquis and Aroostook) and the least vulnerable county (Cumberland) by census tract.

Figure 52. *Vulnerability Distribution within counties*



In Piscataquis County, the most vulnerable populations are clustered in the southeast. In Aroostook, the most vulnerable populations are more evenly distributed across the county—there are only a few census tracts with low vulnerability scores. In Cumberland, Maine's least vulnerable county overall, there are census tracks with high levels of vulnerability located between Portland and Westbrook that are characterized by large percentages of:

- Low-to-no income households (as high as 52 percent, compared to the county-wide average of 15 percent),
- Limited English (as high as 15 percent compared to the county-wide average of 2 percent), and
- People of color (as high as 41 percent compared to the county-wide average of 8 percent).

The SVI suggests that vulnerability is not evenly distributed across Maine or within counties; particular communities and neighborhoods are most vulnerable, each for its own specific reasons. It is also important to recognize that the vulnerable households of today may not be the vulnerable households of tomorrow.

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[131] *U.S. Census Bureau, 2019 American Community Survey 1-Year Estimates. "Earnings in the Past 12 Months" (Table S2001), "Limited English Households" (Table S1602), "Disability Characteristics" (Table S1810), "Age and Sex" (Table S0101), "Race and Population (Table B02001).*

2. Maine's demographics

To provide context while interpreting results from Section 4, this section provides an overview of Maine's demographics and how they compare to the national average. A brief overview of housing in Maine is also included as necessary context for the electric load growth and renewable transition.

Forty-six percent of Maine's households are "middle class" (see Table 6, which presents results for the U.S. Census income category: $35,000 to $99,999).[132] Eleven percent of Maine's households earn more than $150,000 per year (a smaller share than the national average of 16%) and eleven percent of Maine households' income falls below the federal poverty level ($25,926 in 2019 for a household with two adults and two children[133]).

***Table 6.** Household income in Maine and the United States, 2019*[134]

	Maine	U.S.
Total population (millions)[135]	1.3	328
Median household income ($)	$59,000	$66,000
Below poverty level (share of individuals %)	11%	12%
Share of households earning:		
Less than $35,000 (%)	29%	27%
$35,000 to $99,000 (%)	46%	42%
$100,000 to $149,000 (%)	15%	16%
$150,000 or more (%)	11%	16%

Some vulnerable populations in Maine are a notably larger share of the population than the national average while some are substantially smaller. Maine's vulnerable populations are more likely to be made up of older people (above 64 years) and people with disabilities as compared to the national average (see Figure 53).[136] While Maine's share of children (below 18 years), people of color, immigrants, and limited English speakers is smaller than the national average, these communities do live, work and play in Maine and are vulnerable.

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[132] *A Pew Research Center definition of middle-income as "two-thirds to double the US median household income" results in a range of $39,000 to $118,000. The $35,000 to $99,999 range presented in Table 1 is the closest approximation to this grouping available from U.S. Census data. See: J. Bennett, R. Fry, and R. Kochhar, "Are You in the American Middle Class? Find out with Our Income Calculator,"* Pew Research Center, *July 23, 2020, https://www.pewresearch.org/fact-tank/2020/07/23/are-you-in-the-american-middle-class/.*

