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Re: Electrification of Residential Heating and Appliances

The case for the complete electrification of California's homes is becoming irresistible as more renewable energy flows through the state's electricity grid. The state is targeting greenhouse gas emissions from transportation sources with its stringent tailpipe standards, and industry emissions are being tightened in part through California's cap-and-trade market. Energy efficiency in the residential sector is already regulated by the state's Title 24 building codes, but natural gas still makes up 82 percent of energy used by residential space heating systems and 75 percent of energy used by water heating systems in California.[1] The climate dangers of natural gas were spotlighted in 2015 and 2016 during the catastrophic Aliso Canyon methane leak in Southern California. With that background in mind, consensus is growing among California policymakers that residential electrification can help the state meet its goal of reducing greenhouse gas emissions to 80 percent below 1990 levels by 2050. Compared to other decarbonization options, residential electrification offers the lowest cost per ton of carbon dioxide saved, at $100-150 per ton.[2]

Recent updates to Title 24, slated to take effect in 2019, point the state in the direction of complete residential electrification. Among other actions, the California Energy Commission has rewritten Title 24 to require that virtually all new residential homes be wired to deliver 240 volts of electricity, enough to power electric heat pump water and space heaters as well as electric vehicle charging

[1] Sheikh, I. "Decarbonization of residential space and water heating in California." PhD diss., University of California, Berkeley, 2017.
[2] Id.

stations.[3] Starting in 2020, Title 24 will also require solar panels be installed on new homes, which will help heat pump water and air heaters become carbon neutral.

Currently, 6 percent of greenhouse gas emissions in the state come from the residential sector, mostly from the use of natural gas to heat water and indoor spaces, and to a lesser degree, to cook food.[4] Electrifying all residential heat would increase the state's total load factor by only about 5 percent.[5] It remains unclear, however, whether the state's current infrastructure is prepared for a wholesale shift to residential electrical heating, according to Mary Ann Piette, director of the Building Technology and Urban Systems Division at the Lawrence Berkeley National Laboratory.[6]

Arguably the main obstacle to residential electrification in California remains the high price of electricity in the state compared to natural gas. Other obstacles include lack of awareness of heat pump water and air heaters among the public as well as among heating and plumbing contractors. Consumers also face high start-up costs for heat pump water heaters - running about $3,000 to purchase the heaters and rewire electrical systems to handle the additional electrical load.[7] On the policy front, the California Public Utility Commission's three-prong test is also widely seen as an obstacle to investor-owned utilities receiving financial incentives for residential electrification, which they then pass along to customers.[8]

This paper looks at the policy, technological and economic reforms that could help incentivize more California residents to switch to electric heating and cooking. Those reforms include installing smarter water and air heaters that would power on at times of day when electricity rates are lowest. Utilities could also offer financial incentives for customers to install electric heat pump water and space heaters, similar to programs already run by municipal utilities in Palo Alto and Sacramento and by utilities in other U.S. states. Finally, the CPUC could revise its three-prong

[3] Rider, K. Telephone interview conducted by Jack Chang on May 29, 2018..
[4] Sheikh (2017)
[5] Id.
[6] Piette, M. In-person interview conducted by Jack Chang at Lawrence Berkeley National Laboratory on April 13, 2018.
[7] Rider (2018)
[8] Ibid.

test so that utilities could receive state efficiency credits for greenhouse gas emission reductions rather than only for cost or energy savings. This last reform points to a larger policy choice facing California - whether to define energy efficiency predominantly in terms of greenhouse gas emissions even if the technology proves costlier or uses more total energy.

Based on greenhouse gas emissions criteria, complete residential electrification would be a smart statewide move - again, especially as more renewable energy comes online in the state.[9] The CPUC, however, could also look more closely at the impacts of residential electrification on lower-income consumers, especially as more affluent households likely make the switch first to electrification. That would leave those still dependent on natural gas infrastructure - essentially, households who can't afford to make the switch - to pay for its maintenance.[10] In sum, creative policy-making could help residential electrification pass not just the greenhouse gas emissions criteria test but the social equity criteria test as well.

