Beneficial Electrification: Barriers and Opportunities in Maine

STAFF REPORT OF THE EFFICIENCY MAINE TRUST

SUBMITTED TO THE JOINT STANDING COMMITTEE ON ENERGY, UTILITIES AND TECHNOLOGY OF THE MAINE STATE LEGISLATURE

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Acknowledgements

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1 Report Background

In the spring of 2019, the Maine Legislature enacted L.D. 1464 – *An Act To Support Electrification of Certain Technologies for the Benefit of Maine Consumers, Utility Systems and the Environment*.[1] The bill added the following definition to the Efficiency Maine Trust Act (Title 35-A, Section 10102):

> **3-A. Beneficial electrification.** "Beneficial electrification" means electrification of a technology that results in reduction in the use of a fossil fuel, including electrification of a technology that would otherwise require energy from a fossil fuel, and that provides a benefit to a utility, a ratepayer or the environment, without causing harm to utilities, ratepayers or the environment, by improving the efficiency of the electricity grid or reducing consumer costs or emissions, including carbon emissions.

Section 4 of the bill requires the Trust, in consultation with stakeholders, to study barriers to beneficial electrification in the transportation and heating sectors in the state. It requires the Trust to develop a report based on the study.

The bill requires that the report:

1. Identify social, technological, legal, regulatory, and economic barriers to beneficial electrification in the transportation and heating sectors of the State;
2. Identify additional information that the trust may require to make additional recommendations or analyses;
3. Consider potential roles of electric utilities, natural gas utilities, and competitive markets in supporting beneficial electrification;
4. Identify areas or populations in the State less likely to benefit directly from beneficial electrification without additional policy development or utility intervention; and
5. Recommend opportunities for beneficial electrification.

The Trust issued a Request for Information (EM-RFI-006-0020) in August 2019, seeking preliminary input from the public. Over the course of the fall, the Trust also held several one-on-one meetings with specific stakeholders, including representatives from state agencies, nonprofit organizations, academic institutions, and interest groups. The Trust then released a draft report in December, providing the public with further opportunity to submit written information and comments.[2]

[1] Public Law, Chapter 365, L.D. 1464, 129th Maine State Legislature – An Act To Support Electrification of Certain Technologies for the Benefit of Maine Consumers, Utility Systems and the Environment.

[2] For further detail on the stakeholder process and public input, see Section 9.

2 Introduction

In the face of intensifying climate change threats, national, state, and municipal jurisdictions across the world have adopted aggressive greenhouse gas (GHG) emission reduction goals. These goals reflect the level of GHG reduction that scientists estimate is necessary to stave off the worst impacts of climate change. For example, the objectives of all the states in the northeastern United States (including New York and New England) require emissions reductions collectively of about 80 percent below 2001 levels by 2050.[3] To date, most GHG mitigation efforts in the energy space have focused on two strategies: increasing clean, renewable electricity supply and improving energy efficiency. While carbon-free electricity and enhanced energy efficiency are extremely important strategies, they are insufficient by themselves to reach mid-century emissions targets. Experts calculate that without additional, complementary actions, these two strategies can only reduce the region's emissions by about 40% by 2050 – half of the target.[4]

It is in this context that a relatively new GHG reduction strategy is gaining traction. This new approach involves transitioning energy end uses from fossil fuels to cleaner electricity. As the trend toward a decarbonized electricity supply continues, supporting more end uses with electricity means powering more of our energy needs with renewables. Indeed, a growing number of experts agree that electrification is essential to driving deep decarbonization and meeting aggressive climate goals. This consensus is well summarized in a recent issue of *The Electricity Journal:*[5]

> A recent report by Environmental and Energy Economics (E3) states that "critical to the success of long-term GHG goals" is "fuel-switching away from fossil fuels in buildings and vehicles."[6] Lawrence Berkeley National Laboratory similarly concludes that "widespread electrification of passenger vehicles, building heating, and industry heating" is essential for meeting California's GHG reduction goals.[7] Work at Stanford University also indicates that "one potential way to combat ongoing climate change, eliminate air pollution mortality, create jobs and stabilize energy prices involves converting the world's entire energy infrastructure to run on clean, renewable energy."[8]
>
> The United Nations Sustainable Development Solutions Network's Deep Decarbonization Pathways Project[9], the California Council of Science and Technology[10], the Acadia Center's

[3] Northeast Energy Efficiency Partnerships (NEEP). "Northeastern Regional Assessment of Strategic Electrification." July 2017. p. 1.
[4] Id. at p. 1.
[5] Dennis, Keith, Jim Lazar, and Ken Colburn. "Environmentally beneficial electrification: The dawn of 'emissions efficiency'." The Electricity Journal. Volume 29, Issue 6. July 2016. p. 52-58.
[6] Borgeson, Sam, Ben Haley, Elaine Hart, Amber Mahone, Snuller Price, Nancy Ryan and Jim Williams. "California PATHWAYS: GHG Scenario Results." Energy + Environmental Economics. April 6, 2015.
[7] Lawrence Berkeley National Laboratory (LBNL). 2013. "California's Carbon Challenge Phase II Volume I: Non- Electricity Sectors and Overall Scenario Results." September 2013.
[8] Jacobson, Mark Z. "Stanford Engineers develop state-by-state plan to convert U.S. to 100% clean, renewable energy by 2050." *Stanford News*. June 8, 2015.
[9] Williams, J.H., B. Haley, F. Kahrl, J. Moore, A.D. Jones, M.S. Torn, H. McJeon. "Pathways to deep decarbonization in the United States." The U.S. report of the Deep Decarbonization Pathways Project of the Sustainable Development Solutions Network and the Institute for Sustainable Development and International Relations. Revision with technical supplement, Nov 16, 2015.
[10] California Council on Science and Technology. "Policies for California's Energy Future - Electricity Pricing and Electrification for Efficient Greenhouse Gas Reductions." October 2013.

> EnergyVision report,[11] experts like Jeffrey Sachs of Columbia University,[12] and even Bill Nye the Science Guy have all added to this chorus.[13] Many other researchers around the globe are echoing the same conclusions. The consensus on environmentally beneficial electrification, it seems, is in.

Various national, state, and local jurisdictions are heeding this advice, weaving electrification into their official climate plans and energy plans (see Figure 1).

[11] Acadia Center. EnergyVision 2030. 2017.
[12]Rockström, Johan and Jeffrey D. Sachs. "Sustainable Development and Planetary Boundaries." Background research paper for the High-Level Panel on the Post-2015 Development Agenda. May 2013.
[13] Rodriquez, Ashley. "Science Guy Bill Nye's radically simple blueprint for ending Climate Change." December 1, 2015.

Figure 1: State Electrification Policy Examples

- **Massachusetts**'s most recent Clean Energy and Climate Plan (2015) acknowledges that "the only viable path to deep reductions in GHG emissions is through a combination of reduced energy consumption (through increased energy efficiency in vehicles and buildings), expanded availability of clean electricity, and electrification of the transportation and heating sectors."[14] The 2018 Comprehensive Energy Plan (CEP), models a spectrum of energy generation and consumption scenarios to inform the next iteration of the state's Clean Energy and Climate Plan (due in 2020). Even the least aggressive scenario assumes some level of electrification based on a continuation of existing policies. These include state targets to install electric heating technologies, including air source heat pumps, in 2% of single-family homes by 2030, and to electrify 160,000 vehicles by 2025 and 1.2 million by 2030.[15]
- **Vermont**'s most recent Comprehensive Energy Plan (2016) presents a pathway to achieving the state's GHG emission goals based on three strategies: 1) continuing improvements in demand-side thermal and electric efficiency and conservation, 2) fuel switching away from combustion technologies to more efficient electric-powered technologies, and 3) declining source energy requirements of electricity generation.[16] The plan reflects a state target of installing 35,000 cold-climate heat pumps by 2025 and electrifying 10% of vehicle fleet by 2025.[17]
- The latest update to **California**'s Climate Change Scoping Plan (2014) declares that achieving the 2050 GHG reduction target will require energy demand reduction through large-scale electrification of on-road vehicles, buildings, and industrial machinery.[18] California's most recent Integrated Energy Policy Report update (2018) acknowledges the state's advancements in decarbonizing the transportation sector and highlights its ambitious goals of at least 5 million zero-emission vehicles by 2030 and installation and construction of 250,000 electric vehicle (EV) chargers, including 10,000 direct current fast chargers, by 2025.[19] It goes on to identify decarbonization in buildings as the "next innovation,"[20] stating that that building electrification is essential to California's strategy to meet its GHG reduction goals for 2030 and 2050.[21]
- The Biennial Report to the 2015 **New York** State Energy Plan notes that the state will need to pursue three broad strategies to meet its climate goals: 1) energy efficiency and conservation in all sectors, 2) "decarbonized" or zero- and low-carbon electricity, and 3) fuel-switching that replaces fossil fuel-based energy sources with electricity and lower-emitting biofuels. The report explicitly names electrification of thermal end uses in buildings as a core opportunity, calling on the state to develop electrification policies and opportunities.[22]

[14] Massachusetts Executive Office of Energy and Environmental Affairs (EEA). "2015 Update of the Massachusetts Clean Energy and Climate Plan for 2020." December 31, 2015. p. 50
[15] Massachusetts Department of Energy Resources (DOER). "Massachusetts Comprehensive Energy Plan." December 12, 2018. p. ix
[16] Vermont Department of Public Service (VTDPS). "Comprehensive Energy Plan 2016." 2016. p. 7.
[17] Id. at p. 8 and p. 9.
[18] California Environmental Protection Agency Air Resources Board. "First Update to the Climate Change Scoping Plan." May 2014. p 32
[19] California Energy Commission. "2018 Integrated Energy Policy Report Update, Volume II." p. 13.
[20] Id. at p. 17.
[21] Id. at p. 32.
[22] New York State Energy and Research Development Authority (NYSERDA). "Biennial Report to the State Energy Plan." p. 104-5.

It is important to note that much of the literature points to the need for this electrification to be "beneficial" or "strategic," taking care to balance other societal objectives that factor into decision-making. For example, the Regulatory Assistance Project (RAP) asserts that for electrification to be considered *beneficial*, or in the public interest, it must meet one or more of the following conditions, without adversely affecting the other two: saves consumers money over the long run; enables better grid management; and reduces negative environmental impacts.[23]

Indeed, Maine's new statutory definition of beneficial electrification reflects a similar outlook:

> "Beneficial electrification" means electrification of a technology that results in reduction in the use of a fossil fuel, including electrification of a technology that would otherwise require energy from a fossil fuel, and that provides a benefit to a utility, a ratepayer or the environment, without causing harm to utilities, ratepayers or the environment, by improving the efficiency of the electricity grid or reducing consumer costs or emissions, including carbon emissions.[24]

This report is intended to serve as a primer for Maine legislators on beneficial electrification. For the remainder of this report, unless otherwise noted, the term "electrification" is used as synonymous with "beneficial electrification" in applications where it is reasonable to assume that the criteria for the statutory definition would be met. Section 3 describes the types of technologies that can support electrification. Section 4 reviews how electrification can help Maine meet its GHG reduction targets through a focus on a subset of these technologies. Section 5 identifies a range of social, technological, legal, regulatory, and economic barriers to electrification generally and, where possible or applicable, explains how they manifest in Maine specifically. It presents the range of potential solutions to these barriers, as reflected in the literature, identified by stakeholders, and/or actively being implemented in Maine or in other jurisdictions. In this way, it introduces a suite of opportunities for legislators to consider in future policymaking. Section 6 reviews the potential roles of electric and natural gas utilities in supporting electrification and Section 7 identifies which areas or populations in the state are less likely to benefit directly from electrification. Finally, recommendations regarding opportunities for beneficial electrification in Maine are summarized in Section 8.

[23] Farnsworth, David, Jim Lazar, Nancy Seidman and Jessica Shipley. "Beneficial Electrification: Ensuring Electrification is in the Public Interest." Regulatory Assistance Project (RAP). June 19, 2018. p. 9

[24] 35-A Maine Revised Statutes (MRS) §10102.

3 Electrification Technologies

There are several technologies in existence that can technically support electrification of various end-uses currently dominated by fossil fuels. This section provides an overview of these technologies in heating and transportation applications.[25] It ends by identifying the three key electrification technologies for a near-term focus.

3.1 Buildings Sector

Heat pump technology is the current foundation of beneficial electrification of space and water heating in the buildings sector. The process involves the transfer of thermal energy from one area to another using "refrigerant" and an electric-powered vapor compression cycle. Because they move heat rather than generating it through combustion or electric resistance, heat pumps can achieve extremely high efficiency levels. The top models currently sold in Maine can achieve a Coefficient of Performance (COP) of 1.5 even when the temperature outside falls to 0 degrees F. Even after accounting for the energy losses that occur at the power plants that serve the New England grid, together with line losses that occur when electricity is transmitted across the grid to the end user, the average efficiency of high-performance heat pumps in Maine exceeds 100%. Though the focus here is on heating, it is useful to note that this technology also provides air conditioning; by simply operating in reverse, heat pumps can transfer heat out of a space and expel it outdoors.

How do heat pumps make heat when it is freezing cold outside?

Heat pumps have two "heat exchangers" that are made up of tubes and fins, like the radiator in a car. The heat exchangers allow for hot fluid to cool quickly and cold fluid to heat quickly, in a closed loop. As a heat pump's "refrigerant" (a specialized fluid that has a boiling point of -55.4°F at atmospheric pressure) circulates from the outdoor unit to the indoor unit, it is compressed and allowed to expand. For the heating cycle, the fluid is compressed before it gets sent to the indoor unit as a gas. When a gas is compressed, it gets hot. That hot gas is passed through the heat exchanger in the indoor unit. A small fan inside the indoor unit blows air from the room over that heat exchanger, heating the air and pushing it out into the room to warm the space. Inside the heat exchanger, as the gas releases heat it turns to liquid. At this point, the liquid is "decompressed" through an expansion valve, undergoing the same kind of temperature change experienced when you empty a propane tank or a can of whipped cream. This cools the refrigerant. This very cold liquid is then passed through the heat exchanger in the heat pump's outdoor unit. The liquid at this point is colder than the outdoor air; even under pressure, the boiling point of the refrigerant is well below 0°F. Air passing over the heat exchanger warms up the liquid, which literally boils and turns to gas. The warm gas is then compressed again and the cycle repeats. The cycle also can be run in the reverse direction, making the fluid cold and then blowing room air across the indoor exchanger to air cool and dehumidify the space.

[25] LD 1464 requires the Trust to address beneficial electrification in the heating and transportation sectors. The Trust focuses this report on the space heating and domestic water heating that occurs in buildings, but excludes industrial process heating. It also excludes heating associated with cooking.

3.1.1 Space Heating

Air-source heat pumps (ASHPs) transfer heat in and out of buildings using ambient thermal energy in the air as a heat reservoir. They consist of an outdoor unit connected to indoor air handlers by refrigerant lines, which carry thermal energy (either hot or cold) between the two.

A wide range of ASHP systems are available:

- *Air-to-air* heat pumps extract heat from outdoor air and deliver it into a stream of air indoors. (In cooling mode, they reverse this process, extracting heat from indoor air and delivering it to a stream of air outdoors.) They can be ductless or ducted, serve one or multiple indoor units ("heads") that push the heat into the room, and use a variety of indoor unit types (e.g., wall units, floor units, ceiling cassettes, or mini-ducts). Long used for cooling in warm climates, these heat pumps are now able to provide efficient heating in cold climates, even at outdoor temperatures as low as -15 °F.

- *Variable refrigerant flow (VRF)* systems also extract and reject heat from the surrounding air, but they are sized for larger commercial loads. VRF systems run at varying speeds to provide zoned, simultaneous heating and cooling to different parts of a building.

- *Air-to-water* heat pumps also extract heat from outdoor air but deliver it into a stream of water rather than air. This water circulates through a hydronic system (e.g., radiant floors, radiant walls and radiant ceiling panels, fin-tube baseboard), emitting heat into indoor space. Though air-to-water heat pumps can also reverse direction for cooling, they must circulate chilled fluid to a separate air coil to distribute air conditioning.

Ground-source heat pumps (GSHPs) transfer heat in and out of buildings using the ground (or groundwater) as a heat reservoir. GSHPs are an established technology with a variety of different options for the ground loop (e.g., closed loop, open loop, direct exchange) and wells (e.g., horizontal, vertical, standing column). Ground loops can also be placed within nearby bodies of water.

3.1.2 Water Heating

Heat pump water heaters (HPWHs) heat water using heat from the surrounding air inside a building's unconditioned space (typically a basement). They are generally designed as hot water storage tanks with heat pump elements attached to the top. HPWHs can operate at efficiencies of 2-3 times greater than electric resistance water heaters. HPWHs are sometimes called "hybrids" because in addition to a heat pump, they are also fitted with a traditional electric resistance heating element to supplement the heat pump when there is a need for rapid heating of the tank.

In addition to generating space heating, *air-to-water heat pumps* (mentioned in section 3.1.1) can provide hot water. In these applications, the system has an additional component – a dedicated water storage tank. Again, while HPWHs draw heat from an indoor unconditioned space, air-to-water heat pumps draw heat from outdoors.

3.2 Transportation Sector

The transportation sector covers a wide range of activities involving the movement of goods and people from place to place. Traditionally, most travel and freight movement, whether by roads, rail, water, air, or otherwise, involves technologies powered by internal combustion engines (ICEs) that run on fossil fuel. In many cases, these can be replaced with similar technologies powered by electric motors and batteries. In addition to one-for-one replacements, beneficial electrification in the transportation sector can be achieved by mode switching (e.g., moving passenger transit from ICE cars to electric buses or trains).

3.2.1 On-Road Vehicles[26]

Light-duty vehicles (LDVs) include passenger cars and light trucks (such as pickups, vans, and sport utility vehicles). Electric vehicles (EVs) can be powered solely by an electric motor with a battery (a Battery Electric Vehicle or BEV) or by a combination of both an electric motor and a gasoline engine (a Plug-in Hybrid Vehicle or PHEV). EVs are about 60% efficient in translating stored electrical energy into forward motion, which is three times as efficient as an ICE vehicle; as a result, EVs consume 70-80% less energy per mile traveled.[27] Most BEV models can travel farther on electricity alone than PHEVs because they have larger batteries. However, BEVs do not have a fuel backup so when the battery is exhausted, the only way to continue driving is to recharge the battery. Plug-in Hybrid Vehicles have a longer total driving range because they can be powered by the gasoline energy after their battery is exhausted, but PHEVs have shorter range on electricity alone. Light-duty EVs generally, and passenger EVs in particular, are a commercial technology that is slowly but consistently gaining market penetration in the US.

The technologies available for *Medium-duty vehicles (MDVs),* (e.g., delivery trucks, heavy-duty pickups, school buses, bucket trucks) and *Heavy-duty vehicles (HDVs),* (e.g., garbage trucks, city transit buses, tractor trailers, dump trucks, cement trucks) are effectively the same as those available for smaller vehicles. However, MDVs and HDVs are at a less mature state of development than electric light-duty passenger vehicles due to the technological challenge associated with moving more weight. Moving heavier loads requires more energy, and for EVs storing that extra energy requires a larger battery (or a fuel cell with a hydrogen tank). As the energy density of batteries (the amount of energy stored per unit weight) increases, electric models of MDVs and HDVs may become more prevalent. For the moment, they are being deployed in applications that involve short-distance travel and frequent stops, such as city transit and delivery. For example, New York City is actively phasing out its diesel buses and plans to have an all-electric fleet by 2040.[28] Amazon recently announced the order of 100,000 electric delivery vehicles that will start to deliver packages to customers in 2021.[29]

[26] Vehicle classification by the U.S. Department of Transportation's Gross Vehicle Weight Ratings (GVWR) and Vehicle Inventory Use Service (VIUS) categories.
[27] McCoy, JJ. "Building 'good load' to reduce carbon emissions: Getting Northwest utilities more involved in widespread transportation electrification." Northwest Energy Coalition. January 22, 2016.
[28] Spivack, Caroline. "MTA retires old diesel buses as it moves toward all-electric fleet." Curbed New York. May 6, 2019.
[29] Amazon. "Amazon Co-founds The Climate Pledge, Setting Goal to Meet the Paris Agreement 10 Years Early." Press Release. September 19, 2019.

3.2.2 Watercraft

Electric motors and batteries can also propel all manner of watercraft, including ships, boats, and offshore supply vessels. As with on-road vehicles, watercraft that travel shorter distances and carry less weight are currently better candidates for electrification due to the state of battery technology. Globally, there were 185 battery-powered vessels operating or scheduled for delivery in 2018, 58 of which were passenger ferries.[30] A related opportunity in this category is the provision of shoreside electrical power ("shore power"), whereby docked vessels plug into the electric grid for any idling needs rather than using on-board electricity powered by the ICE or external fossil-fuel fired generators.

3.2.3 Non-road Vehicles and Mobile Machinery

Recreational off-road vehicles, such as snowmobiles and all-terrain vehicles (ATVs) are also good candidates for electric motors and batteries. There are several emerging electric models of these vehicles. For example, the Taiga Ekko snowmobile extended range model can travel 81 miles on a single charge.[31] Tesla recently introduced the CyberQuad ATV in connection with its release of its new all-electric pickup truck.

The non-road mobile machinery category of technologies covers a host of vehicles that are typically intended to carry out a specific task in a specific environment. They include everything from large construction and agricultural equipment (e.g. excavators, tractors, combines, skid-steer loaders) to lawn mowers, warehouse forklifts, ground support equipment at airports, and cargo-handling equipment at ports, terminals, and railyards. Many of these vehicles require energy for both propulsion and their intended work task. Once again, lighter equipment with less energy-intensive work tasks have greater market penetration at this time.

3.2.4 Rail

Electric trains leverage power from a conductor running along the track, either in the form of a suspended overhead line or a third rail mounted at the track level. This technology can replace trains using on-board, diesel-fueled engines.

[30] Hodges, Jeremy and Mikael Holter. "The Next Ferry You Board Might Run on Batteries." Bloomberg. March 13, 2018.
[31] Mountain Sledder. "Taiga Motors Ekko Electric Mountain-Specific Snowmobile." June 11, 2019.

3.3 Near-Term – Key Electrification Technologies

Among the wide range of electrification technologies introduced above, there are several that merit particular attention due to their significant potential to advance Maine's goals of reducing carbon emissions and lowering energy costs. This report refers to these technologies of focus as "key electrification technologies."

This report relies on several criteria for determining the key electrification technologies. First, the technology must be commercially available now; it should not be years away from coming to market. Second, the performance of the technology, including its functionality and economics, must be sufficiently attractive to Maine consumers that it holds the promise of widespread adoption in the next decade. While there are certain to be important electrification technologies that will play an important role in future decades, the Trust has elected to focus the remainder of this report on those technologies facing barriers and solutions that Maine, as a state, is in a position to address through near-term policies and programs. Third, the potential savings (whether measured in dollars or greenhouse gases) on individual units, and across the entire Maine economy, must be significant. Thus, technologies that hold potential for widespread use in future decades, or that offer savings now but only for limited application or with limited market demand, are not considered "key" in this report.

In 2018, Northeast Energy Efficiency Partnerships (NEEP) released the *Action Plan to Accelerate Electrification in the Northeast,* laying out a near-term (5-year) strategy for the region. The plan states:

> A handful of mass-market advanced electric technologies will account for the bulk of strategic electrification. While a number of important technology applications exist for the buildings, transport, and industrial sectors, three technologies will likely form the backbone of most program and policy efforts to replace direct use of fossil fuels with renewable electricity: EVs, heat pumps, and HPWHs.[32]

Indeed, heat pumps,[33] HPWHs, and EVs are the three key electrification technologies that we focus on in this report. They are commercially available today. They are attractive to Maine customers due to their functionality and their economics. As such, these key technologies have the potential for rapid penetration of Maine's marketplace which in turn could lead to very significant carbon savings and benefits to the Maine economy. The remainder of this report will focus on this subset.

[32] Northeast Energy Efficiency Partnerships (NEEP). "Action Plan to Accelerate Strategic Electrification in the Northeast." 2018. p. 14

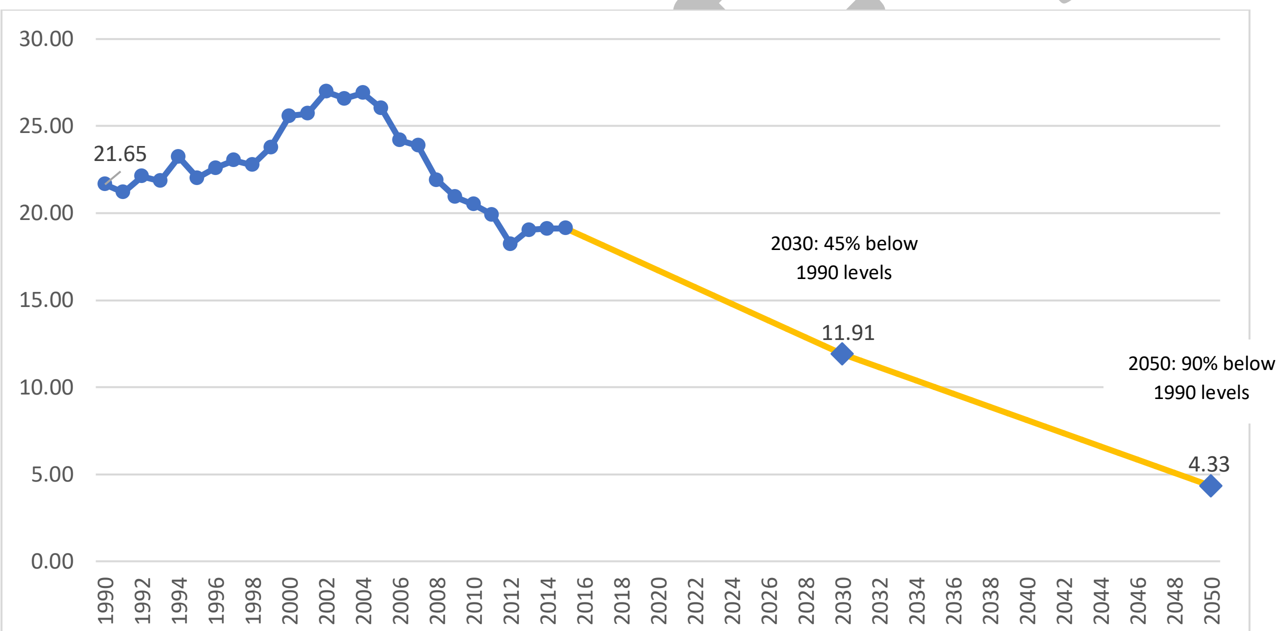
[33] Unless otherwise specified, the term "heat pump" will refer to high-performance air-to-air heat pumps as defined by the Trust.

4 Meeting Maine's Carbon Reduction Targets

Along with a growing number of other jurisdictions, Maine has adopted aggressive greenhouse gas (GHG) emission reduction goals to address climate change. In the spring of 2019, the Maine Legislature set the following binding targets through *LD 1679 – An Act To Promote Clean Energy Jobs and To Establish the Maine Climate Council*:

- By January 1, 2030, the State shall reduce gross annual greenhouse gas emissions to at least 45% below the 1990 gross annual GHG emissions level; and
- By January 1, 2050, the State shall reduce gross annual greenhouse gas emissions to at least 80% below the 1990 gross annual GHG emissions level.[34]

Figure 2: Maine's historical GHG emissions and reduction targets[35]



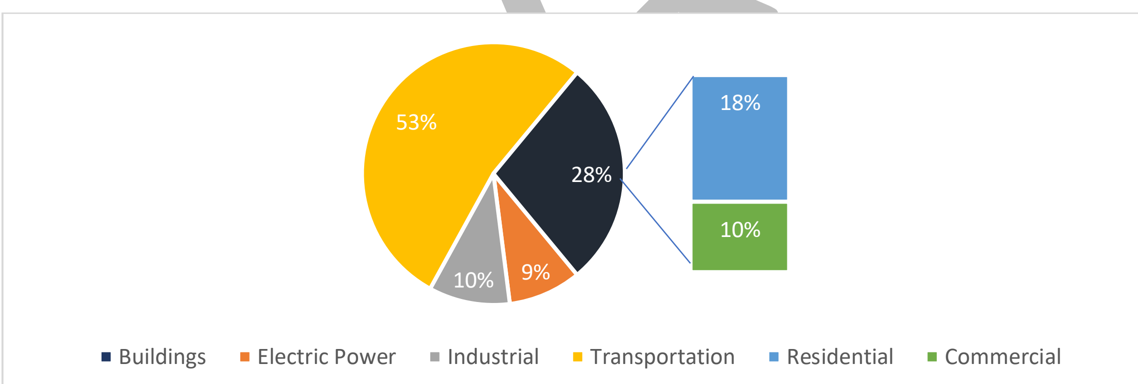
Similar to most other state and market actors, Maine has thus far focused much of its GHG reduction efforts on increasing renewable electricity supply and improving energy efficiency. For example, the recently amended Renewable Portfolio Standard (RPS) requires 80% renewables for retail sales of electricity in 2030 and 100% in 2050.[36] The RPS has been complemented with a directive for procurement of long-term contracts for solar electricity and amendments to laws governing net metering for clean distributed generation. On top of these policies, State law directs the electric utilities and natural gas utilities to fund, through rates, programs planned and administered by the Trust to

[34] Public Law, Chapter 476, L.D. 1679, 129th Maine State Legislature – An Act To Promote Clean Energy Jobs and To Establish the Maine Climate Council. §576-A.
[35] Maine Department of Environmental Protection (DEP). "Seventh Biennial Report on Progress toward Greenhouse Gas Reduction Goals." January 2018. Appendix A.
[36] Public Law, Chapter 477, L.D. 1494, 129th Maine State Legislature – An Act To Reform Maine's Renewable Portfolio Standard.

capture "the maximum achievable cost-effective energy efficiency."[37] It is important to note that in Maine, the Trust is limited to investing *electric* utility ratepayer funding for measures[38] where *electricity* cost savings is a significant contributor to achieving cost-effectiveness. Similarly, the Trust is limited to investing *natural gas* utility ratepayer funding for measures where *natural gas* savings is a significant contributor to achieving cost-effectiveness. This means, for example, that unless there is evidence of significant use of electricity for space heating, air sealing and insulating a home that is heated principally by oil, propane or kerosene is not an eligible use of funding derived from electricity.

Notwithstanding the progress in GHG reduction from the policies mentioned above, there remain significant emissions resulting from direct fossil fuel use in buildings (residential and commercial), transportation, and industry as shown in Figure 3. Maine's RPS and solar policies have limited direct impact on those fossil fuel emissions for all but the electric power sector. And what funding the Trust is allowed to use conserve fossil fuels (i.e., revenues from RGGI, the Forward Capacity Market, and the Volkswagen Settlements) is vastly less than the size of the opportunity for GHG savings from heating and transportation. Figures 4 and 5 show the emissions attributable to specific fossil fuel types in the buildings sector. In the transportation sector, emissions are overwhelmingly driven by gasoline use, as well as some diesel.[39]

Figure 3: Maine emissions from fossil fuel combustion by sector for 2015



[37] 35-A MRS §10104. In other jurisdictions, this requirement is often referred to as the "all cost-effective standard." An energy conservation measure is considered to achieve "cost-effectiveness" where the net present value of the measure's economic benefits exceeds the net present value of the costs over the full lifetime of the measure.
[38] The Trust uses the term "measure" to describe an action, such as the purchase and installation of various appliances, pieces of equipment, control systems, or energy practices, that achieves savings (of energy, cost, and/or carbon) that would not have otherwise occurred. As used in this report the term does not mean "metric" or the act of measuring.
[39] Figures 3, 4 and 5 Adapted from Maine DEP Seventh Biennial Report on Progress toward GHG Reduction Goals.

Figure 4: Maine's 2017 residential building emissions from direct fossil fuel combustion by fuel type

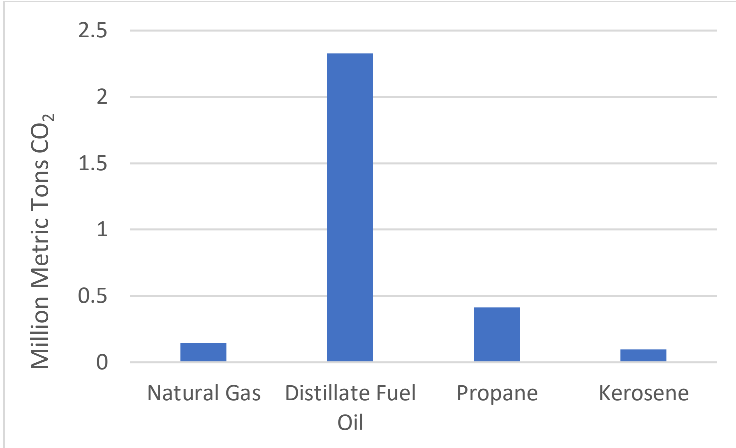
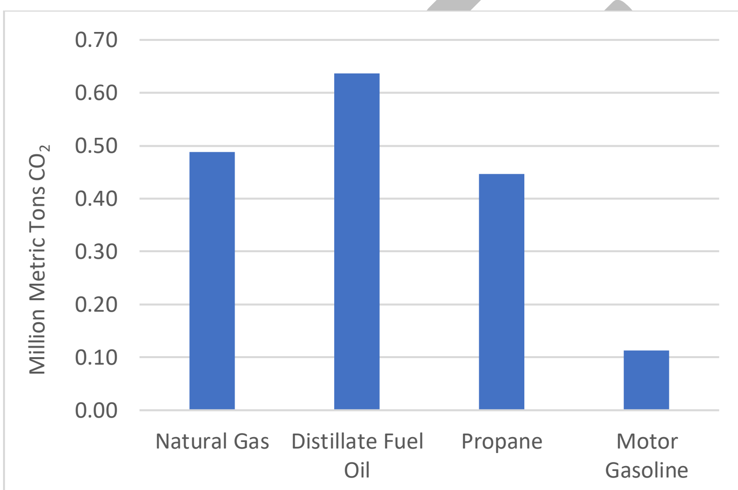


Figure 5: Maine's 2017 commercial building emissions from direct fossil fuel combustion by fuel type



As seen in Figure 6, the bulk of direct fossil fuel end use (70%) is attributable to space and water heating in the buildings sector and LDVs in the transportation sector. These are the same end-use targets for the key electrification technologies identified in section 3.3 (heat pumps, HPWHs, and EVs). That said, the key electrification technologies can play a significant role in curbing a large portion of the state's overall emissions. Indeed, a regional analysis from the Brattle Group shows the major impact of targeting electrification of heating and transportation with respect to achieving emissions reduction targets (see Figure 7). Though the breakdown for Maine would be slightly different than for the region reflected in this graph, the differences are minor and the general takeaways are transferable.

Figure 6: Direct fossil fuel use by end use and sector in Maine (BTUs) [40]

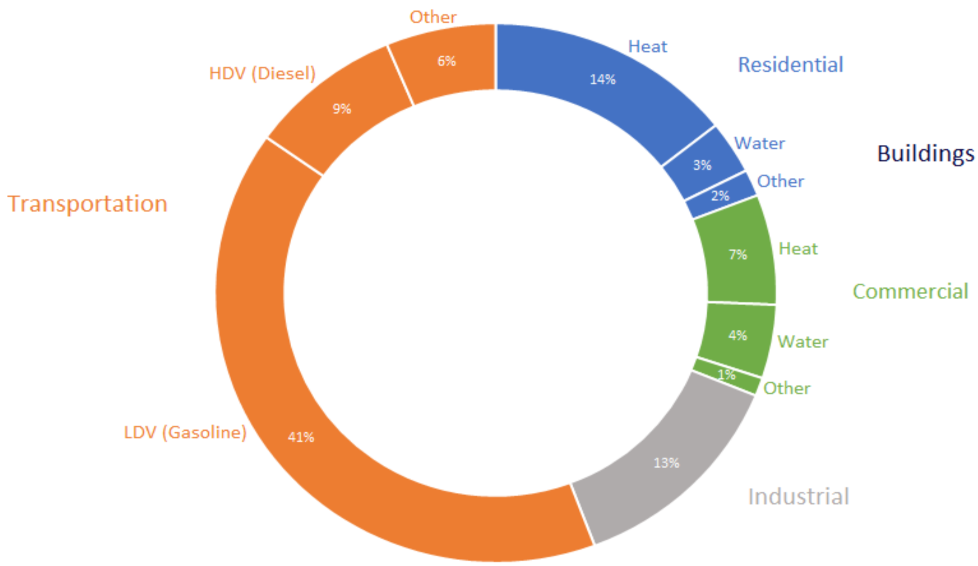
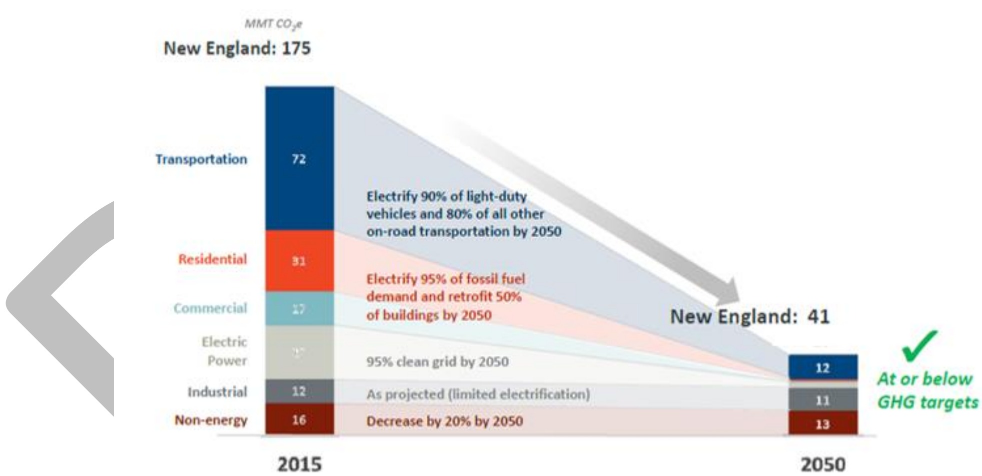


Figure 7: Brattle Group - One Potential New England Decarbonization Path[41]



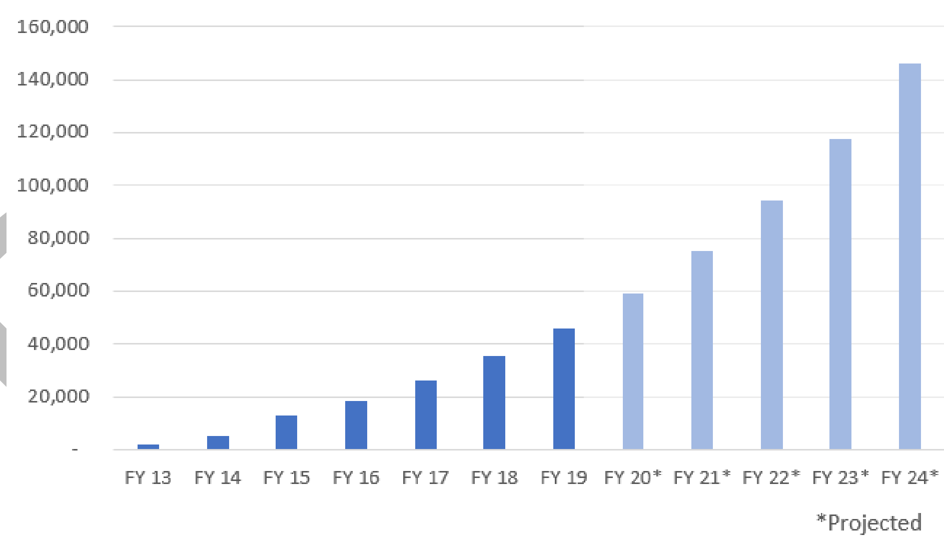
Determining a precise estimate of the number of heat pumps, HPWHs and EVs required to achieve Maine's emissions reduction targets is beyond the scope of this report and should be considered as a potential topic for future analysis. Nevertheless, it is worth putting some of these carbon reduction figures into context. For example, electrifying 90% of LDVs could mean that over 1.2 million passenger

[40] Extrapolated from northeast data in NEEP 2018 Action Plan p. 12
[41] Hagerty, Michael J. and Jurgen Weiss. "Achieving 80% GHG Reduction in New England by 2050." The Brattle Group. September 2019. p. 6

EVs would be registered and operating in Maine by 2050; there are currently only about 3,000.[42] Electrifying 95% of fossil fuel demand for heating in residential buildings could mean installing well over a million heat pumps and 500,000 HPWHs[43]; there are currently about 43,000 and 24,500 respectively. While these estimates are based on some crude assumptions, they are helpful in capturing the relative magnitude of the task ahead.

Though it may seem small relative to the scale of the Brattle Group's decarbonization trajectory, Maine has made notable progress and set forth aggressive goals with respect to the key electrification measures. Maine has the highest per-capita penetration of heat pumps in the U.S., with at least 46,000 installed over the past seven years in residential and commercial settings.[44] In the spring of 2019, the Maine Legislature enacted LD 1766: *An Act To Transform Maine's Heat Pump Market To Advance Economic Security and Climate Objectives*, establishing a goal of installing 100,000 new high-performance heat pumps in Maine over five years and providing a supplementary funding mechanism for the Trust's incentive programs. For scale, note that Massachusetts plans to install roughly 62,000 units between 2019 and 2021[45] and Vermont plans to install 35,000 units between 2016 and 2025[46]. New York has a target of 5 TBtu of customer energy usage reduction through heat pumps by 2025; assuming Maine's patterns of consumer demand, this would equate to roughly 167,000 units.[47]

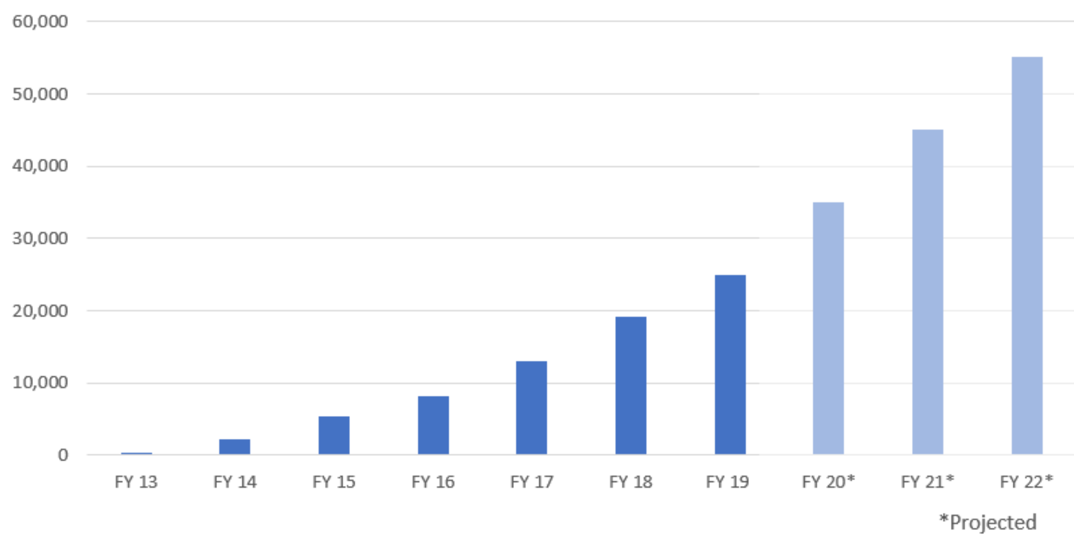
Figure 8: Cumulative Efficiency Maine-funded Heat Pump Installations



[42] Registration data from Maine Bureau of Motor Vehicles as of October 23, 2019.
[43] These estimates assume two heat pumps and one HPWH per household, and account for installations that have been made as of 2019. They further assume that these technologies would be suitable to all dwelling types, which we know is not the case. While these assumptions are imperfect, they are useful illustrating the challenge and opportunity for electrification of space heating and water heating in Maine.
[44] This is the number of heat pumps incentivized through the Trust's programs from FY2013-FY2019. For the commercial and industrial sector, the count is based on the number of outdoor units. For the residential sector, the count is based on the number of indoor units. Beginning in 2020, the Trust will transition to counting outdoor units for all installations.
[45] McCarey, Maggie. "Massachusetts 2019-2021 Energy Efficiency Plan." Massachusetts Department of Energy Resources. Presentation June 20, 2019.
[46] VT 2016 Comprehensive Energy Plan, p 8.
[47] The Trust models predict 30 MMBtu/year for the first single-zone high-performance unit installed.

Maine is also leading the nation with respect to HPWH adoption. The Trust has incentivized 25,000 units over the past seven years and plans to incentivize an additional 30,000 over the next three years. These programs are driving impressive market penetration; 60% of new electric water heaters sold in Maine are HPWHs, compared to 2% in the rest of the country.[48]

Figure 9: Cumulative Efficiency Maine-funded HPWH Installations

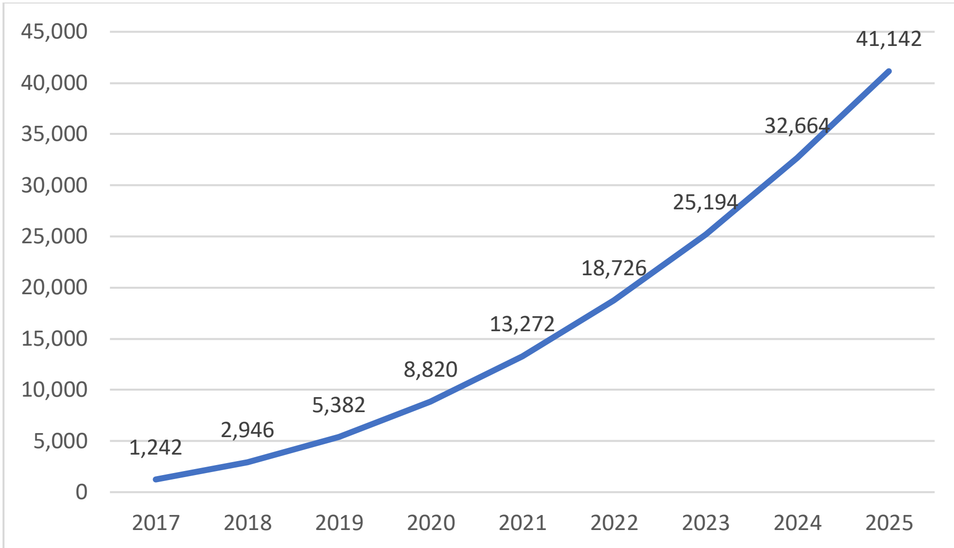


With regard to EVs, Maine is one of 10 states that have adopted California's Zero Emission Vehicle (ZEV) program that requires automakers to achieve prescribed targets of ZEVs.[49] Figure 10 depicts an adoption curve for Maine based on the ZEV delivery requirements for all participating states under the program through the 2025 vehicle model year. It is important to note that this is a rough estimate, and estimates vary; the requirements do not reflect the actual number of ZEVs that may be in operation on the road in a given state in the corresponding years due to the credit earning, banking, and regional pooling provisions of the ZEV regulation.

[48] Efficiency Maine Trust Board Meeting Minutes. October 30, 2019.

[49] Governor Mills formally signed the ZEV Task Force Memorandum of Understanding in November, 2019, committing to coordinated action to ensure the successful implementation of state zero-emission vehicle (ZEV) programs.

Figure 10: Cumulative EV Registrations in Maine based on ZEV Mandate Projections[50]



[50] Bainwol, Mitch. Letter from the Auto Alliance to Governor Paul LePage. May 31, 2018.

5 Overcoming Barriers to Electrification

This section of the report identifies a range of social, technological, legal, regulatory, and economic barriers to electrification generally and, where possible or applicable, explains how they manifest in Maine specifically. It presents the range of potential solutions to these barriers, as reflected in the literature, identified by stakeholders, and/or actively being implemented in Maine or in other jurisdictions. In this way, it introduces a suite of opportunities for legislators to consider in future policymaking. Subsection 5.1 reviews cross-cutting barriers and solutions that apply to any and all electrification measures, while Subsection 5.2 reviews barriers and solutions associated with the key electrification technologies specifically.

5.1 Cross-Cutting Barriers and Solutions

5.1.1 The Grid

Barriers

Demand Growth

Shifting energy end uses to the electrical grid will drive up demand for electricity and add to electric load. Take the example of a home that electrifies its space and water heating and transitions from an ICE vehicle to an EV. If the household is heating with a heat pump on a cold evening, starts to charge the car upon arrival home from work, and draws down on the hot water heater for dishwashing and showers, the peak demand from the home could more than double.[51] The Brattle Group's analysis of an emissions goal-driven electrification scenario for New England predicts a similar impact across the region, with annual electricity usage in the region increasing 103% by 2050[52] (See Figure 11). It also points to a significant shift in the size and timing of peak demand (See Figure 12). While the current peak occurs in the summer months due to high air conditioning usage, electrification of heating drives a considerable increase in the winter months. Overall peak demand increases 134%. By extrapolating from the Brattle Group's regional projections and applying them to baseline load growth forecasted by ISO-New England, we can make a rough estimate of the predicted impacts for Maine under this scenario: electricity usage would increase from 13.2 million MWh to 16.7 million MWh and peak demand would increase from 2,217 MW to 5,188 MW.[53]

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[51] NEEP. "Northeastern Regional Assessment of Strategic Electrification." 2017. p. 61

[52] Brattle. "Achieving 80% GHG Reduction in New England by 2050." 2019. p. 8. In the winter months, the Brattle Group analysis projects that monthly usage could increase under this scenario by as much as 170%.

[53] For baseline regional load growth forecasts, see Independent System Operator for New England (ISO-NE), 2019 Forecast Data, May 2, 2019.

Figure 11: Projected 2050 New England Demand – Monthly Energy (TWh)[54]

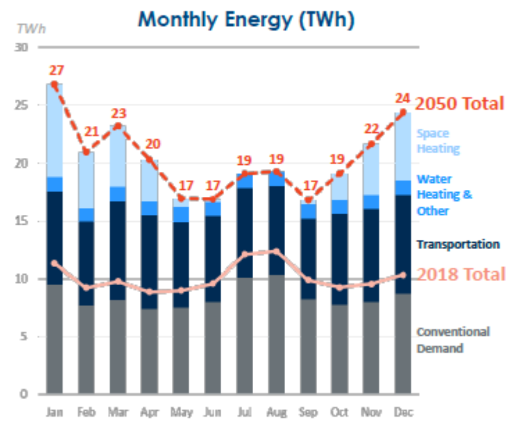
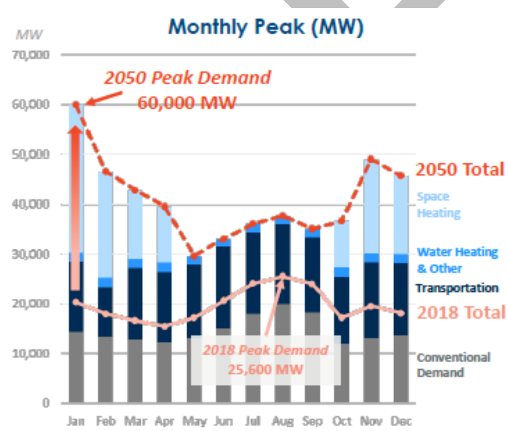


Figure 12: Projected 2050 New England Demand – Monthly Peak (MW)[55]



Renewable Energy Supply

Meeting increased demand for electrification will require additional supply. As previously mentioned, Maine's new Renewable Portfolio Standard requires 100% renewable power generation by 2050. Supplying a significant increase in electricity while replacing almost all the fossil-fuel fired power plants with emissions-free generation is a considerable undertaking. Further compounding this challenge is the variable nature of renewables. Given that the typical renewable resource – a solar panel or wind turbine – is not dispatchable at all hours, the capacity of all resources, including short- and long-duration storage needed by 2050, will need to grow even more.[56] The Brattle Group's analysis estimates that, for New England as a whole, this could require a total of 160 GW of generation capacity by 2050 – five times the current installed capacity. Though the pace of renewable resource deployment is picking up, Brattle estimates that New England will need to accelerate annual deployments four- to eight-fold compared to what is planned for the coming decade.[57]

[54] Brattle. "Achieving 80% GHG Reduction in New England by 2050." 2019. p. 9
[55] Id. at p. 9
[56] Id. at p. iv
[57] Brattle. "Achieving 80% GHG Reduction in New England by 2050." 2019. p. v

Long-term investments in transmission and distribution (T&D) will be required to both support a larger electrical load and integrate new, variable sources of renewable power while maintaining reliability. Inasmuch as these investments involve significant financial, logistical, and political undertakings, they represent a barrier to beneficial electrification. The potential costs and benefits for ratepayers is an issue that must be considered. Determining the Maine-specific magnitude and timing of those costs is beyond the scope of this report, representing an area for further research and input from the state's electric utilities. It is worth noting, however, that the short-term outlook is generally positive; up until the point that increased electricity consumption requires additional T&D investment, it will tend to lower the per-unit cost of electricity for consumers. This is particularly helpful in areas of the Maine grid that are experiencing surplus capacity. For example, in the territory of Emera Maine (Emera), changes in demographics and the loss of several large paper mills has resulted in surplus capacity on the T&D system. Emera estimates that "the additional revenues associated with 20,000 new heat pumps [in its territory] would reduce overall rates by approximately $6 million per year."[58]

It is also worth mentioning that a recent statutory change requires that future T&D infrastructure build-out requests from electric utilities in Maine be subject to a more rigorous non-wires alternatives (NWA) assessment process by an independent coordinator housed at the Office of the Public Advocate (OPA) and by the Public Utilities Commission (PUC).[59] The NWA Coordinator, working in collaboration with the Trust will have the opportunity to assess whether demand reduction strategies can meet reliability needs at a lower cost, ultimately ensuring the best value for ratepayers.

Solutions

Load Flexibility

The capacity needs of the grid (for both T&D infrastructure and energy supply) are determined by the peak load; power generation potential and infrastructure must be in place to accommodate the highest possible usage point. Therefore, any efforts to reduce peak load mitigate the need for additional grid investment, and thus, reduce the costs to ratepayers. The more evenly that electricity use is spread across the hours of the day, the more efficiently we are using the grid. At the same time, the system will need to become increasingly flexible in order to reliably integrate growing amounts of intermittent renewable generation. Loads that more closely follow renewable generation profiles will reduce the need for curtailments, clean energy capacity, and storage capacity.

An interesting feature about the key electrification measures under consideration in this report is that, to varying degrees, they can contribute to load management. For example, HPWHs can preheat water for use at a later time, and EVs can delay charging up their batteries. With this flexibility, these measures can shift their use/charging at times when there is lower demand for electricity or when renewable energy generation is being curtailed, and away from times where there is greater demand and the need to dispatch dirtier generation resources. Beyond mitigating the impact of the end-uses themselves, this characteristic of the key electrification measures makes them well-suited to serving as distributed energy resources (DERs) to increase operational flexibility on the part of grid operators. These end-uses

[58] Cohen, Jim. Testimony of Emera Maine to the Joint Standing Committee on Energy, Utilities and Technology. LD 1766 – An Act To Transform Maine s Heat Pump Market To Advance Economic Security and Climate Objectives. May 23, 2019.
[59] Public Law, Chapter 298, L.D. 1181, 129th Maine State Legislature – An Act To Reduce Electricity Costs through Nonwires Alternatives.

are prime candidates for shaping dynamic loads and providing grid services because of the energy storage capacity associated with their use: EVs have electric batteries, HPWHs have water tanks, and heat pumps heat and cool spaces that have the ability to store that heat (or cooling) for a period of hours.[60]

A study by the National Renewable Energy Laboratory (NREL) explores the impact of shifting electric end uses to reduce peak demand in a hypothetical, highly electrified 2050 scenario for the United States. Under very conservative assumptions about load-shifting, more flexible loads reduced peak by 17,000 MW (1.5%).[61] The report's authors write: "Although seemingly modest in magnitude relative to the overall system, the avoided capacity could help reduce billions of dollars in system expenditures, which presumably would be passed on to consumers."[62] The authors also note: "Changes to peak load, and shifts to load shapes more generally, can be sensitive to the degree of demand-side flexibility, which we include in our modeling but only to a limited extent."[63] Though the exact load flexibility potential in Maine is a subject for further research, it is fair to say that it can generate meaningful savings for utilities and ratepayers, thereby helping to overcome barriers associated with electrification-driven load growth.

Rate Mechanisms

One way to leverage the benefits of this load flexibility is through rate mechanisms that set price signals to incentivize or disincentivize certain behaviors. Indeed, the value of flexible electrified loads must be communicated through the electricity prices consumers pay or avoid. To that end, electric utilities can use various forms of time-varying pricing, charging different rates per kWh consumed depending on the time of day, season, and type of day (e.g., critical peak day) to better align prices with costs of producing and delivering electricity.

Several jurisdictions are using this approach to mitigate the grid impacts of electrification, particularly with respect to EV charging. A pilot study in San Diego concluded that Time of Use (TOU) rates (set at specific levels for specific hours of the day) are highly effective at encouraging customers to charge during low-cost times, with up to 90% of customers choosing to charge during "super off-peak" periods.[64] Generally, the wider the difference between on- and off-peak rates, the greater the likelihood that customers will respond to the price signal. For example, NV Energy in Nevada has a TOU EV rate which includes significant differentials between on- and off-peak power (40.7 cents versus 5.53 cents).[65] Some jurisdictions use more variable, fluctuating "real-time pricing" reflecting the actual cost of electricity in a given hour. Though this approach requires considerable monitoring on the part of

[60] While preheating air is technically feasible (and more effective in buildings with robust envelopes with better temperature retention) it has a higher potential for customer dissatisfaction. Another option is for heat pumps to store thermal energy in water tanks so the hot water can be used later in hydronic heating systems.

[61] Mai, Trieu, Paige Jadun, Jeffrey Logan, Colin McMillan, Matteo Muratori, Daniel Steinberg, Laura Vimmerstedt, Ryan Jones, Benjamin Haley, and Brent Nelson. "Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States." 2018. National Renewable Energy Laboratory (NREL). p. 78.

[62] Id. at p. 79.

[63] Id. at p. xv.

[64] The Regulatory Assistance Project (RAP). "Getting from Here to There: Regulatory Considerations for Transportation Electrification." May 2017. p. 16.

[65] Id. at p. 16.

customers, the savings can be a strong motivator; for example, Commonwealth Edison customers in Illinois that charged their EVs at off-peak times reduced their average costs by 45%.[66]

These and other rate mechanisms could certainly be implemented in Maine as a way to incentivize load shifting. The state already has the basic infrastructure in place with its high penetration of advanced smart meters with two-way communication. In fact, Central Maine Power (CMP) and Emera have experimented with time-varying rates in the past for certain circumstances. At the moment, however these are not available for standard offer rates. In considering this strategy, policymakers should be aware that it is not always effective. As alluded to above, if the rates are not significantly differentiated between on-peak and off-peak times, they are less likely to change behavior. Additionally, to the extent they result in bill increases for some customers, time-varying pricing can be politically unpopular.

Controls

Another way to leverage the flexibility of the key electrification measures is through controls – embedded technology that responds to programmable time presets, price signals, or real-time third-party commands. For example, many EVs have the ability to schedule charging for a specific time, allowing drivers to delay energy usage until off-peak hours. Embedded technology can also allow third parties to modulate and dispatch devices remotely, moving energy use to times when the grid is most capable of providing the service. For example, Southern California Edison (SCE) has applied demand response to workplace EV charging, providing customers favorable rates for their willingness to allow charging to be slowed or stopped when background power grid demand increased.[67]

Load Flexibility Pilot Projects in Maine

The Trust is currently managing a number of pilot projects that seek to study and demonstrate load flexibility strategies in Maine and are relevant to the solutions described in this section. Lessons learned from these pilots will be useful in designing any future programs, which could be operated by the Trust or the electric utilities.

The first of the Trust's pilots involves the installation of a fleet of between 50-100 dispatchable smart DERs, including a mix of ASHPs, HPWHs, EV chargers and residential battery storage systems. Each device is both fully programmable and interconnected to a central operations and dispatch network operated by a third party. Throughout the test year, the provider will run a series of demand response use cases using both automated controls and centralized dispatch to demonstrate the ability of DERs to participate in and respond to time-varying pricing, discrete dispatch events, and (simulated) wholesale regional markets. One goal is to analyze the benefits that may accrue to the participants in terms of customer energy savings and cost reductions. A second goal is to analyze the potential benefits that may flow to ratepayers as a whole. To this end, the Trust is evaluating the potential for aggregated DER fleets to contributed to energy and capacity price reductions, non-transmission alternatives to grid reliability needs, and reduced long-term grid infrastructure investments.

The Trust's second relevant pilot involves working with Isle au Haut Electric Power Company. This pilot is designed to leverage the thermal storage capacity of various air-to-thermal storage heat pumps (including air-to-water heat pumps, air-to-phase change material heat pumps and refrigeration loads) as

[66] RAP. "Getting from Here to There." 2017. p. 17
[67] Id. at p. 23.

a way to move abundant, but low-value or wasted, daytime solar production to evening and nighttime hours. The project plans to achieve this reallocation of energy consumption by automatically “charging” the devices while the sun is shining and using them when it is not.

In a third pilot, the Trust is working to implement passive load management using phase change material (PCM) technology in cold storage applications at grocery stores and warehouses. In this pilot, the Provider will deploy and evaluate the impact of PCM-based thermal storage technologies with advanced, intelligent controls.

With respect to EVs, the Trust is currently analyzing the interval data for a subset of EV drivers in Maine to better understand their charging behavior and timing, as well as the resulting coincident load. This work will inform a future pilot project currently under consideration by the Trust involving the use of incentives to encourage off-peak charging.

5.1.2 Upfront Costs

Barriers

The upfront cost of electric technology to replace or displace conventional fossil-fired options is a critical barrier to electrification. This effect is particularly strong in the “retrofit” scenario, where a customer replaces a piece of fossil-fuel burning technology before the end of its useful life. It is difficult to rationalize investing money on a new piece of equipment when the current piece is fully functional and may continue to operate for many years (e.g., as in the case of an existing car or heating system). Even in the “lost opportunity” scenario, where the customer is actively seeking a new piece of equipment, whether to replace “burned out” equipment or in the context of new construction, the price of the electric technology is often higher than the fossil-fuel burning alternative. Consumers naturally tend to choose the model that has the lowest purchase price, even though the electric equipment might save money in the long run.

Obviously, the upfront cost barrier is exacerbated for customer sectors with disproportionate financial limitations, such as low-income households, small businesses, and municipalities, and for those who face aggressive expectations for return on investment (ROI) such as large, multi-national manufacturers. This topic is discussed in greater detail in section 5.1.5. The upfront cost barrier is also intensified in property rental situations, where the landlord owns and operates the building heating equipment, but the tenant pays the utility bills. Here, the “landlord-tenant split incentive” is at play: the landlord has even less of an incentive to pay the upfront cost of electrification, given that he will not benefit from the associated operating cost savings.

For detail on cost barriers as they relate to each key electrification measure specifically, see section 5.2 (Measure-Specific Barriers and Solutions).

Solutions

Financial Incentives

Financial incentives help defray the incremental upfront costs of electric replacement technology, thereby encouraging customers to make the alternative investment. They include rebates, grants, loans, tax credits and tax exemptions.

In Maine, the Trust is the primary administrator of energy-related rebates and grants. It currently offers incentives for all of the key electrification technologies: heat pumps, HPWHs, and EVs. For some measures, customers can sometimes access additional rebates from manufacturers.[68] Additionally, other third parties occasionally provide grants to support electrification; for example, the Maine Department of Transportation continues to leverage Volkswagen (VW) settlement funds to support all manner of projects to reduce NOx emissions, including electric shuttle buses.[69] In some cases, third-party funds can complement and enhance the incentives offered through the Trust. Though the Trust has yet to leverage this type of partnership for electrification specifically, it has done so for various energy efficiency initiatives. For example, The Nature Conservancy in Maine recently offered an additional 50% incentives for small municipalities completing lighting upgrades through the Trust's Commercial and Industrial Prescriptive Program. Nonprofit groups and other stakeholders in Maine are keen to replicate this model in the future, fostering positive synergies and avoiding duplication of efforts.

Loans can cover the upfront cost of an electrification project and allow the customer to pay the balance over time. Any number of loan programs can support this type of investment, whether it be a simple bank loan, a loan from a dedicated green bank, a property-assessed loan, or a loan from a utility in the form of on-bill financing. In Maine, the Trust offers a variety of loans for residential and small business customers to support building energy projects but the capital currently available for growing the number and size of loans is limited.

Tax credits allow customers to subtract a certain amount from the total taxes they owe, while tax exemptions relieve customers of having to pay the tax to begin with. In recent years, federal income tax credits have been available for EVs and GSHPs though their continued availability is uncertain. Maine does not provide any state-level tax credits or tax exemptions for the key electrification measures. By contrast, Colorado offers a state income tax credit on the purchase or lease of new EVs[70], Maryland provides a credit against the excise tax for EVs,[71] and New Jersey exempts EVs from sales tax.[72]

Mandatory Codes and Standards

While incentives can *encourage* electrification investment, mandatory energy codes and standards can *compel* it. They also have the benefit of accelerating market transformation of electrification technologies, improving economies of scale and driving costs down relative to their fossil fuel counterparts.

Generally, codes and standards apply to lost opportunity scenarios (new construction, major renovations, replacements of equipment at the end of its useful life). This focus has the advantage of being more cost-effective; the value proposition for integrated electrification at the time of design and construction likely to be high, and upfront installation obviates the need for costly retrofits in the future. For example, several studies estimate that installing EV-ready parking spaces at the time of construction

[68] See, e.g., Nissan's rebates.

[69] Maine Department of Transportation, Maine Department of Environmental Protection, Governor's Energy Office. "Maine Beneficiary Mitigation Plan Pursuant to Volkswagen Partial Consent Decree, Appendix D." 2019.

[70] Colorado Energy Office. Alt Fuel Vehicle Tax Credits.

[71] U.S. Department of Energy. Alternative Fuels Data Center. Plug-In Electric Vehicle (PEV) and Fuel Cell Electric Vehicle (FCEV) Tax Credit.

[72] New Jersey Motor Vehicle Commission. Vehicles Exempt From Sales Tax.

can be 75% less expensive than post-construction installations.[73] As it stands, Maine's building codes do not require any electrification measures or infrastructure[74], and the state does not have appliance standards exceeding the federal minimums.

Many jurisdictions are exploring ways to use building codes and standards to support electrification. In California, for example, the state has established goals to achieve net zero energy in all new residential construction by 2020, and all new commercial construction by 2030, and is working to codify those goals in building codes.[75] Some municipalities in California and Massachusetts have even passed ordinances banning natural gas hookups in new buildings.[76] Additionally, California has mandatory building standards for EV charging infrastructure installation in parking spaces at one- and two-family dwellings with attached private garages, multifamily dwellings, and non-residential developments.[77] Though codes and standards typically apply to lost opportunity scenarios, it is possible to target retrofits as well. For example, New York City recently instituted an emissions limit for all buildings over 25,000 square feet, requiring existing buildings to make the necessary investments by 2024 or face fines.[78]

Appliance and equipment standards are theoretically another way to compel electrification, though this has yet to be adopted by any jurisdictions.[79] The challenge lies in the fact that appliance standards are typically adopted separately for fossil fuel and electric devices. For example, there is a separate standard for gas water heaters and electric water heaters. In order to support electrification, the standard-setting process will have to consider the relative efficiency of electric appliances compared to non-electric alternatives.[80] For example, an appliance standard requiring all models of water heaters to achieve a COP greater than 2.0 would rule out everything but HPWHs.

5.1.3 Ongoing Operating Costs

Barriers

In recent decades, conventional wisdom has been that electricity is an expensive way to heat Maine homes. While this is true for electric *resistance* heating used in baseboard systems, small space heaters, and water heaters, the outcome is entirely different when electricity is run through high-performance, heat pump space heaters and water heaters. In fact, high-efficiency electrification measures reduce overall energy consumption enough to deliver lower operating costs than their fossil-fuel burning

[73] Pike, E. et al. "Driving Plug-in Electric Vehicle Adoption with Green Building Codes." 2018 ACEEE Summer Study on Energy Efficiency in Buildings.

[74] The Maine Uniform Building Code and Uniform Energy Code consists of a compilation of international and national standards from 2013 and 2015, including the 2015 International Building Code and the 2013 American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards.

[75] California Public Utilities Commission and California Energy Commission. "New Residential Zero Net Energy Action Plan 2015-2020." June 2015.

[76] See e.g., Berkeley, Menlo Park, San Luis Obispo (CA) and Brookline (MA).

[77] U.S. Department of Energy. Alternative Fuels Data Center. Mandatory Electric Vehicle Supply Equipment (EVSE) Building Standards.

[78] New York City Mayor's Office of Sustainability. Climate Mobilization Act summary.

[79] Email correspondence with Steve Cowell at E4 the Future Octobe 23, 2019.

[80] Deason, Jeff, Max Wei, Greg Leventis, Sarah Smith, Lisa C Schwartz. "Electrification of buildings and industry in the United States: Drivers, barriers, prospects, and policy approaches." Lawrence Berkeley National Laboratory. March 2018. p. 43.

alternatives. For example, heating water with a HPWH saves the average residential customer $280 annually as compared to heating it with his or her propane boiler.[81]

Indeed, the price of electricity relative to fossil fuels is critical to the prospects for beneficial electrification; to the extent electricity prices increase, this will tend to reduce or possibly even eliminate the lifetime cost savings that high-efficiency electrification options have over fossil-fired alternatives. Rising electricity prices would constitute a barrier to beneficial electrification because where operating costs of electric measures exceed those of fossil-fuel burning alternatives, customers will be less inclined to choose the electric options. Even if the economics favor an electric alterative, lower fossil fuel prices will tend to slow the pace of transition to electrification.

For policymakers seeking to use market forces to meet carbon targets, it is important to consider the suite of policies applied to each of the competing fuel types and determine if there is a level playing field. For example, electricity sold in Maine currently is subject to three charges that are not universally applied to all fossil fuels: 1) a conservation charge to fund energy efficiency programs, 2) a carbon charge associated with power generator compliance with the Regional Greenhouse Gas Initiative (RGGI)[82], and 3) sales tax.[83] There is a conservation charge for natural gas and a sales tax on most motor fuels.[84] Unregulated heating fuels, by contrast, are exempt from these charges.

Solutions

Rate Mechanisms

As mentioned in Section 5.1.1, rate mechanisms are a tool for influencing customer behavior and shifting electricity usage to off-peak hours. To the extent customers using key electrification technologies are compensated for this grid benefit, it can also improve their ongoing operating costs when compared to the status quo of flat rates. Another option is for utilities to offer favorable rates for specific electrified end-uses to further improve their value proposition. For example, Great Lakes Energy (GLE) in Michigan offers an “efficient electric heat rate” to homeowners who install qualifying ASHPs or GSHPs.[85] Emera currently offers a special residential space heating rate in Maine, though it is not limited to efficient technologies (i.e., includes electric resistance heating) and only applies to systems installed prior to 1995.[86]

Consistent Price Signals

If the inconsistency in charges exacerbates the operating cost differentials between electricity and fossil fuels, applying consistent price signals across the fuel types is one way to improve the economics of electrification. In Maine, this could mean establishing a conservation charge and/or sales tax on unregulated heating fuels. This strategy is operational in Vermont, were a $0.02 per gallon tax on

[81] Per Efficiency Maine Water Heating Cost Calculator. October 22, 2019.
[82] RGGI is a nine-state regional initiative to limit carbon emissions from electricity generators. Large generators are required to purchase “carbon allowances” in an amount equal to their annual carbon emissions. Allowances are sold at quarterly auctions for this purpose. In Maine, proceeds from the auctions are transferred to and managed by the Trust.
[83] In Maine, there is a sales tax exemption for residential electricity consumption below 750 kWh and for certain commercial activities. See Maine Revenue Services - Sales, Fuel & Special Tax Division. Instructional Bulletin No. 13. Sales of Fuel and Utilities (Coal, Oil, Wood, Electricity, Gas, and Water). May 15, 2018.
[84] See Maine Revenue Services Fuel Tax Rates listing.
[85] Great Lakes Energy. Efficient Electric Heating Rate.
[86] Emera Maine. Maine Public District Tariffs. 2019.

heating oil, propane, kerosene, and other dyed diesel fuel helps fund the state's Low-Income Weatherization Program.[87]

It could also mean instituting a price on carbon for all fuels, including natural gas, unregulated heating fuels, and motor vehicle fuels. With respect to motor vehicle fuels, it should be noted that Maine is currently taking part in the Transportation Climate Initiative (TCI) – a collaboration of Northeast and Mid-Atlantic states that is discussing a regional cap-and-trade initiative for emissions from transportation fuels. The current proposal calls for regulation of large upstream fuel suppliers, requiring them to hold allowances to cover reported emissions.[88] Much like RGGI, suppliers would embed these added costs in the price of their products, thereby transferring the price signal to consumers.

5.1.4 Funding for Incentive Programs

Barriers

As described above, financial incentives are an important tool in helping overcome the upfront cost barriers associated with transitioning to electric end-uses. A related challenge is the lack of appropriate, sustainable funding sources to support those incentives.

Though the Trust does not leverage electric or natural gas utility ratepayer funding for fuel switching *per se* (as described in Section 4), it currently has several other funding sources available to support incentives for electrification. As previously mentioned, the new Maine law establishing the goal of installing 100,000 high-performance heat pumps directs the Trust to use all Forward Capacity Market (FCM)[89] revenues to supplement its existing rebate programs.[90] Additionally, the Trust is managing over $8 million in VW settlement funds to support EV rebates and grants for EV charging stations.[91] Finally, Maine statute allows the Trust to use RGGI funds for measures that reduce GHG emissions. [92]

While these funding sources are critically important to enable the Trust to offer incentives for cost-saving electrification measures, they do not offer sustained support for large-scale electrification beyond the next three years. New power generators coming online to abate the region-wide shortage of generation capacity are causing the Trust's FCM revenues to decline. The VW settlement is a one-time,

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[87] Vermont Department of Taxes. FORM FGR-615 Instructions - Fuel Tax and Petroleum Distributor Licensing Fee Tax Return. September 2019.

[88] Transportation & Climate Initiative of the Northeast and Mid-Atlantic States. Framework for a Draft Regional Policy Proposal. October 1, 2019.

[89] FCM funds are proceeds from the Trust's capacity resources, which are bid into the Independent System Operator for New England (ISO-NE) markets. The compensation the Trust receives from the FCM is for the reduction of demand delivered through qualifying efficiency projects that are tracked and reported by the Trust.

[90] Public Law, Chapter 306, L.D. 1766, 129th Maine State Legislature – An Act To Transform Maine's Heat Pump Market To Advance Economic Security and Climate Objectives.

[91] In 2016 and 2017, Volkswagen (VW) agreed to settle allegations that it violated the federal Clean Air Act by installing "defeat devices" on certain diesel vehicles. Under consent decrees reflecting one settlement agreement, Maine (through the Maine Department of Transportation) received settlement funds from VW. Through a Memorandum of Understanding, the State contracted with the Trust to administer approximately $3.15 million to promote electric vehicle charging infrastructure to help reduce greenhouse gases and improve the energy efficiency of transportation in the state. Separately, VW settlements funds also were awarded to the Office of the Attorney General for the State of Maine. Of these funds, $5.1 million were transferred to the Trust for the purpose of running a program to reduce carbon and nitrogen oxide (NOx) emissions through the promotion and increased use of electric vehicles.

[92] 35-A MRS §10109.

discrete payment that is likely to be exhausted in the next two years. RGGI revenues, while steady, are limited and represent the Trust's only funding source available for home weatherization.

Solutions

There are no easy answers for where or how revenues could be generated to facilitate incentives promoting electrification in Maine. Maine has, since the 1990s, directed regulated utilities to fund energy conservation programs. These investments have helped Maine consumers lower their energy bills by hundreds of millions of dollars and have reduced the long-term cost of the grid. Also, Maine has more than a decade of experience funding incentives for energy and carbon savings through RGGI.

Nationally and regionally, there are emerging proposals to apply the RGGI concept to sources of carbon other than large power plants. In addition to sending important price signals that help level the playing field among fuel types, regulating carbon from other major sources, such as transportation fuels and heating fuels, could generate revenue streams that could be strategically invested to support customer incentives for electrification.

Similarly, policy tools like sales taxes and conservation charges can also serve the dual price-signal, revenue stream purpose, though reinvestment initiatives using these funds are typically limited to the fuel type from which they were derived. In 2010, the Maine Legislature directed the Trust to study, among other things, instituting some type of charge on unregulated heating fuels in order to support incentives for heating fuel efficiency projects (e.g., weatherization). In its 2010 *Heating Fuels Efficiency and Weatherization Fund Report* to the Maine Legislature, the Trust recommended a conservation charge for heating fuels as the most reliable and sustainable funding mechanism for this subset of projects.[93]

Another approach, in place in other states, is to allow energy efficiency programs to leverage conservation funds for fuel-switching incentives. Indeed, many jurisdictions are revisiting energy efficiency policies in light of the fact that beneficial electrification conflicts with certain traditional energy efficiency goals (e.g., driving a net reduction in electricity load), but advances carbon emissions reduction goals. As the authors of a recent article in *Electricity Journal* write:

> Policy goals are shifting from the simple energy conservation focus of yesteryear toward achieving greenhouse gas (GHG) reductions. Therefore, we need to assess the GHG emissions associated with various ways to power end uses, as opposed to simply the number of kilowatt-hours consumed. To that end, we submit that "emissions efficiency" may be as or more important than "energy efficiency" moving forward.[94]

For example, regulators in Massachusetts recently approved a three-year energy efficiency plan that shifts electric programs to recognize the benefits of strategic electrification, and for the first time offers incentive programs for fuel switching.[95] Similarly, regulators in California recently updated the state's "Three-Prong Test for Fuel Substitution" allowing the $1 billion annual budget for energy efficiency to be

[93] Efficiency Maine Trust. "Heating Fuels Efficiency and Weatherization – Final Report." December 15, 2010.
[94] Dennis et al. "Environmentally beneficial electrification." 2016. p. 52
[95] MassSave. "Massachusetts Joint Statewide Electric and Gas Three-Year Energy Efficiency Plan – 2019-2021." April 30, 2018. p. 18.

directed toward aggressive building electrification goals. It is important to note that California's new rules apply to natural gas only, and do not allow funding for switching away from unregulated fuels.[96]

5.1.5 Access for Customer Groups Facing Particular Investment Challenges

There are multiple categories of customer groups in Maine, as elsewhere, that face particular challenges investing in efficient, clean technology. These categories include, but are not limited to, low-income households, small businesses, and large, publicly traded industrial customers. While they each have some unique features, they share at least one common barrier when it comes to energy efficiency and carbon reductions: overcoming the upfront costs of investing in the project or purchase is relatively harder for them than it is for other customer groups.

Barriers

According to the Maine Department of Health and Human Services, there are roughly 175,000 households who qualify to receive assistance through any State or federal program in which low income and/or limited assets are criteria for eligibility. This represents approximately 31.5% of all households in the state.[97] Unsurprisingly, Maine's low-income residents spend proportionally more of their budgets on energy than higher income residents. The statewide, average (mean) home energy burden (portion of household income spent on heat and electricity) for low-income households is 19 percent. In contrast, the mean energy burden for all households in the state is 6 percent.[98] The challenge for low-income Mainers dealing with transportation costs is similar.

To the extent electric measures enjoy lower operating costs than their fossil-fuel alternatives, low-income Mainers stand to save money from electrification. Nevertheless, upfront cost barrier is particularly acute for low-income households. It is also a disproportionately significant barrier for other customer groups with financial limitations, including small businesses and municipalities. Without tax obligations, municipalities and some low-income individuals have the added disadvantage of not being able to make use of tax credits.

Solutions

One way to overcome the exacerbated upfront cost barrier for these groups is to provide enhanced incentives. For example, the Trust's rebates for residential heat pumps are higher in its income-qualifying Affordable Heat Initiative than they are through the standard Home Energy Savings Program. As the Trust begins to roll out program changes associated with LD 1464's new 100,000 heat pump initiative, it will have further financial capacity to support enhanced incentives for low-income households. With respect to EVs, the Trust also provides a 50% higher incentive for low-income individuals and a 100-375% higher incentive for Maine governmental entities or tribal governments.

In many cases, these customer groups lack the upfront capital to take advantage of cost-share incentives. Another option therefore is to deliver programs that purchase and install beneficial electrification equipment at no charge to the customer. For example, the Trust covers the full cost and

[96] Borgenson, Merrian. "CA's $1 Billion for Efficiency Now Open to Electrification." August 1, 2019.
[97] U.S. Census. QuickFacts: Maine. 2013-2017.
[98] Allison, Avi, Jennifer Kallay and Alice Napoleon. "Maine Low-Income Home Energy Burden Study." Prepared for the Maine Office of the Public Advocate. Synapse Energy Economics, Inc. June 3, 2019.

coordinates installation of HPWHs for qualifying low-income households. Similarly, the Maine State Housing Authority now provides heat pump installations for the state's neediest families through its federally funded Low-income Home Energy Assistance Program).

5.1.6 Consumer Awareness

Barriers

Lack of consumer awareness presents a barrier to electrification in that it inhibits adoption of electric replacement technologies. Fossil-fuel burning vehicles and space and water heating technologies benefit from the inertia of the "known and familiar." In many cases, consumers are simply not aware of the range of electric replacement technologies available on the market or do not understand how they operate or the extent of their capabilities. Furthermore, consumers might not know of the long-term benefits associated with transitioning to electric, and may not be familiar with the range of incentives available to improve that calculation. Generally, the less of this information a consumer has, the less likely they are to make an investment.

Solutions

To the extent there are specific consumer awareness barriers and solutions that apply to the key electrification measures, those will be discussed in the measure-specific barriers section. However, here it is worth noting the basic strategies for overcoming this challenge: marketing, outreach, and education.

Private entities along the supply chain play a critical role in raising consumer awareness through their marketing efforts. For example, manufacturer advertising, distributor or retail point-of-purchase materials, and one-on-one conversations with one's contractor, all have the effect of raising awareness and potentially starting a conversation about electrification options.

The Trust complements these efforts in its role as the impartial source of energy information as it relates to Maine consumers. Its day-to-day activities involve reaching potential customers through tailored marketing and outreach campaigns across its various programs. The Trust also provides general energy information and education through its website, events, and other activities to help consumers considering the installation of energy conservation measures. It delivers tools and resources to support decision making related to energy conservation, including best practices, usage tips, calculators, purchasing guides, and vendor locators. The Trust seeks to boost energy savings by increasing awareness of the benefits of cost-effective, customer-sited energy resources and operating practices and behaviors, and by providing basic guidance in how to access Efficiency Maine programs.

Any additional marketing, outreach, and education efforts on the part of government entities, non-profit organizations, and utilities help to further amplify these important messages. It is important that these groups work together to provide consumers with clear and consistent information.

5.1.7 Supply Chain Challenges

Barriers

In the same way that lack of consumer awareness presents a barrier to the adoption of beneficial electrification measures, so too does the lack of awareness among those in the supply chain. If engineers, vendors, and installers are unfamiliar with these technologies, they are less likely to pitch, supply, and market them to their customers. If they are misinformed about product capabilities or other details, they might share incorrect information with their customers.

In some cases, awareness is not the issue. On one hand, a manufacturer, vendor, or installer may have simply determined that focusing on fossil-fuel technologies will yield better returns, and therefore does not make electric measures a business priority. On the other hand, the electric technology business might be so strong that they do not have sufficient inventory or workforce to keep up with demand. Building workforce is a particular challenge given Maine's record low unemployment and ongoing labor shortage.[99]

Solutions

To the extent there are specific supply chain barriers and solutions that apply to the key measures, those will be discussed in section 5.2. However, here it is worth noting the basic strategies for overcoming these challenges: outreach and education, training, codes and standards, and incentives.

Outreach and education about electrification can raise awareness among the general public, reaching supply chain entities in the same way that it does all consumers. Once again, the Trust is well-positioned to champion this effort with the support of other stakeholders. It is also worth noting that the Trust holds periodic webinars and technology-specific advisory committee meetings with the supply chain community, using these and other platforms for the reciprocal exchange of information on program design and messaging. It could leverage these forums to support informed information sharing on electrification.

Training is an important way to not only deepen awareness in the supply chain community, but also equip businesses with the knowledge, skillset, and workforce necessary to support actual implementation of electrification. In Maine, the Trust is actively involved in technical trainings offered by manufacturers and community colleges, sharing best practices in marketing, installing, and maintaining energy upgrades to maximize energy savings, cost-effectiveness, and customer satisfaction. The Trust also provides financial support for trainings in the form of participant scholarships and equipment grants.

If codes and standards require consumers to purchase electrification technologies, they compel the supply chain to manufacture and stock those technologies. They can thereby accelerate market transformation, improving economies of scale and driving costs down relative to fossil fuel counterparts. This improves the value proposition for consumers and suppliers alike.

Similarly, incentives can encourage customers to purchase electrification technologies, thereby pushing the supply chain to manufacture and stock those technologies. To the extent a customer-based incentive fuels demand for a certain product, the supply chain will have an interest in meeting that demand.

[99] Anderson, J. Craig. "Maine's preliminary unemployment rate for July hits record low." *Portland Press Herald*. August 16, 2019.

5.2 Measure-Specific Barriers and Solutions

5.2.1 Heat Pumps for Smaller Buildings

Barriers

Cost

The cost of switching to heat pumps varies greatly depending on the size of the number of units installed and the complexity of the installation. Even in the simplest and most cost-effective scenario – a single-head heat pump installation in a relatively large, residential open space that is easy for installers to access – the average installed cost in Maine is roughly $3,750.[100] In these cases, the heat pump typically serves as a supplemental heating source, allowing the customer to displace fuel consumption from an existing fossil-fuel heating system. The Trust's analysis indicates that when properly installed and operated, high-performance heat pumps will save between $300-600 per year, depending on the characteristics of the home.

Lack of Consumer Awareness

Though basic awareness of heat pumps is seemingly on the rise in Maine, there are significant misconceptions about their technical capabilities. Unlike older generations of the technology, new high-performance heat pumps operate at temperatures as low as negative 15 °F and are well-suited to continue providing heat during Maine winters. Nevertheless, many heating technicians and homeowners are under the mistaken belief that it is better to turn off heat pumps in the winter months (relying entirely on their central fossil-fuel fired systems). In past years, this message was conveyed by fuel dealers across the state.[101] By turning this message around, Mainers will be able to maximize the savings they could achieve from this technology.[102]

There is also a lack of consumer awareness about efficient heat pump operation. For example, the technology appears to work best when maintaining a constant temperature. Unlike older heating systems, turning the heat pump down at night may actually cost more. Additionally, in cases where the unit is providing supplemental heat, it is important to coordinate the thermostats and operation of the heat pump and the central system, prioritizing the heat pump in the room(s) it services. If a central system has zones, the customer should turn down, or off, the thermostat for the zone where the heat pump is located. If the central system is not zoned or the zone of the heat pump is large, the customer should consider closing dampers, registers, or radiators in the room where the unit is located.

Finally, there are a number of maintenance requirements that help ensure maximum heat pump performance: dust filters should be cleaned regularly, allergen cartridges should be washed or replaced according to manufacturer recommendations, and outdoor units should be clear of obstructions like leaves or snow. To the extent a customer is unaware of these various operations and maintenance principles, he or she will not get the full benefit of efficient electric heat from his or her heat pump.

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[100] Financial Example on Efficiency Maine website.

[101] Turkel, Tux. "Heat pumps in Maine: Set it and forget it? Or turn it off in the winter?" *Portland Press Herald*. October 28, 2018.

[102] West Hill Energy and Computing. "Efficiency Maine Trust Home Energy Savings Program Impact Evaluation: Program Years 2014-2016." August 23, 2019

Supply Chain Challenges

The same awareness barriers that exist with general consumers extend to entities in the supply chain. As described above, there are significant misconceptions about heat pump technology among heating technicians, which in turn percolate down to customers. Additionally, contractors may not be aware of the installation requirements or operations and maintenance considerations for achieving maximum efficiency.

Additionally, the lack of workforce capacity is an active barrier in many parts of the state. In certain areas, it is not uncommon to have to wait several months just to get a consultation on a heat pump system; local installers are having trouble keeping up with demand, particularly in the summer and fall months. This may become even more of an issue as the push for additional installations accelerates.

Solutions

Reducing Costs

The full range of solutions to cost barriers described in sections 5.1.2 and 5.1.3 is applicable for heat pumps. In Maine, the Trust currently offers rebates and loans. It is worth reiterating that Maine's new heat pump legislation puts forth a funding mechanism to support significant expansion of the Trust's incentive program, allowing it to target a larger number of fuel-switching applications moving forward. Further to the goal of reducing costs and rapidly scaling up to meet aggressive carbon reduction targets, the Trust notes the nation-leading success it has achieved in part by minimizing complexity and limiting pre-requisites associated with its heat pump rebate programs.

Raising Consumer Awareness

The solutions to consumer awareness barriers are described in section 5.1.6. Indeed, the Trust has done significant public outreach to debunk performance myths and share up-to-date information with customers. For example, the Trust requires installers to provide each program participant with a copy of its User Tips,[103] and follows up with an email in the weeks following the installation. The User Tips are also available on the Trust's website, along with helpful videos and links. The Trust leverages Google Ads to drive customers toward this information. Staff also disseminate brochures, give presentations, and hold one-on-one conversations with customers at various energy fairs and other events across the state.

Automated Controls

One, more technical, solution to the underusage problem worth mentioning is automated controls; these are advanced thermostats that prioritize the heat pump over the central heating system, obviating the need for any manual adjustments on the part of the customer. The Trust is currently conducting a study to assess the energy savings from remote thermostats and/or integrated thermostats that can control both a heat pump and a boiler in 120 homes.[104] Results from this initiative may help inform a future incentive program for this type of technology.

Supply Chain Education and Workforce Development

[103] Efficiency Maine Heat Pump User Tips.
[104] Efficiency Maine Trust. "Program Opportunity for Remote and Integrated Thermostat Project." PON EM-008-2020. October 23, 2019.

Again, the range of possible solutions to these supply chain barriers is described in Section 5.1.7. In Maine, beyond its customer-facing outreach and education (which also indirectly targets the supply chain), the Trust is actively engaged in various initiatives focusing on manufacturers, distributors, and installers.

For example, in an effort to raise awareness and ensure quality installations, the Trust is instituting more rigorous training requirements for participating heat pump contractors. All qualifying training programs must cover certain topic areas and include the Trust's vetted PowerPoint presentation that highlights best practices, reviews system siting and selection considerations, and dispels common myths. All participating contractors will be subject to an annual recertification process, in which they will be required to take part in a short webinar and pass a quiz. The Trust is also in constant communication with the vendor community outside of formal trainings, engaging supply chain participants through advisory groups and targeted events.

The Trust promotes workforce development by providing training scholarships and by reimbursing community colleges for training equipment costs. Community colleges are also stepping up to meet the anticipated growth in demand for heat pumps in Maine. Central Maine Community College, for example, recently renovated one of its buildings to accommodate an expanded heat pump training facility. The private sector is following suit, with installers increasing staffing, new distributors moving to the state, and various entities offering more training opportunities.

5.2.2 VRF Heat Pump Systems for Larger Buildings

Barriers

Cost

A recent comparison of commercial heating system options in Maine found that, on average, VRF heat pump systems provide some of the lowest operating costs. Nevertheless, upfront installation costs are significant compared to fossil-fuel alternatives (See Figure 13). Among electric alternatives, however, VRFs are relatively cost-effective; results show that the average VRF system uses 15% less energy than a GSHP system and costs 56% less to install.

Figure 13: Cost Comparison for Commercial Heating Systems in Maine[105]

Heating System	Average Operating Cost (per kBtu)	Average Installed Cost (per kBtu)
rooftop unit with natural gas heating	$19.50	$412
air handler unit with air-cooled chiller with oil-fired hot water boiler	$38.60	$470
closed-loop GSHP	$18.15	$910.25
VRF system	$16.10	$506.25

It is important to note that VRF costs are highly dependent on building conditions and configurations. As expected, new construction installations tend to be the most cost-effective. To the extent retrofit

[105] Preliminary results of Energy & Resource Solutions (ERS) analysis for the Trust. December 5, 2019.

installations involve any interior renovations or wall repairs, they can be more costly. In cases where customers would otherwise have to undertake the expensive task of adding, reconfiguring, or replacing ductwork, however, VRFs can be more cost competitive. These systems can run refrigerant lines through existing ductwork and/or use ductless layouts. VRF systems are most effective when installed in buildings with multiple zones with divergent conditioning needs and are especially cost-effective when heat recovery is possible.[106]

According to Daikin North America LLC, the VRF market is the fastest growing segment of the commercial Heating Ventilation and Air Conditioning (HVAC) market, and is expected to experience double-digit growth continue over the next five to 10 years.[107] As the market matures, customers can expect to see a decline in equipment costs, making VRFs increasingly affordable.

Site Suitability

As mentioned above, VRF systems are reasonably well suited to retrofit applications in buildings with or without ductwork. However, if a building's existing ductwork is in good shape and meets the customer's configuration needs, updating the existing fossil-fuel heating system is likely to be significantly more economical.

Manufacturers report that VRFs are not well suited to large open spaces or big box-type stores.[108] In buildings with open floor plans and homogeneous heating and cooling demands, there is little opportunity to exchange energy between zones, limiting the heat recovery potential of VRF systems. These buildings would require energy-intensive fan power to adequately distribute conditioned air.

HVAC Contractor Familiarity

Though VRF systems are a growing market segment nationally, the fact remains that they are relatively new to the Maine marketplace compared to other heating systems. There are currently at least 86 VRF installations in the entire state.[109] Generally speaking, there is a lack of broad-based knowledge of these systems among the HVAC contractor community. VRF systems are considerably different than the traditional plug-and-play rooftop unit ducted systems. As a result, it is currently typical for manufacturers to provide substantial support to contractors in the VRF system design process, further driving up costs.[110]

Solutions

Reducing Costs

Again, the full range of solutions to cost barriers described in Sections 5.1.2 and 5.1.3 is applicable for VRFs. In Maine, the Trust offers incentives for VRF systems in new construction through its Commercial and Industrial (C&I) Prescriptive Program, and for retrofit systems through its C&I Custom Program. The

[106] Energy and Resource Solutions (ERS). "Emerging Technologies Incremental Cost Study Final Report." Prepared for Northeast Energy Efficiency Partnership. 2016. p. 15.
[107] Turpin, Joanna R. "VRF Market Expected to Hit $24B by 2022." The ACHR News. February 17, 2017.
[108] ERS. "Emerging Technologies Incremental Cost Study Final Report." 2016. p. 5
[109] These are the number of VRF installations that have received Efficiency Maine incentives.
[110] [FULL CITATION] ERS draft Report on VRF technology for the Efficiency Maine Trust, 2019.

Trust is actively monitoring this technology and the Maine market in hopes of refining its program offerings in the near future.

5.2.3 HPWHs

Barriers

Cost

In terms of operating costs, HPWHs are generally the cheapest way to heat domestic hot water.[111] However, the upfront cost of the equipment is relatively high. Additionally, given the size of the average HPWH unit, it typically requires two individuals to lift, adding to installation costs. Combining these factors, the average installed cost of a HPWH in a Maine home is $1,078.[112] The average installed cost of a natural gas storage water heater is $576.[113]

Site Suitability

HPWHs are not appropriate for all building types and configurations. They must be placed in a room with enough clearance from walls and ceilings to ensure adequate air circulation. They also require ambient air temperature above 35 °F to maintain efficiency. HPWHs are better suited to unconditioned basements than living spaces. Finally, due to storage tank limitations, HPWHs are currently only suitable for residential or small commercial applications with relatively small hot water demand.

Emergency Replacements

Over 80 percent of water heater replacements in the U.S. are failure-based unplanned purchases.[114] Many replace-on-burnout situations have a short decision cycle for replacement. Capturing these emergency replacements is a challenge, especially if it requires the adoption of a new or unfamiliar technology; there may not be time to educate decision makers before the purchase. Upfront cost is the primary driver in these situations. The tendency is often to replace the old equipment with the same model.

Limited Turnover

HPWHs are somewhat limited by turnover of existing water heating systems. Across the Northeast, the annual replacement rate of domestic hot water systems is less than 10%.[115]

Solutions

Reducing Costs

Again, the full range of solutions to cost barriers described in sections 5.1.2 and 5.1.3 is applicable for HPWHs. Currently, the Trust's Retail and Distributor Initiatives address the upfront-cost barrier by discounting the cost of the high-efficiency option to make it cost-competitive with the conventional option; this amount is set high enough to guide contractor or customer choice to the high-efficiency

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[111] Efficiency Maine Water Heating Cost Calculator.
[112] Efficiency Maine Trust. "Retail/Residential Technical Reference Manual." Version 2020.3, November 1, 2019. p 57.
[113] Id. at p 65.
[114] LeBrasseur, Francois. "How to increase the market penetration of HPWH." General Electric Appliances. p. 4.
[115] NEEP. "Northeastern Regional Assessment of Strategic Electrification." 2017. p. 16.

model. The markdowns also address the barrier presented by emergency replacements by having efficient options readily available at a competitive price compared to the conventional replacement model. This helps to overcome barriers presented by lack of information about efficient options or lack of time to research efficient options and available incentives.

5.2.4 Electric Vehicles

Barriers

Cost of new EVs

Though the incremental upfront cost differential is consistently shrinking over time, EVs remain more expensive to purchase new than ICE vehicles today.[116] This price differential is driven largely by the cost of batteries. Home charging equipment, for those who elect to install it, poses an additional expense for new EV owners (See Figure 14).

Notwithstanding the higher upfront cost of EVs, it is important to note that the ongoing operating costs for EVs are significantly lower than ICEs, given the relatively lower fuel price of electricity and the reduced maintenance requirements for EVs. In some cases, this can result in a net savings to the owner over the life of the vehicle. Though the calculation varies depending on the type of vehicle, it is fair to say that the higher the utilization rate (i.e., the more miles driven per year), the faster the return on investment.

[116] Coren, Michael J. "The median electric car in the US is getting cheaper." Quartz. August 27, 2019.

Figure 14: Three Primary Types of EV Charging Equipment[117]

	Description	Best Suited	Power Supply	Approximate Charging Time	Typical Costs*
Level 1	Typically the charger included with an EV purchase or lease.	Residential, workplace	Standard 120V outlet (standard home outlet)	8-15 hours	$300-$1,500 equipment; 0-$3,000 installation
Level 2	Most home and public chargers are Level 2.	Residential, workplace, multifamily dwellings	240 V (similar to an electric dryer outlet)	3-8 hours	$400-$6,500 equipment; $600-$12,700 installation *(networking typically increases costs)*
Level 3 or DC Fast Charging	Fastest kind of charging available.	Sites catering to through-travelers or sites with high demand	20-150 kW	20 min – 1 hour	$10,000-$40,000 equipment; $4,000-$51,000 installation

Technological limitations

EVs generally have a shorter range than ICEs. The median range is 412 miles for ICE vehicles. In 2016, the median range for EVs was 83.5 miles.[118] However, battery technology has improved considerably since then and continues to evolve. For example, the new Chevrolet Bolt can drive 238 miles on a single charge.[119] Moreover, there is a growing list of Plug-In Hybrid EV (PHEV) models that have 20-30 miles of battery range and a supplemental ICE engine that is available when traveling longer distances. Range limitation presents a barrier, whether real or perceived, to some drivers. It is worth noting that range concerns are exacerbated during Maine's cold winters; battery range diminishes under cold weather conditions.

For context, the average single-car household in the U.S. drives 30.5 miles per day.[120] Over half of all vehicle trips are between 1 and 10 miles, and trips of 100 miles or more account for less than one percent of all vehicle trips.[121] Though Mainers drive roughly 12% more miles annually than the national

[117] Efficiency Maine website.
[118] United States Department of Energy. "All-Electric Vehicle Ranges Can Exceed Those of Some Gasoline Vehicles." Fact #939. August 22, 2016.
[119] Autotrader. "Here are the 10 Electric Vehicles with the Longest Ranges." April 2017.
[120] United States Department of Energy. "Daily Vehicle Miles Traveled Varies with the Number of Household Vehicles." Fact #1037. September 17, 2018.
[121] United States Department of Transportation. "National Household Travel Survey." Federal Highway Administration, Office of Highway Policy Information.

average,[122] it is likely that these general trends persist; in other words, the vast majority of day-to-day driving behavior in Maine could be sufficiently served by the ranges provided by the current generation of EVs on the market.[123] Nevertheless, drivers are accustomed to the flexibility ICE vehicles, and wary of the constraints associated with limited range, which poses a barrier to increasing EV use in Maine.

On a related note, charge speed represents another technological barrier; while ICE vehicles can fully replenish their energy stores (a tank of gas) in a few minutes, most EVs take anywhere from 20 minutes to 15 hours, depending on the type of charger (See Figure 14).

Limited availability of reliable public charging stations

In order to facilitate broad adoption of EVs, it is widely accepted that the market will need to develop a network of publicly accessible charging stations where EV drivers can charge their cars when they are away from home. Even though, as mentioned above, most trips are short, and 80% of EV charging occurs at home,[124] it is important to accommodate the occasional situations where charging is needed outside the home. For example, some vehicle owners may not have sufficient range to complete a round-trip business trip or commute, or to reach a faraway destination at the end of the occasional road trip. Others, including residents of multifamily buildings, may not have access to off-street parking with charging infrastructure at home.

Beyond these very real practical concerns, studies show that the presence of publicly accessible charging infrastructure itself is important for driver peace of mind and general EV acceptance.[125] Surveys indicate that the availability of charging is a top concern of prospective car buyers in the northeast.[126] "Range anxiety" has emerged as a common term describing an EV owner's fear that a vehicle has insufficient range to reach its destination and would thus strand the vehicle's occupants.

Scaling up investment in charging infrastructure at workplaces, destination locations, and along commuting and major travel corridors helps increase consumer awareness of EV technology and build consumer confidence in a convenient and reliable charging network. This infrastructure should be uniformly accessible, avoiding interoperability barriers; some charging stations have specific network membership requirements or do not offer the full universe of plug types. Having the charging stations "networked" (i.e., connected to the Internet) also provides real-time information to drivers about where the stations are located, and whether they are in good working order and available (or occupied) – an important feature when charging infrastructure is limited.

Due to the modest upfront cost of the slower, Level 2 chargers, the barriers to host sites purchasing and installing publicly available Level 2 chargers are modest. Many hotels and B&Bs, as well as college campuses and municipalities, are installing Level 2 chargers around Maine. The main challenges are lack of familiarity with the product, deciding whether and where to dedicate parking spaces to EV chargers, and deciding whether to network the chargers and bill customers for the service of charging up their

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[122] Eno Center for Transportation. "U.S. VMT Per Capita by State - 2017."
[123] ME DOT recently subscribed to StreetlightData – an on-demand mobility analytics platform driven by big data from mobile devices. In the future, this platform will be able to provide more granular data, including information on daily vehicle miles travelled, as well as origin and destination.
[124] United States Department of Energy. "Charging at Home."
[125] Levinson, Rebecca S. and Todd H. West. "Impact of Public Electric Vehicle Charging Infrastructure." Sandia National Laboratory, Transportation Research Board 97th Annual Meeting. January, 2017.
[126] Edelman Intelligence. "Electric Vehicle Audience and Benchmark Survey." January, 2017.

batteries. By contrast, the barriers to purchasing and installing the Level 3 "fast chargers" are significant. In the contexts today, the business case for investing in, owning, and operating Level 3 public charging infrastructure is not adequately attractive for most private investors. There are considerable upfront costs associated with equipment and utility infrastructure, particularly for Level 3 stations. Additionally, electricity rates can be significant. Like other large electricity users, Level 3 charging stations are typically subject to utility tariffs that contain demand charges based on the maximum instantaneous power draw. While demand charges send an important price signal to utility customers and ensure the reasonable and equitable recovery of fixed distribution costs, they represent a significant barrier to the deployment of Level III charging infrastructure. When Level 3 charging usage is low, as it will be in the early phases of EV adoption, the demand charge can represent up to 90% of a station's monthly electricity bill, which is a prohibitively high operating cost.[127]

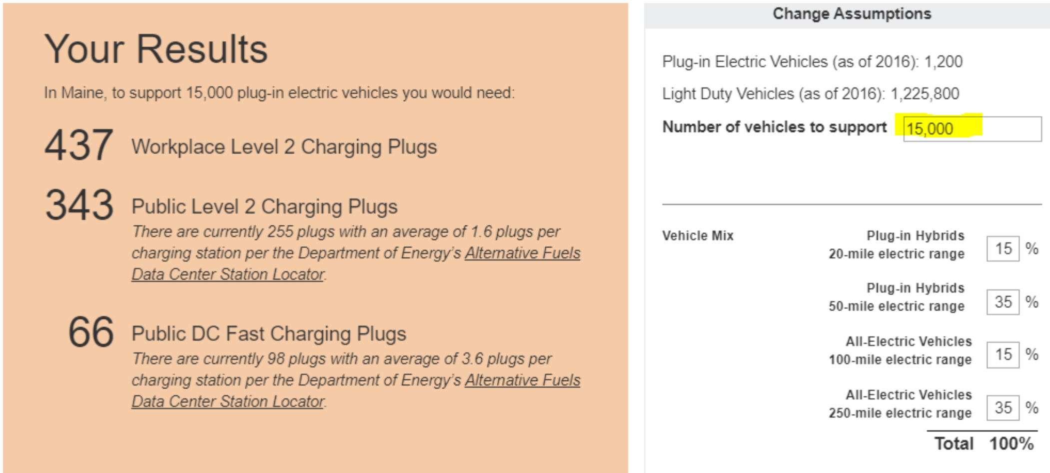
Of course, if private sector interest in charging stations is lacking, the public sector can step in to facilitate investment. However, to the extent a subset of customers (EV owners) enjoy the benefit of these investments, deploying public or ratepayer funds for this purpose raises equity concerns.

One additional barrier in some jurisdictions is that charging station providers, because they technically sell electricity, are subject to regulation as a utility. The Maine Legislature eliminated this barrier in 2015 with the passage of LD 593 – *An Act To Allow the Resale of Electricity by Electric Vehicle Charging Stations*. Along with 50% of states,[128] Maine now exempts any charging station provider from being considered a competitive electricity provider and allows it to install an electrical submeter and to charge for the kilowatt hours used.[129]

Finally, there is the question of quantity. How much public charging infrastructure do we need? Some analyses attempt to estimate the amount of charging infrastructure required per vehicle. For example, the U.S. Department of Energy (US DOE) has developed the EV Infrastructure Projection Tool (EV-Pro), which has been used for detailed planning studies in Massachusetts, Columbus, California, Maryland.[130] Using the US DOE's online calculator tool and applying the default assumptions, we can estimate the number of publicly accessible charging stations that would be needed in Maine under the middle and the high range of EVs. The results, illustrated in Figure 15 below, suggest that for 15,000 EVs, Maine should have 437 Level 2 plugs at Maine workplaces and another 343 Level 2 plugs at (other) public places. However, it is important to note first that Maine is unlikely to reach 15,000 EVs on the road for several years, and second that this is not a precise science. As battery technology improves and ranges get longer, it could be that the need for extensive public charging infrastructure is reduced.

Figure 15: Number Plugs Needed in Maine to Support 15,000 EVs

[127] Fitzgerald, Garrett and Chris Nelder. "EVgo Fleet and Tariff Analysis." Rocky Mountain Institute. 2017.
[128] Morehouse, Catherine. "Should EV charging stations be regulated as utilities? Kentucky joins majority in saying no." *Utility Dive*. June 17, 2019.
[129] Public Law, Chapter 29, L.D. 593, 127th Maine State Legislature – An Act To Allow the Resale of Electricity by Electric Vehicle Charging Stations.
[130] See EVI-Pro tool on the U.S. Department of Energy website.



Supply availability in Maine

Maine is one of 10 states that have adopted California's ZEV Program, requiring automakers to produce and sell a certain volume of ZEVs.[131] Though manufacturers are offering an increasing diversity of ZEV models at a variety of price points, many of these models have been unavailable for sale outside of California. This is partly due to the fact that, prior to 2018, manufacturers could comply with the state ZEV regulations by selling vehicles solely in California. Though the law has changed, regional pooling is still allowed through 2022. Even where models are available, the inventory is typically low.

Lack of general consumer awareness

The majority of consumers still have minimal understanding and several misconceptions about the capabilities, advantages, and general operations of EVs.[132] 75% of consumers know little or nothing at all about EVs.[133] Consequently, most people do not consider EVs when making a vehicle purchase.

Solutions

Some of the barriers outlined above will be addressed as EV technology continues to develop. For example, as battery costs decline, EVs are becoming more cost-competitive with ICE vehicles. The unsubsidized sticker price of EVs is expected to drop below that of ICEs sometime between 2025 and 2029, due in large part to the declining cost of lithium ion batteries.[134] Battery technology is also improving, increasing vehicle range and boosting charge speed. As the market expands to include more EV options, such as four-wheel drive EVs and electric trucks, EVs will appeal to a wider consumer base. All of these developments will help increase the number of people willing to consider an EV for their next vehicle, and improve the likelihood that dealers will carry inventory.

However, while this market develops, there are a number of actions policymakers and other stakeholders can take to encourage its growth and prepare to accommodate the charging demands that

131 The federal government recently finalized a rule that allows for preemption of state fuel economy regulations, including ZEV programs. This is the subject of an ongoing multi-state coalition lawsuit.
132 Jin, Lingzhi and Peter Slowik. "Literature review of electric vehicle consumer awareness and outreach activities." The International Council on Clean Transportation. March 21, 2017.
133 Consumer Federation of America. 2016 survey on attitudes toward EVs. August, 2016.
134 RAP. "Beneficial Electrification: Ensuring Electrification is in the Public Interest." 2018. p. 8 .

will accompany that growth. The Multi-State Zero-Emission Vehicle (ZEV) Task Force's 2018-2021 Action Plan (the ZEV Action Plan) presents a host of strategies to that end.[135] These cover five core areas: consumer education and outreach, charging infrastructure[136], consumer purchase incentives, light-duty fleets, and dealerships.

Consumer Education and Outreach

The ZEV Action Plan calls for increasing consumer awareness in ZEVs through brand-neutral campaigns, experiential events such as "ride and drives", and brand-specific advertising and marketing.

Through its EV Initiatives, the Trust is emerging as a brand-neutral source of EV-related information in the state of Maine. This role builds upon the organization's existing reputation as a trusted, impartial source of energy information generally. Alongside outreach and information about its rebates for EVs and grants for charging infrastructure, the Trust is sharing generic educational resources through its website, social media, and earned media. The Trust has also developed plans to produce and disseminate various "how-to" guides, including manuals and videos on installing a Level 2 home charging system, and best practices for charging at home and away. The Trust's plan for developing these guides is contingent upon being awarded additional funding.

All manner of stakeholders, including the Trust, government entities, employers, nonprofits, and auto dealers can support and encourage efforts to increase consumer experience with EVs through events such as ride and drives. The goal of these types of educational events is to share the experience of EV owners and bring information about the many reasons to adopt EVs to consumers, policymakers, the media, and the general public. Survey results out of Massachusetts indicate that they can be effective in changing consumer receptivity to EVs; 79% of participants stated they were more likely to purchase an EV post test drive, and 11% actually leased or purchased an EV within six months of their experience.[137] There have been a number of these types of events across Maine, particularly during the annual National Drive Electric Week. The Trust plans to ramp up its efforts in 2020 and 2021.

The third element of the ZEV Action Plan – brand-specific advertising and marketing – falls to the private sector. If automakers and dealers promote EV models in their collateral, this will raise the level of public awareness of EVs and drive sales.

Charging Infrastructure

The ZEV Action Plan calls for facilitating public and private investment in the development of ZEV charging infrastructure to build consumer confidence and support rapid growth in consumer demand for EVs.

As previously mentioned, the Trust is actively managing $3.15 million of VW settlement funds for the purpose of supporting EV charging infrastructure projects in Maine. The Trust developed the Maine Electric Vehicle Supply Equipment Initiative (EVSE Initiative) in collaboration with the Maine Department of Transportation, the Maine Department of Environmental Protection, the Governor's Energy Office, and other EV stakeholders. The initiative includes a plan to install approximately 24 public Level 3

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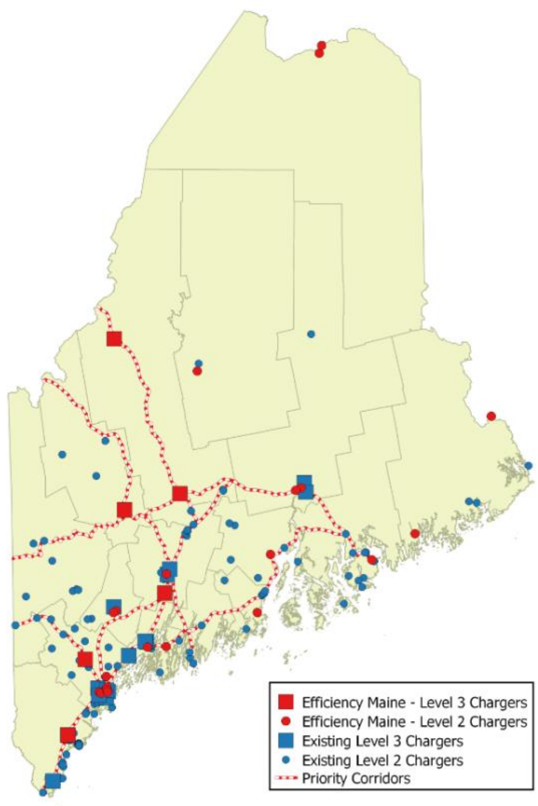
[135] Zero-Emission Vehicle (ZEV) Task Force. "Multi-State ZEV Action Plan 2018-2021." 2018.
[136] Full ZEV Action Plan category is "Charging and Hydrogen Fueling Infrastructure" – focus here will be on charging only, given the electrification focus.
[137] ZEV Action Plan. 2018. p. 15.

charging stations along priority corridors and approximately 100 Level 2 charging plugs at municipal properties, tourist destinations, workplaces, and multiunit dwellings. Figure 17 shows the progress toward this goal, along with the state's other existing public charging infrastructure. Consistent with recommendations in the ZEV Action Plan regarding publicly funded projects, the Trust's solicitations required bidders to accommodate multiple plug types and provide network interoperability with multiple point-of-sale methods. The solicitations also facilitated a certain amount of private investment by requiring bidders to put forth a cost-share.

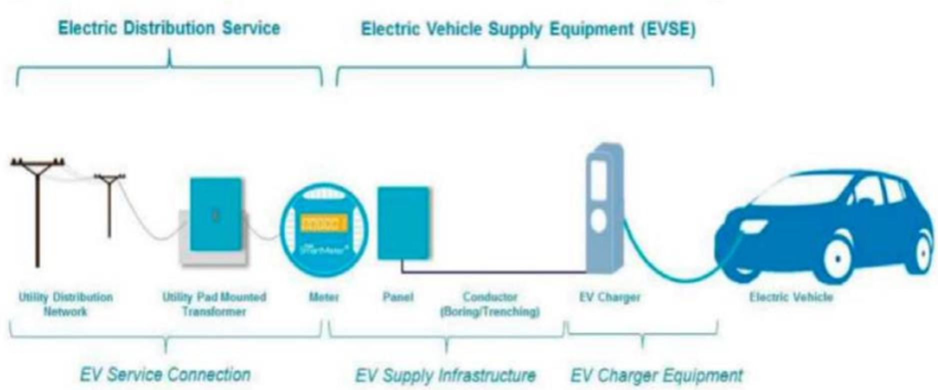
Figure 16: Public EV Charging Infrastructure in Maine (as of 10.24.2019)



Another specific recommendation in the ZEV Action Plan is for states to revise residential and commercial building codes to require supporting EV infrastructure in new construction and major renovations. It also calls on states to encourage local governments to adopt ordinances requiring a minimum percentage of EVSE-ready parking spaces in new or re-constructed residential and commercial parking structures.

One recommendation that appears in the ZEV Action Plan and elsewhere is to enable utility investment in EV charging infrastructure. New Level 3 charging stations typically go through utility "new service" request processes where the utility evaluates interconnection needs and conducts system studies to identify any necessary infrastructure upgrades (transformers, pole(s), conduit, and service drop). One way to encourage private investment in public Level 3 chargers is for utilities to cover these "make-ready" investments and waive or reduce fees to the operator.

Figure 17: EV Charging Infrastructure[138]



Policymakers continue to debate the appropriate role of electric utilities in the EVSE marketplace.[139] First, utilities may have a competitive advantage in owning and operating EVSE that may adversely affect the development of a competitive market for EV charging. Also, traditional regulatory principles dictate that incremental costs to the utility system are allocated to those who cause the costs to be incurred and reap the resulting benefits. Following this cost-causation principle, it might be argued that charging station operators should be required to pay for all costs associated with building out that station. Leveraging ratepayer dollars to pay for these costs would mean other utility customer classes are subsidizing charging station customers.

Utility proposals for ratepayer-funded charging infrastructure programs have been approved or are pending in a majority of the ZEV Task Force states.[140] Stakeholders argue that utilities can be helpful in spurring the early stages of charging infrastructure build-out, particularly in underserved areas where the economics are not currently attractive enough for private investment. Several of these states have introduced public-interest tests for utility investments in EV charging stations as a way to mitigate potential negative impacts. For example, the Massachusetts Department of Public Utilities articulated a test for approval of EV-related investments that considers whether utility proposals: (1) are in the public interest, (2) meet a need regarding the advancement of EVs in Massachusetts, and (3) do not hinder the development of the competitive EV charging market.[141] States generally agree that, like other public charging stations, utility-owned stations should be accessible to all drivers, providing interoperability in plug type and payment method. On the other hand, it is possible that as EVs become more prevalent on Maine roads, the prospect of charging for the service or simply attracting more visitors (or shoppers) will be sufficient to encourage investors to develop more Level 3 charging using their own funds.

The role of utilities in the Maine charging infrastructure marketplace is likely to be the subject of future discussions at the Legislature and the PUC. Policymakers, regulators, and stakeholders would be well served to look at considerations discussed in similar proceedings in other states. As the authors of a

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[138] Proposed Decision of ALJ Farrar before the Public Utilities Commission of the State of California. Decision Directing Pacific Gas and Electric Company to Establish an Electric Vehicle Infrastructure and Education Program. December 15, 2016. p. 8.

[139] RAP. "Getting from Here to There." 2017. p. 25.
[140] ZEV Action Plan. 2018. p. 16.
[141] Massachusetts Department of Public Utilities. "Order on department jurisdiction over electric vehicles, the role of distribution companies in electric vehicle charging and other matters." D.P.U. 13-182-A. August 4, 2014. p. 13

recent Regulatory Assistance Project whitepaper write: "Regardless of how a state pursues the development of an EV market, stakeholders will benefit from regulators explaining what they expect from public utilities in this new market for utility services, and how regulators plan to ensure the public good as a market develops in their state."[142]

Another, somewhat related, solution to the shortage of desirable EV charging infrastructure investment opportunities is for utilities to reduce demand charges for Level 3 charging stations. The ZEV Action Plan suggests that states consider allowing utilities to offer incentives in the form of alternative demand charge rate designs, waivers, or other options for public charging to provide the most equitable and least burdensome price signals to station hosts and end-users. In other words, the mechanism should meet both the utility's need to recover its costs and an EV charging station owner's need to provide an economically viable service that is attractive to drivers. For example, New York achieves this outcome by providing annual credits for Level 3 chargers that are designed to mimic and offset the anticipated uneconomic portion of demand charges.[143] Southern California Edison has implemented a five-year demand charge waiver for Level 2 charging stations, followed by a five-year phase-in to a new demand charge 40% below the current charge. [144] Pacific Gas & Electric (also in CA) has taken a different approach, instituting a monthly subscription charge that replaces the demand charge, but covers the site's fixed costs.[145]

Consumer Purchase Incentives

The ZEV Action Plan calls for providing, publicizing, and improving access to financial and non-financial incentives for the purchase and lease of ZEVs to raise consumer awareness and expand sales.

There are currently several consumer purchase incentives available to prospective EV buyers in Maine. These include rebates offered through the Trust's VW-settlement funded EV Accelerator Program, which range from $1,000-$7,500 depending on the type of vehicle and customer sector. Incentives for low-income residents and government entities are higher, given that these groups face higher upfront cost barriers and may not be able to take advantage of tax credits. The Maine Department of Transportation is also providing grant awards for various larger EVs (such as buses) through a VW-funded RFP.[146] There has for the past several years been a federal tax credit available ranging between $1,875 to $7,500 per vehicle, depending on the manufacturer. This tax credit will be available until 200,000 qualified EVs have been sold in the U.S. by each manufacturer, at which point the credit begins to phase out for that manufacturer (See Figure 18). Finally, some EV manufacturers offer their own additional rebates to further improve the value proposition for buyers.[147]

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[142] RAP. "Getting from Here to There." 2017. p. 25.

[143] New York State Department of Public Service. "Order Establishing Framework for Direct Current Fast Charging Infrastructure Program." Proceeding on Motion of the Commission Regarding Electric Vehicle Supply Equipment and Infrastructure, Case No. 18-E-0138. February 7, 2019.

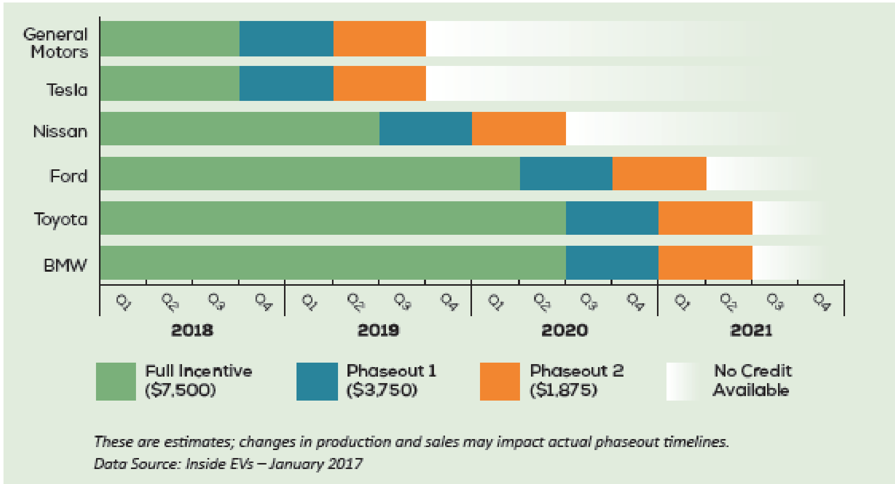
[144] Trabish, Herman K. "PG&E, SCE, SDG&E pursue subscriptions, time-of-use rates to drive more California EVs." Utility Dive. January 23, 2019

[145] Id.

[146] See Maine Department of Transportation Applications for Funding.

[147] See e.g., Nissan's rebate.

Figure 18: Projected Phase Out of Federal EV Tax Credit[148]



As mentioned in section 5.1.2, another option is to provide state-level tax credits or tax exemptions for EVs. For example, Colorado offers a state income tax credit on the purchase or lease of new EVs[149], Maryland provides a credit against the excise tax for EVs,[150] and New Jersey exempts EVs from sales tax.[151] Maine does not currently offer any such tax incentives.

The ZEV Action Plan also recommends a host of customer incentives that are unrelated to offsetting upfront costs. For example, high-occupancy vehicle (HOV) lane access and toll discounts are available in New Jersey, New York and Maryland.[152] Other ideas include vehicle registration fee reductions, low-cost charging rates, and preferential parking.

Light-Duty Fleets

The ZEV Action Plan calls for promoting and supporting the electrification of public and private fleets to build broader consumer interest through exposure to EV technologies, while reducing the adverse environmental impacts and operational costs of fleet operations.

Fleets represent a sizeable share of total vehicle purchases; in 2018, 16.2% of all automobiles and 15.3% of all light trucks sold in the U.S. were for fleet use.[153] Many of these vehicles have higher utilization rates and are replaced more frequently than those owned by individuals. These factors magnify the impact of fleet electrification in overcoming several of the barriers to EV adoption generally.

To that end, the ZEV Action Plan points out that fleets can serve as "anchor tenants" for Level 3 charging networks, improving the business case for Level 3 charging investment. Organizations with electric fleets can also serve as showrooms for the technology. Employees gain familiarity driving the vehicles and talk with each other about the driving experience. Additionally, as people see these vehicles parked or on

[148] ZEV Action Plan. 2018. p. 26.
[149] Colorado Energy Office. Alt Fuel Vehicle Tax Credits.
[150] U.S. Department of Energy. Alternative Fuels Data Center. Plug-In Electric Vehicle (PEV) and Fuel Cell Electric Vehicle (FCEV) Tax Credit.
[151] New Jersey Motor Vehicle Commission. Vehicles Exempt From Sales Tax.
[152] ZEV Action Plan. 2018. p. 24.
[153] United States Energy Information Administration. "Annual Energy Outlook 2018." February 6, 2019.

the road, it sends a positive message to the public about the viability of the technology. Fleet managers have negotiating power in making an aggregated purchase and may be able to secure favorable bulk pricing. Fleet investment also simply increases the number vehicles purchased, accelerating market transformation; dealers are more motivated to increase inventory, and eventually economies of scale lower prices.

The ZEV Action Plan identifies promoting the incorporation of EVs into state and local government, corporate, and institutional fleets as a high priority. It recommends that states set specific near- and long-term electrification goals and procurement policies for public fleets. It calls for fleet-manager-focused outreach and education initiatives, and for dedicated incentive programs. It also suggests that states, local governments, and private fleet managers collect data as EVs are integrated into fleets – including information on fuel use, maintenance, driver utilization and charging patterns – to inform future decision-making.

The status of EV penetration in Maine fleets is a subject for further research. It will be helpful to gain access to an inventory in order to target opportunities and measure progress. It is worth reiterating that the Trust's EV Accelerator Program currently offers an enhanced rebate for municipalities of $7,500, which will help in expanding EV adoption in a key subset of the state's fleets.

Dealerships

The ZEV Action Plan calls for supporting dealerships and dealership associations in efforts to grow consumer awareness of EVs, improve consumer shopping experiences, and increase EV sales.

The range of barriers presented above makes marketing EVs challenging for dealers. Customers considering EVs must accept a higher incremental upfront cost and become comfortable with a new technology and fueling routine. The complicated sales pitch, along with relatively low base level of customer demand and small inventories, can cause dealers to not prioritize EV sales.

ZEV program requirements taking effect in 2018 will result in delivery of more vehicles in northeast markets, and the expiration of regional pooling provisions in 2022 will push this even further. This will help mitigate the current barrier associated with lack of inventory in Maine dealerships. However, as more EVs are delivered, automakers and dealers will have to collaborate to ensure that there is effective and aggressive marketing to improve awareness and interest among mainstream consumers.

To incentivize this activity, the ZEV Action Plan recommends that states identify ways to showcase successful ZEV dealerships (and the practices they are using to expand sales) through media strategies, case studies, and dealership recognition awards. It also suggests brand-agnostic dealer training workshops or videos, distributing informational materials for display at dealerships. Finally, it recommends using financial incentives for dealers. The Trust is currently considering this approach, offering dealer sales performance incentive (SPIF) for each EV sale associated with an EV Accelerator Program rebate.

6 The Role of Utilities

LD 1464 calls on the Trust to consider the potential roles of Maine's electric and natural gas utilities in supporting beneficial electrification. Though this topic has been touched on in prior sections of the report, it is useful to recap the chief points again here. This section also covers some discussion points that have yet to be raised.

As discussed in section 5.1.1, electric utilities will play a critical role in assessing and planning for grid capacity needs as demand for electricity rises. They will need to monitor circuit-specific load growth and plan for the accommodation of an increasing number of renewable energy sources, determining the magnitude and timing of any associated T&D infrastructure investment. This process will require close coordination with the Non-Wires Alternative (NWA) Coordinator, the Trust and other parties as part of the newly bolstered NWA assessment process enacted by the Maine Legislature through the recent passage of LD 1181. Electric utilities may also be involved in active management of flexible loads in an electrified future, whether through their own operations or in coordination with third-party entities.

As noted in sections 5.1.1 and 5.1.3, electric utilities are also instrumental in implementing any rate design incentives that encourage load shifting or that improve the value proposition for electrification. Though many utilities in the U.S. also play a role in managing upfront financial incentives for electrification, Maine has pursued a different model; in Maine, the Efficiency Maine Trust serves as the independent administrator of programs promoting and developing cost-effective resources behind-the-meter (BTM). The Trust has been tasked with this role even when some of the funding comes from the utilities (ratepayers) and other sources. Where the Trust is the lead player in planning and administering programs, it is still the case that the electric utilities have an important role to play participating in the Triennial Plan process, sharing and analyzing consumer data, and working to build and maintain a reliable grid that can accommodate beneficial electrification at an affordable cost. In the event policymakers call for a discussion about leveraging electric ratepayer funds for fuel switching incentives, the electric utilities should be involved in that proceeding.

Section 5.2.5 observed that the ZEV Action Plan calls for enabling electric utility investment in EV charging infrastructure, whether for facilitating non-utility-owned charging stations with "make-ready" infrastructure, or extending this to play a role investing in the actual charging equipment. As noted previously, policymakers continue to debate the appropriate role of utilities in the EV charging infrastructure marketplace. First, utilities may have a competitive advantage in owning and operating EVSE that may adversely affect the development of a competitive market for EV charging. Also, leveraging ratepayer dollars to pay for these costs can challenge traditional cost-causation principles. Nevertheless, stakeholders argue that utilities can be helpful in spurring the early stages of charging infrastructure build-out, particularly in underserved areas where the economics are not currently attractive enough for private investment.

Electric utilities may also play an important role in raising consumer awareness surrounding electrification. While the Trust is well positioned to serve as the centralized, unbiased source of energy-related information for Maine consumers, it recognizes the need for partnerships in maintaining consistent messaging.

So far, this report has not addressed the role of natural gas utilities in supporting beneficial electrification. Based on the literature and policies emerging in other states, it would seem that this role is limited. Indeed, electrification involves switching away from fossil fuels – natural gas among them. In California, several municipalities are banning new natural gas hookups as they strive to meet net zero building goals. Many fear that, as natural gas end uses shift to electricity, having fewer customers and less usage on the natural gas system will drive up rates and lead to stranded costs. Data from the consulting firm Energy and Environmental Economics (E3) shows natural gas rates rising steeply in California in coming years as the cost to safely maintain the aging system rises following two major disasters, and the demand for gas dries up as California moves forward with its clean electricity and climate targets.[154] California's stakeholders warn that that these increases will disproportionately affect low-income residents who will be slower to transition to electric alternatives.[155] Though the bulk of electrification opportunity in Maine lies in shifting unregulated heating fuel and gasoline usage (see Figures 4, 5, 6), the dynamics for natural gas are something to watch. The Trust urges further analysis and discussion of this issue in coordination with the state's natural gas utilities.

7 Disadvantaged Communities

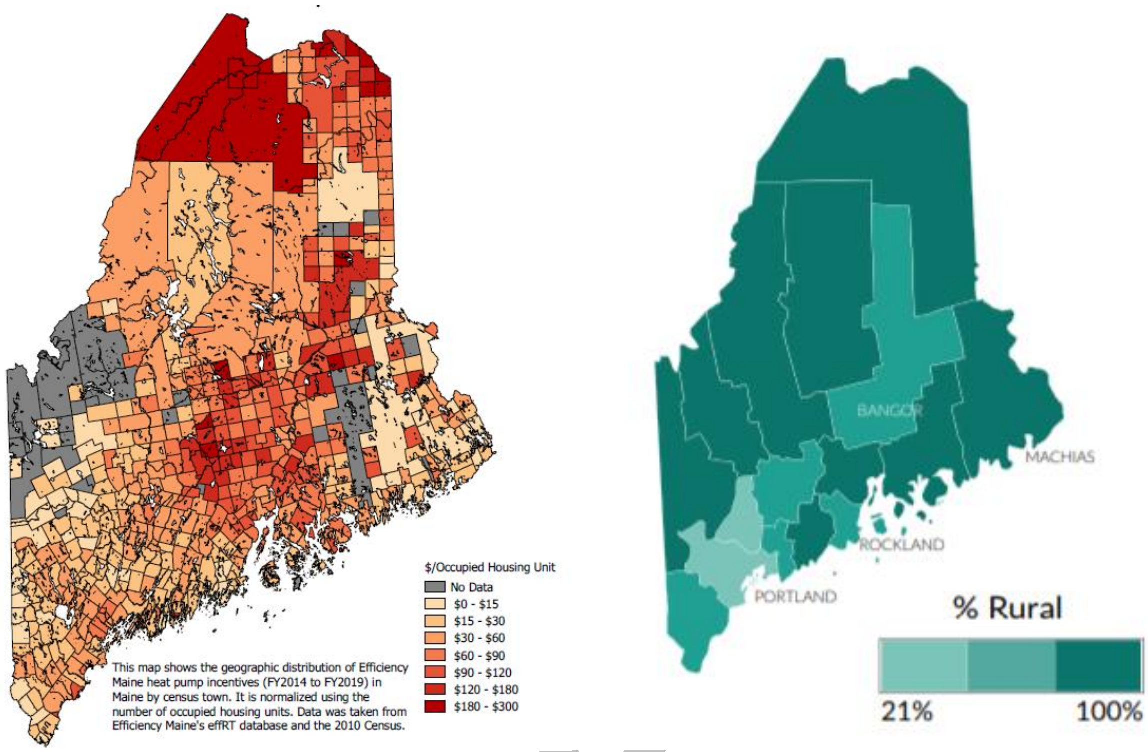
LD 1464 calls on the Trust to identify areas or populations in the State less likely to benefit directly from beneficial electrification without additional policy development or utility intervention. The report touched on this topic briefly in section 5.1.5, highlighting exacerbated upfront cost barriers for customer groups with financial limitations, including low-income residents, small businesses, and municipalities. Here, the report reviews concerns regarding other barriers for disadvantaged communities in Maine.

First, some stakeholders assert that Maine's rural, remote, and island communities are less likely to benefit from electrification than their urban counterparts. This stems from the fact that these communities are geographically isolated from supply chain resources and are more prone to lack a qualified local workforce.[156] This is certainly a concern worthy of additional attention and monitoring, given that Maine is the most rural state in the nation (61.3% of the population lives in rural areas). However, the Trust's internal data suggests that penetration of certain important energy efficiency project incentives is relatively well spread out across the state (see, e.g., Figure 19).

With respect to EV adoption specifically, there is the concern that longer average driving distances and fewer public charging stations will limit uptake in rural areas. In fact, it might be the case that EVs make more economic sense for these drivers; as discussed in section 5.2.5, the value proposition increases with higher utilization rates. As battery technology improves and EV range increases, these customers might be poised to realize even greater fuel and vehicle operating savings than those in other places. It is also worth noting that the Trust's EVSE initiatives have prioritized geographic distribution in their award criteria, resulting in a growing number of public charging options in some of the state's most remote locations (see Figure 16). Finally, some stakeholders maintain that in rural locations where poor grid reliability erodes confidence in electrification, customers are less likely to adopt electrification technologies.

[154] Energy+Environmental Economics (E3). "Draft Results: Future of Natural Gas Distribution in California." Presentation for CEC Staff Workshop for CEC PIER-16-011. June 6, 2019.
[155] The Greenlining Institute and Energy Efficiency for All. "Equitable Building Electrification – A Framework for Powering Resilient Communities." 2019.
[156] Island Institute. "Bridging the Rural Efficiency Gap – Expanding access to energy efficiency upgrades in remote and high energy cost communities." March 7, 2018.

Figure 19: Distribution of Efficiency Maine heat pump incentives[157]



Other stakeholders point out that electrification is likely to be less attractive to customers in electric utility territories with higher rates, including Emera and various smaller municipal and consumer-owned utilities. Though this is a concern, it should be reiterated that increased grid utilization associated with electrification has the potential to actually decrease rates in the short term (see section 5.1.1). Stakeholders also note that the state's smaller utilities are less equipped to manage sophisticated grid operations associated with a highly electrified future powered by renewables and distributed energy resources (DERs).

Entities that are part of the state's fossil-fuel economy and supply chain are likely to be impacted by widespread electrification. According to the Maine Energy Marketers Association, there are over 5,000 direct employees and 5,000 indirect employees in the heating fuels delivery market. There are approximately 10,000 employees working in over 1,000 convenience stores throughout the State, most of which sell motor fuels.[158] Interestingly, of the 183 Efficiency Maine residential registered vendors that provide fossil-fuel equipment services, 144 are also qualified to install ASHPs[159]. It is conceivable that this workforce will shift its focus in response to market trends.

Renters are another customer group that face exacerbated barriers when it comes to adopting electrification technologies. As mentioned in section 5.1.2, the "landlord-tenant split incentive" is at play when the landlord owns and operates the building heating equipment, but the tenant pays the utility

[157] Percent Rural map from Island Institute. "Bridging the Rural Efficiency Gap." 2018. p 19
[158] Maine Energy Marketers Association. "Testimony of Jamie Py – LD 1464." April 17, 2019.
[159] Efficiency Maine "Find a Residential Registered Vendor" tool. December 20, 2019.

bills; the landlord does not have a strong incentive to pay the upfront cost of electrification, given that he will not benefit from the associated operating cost savings. This barrier can be addressed through incentives, as well as building codes and appliance standards. Renters in multifamily buildings are also generally at a disadvantage when it comes to EVSE, making EV ownership challenging. Even if they are fortunate enough to have off-street parking, they are unlikely to have a say in whether it includes charging infrastructure. As previously mentioned, some jurisdictions are incorporate EVSE requirements into building codes to overcome this barrier.

8 Recommendations

TBD

- Summarize recommendations for further study as noted above
- Summarize recommendations received from stakeholders

9 Stakeholder Process and Input

TBD

- Description of RFI process
- Reference 1:1 meetings
- Reference comments on draft
- Reference dates, list of commenters, links to submitted comments (posted on EMT website)