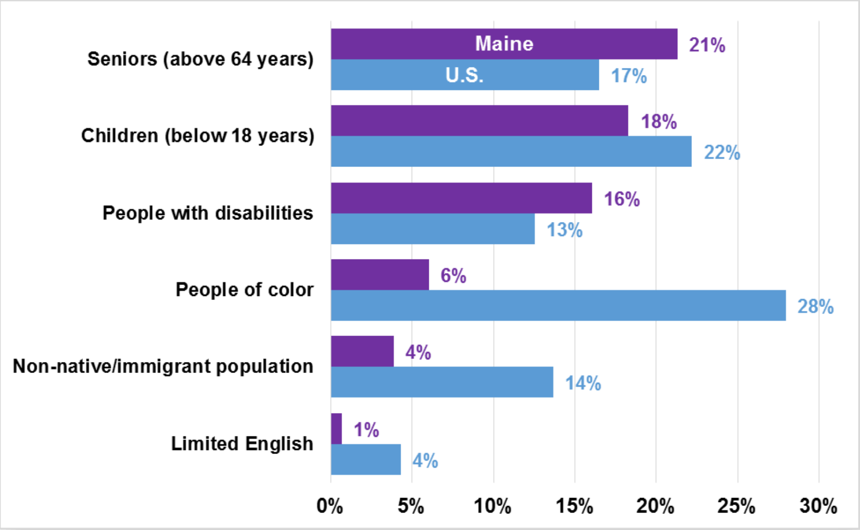
[133] *U.S.Census Bureau,* Poverty Thresholds, *2020, https://www2.census.gov/programs-surveys/cps/tables/time-series/historical-poverty-thresholds/thresh19.xls.*

[134] *U.S. Census Bureau, 2019 American Community Survey 1-Year Estimates. "Earnings in the Past 12 Months" (Table S2001), "Poverty status in the past 12 months" (Table S1701).*

[135] *This was incorrectly stated as "Total households (millions)" in the February 2021 version of the report and was corrected in March 2021.*

[136] *U.S.Census Bureau, "ACS Demographic and Housing Estimates,"* in TableID: DP05, *2019, https://data.census.gov/cedsci/table?q=DP05&g=0100000US_0400000US23&tid=ACSDP1Y2019.DP05&hidePreview=false.*

Figure 53. *Maine and the U.S. demographic comparison, 2019*[137]



While Mainers are more likely than the average American to own their housing (72% of Mainers versus 62% of all Americans), over 155,000 Maine households rent their homes.[138] Nearly 40% of all homeowners (approximately 150,000 households) in Maine do not pay a mortgage. A quarter of Maine's renters (approximately 40,000 households) receive rent assistance (see Figure 54).

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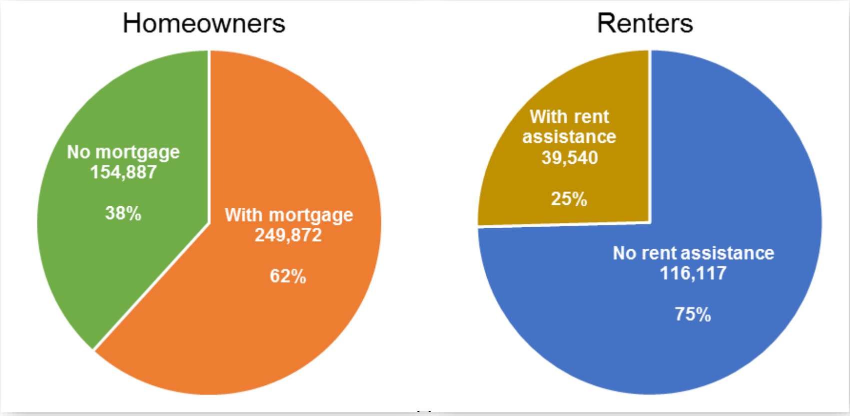
[137] *U.S. Census Bureau, 2019 American Community Survey 1-Year Estimates. "Limited English Households" (Table S1602), "Nativity and Citizenship Status in the United States" (Table B05001), "Disability Characteristics" (Table S1810), "Age and Sex" (Table S0101), "Race and Population (Table B02001).*

[138] *U.S.Census Bureau, QuickFacts, 2020, https://www.census.gov/quickfacts/fact/table/US,ME/PST045219.*

Figure 54. *Maine households by housing type, 2019*[139]



3. Maine's energy burdened households

Maine's low-income households experience the greatest energy burden: That is, low-income households in Maine spend more on energy bills (as a share of their income) than wealthier households (see Figure 55). According to the 2019 MEOPA study, the average Maine two-person household earning less than $16,500 per year spends 24% of their income on energy costs, while the same sized household earning more than $50,000 spends just 4% of their income on energy costs. The study also found that low-income Maine households heating with propane have the highest average energy burden of any fuel type (an astounding 40% of the average propane low-income household's income is spent on propane heating), followed by natural gas and wood heating (both approximately 20% of income spent on heating),[140] and that low-income household energy burdens are higher for homeowners than renters (22% and 16%, respectively).[141] The most energy burdened households in Maine are low-income and own their home.

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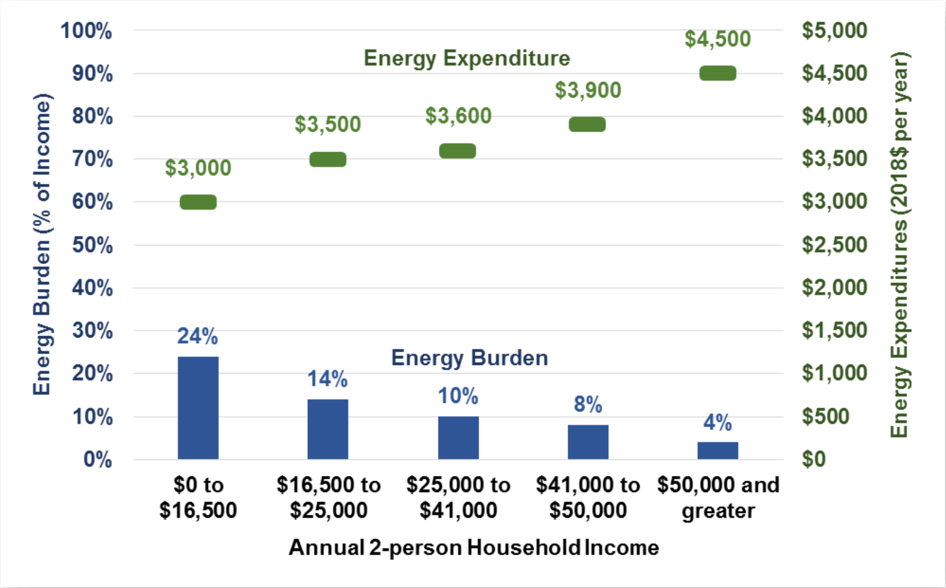
[139] *MaineHousing, "Characteristics of Maine Housing," n.d., https://www.mainehousing.org/docs/default-source/policy-research/research-reports/housing-profiles/characteristics-of-housing-in-maine---january-2019.pdf?sfvrsn=5a63a815_10&sfvrsn=5a63a815_10; U.S. Census Bureau, "ACS 1-Year Estimates Table B25081," 2019, https://data.census.gov/cedsci/table?t=Housing%3AMortgage%20Costs&g=0100000US_0400000US23&d=ACS%201-Year%20Estimates%20Detailed%20Tables&tid=ACSDT1Y2019.B25081&hidePreview=true.*

[140] *Ibid. p.16.*

[141] *Ibid. p.9.*

Figure 55. Maine household's energy burden (% of income) and energy expenditure (2018$), by income[142]



C. Release notes for revised report – March 2021

"State of Maine Renewable Energy Goals Market Assessment" report was originally released in February 2021 and was revised in March 2021. The following explains the changes made in this revision.

The results of this study were updated in March 2021 to correct cost projections for solar PV & storage. The full list of figures and tables affected by this update is provided below. The study's key conclusions and takeaways were not affected by this update.

- Figures: 15, 21, 27-33, 43-50.
- Tables: 4, 5.

In addition, a label in Table 6 was corrected as shown below.

- Table 6: The first-row label was corrected to "Total population (millions)".

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[142] *Allison, A., Napoleon, A., and Kallay, J. June 3, 2019. Maine Low-Income Home Energy Burden Study. Synapse Energy Economics. Prepared for Maine Office of the Public Advocate.*