Three-prong test

The CPUC could most immediately encourage residential electrification by updating its three-prong test, according to interviews with officials in the California Energy Commission, the Lawrence Berkeley National Laboratory, municipal utilities in Palo Alto and Sacramento and environmental advocacy groups.[11] The test determines the types of fuel substitution measures that utilities can encourage with energy efficiency incentives. That determines the types of efficiency measures that can be spurred with consumer rebates and other types of aid programs.

The three-prong test requires that fuel substitution measures clear three hurdles. First, they must pass a cost-effectiveness test showing that switching to another type of fuel won't significantly increase the cost to the consumer. They must also not increase total energy consumed. And they must "not adversely effect the

[9] Sheikh (2017)
[10] Rider (2018)
[11] Tam, C. Telephone interview conducted by Jack Chang on May 30, 2018; Blunk, Scott. Telephone interview conducted by Jack Chang on May 30, 2018.

environment" based on "avoided costs of emissions," generally interpreted to mean create more air pollution. Since its adoption in the early 1990s, the test has essentially blocked utilities from embracing the move away from natural gas in favor of electric-powered space and water heating, said Ken Rider, an advisor to California Energy Commission Commissioner David Hochschild.[12] While that made sense when the grid used electricity from more greenhouse gas-intensive sources, the steady growth of renewable electricity on the state's grid has made natural gas a less sensible option, especially in the greenhouse gas picture. In 2017, 30 percent of retail electricity sales in the state were served by renewable energy facilities, up from 12 percent in 2009.[13] The Natural Resources Defense Council has submitted a motion to the CPUC's Energy Efficiency Proceeding to rewrite the three-prong test, and among the organizations signing onto the motion are the Association of Bay Area Governments, the University of California Office of the President and several Bay Area cities and counties.

Especially for a technology such as electric water heating that comes with substantial up-front costs, the three-prong test places real financial obstacles to more widespread adoption, Piette said. "It's completely out of date," she said. "Greenhouse gas was not part of the consideration. ... As we move toward solar and wind and renewables, that changes the framework. That's what turns the space and solar water heat load on its head."[14]

Critics of the three-prong test say the test errs in using the following criteria:

- Unclear measurement criteria and baselines for judging whether a particular fuel switch passes the three-prong test.
- Outdated criteria for measuring energy efficiency by using BTUs expended rather than greenhouse gas emitted.
- Cost-effectiveness energy efficiency tests that don't take into account greater greenhouse gas savings despite higher prices paid for energy.

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[12] Rider (2018)
[13] California Energy Commission. "Tracking Progress." December 2017; California Energy Commission. "2009 Total Electricity System Power."
[14] Piette (2018)

- Air quality tests rather than greenhouse gas emissions to judge the environmental impacts of a fuel switch.[15]

Again, the criticism raises the larger question of how far should regulators go to incorporate greenhouse gas emissions in metrics such as the three-prong test, and how quickly should the commission move away from using BTUs or costs expended on energy as a principal metric for fuel-switching. The CPUC's April 26, 2018, scoping memo, doesn't call for commissioners to specifically consider using greenhouse gas emissions as a metric in the three-prong test. However, it does ask if "the energy efficiency cost-effectiveness calculator [is] adequate for calculating the cost-effectiveness of potential fuel substitution programs or are modifications to the calculator for these programs needed."[16] That appears to open the door for possibly substituting greenhouse gas considerations for cost or energy used as a criteria. Similarly, a May 9, 2018, presentation prepared by the California Energy Commission on the new building efficiency standards identified a future focus of attention as a "move to a more (greenhouse gas)-based metric that promotes electrification."[17] On that note, the Energy Commission identified in its 2018 Integrated Energy Update one of its top issues as "advancing greenhouse gas reductions in California's buildings," and in particular "the long-term role of natural gas in California buildings."[18]

Critics of the three-prong test recommend the CPUC establish: a clearer baseline for comparing fuel substitution; adopt greenhouse gas measures to evaluate energy efficiency; remove or scale back cost-effectiveness tests; and remove air quality measures from the three-prong test, instead letting other bodies such as the California Air Resources Board regulate air pollution.[19] Rider, of the California Energy Commission, said the three-prong test could also be improved by

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[15] Golden, R. "The Role of Building Electrification in Achieving Long-Term Climate Goals in the U.S." Master's thesis, University of California, Berkeley, 2016.
[16] California Public Utilities Commission. (2018) Assigned Commissioner and Administrative Law Judge's Ruling and Amended Scoping Memorandum.
[17] Presentation - 2019 Building Energy Efficiency Standards Adoption Hearing, California Energy Commission. (May 9, 2018).
[18] California Energy Commission (2018) 2018 Integrated Energy Policy Report Update.
[19] Golden (2016)

allowing the state to run the test on a portfolio of energy-efficiency measures rather than on individual measures. Doing that would give the state more flexibility to experiment with individual measures without running the risk of failing the three-prong test, he said.[20] For example, a utility could experiment with one type of heat pump water heater more easily if it wasn't evaluated on its own merits according to the three-prong test, rather than evaluated as part of a bundle of heat pump water heaters.[21]

In its filing with the CPUC, the Southern California Gas Company argued that the three-prong test should be kept as is because it lowers consumer costs and ensures "demand reduction resources that are cost-effective, reliable, and feasible." Again, the filing focuses on the traditional standard embodied by the three-prong test, that of energy efficiency and cost rather than reductions in greenhouse gas emissions. Considering changing the three-prong test will mean deciding whether California will reconsider the criteria by which it makes such energy switching decisions.

Technical considerations

Significant technological changes are needed to help residential electrification make more economic sense. Crucial to a wholesale shift to residential electrification will be the development of more efficient controls on the consumer end that will fire up heat pump water heaters during the afternoons, when renewable energy production is at its highest, so that the hot water can be used at night or in the morning, when renewable energy production dips.[22] That could mean adopting more flexible load controls that would monitor real-time energy prices and turn on electric water heaters during lower-priced times of the day.[23] Such innovations would tackle another major obstacle to residential electrification: wide differentials between more expensive electricity and lower natural gas prices, especially in California, which has among the nation's highest retail electricity

[20] Rider, K. Telephone interview conducted by Jack Chang on May 2, 2018.
[21] Ibid.
[22] Piette (2018)
[23] Ibid.

rates.[24] Electricity in much of the state costs on average more than 17 cents per kilowatt hour, compared to less than 8 cents per kilowatt hour in places such as Washington state and Louisiana.[25] That type of electricity-natural gas price difference means that to achieve the same operating cost, an electric heat pump water heater must be 275 percent efficient while a natural gas-powered water heater must be 82 percent efficient.[26] In this context, efficiency measures how much energy is produced compared to energy used in the production process. Heat pump heaters obtain high efficiency percentages by taking heat from the ground or other environments and pumping it into the treated water or air, essentially using energy to produce even more energy. Faced with that spread, any technology or policy that bridges the price gap would help make residential electrical heat more attractive to consumers. That could come in the form of subsidies to consumers, as will be discussed later in this memo, or increased efficiency in the heaters and appliances themselves.

Successfully pushing residential electrical heating would first require what Piette, of the Lawrence Berkeley National Laboratory, calls "the retrofit package" of heating options.[27] Such a package would offer consumers a range of choices, from heat pump water and space heaters without storage, to those with storage in a variety of capacity sizes. Essential to these packages would be sophisticated controls that would use dynamic systems to monitor energy demand and prices and turn heaters off and on to take advantage of the lowest electricity rates at different times of day. Storage capacity would also play an important role, allowing smart heaters to operate during afternoon hours when renewable energy production is highest - and cheapest - for later use during peak consumption times.

"I'd be concerned about moving ahead without these retrofit packages along with the controls and the incentives for pricing so that people control the potentially flexible thermal loads in response to demand," Piette said. "To do it without controls

[24] Borenstein, S., Bushnell, J. (2018) "Are Residential Electricity Prices Too High or Too Low? Or Both?"
[25] Ibid.
[26] Sheikh (2017)
[27] Piette (2018)

makes the Duck Curve worse. It's not just about how much electricity we use. It's about when we use it."

Another technical requirement would be rewiring homes to handle the increased load used by electric heat pump heaters, an expense that can prove prohibitive for lower-income households. For households that can afford it, completing such electrical work could offer an opportunity to install electric vehicle-charging stations at the same time - another statewide priority given California's goal of putting 5 million zero-emission vehicles on the roads by 2030. What often happens now, however, is that plumbing and HVAC contractors don't offer heat pump water heating options or don't know about the technology if they're asked about it by customers.[28] Additionally, homeowners often replace their water heaters when their old model has broken down and the household goes without hot water, which means they're unwilling to wait for a heat pump water heater to be ordered when a natural gas-powered model is already available to be installed. Further, installing a heat pump water heater now requires visits by both a plumber to connect the heater to the household water infrastructure and an electrician to upgrade the wiring to handle the additional electrical load. Again, that can prove impractical when residents are already making do without hot water.[29]

The Sacramento Municipal Utility District, or SMUD, is trying to overcome that awareness gap among contractors by telling more of them about the utility's generous subsidies for installing electric heat pump heaters and appliances. Starting on May 14, 2018, SMUD began offering a $3,000 rebate to fuel substitute a heat pump water heater in an existing home, $4,500 to fuel substitute a heat pump space heating system in an existing home, $250 to install an induction cooking stove that uses electricity rather than gas and a $2,500 bonus to residents of existing homes who install heat pump water and space heaters as well as an induction cooking stove. Such households can receive the bonus also if they upgrade their electrical panel and install heat pump space and water heating.[30] In March 2018, SMUD began

[28] Tam (2018)
[29] Blunk (2018)
[30] Ibid.

offering a $5,000 incentive for all-electric new construction homes and a $1,500 incentive for all-electric new construction multifamily units. SMUD launched the incentive programs estimating that it would not add pressure to raise rates and would not raise customer energy or operating costs. SMUD also estimated it could generate more revenue through additional electricity sales.[31] SMUD's message to contractors was that the incentive program would help them drum up new business, especially as the incentives essentially paid for customers' installation costs.

For lower-income households, those sorts of incentive programs as well as the right rate structure will be key to not leaving people behind in an all-electric future, said Merrian Borgeson, a senior scientist with the Natural Resources Defense Council.[32] Restructuring tiered rate designs to allow more electricity use at certain times of the day, especially during off-peak hours, would help offset higher heating electricity use.

"It's not necessarily a higher cost to reduce emissions in buildings if you use super-efficient heat pumps and the right rate structure - low-income CARE rates - with 30 to 40 percent of customers on those rates," Borgeson argued.

A final technological obstacle is the continued need of industrial facilities such as oil refineries to use natural gas in production processes. No electricity-based technology can yet replace natural gas-fired equipment to produce sufficiently intense heat for heavy industrial uses.[33] That means that even in the event of complete residential electrification in California, natural gas infrastructure will need to be built and maintained to serve industrial customers. Conceivably, natural gas would remain a purely industrial service in the event of wide-scale residential electrification, which would impact the infrastructure and regulatory framework around natural gas delivery.

Other residential electrification reforms

[31] Ibid.
[32] Borgeson, M. Telephone interview conducted by Jack Chang on April 12, 2018.
[33] Piette (2018)

The Energy Commission's most recent updates to Title 24 cleared a wider path for residential electrification in California. By requiring that all new homes be wired for 240 volts, the commission removed a major technical obstacle to residential electrification and essentially made new homes installation-ready for heat pump water and air heaters.[34] The updated rules also removed the burden of homeowners to hire contractors to run technical energy models if they want to switch to appliances using different fuel types. Instead, the new rules let homeowners adopt heat pump water heaters as long as the appliances meet a 2.8 efficiency factor, meaning they generated 2.8 times more energy than the energy that went into the process. Most heat pump water heaters already meet that standard, with some achieving a 350 percent efficiency level.[35] And by requiring that most new construction be built with solar panels, the Energy Commission has helped make electrical heating and cooking even more cost effective and a better bet for reducing greenhouse gas emissions.

The commission's updates, however, are limited to new construction, which means their impact will prove constrained in cities such as Palo Alto that are already built out.[36] The challenge for such jurisdictions will be incentivizing current homeowners to make the switch to electric heating and appliances. Palo Alto has been a pioneer in offering such incentives, but so far to little effect, said Christine Tam, a senior resource planner with the city.[37] Palo Alto offers rebates of $600 to $1,500 to switch to electric heating, but less than 30 households in total have taken advantage of the incentives since they were launched last year. Tam attributed the low adoption rate to the lack of availability and awareness of such heat pump heaters as well as the complicated process for installing them. She added that small jurisdictions such as Palo Alto's municipal utility, with 25,000 residential customers, don't have the market power to convince contractors in the region to stock heat pump water heaters and reorder the supply chain. "We need the whole Bay Area to

[34] Rider (2018)
[35] Ibid.
[36] Tam (2018)
[37] Ibid.

move together," Tam said. "We can't change the supply chain because we are too small."

Scott Blunk, a strategic business planner with SMUD, said the education campaign about heat pump water and space heaters needs to extend to city building inspectors and planners. He recounted the experience of one homeowner in the Sacramento area who tried to win the necessary permit to switch out a natural gas-powered water heater for an electric heat pump water heater, but was told by the city that such a fuel switch was not permitted by building codes. After finally receiving permission to make the switch, the homeowner was again told by the building inspector that the heat pump water heater that was just installed was not permitted by code and would have to be removed. On the positive side, each successful installation of such electric heat pump water heaters educates more contractors, planners and inspectors about the technology and the regulations, Blunk said.[38]

The 2019 Title 24 updates did provide a significant boost to building all-electric homes. The commission created an electric water heater baseline that allowed a comparison of the installed heat pump water heater with a code approved electric model. According to Blunk, this represented a significant step forward from existing codes and allows more options for builders and lowers the cost of building all electric homes. The previous time dependent valuation metric in Title 24 required the cost of electricity use be compared to lower-priced natural gas. Under the current pricing structure for both fuel sources, that requirement disadvantaged the use of electricity compared to natural gas.[39]

The state of California has other tools on hand to encourage and incentivize residential electrical heating and appliance use. One possibility would be for the state to require that building codes focus on greenhouse gas emissions rather than the cost of energy used when evaluating energy efficiency. Doing that, however, would require the California state Legislature amend the Warren-Alquist Act that

[38] Blunk (2018)
[39] Id.

created and gave statutory authority to the California Energy Commission.[40] Assembly Bill 3232, by Assembly member Laura Friedman, would push the state in that direction by requiring all new residential and non-residential buildings be zero emissions. In particular, the pending bill would require the California Energy Commission to look at the cost effectiveness of reducing greenhouse gas emissions from space and water heating in both existing and new residential and commercial buildings.

In another area of potential improvement, Title 24's use of time dependent valuation, which measures energy savings differently depending on energy costs at that time of day, still bases efficiency on the costs of delivering and producing energy at the time consumption occurs.[41] Electricity modeling has found that electric heat pump water heaters produce less lifetime greenhouse gas emissions than standard natural gas-powered tankless water heaters, although they produce higher time dependent valuation results.[42] That difference can be traced back to higher electricity prices compared to natural gas rates as well as to what critics say is the undervaluing of greenhouse gas emissions in natural gas and electricity rates. Again, the Energy Commission has indicated it plans to look at using greenhouse gas emissions as an efficiency metric rather than cost or total energy use.[43] As cheaper renewable energy comes online in California and as electric heat pump heaters become far more energy efficient than natural gas-powered heaters, cost-based efficiency measurements will tilt in favor of heat pump water heaters.[44]

Already, state law SB 350 requires the CPUC to meet high energy efficiency and renewable energy goals. Two bills pending in Sacramento would also give a big push to residential electrification. The first is Assembly Bill 3232, as mentioned above, which would require the California Energy Commission to create a plan by Jan. 1, 2020, to require all buildings constructed in the state on or after Jan. 1, 2030, to be zero emission. The bill would also require the commission to develop a plan to

[40] