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21-05002

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BEFORE THE PUBLIC UTILITIES COMMISSION OF NEVADA

Investigation regarding long-term planning for natural gas utility service in Nevada.) Docket No. 21-05002

COMMENTS OF NATURAL RESOURCES DEFENSE COUNCIL, WESTERN RESOURCE ADVOCATES, SIERRA CLUB, THE NEVADA CONSERVATION LEAGUE, AND THE SOUTHWEST ENERGY EFFICIENCY PROJECT[1]

1. Introduction

Western Resource Advocates ("WRA"), the Natural Resource Defense Council, Sierra Club, the Nevada Conservation League, and the Southwest Energy Efficiency Project ("SWEEP") (collectively, the "Conservation Advocates") submit these comments in response to the Procedural Order issued by the Public Utilities Commission of Nevada's ("Commission") in Docket No. 21-05002. The Commission requested interested parties submit comments responsive to the questions outlined in the Procedural Order. The Conservation Advocates respond to selected questions asked in Phase 1 of the docket, as appropriate, below.

The Conservation Advocates deeply appreciate the Commission's interest in this topic. Investigating the future of natural gas ("fossil gas") in Nevada is of utmost importance, both from ensuring that Nevada is doing its share to prevent the worst effects of climate change, but also being among the leading states in addressing this issue directly. While we acknowledge that this investigation is not intended to resolve the issues posed by the use of fossil gas in Nevada or some of its alternatives, this investigation is an incredibly important step in understanding what the options are, and what Nevada can do in the next five, ten, and twenty years to achieve its goals.

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[1] Synapse Energy Economics assisted with the development of the comments.

2. Phase 1 (ii): To achieve Nevada's goals of reducing greenhouse gas emissions, is it necessary to reduce the use of natural gas within the State? How much does natural gas use contribute to statewide greenhouse gas emissions, and what is the breakdown of emissions by type and location of natural gas use?

a. To achieve zero or near-zero greenhouse gas emissions by 2050, Nevada needs to nearly eliminate the use of fossil methane gas.

As acknowledged by the Commission in this query, Nevada's state policy is to reduce emissions of all greenhouse gasses ("emissions") to "zero or near-zero" ("zero") by 2050.[2] Similarly, the legislature set goals for reducing emissions by 28 percent by 2025, 45 percent 2030 relative to 2005 levels, and to zero or near-zero by 2050[3]. Finally, Nevada continues to advance the 2025, 2030, and 2050 legislative goals through executive action,[4] Executive Order 2019-22,[5] and additional legislation.[6] The Conservation Advocates strongly recommend the Commission consider both near-term, 2025 through 2030, and long-term, 2050, emissions reduction goals. A long-term focus is needed for Nevada to make good decisions about long-lasting infrastructure and avoid locking itself into technologies that cannot be part of a zero-emission future. Even shorter-lived, reversible investments should be scrutinized if they encourage or require additional investment in infrastructure that is incompatible with a zero-emissions future.

Nevada's 2020 State Climate Strategy states that "[i]n order to meet Nevada's long-term goal of zero or near-zero greenhouse gas…emissions by 2050, transitioning away from natural gas is necessary."[7] Residential and commercial sector use of fossil gas accounted for 8.8 percent of

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[2] NRS 445B.380(2)(d).
[3] *Id.* Subs. 2(c)(1) and (2).
[4] Steve Sisolak, "Letter to Governor Cuomo, Inslee, and Newsom," March 12, 2019, https://bit.ly/3aZtA3r
[5] Accessible at https://bit.ly/3n9hx9z
[6] NRS 445B.380(2)(d); also NRS 704.7820, *et seq.*, "Senate Bill 448" (2021), [cite].
[7] "State Climate Strategy", State of Nevada Climate Initiative, (December 1, 2020), p. 165, https://bit.ly/3aV2ASJ

Nevada's gross emissions in 2016.[8] These emissions are not expected to decline without new actions, according to the Nevada Division of Environmental Protection's 2019 inventory[9]. The Reference Scenario in Evolved Energy's Nevada-specific analysis,[10] an analysis discussed in detail in Section 2-c below, shows increasing building sector emissions in the future absent new actions. If other sectors in Nevada, such as power and transportation, cut emissions, but those from fossil gas use stay the same or increase, it will be impossible for Nevada to meet 2050 goals.

b. Economy-wide modeling should be leveraged to answer questions about the future of the gas system in the state, in the context of the state's goals.

To understand the potential future role of fossil gas in the state, Nevada needs to look not at gas distribution utilities in isolation, but as part of the broader energy economy. Reaching zero emissions statewide by 2050 will require all sectors to act, but not every sector will need to reduce emissions on the same schedule: it is easier and cheaper to reduce emissions in some sectors. For example, Nevada has experienced large reductions in its electricity sector, where emissions decreased 51 percent between 2005 and 2017,[11] compared to the transportation (the next most-reducing sector) where emissions decreased by 8 percent.[12] However, other sectors' emissions have increased. Sectors like aviation or high-temperature heating in industry, may be harder and more costly to decarbonize, and thus, may decarbonize later.

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[8] "Nevada Statewide Greenhouse Gas Emissions Inventory and Projections, 1990-2039, 2019 Report", Nevada Division of Environmental Protection, (2019), Tables 2-1 and 6-1, p. 8 and 49, respectively, https://bit.ly/3pxym0X.

[9] *Id.*, Figure 6-4, p. 50.

[10] Dylan Sullivan, et al., "Pathways and Policies to Achieve Nevada's Climate Goals: An Emissions, Equity, and Economic Analysis" (Evolved Energy, GridLab, NRDC, Sierra Club, October 2020), Figure 22, p. 51, https://bit.ly/3BZbISq

[11] "Nevada Statewide Greenhouse Gas Emissions Inventory and Projections, 1990-2040, 2020 Supplemental Report" (Nevada Division of Environmental Protection, 2020), https://bit.ly/3jhRa0d

[12] *Id.*, Table 3-1, p. 25.

The Commission should be cognizant of the linkages between sectors as it compares pathways to reaching zero emissions. Stated another way, many sectors will likely end up competing for resources to decarbonize, such as feedstocks. For example, using a large share of Nevada's available waste biomass in gas distribution to use in buildings would preclude the use of those same resources to provide high temperature heat in industry or long-duration energy storage for the electricity sector. Another consideration is the total cost of decarbonization, where some sectors will require more resources to abate emissions than others. Again, the aviation sector has a much higher "abatement" cost (i.e. the cost of reducing its reliance on fossil fuels) than gas distribution. As a result of the higher abatement cost, a large share of alternative fuels will likely be used in this sector.

Economy-wide decarbonization modeling, often referred to as "pathways" modeling after the original model[13], helps policymakers understand the tradeoffs between different emissions reductions strategies. These models start with a detailed description of how energy is used in a state or other geographic area, and how the energy-using items in the economy—cars, water heaters, commercial HVAC systems, etc.—could be changed to reduce emissions. This description incorporates the age of the energy-using item and each item's average lifetime, allowing the items to be replaced at the end of their lifetime (called "turnover"). The model also accounts for the cost of these changes. This stage of modeling depends on the inputs of the modeler: a modeler could decide to model a scenario where cars keep using liquid fuels or a scenario where methane gas or other piped fuels remain in wide use in buildings. The result of this description of energy demand—referred to as the "demand side" of the model—is a set of

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[13] See "Section 2.3 The role of pathways in planning" in Jones, *et al*., "Energy Pathways to Deep Decarbonization: A Technical Report of the Massachusetts 2050 Decarbonization Roadmap Study," December 2020, https://bit.ly/3DXIKD2

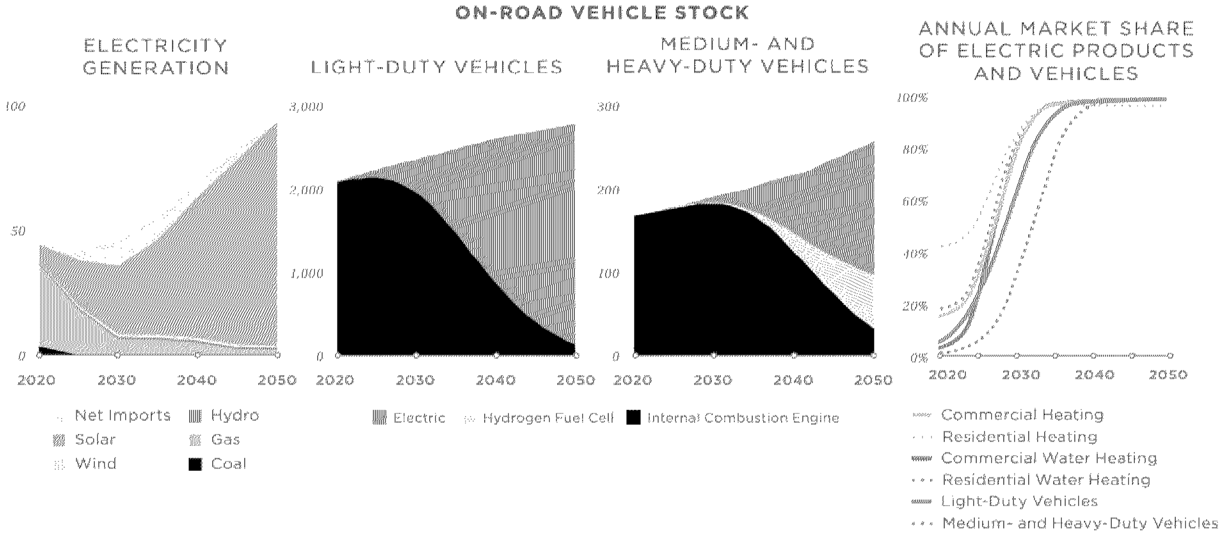
demands for different energy sources: how much the inventory of energy using items in the geographic area demands from each fuel type each year. These fuel demands are then given to the "supply side" of the model. On the supply side, the model builds and operates the energy supply system (power plants, refineries, hydrogen electrolyzers, digesters, etc.) in order to meet each scenario's fuel demands at lowest cost, subject to constraints and the need to meet greenhouse gas reduction goals.

c. Evolved Energy Research conducted Nevada pathways modeling that shows Nevada can get to zero emissions at reasonable cost; however, to do that gas use in buildings is eliminated through electrification.

As input for Nevada's climate planning, NRDC, Sierra Club, and Gridlab commissioned Evolved Energy Research ("Evolved") to conduct pathways modeling. Evolved modeled emissions reduction pathways to meet Nevada's 2030 and 2050 goals, using the EnergyPATHWAYS and RIO models to study the energy system. Collectively, these tools model Nevada's energy supply and demand, including turnover, over time, of the stock of energy demand and supply equipment, hourly electricity dynamics, and sectoral interactions, as described in the previous section.

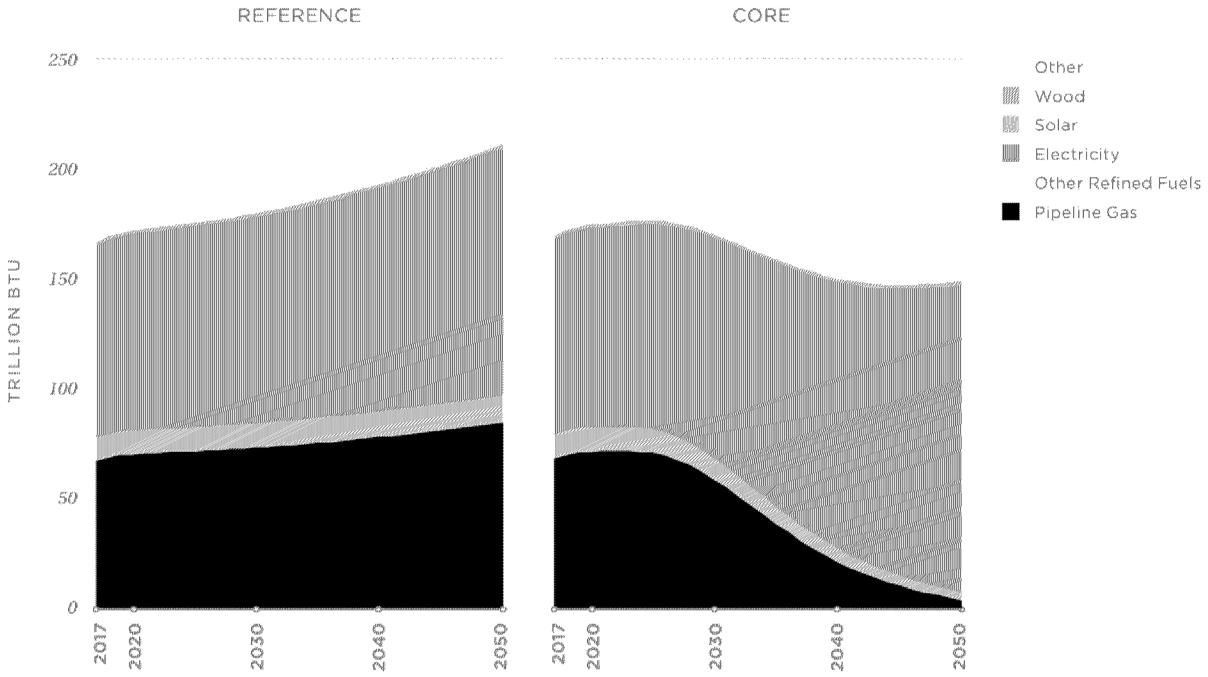
The modeling's key scenario, referred to in the report as the "Core" scenario, meets 2030 and 2050 goals with a rapid shift toward electric vehicles and electricity-using devices and appliances in buildings, coupled with a fast increase in the use of renewable energy sources and storage to meet existing and increased electricity demands. The key results by sector are in the graph below, included in the report as Figure ES-2.

Figure 1. Pathways Key Results



In the Core scenario, gas use in buildings is nearly eliminated through the replacement of expired gas equipment with efficient electric alternatives, such as heat pumps for space and water heating, as shown in the graph below, Figure 2, that compares total building energy use, by fuel, in the Reference Scenario and Core Scenario. The base of the graph, in black, is pipeline gas, which declines to near-zero by 2050 in the Core Scenario, which reaches net-zero greenhouse gas emissions.

Figure 2. Total Building Energy Use, by Fuel, in the Reference and Core Scenarios.



This analysis shows that electrifying current uses of gas would help Nevada reach its goals, at a reasonable cost. Electrification is useful for two reasons. The first reason electrification is useful is because it shifts energy use from a fuel, fossil gas, where the "drop-in" options to switch throughput away from fossil fuels (synthetic natural gas, biomethane) are limited in availability and costly, to a different fuel, electricity, where zero-carbon options are comparatively cheap and abundant. In other words, the path to near-zero emissions in electricity includes proven, available, cheaper technology options. The second reason electrification is useful is because modern electric equipment, such as heat pumps and induction cooking, is far more efficient than gas equipment illustrated by the large decline in total energy use from the buildings sector between the Reference and Core scenarios.

But Evolved's Nevada pathways analysis has a limitation. Specifically, it did not compare the electrification pathway in the Core scenario to a pathway that seeks to retain building use of piped fuels while meeting Nevada's goals. In other words, the analysis showed that Nevada can meet its goals at a reasonable cost and risk with building electrification, but it did not examine whether it would be possible, at reasonable cost and risk, to meet zero emission goals while retaining use of piped fuels. However, other pathways analyses have examined how a decision to retain use of the gas distribution system to provide heat in buildings would affect a state's overall decarbonization effort.

d. Pathways Analyses for Other States

The most comprehensive pathways analysis examining the future of gas utilities in the context of long-term emissions reduction goals is entitled the "The Challenge of Retail Gas in California's Low-Carbon Future: Technology Options, Customer Costs and Public Health Benefits of Reducing Natural Gas Use,"[14] conducted by Energy and Environmental Economics, Inc., ("E3") and the Advanced Power and Energy Program at the University of California, Irvine, on behalf of the California Energy Commission, in 2020. E3's study evaluates scenarios for meeting California's climate goal of an 80 percent reduction in greenhouse gas emissions by 2050 relative to 1990 levels by focusing on the impacts of those goals on gas customers and the gas system. The study characterized, in detail, the cost and availability of fossil gas alternatives (biomethane, hydrogen and synthetic natural gas ("SNG"), which is methane produced by combining hydrogen and carbon), and concludes that "building electrification is likely to be a lower-cost, lower-risk long-term strategy compared" to relying on fossil gas alternatives.[15] Chapter 2, Technology Options to Decarbonize the Natural Gas System, and Chapter 3,

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[14] Dan Aas, *et al.*, "The Challenge of Retail Gas in California's Low-Carbon Future - Technology Options, Customer Costs, and Public Health Benefits of Reducing Natural Gas Use" (April 2020), https://bit.ly/3jkyjkS

[15] Id., Page iii.

California Economywide Decarbonization Scenarios, especially merit the Commission's attention in this phase of the Docket.[16] Key results include:

- Decarbonization with blended and "drop-in" piped fuels results in fuel costs that are prohibitively expensive. In the scenario where 80 percent emissions reductions are achieved without building electrification, and where the gas pipe transports a mix of biomethane, green hydrogen,[17] and power-to-gas methane, the aggregate commodity costs of piped fuels increase from $0.059/therm in the reference scenario (reflecting just the EIA's forecast of 2050 fossil gas costs in the Pacific region) to $1.8/therm and $2.9/therm, depending on whether optimistic or conservative assumptions are used for the cost of power-to-gas methane.[18] These per-therm costs of piped fuels in the "retains gas" scenario assume that in 2050 56 percent of piped gas is fossil gas, which is possible because California's "80 percent by 2050" goal leaves some room for remaining emissions from fossil gas. In a scenario where gas distribution completely decarbonizes—a scenario that best represents Nevada's zero emissions goals—E3 estimates the commodity cost would be between $5.50/therm and $9.00/therm.[19]
- The supply of biomethane is limited. E3 concluded that "relatively low-cost [renewable natural gas, or "RNG"]" is sufficient to meet less than half of California's pipeline gas demand in 2050, so a "no electrification" scenario requires much more costly power-to-gas resources.[20]

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[16] The full report is attached to these comments at Attachment 1.

[17] As discussed in Section 3(b)(2) below, so-called "green" hydrogen is produced by splitting water using electrolysis, with electricity derived from non-emitting sources. In theory, this process could produce nearly zero-emission hydrogen, depending on the source of electricity used for electrolysis.

[18] *Id.*, p. 34.

[19] Ibid.

[20] *Id.*, p. 24-25.

- The “no building electrification” scenario, which relies on fossil gas alternatives to reduce emissions, incurs higher cost and risk than the building electrification scenario. The costs to operate an electric heat pump space heater are expected to be lower than the costs of operating a gas furnace in 2050, even if the gas furnace is burning 100 percent fossil gas. In scenarios that actually reach California's goals, the difference increases.[21] The all-in, economy-wide costs of the “no building electrification” scenarios are higher, by an extra $5 to $15 billion in 2050.[22]

The second study of note is Evolved’s work for the Washington State Energy Strategy. Evolved compared a building electrification scenario to one where gas use in buildings is retained and found that the share of state GDP spent on energy costs is lower under the electrification scenario.[23] Third is Evolved’s report for the Massachusetts 2050 Decarbonization Roadmap Study.[24] The study found that a scenario that retains gas for heating buildings (the “low building electrification pathway”) results in energy system costs more than $1.5 billion per-year higher in 2050 than a scenario that relies on building electrification.[25] While a “retains gas” scenario avoids some building equipment and electricity cost, this is more than offset by increased gas commodity costs, and ripple effects on other, harder-to-decarbonize sectors.[26] The Massachusetts study summarized its conclusion on building electrification as follows:

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[21] *Id.*, p. 40.

[22] *Id.*, p. 36.

[23] See Washington State Department of Commerce, “2021 Washington State Energy Strategy: Chapter B. Achieve the State’s Greenhouse Gas Emission’s Limits,” (2021), at p. 39, https://bit.ly/3G8NjMG; and “Appendix A, Washington State Energy Strategy Decarbonization Modeling Final Report,” https://bit.ly/3vBCCgx

[24] Jones, *et al.*, “Energy Pathways to Deep Decarbonization: A Technical Report of the Massachusetts 2050 Decarbonization Roadmap Study,” December 2020, https://bit.ly/3DXIKD2

[25] *Id.*, Figure 62, p. 121.

[26] *Id.*, Figure 7, p. 34-35.

- "Given the assumptions of this analysis, high levels of building electrification lowered the long-term cost of reaching Net Zero. With less building electrification, the long-term cost of the decarbonized fuel required to reach the emissions target more than offset modest cost savings from avoiding electrification in the near term.
- The large quantity of decarbonized drop-in fuels required is a risk factor for a low building electrification pathway. Even with nearly complete electrification of on-road vehicles, bioenergy imports would nonetheless need to increase to five times the level of ethanol imports today.
- In a low building electrification pathway, average gas rates increased from roughly \$10/MMBtu to \$20- \$30/MMBtu due to a combination of biogas cost, lower pipeline throughput, and the marginal carbon price of the remaining natural gas in the system. This makes gas less competitive with electricity than it is today. If adoption of electric technologies is seen by customers as cost effective based on the relative retail rates of gas and electricity, there could be an uncontrolled exit from the gas system and escalating rates for the remaining customers.
- A high building electrification pathway, whether resulting from explicit policy or market choices by consumers, will require a policy strategy for how to manage an orderly and equitable exit from the gas distribution system."[27]

The entire report is attached as well.[28]

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[27] *Id.*, p. 4.
[28] Attachment 2.

3. **Phase 1 (iii). What are the options for converting the identified categories of natural gas usage to a decarbonized energy source (e.g., electrification, renewable natural gas, hydrogen, etc.)? Compare the options, accounting for the relative reduction in greenhouse gas emissions (full fuel-cycle analysis), feasibility/scalability, and functionality as an alternative to natural gas.**
    - **A. How can low-income and historically underserved communities be protected during any transition to a decarbonized energy system?**
    - **B. Please identify any equity issues that may arise under paths toward decarbonization of the natural gas system.**

The following sections address the Commission's questions in subsection iii of Phase 1 by examining the different categories of alternative energy sources, the emissions impact of using those sources, and the feasibility, scalability, and functionality of different energy sources is. Following these analyses is a discussion on the equity implications of different energy sources.

a. Alternative energy options by usage category

i. Space Heating

Air conditioner and heat pump technologies have existed for many decades. Electric heat pumps are energy efficient heating and cooling systems. Heat pumps use the same vapor-compression refrigerant cycle as air conditioners do and have a function to reverse the cycle to produce heat. Heat pumps can provide space and water heating in all types of buildings and are already cost-competitive alternatives to fossil gas space and water heating systems, largely because they have a 250 percent efficiency for space and water heating. By comparison, methane gas systems typically operate at 90 percent efficiency for space heating. Furthermore, heat pumps can feasibly provide zero emission heating in a fully decarbonized grid. In recognition of heat pump's efficiency, the 2022 ENERGY STAR Most Efficient recognition criteria exclude gas-fueled equipment.[29]

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[29] U.S. Environmental Protection Agency, *ENERGY STAR Most Efficient 2022 Final Criteria Memo* (September 28, 2021). Available at https://bit.ly/3G3uhHn

However, heat pump deployment has been more limited in cold climates because the ability of early air-source heat pumps ("ASHP") that use ambient air as a heat reservoir to effectively operate as space heaters degrades as the temperature drops. Conventional heat pumps typically use inefficient electric resistance heaters as a backup in cold climates. However, cold climate ASHPs have become widely available across the country over the past several years. Cold climate ASHPs can provide comfortable heat even under freezing temperatures (e.g., down to -20°F) without a backup heater, meaning that they can meet heating needs even in Nevada's coldest cities such as Elko and Reno. A field study in Vermont observed that cold climate ASHPs operated at 5°F with a Coefficient of Performance ("COP")[30] of 1.6 and even at -20°F at above 1 COP.[31]

Since cold climate ASHPs have become available, some northern states have been aggressively promoting and installing heat pumps. For example, Efficiency Maine, tasked with meeting Maine's goal of 100,000 heat pump installations, has installed over 82,000 high-performance ASHPs over the past nine years, with the highest single year installation of 27,326 in FY2020 (July 2020–June 2021).[32] Efficiency Maine's efforts represents a cumulative installation of nearly 15 percent of homes and a single year installation of nearly 5 percent of homes in FY2020, assuming that all installations are in residential buildings.[33] Efficiency

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[30] COP indicates the ratio of useful heating or cooling to the total energy input. For example, a COP of 3 means that heat output is 300 percent of the energy input.

[31] Cadmus Group. 2017. *Evaluation of Cold Climate Heat Pumps in Vermont*. Prepared for the Vermont Public Service Department. Page 24. Available at: https://bit.ly/2Z2XzoC

[32] Efficiency Maine. 2020. *FY2020 Annual Report*. Available at: https://bit.ly/3DUpczg; State of Maine Office of Governor Janet T. Mills, "For Climate Week, Governor Mills Celebrates Maine's Progress Toward Installing 100,000 Heat Pumps by 2025." (2021) Available at: https://bit.ly/3AZLQEF

[33] Maine has approximately 560,000 households, according to U.S. Census Bureau *QuickFacts: Maine*. Available at: https://bit.ly/2Z5CYk1

Maine's energy efficiency program administrator reported reliable heating operations below -15°F.[34]

Other types of heat pumps such as ground-source heat pumps and water-source heat pumps have higher performance than ASHPs because they can use heat reservoirs with a higher temperature than ambient air during the winter. However, they are more expensive to install than ASHPs and are thus generally limited to larger scale installations.

A 2018 study by the Southwest Energy Efficiency Project ("SWEEP") found that heat pumps are substantially cheaper to install for new construction homes and also cheaper on a lifecycle basis including operating costs in Reno and Las Vegas.[35] Notably, SWEEP's study does not include the avoided cost of the new gas connection service for new all-electric homes, which would substantially improve heat pump economics as the cost of a new gas service connection is typically very expensive.[36] The SWEEP study also found that heat pumps reduce emissions by 36 to 42 percent for new construction and 14 to 22 percent for existing buildings, based on projected emissions factors through 2036. For existing homes, the SWEEP study found that heat pumps are slightly more expensive than fossil gas heating on a lifecycle basis. This means that heat pumps are likely to be the least-cost options even in retrofits in the near future as the cost of heat pumps decline due to economies of scale and as fossil gas prices increase due to customer defection and federal carbon policies that impose costs on fossil gas.

A more recent analysis submitted to the Commission by Jim Grevatt of Energy Futures Group examined the cost-effectiveness of electrification in the northern and southern territories of the

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[34] Efficiency Maine, "Heat Pumps," (accessed October 15, 2021), available at https://bit.ly/3lZ7m8h

[35] Kolwey, N., Geller, H., *Benefits of Heat Pumps for Homes in the Southwest* (2018). Table 5a on p. 17 and Appendix A at p. 33, available at: https://bit.ly/3jlIXb3

[36] For example, a 2016 study by TRC estimated about $6,400 for installing a gas service connection for a single-family home. See TRC, *Palo Alto Electrification Final Report* (2016), available at: https://bit.ly/3vwQeK5.

Southwest Gas Company.[37] The analysis included three scenarios: the current standard rate, the current time-of-use rate, and the current standard rate with a $100/ton carbon price. Mr. Grevatt found that all of the electrification options—central heat pumps for heating and cooling, heat pump water heaters ("HPWH"), and all-electric new homes—are cost-effective relative to fossil gas options in all scenarios in the northern service territory.[38] On the other hand, the analysis found that the electrification options are not cost-effective using the standard rates within the southern service territory, partly because of lower gas rates there. The analysis also found electrification of space heating and all-electric new homes can be cost-effective in the southern territory under the current time-of-use rate without carbon pricing as well as at the current rate with $100/ton carbon pricing.[39] While the HPWH was not cost-effective under the $100/ton carbon scenario, a doubling of the carbon price to $200/ton[40] would result in this option becoming cost-effective.

Other alternatives to fossil-based space heating include biomethane/RNG and hydrogen. Processed biomethane and SNG can be delivered interchangeably with fossil gas in existing infrastructure.[41] Important considerations for these fuels are discussed in the sections on GHG emissions and feasibility below. Hydrogen cannot be interchanged with methane, and consumers

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[37] Application of Southwest Gas Corporation for approval of its Conservation and Energy Efficiency Plan for the period 2022-2024, Commission Docket No. 21-05001, Direct Testimony of Jim Grevatt, submitted July 29, 2021.

[38] *Id.* Table 5, p. 22.

[39] *Id.* At Table 6. p. 23.

[40] Note that $200/ton is still below many estimates of the social cost of carbon. A recent Synapse Energy Economics study recommends the use of $393 per short ton for Massachusetts, which was based on the Federal Interagency Working Group's most recent recommendation on the social cost of carbon and a 1 percent discount rate instead of 3 percent discount rate. See Synapse, "AESC 2021 Supplemental Study Update to Social Cost of Carbon Recommendation," (2021), available at https://bit.ly/3jmzRuH

[41] In these comments, biomethane and SNG are distinguished from RNG wherever possible as the scalability and carbon implications of these fuels are different. Biomethane is produced by the digestion or gasification of biological matter. SNG is produced by combining non-fossil carbon atoms with green hydrogen.

will require different equipment to burn it safely beyond relatively low hydrogen blends.[42] Hydrogen's higher burning temperature is also prone to creating more nitrogen oxide ("NOx") pollution, potentially worsening air quality inside and outside of buildings unless additional measures are taken to control emissions, e.g. using low NOx burners.[43]

ii. Water Heating

Residential and small commercial scale HPWHs are now widely available across the country. The most popular model is a hybrid HPWH which includes an air-to-water heat pump, back-up electric resistance coils, and a hot water storage tank. While typical storage gas water heaters have 0.65 to 0.7 Uniform Energy Factors ("UEF") (which translates to between 65 and 70 percent energy efficient), HPWHs typically have a UEF above 3, making them far more efficient than gas water heaters. Best-in-the-market HPWHs are rated with upwards of 4.0 UEF, with most manufacturers currently producing models rated at 3.5 UEF. Current federal appliance standard on storage water heaters sets the minimum efficiency levels so high for a storage volume greater than 55 gallons that the only available ENERGY STAR storage water heater at this storage capacity level are HPWHs.[44]

While HPWHs are becoming mainstream water heaters, one major remaining barrier is the potential cost to upgrade the electrical panel. HPWHs typically require a 240-volt outlet, which may require a panel upgrade for old homes. To address this issue, some manufacturers including

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[42] For a technical discussion of the issues discussed here, see Livermore, S., "Exploring the potential for domestic hydrogen appliances," The Engineer (2018), available at https://bit.ly/3C2vigD

[43] Frazer-Nash Consultancy, "Appraisal of Domestic Hydrogen Appliances", (2018), available at https://bit.ly/3B2ULFn

[44] Appliance Standards Awareness Project, "Water Heaters," (accessed October 17, 2021), available at: https://bit.ly/3G3jbSN.

AO Smith, Rheem, and GE, are now testing retrofit-ready HPWH models that require only 120 volt and 15 amp, which is a standard outlet rating in homes.[45]

Large-scale HPWHs are also available for commercial and industrial applications including large multifamily buildings. Such applications have been limited in the country relative to the residential applications due, in part, to the limited knowledge of large-scale HPWHs among building owners, architects, and HVAC engineers. In response, recent studies have investigated large-scale HPWHs in order to increase the awareness of these technologies.[46] Further, a growing number of new products are coming onto the market. For example, a U.S.-based HVAC manufacturer called Lync recently introduced the new large-scale HPWH "Aegis A" into the market that uses CO2[47] as a refrigerant and can heat up water to 185°F.[48]

HPWHs for commercial applications can have some advantages over residential applications because some commercial buildings have unique heat reservoirs such as waste heat or locations with warm temperatures. For example, some commercial buildings have a below-grade garage; HPWHs can be configured to use these milder temperatures in the garage as a heat reservoir to produce hot water.[49] HPWHs can also be placed where they can use waste heat from mechanical rooms or laundry rooms and also provide the added benefit of cooling and dehumidification in those rooms. HPWHs can also extract waste heat produced in certain commercial facilities such

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[45] Building Decarbonization Coalition and New Buildings Institute, "The Retrofit-ready Heat Pump Water Heater: 120 Volts to the Future," (2021) available at: https://bit.ly/2Z8mqb8.

[46] Armstrong, S., et al., A Zero Emissions All-Electric Multifamily Construction Guide. Redwood Energy, (2019) Available at: https://bit.ly/3aWMckQ; Peter, A., et al, *Toward Carbon-Free Hot Water and Industrial Heat with Efficient and Flexible Heat Pumps* (2021), available at: https://bit.ly/3DYTQaL

[47] CO2 has a global warming potential of 1, by definition. Many refrigerants commonly used in air conditioning, heat pumps, and other applications have higher global warming potentials than CO2. For example, R-22 has a 100-year global warming potential of 1,810—almost 2,000 times the potency of CO2. See California Air Resources Board, "What is Global Warming Potential?" (accessed October 20, 2021), https://bit.ly/3E1E9zw

[48] Lync. "Lync Introduces Aegis, the First Commercial CO2 Heat Pump Water Heaters in North America," (accessed October 18, 2021), available at https://bit.ly/30MAGXp

[49] Ecotope, *RCC Pilot Project: Multifamily Heat Pump Water Heaters in Below Grade Parking Garages in the Pacific Northwest* (2015), available at https://bit.ly/2ZhUilE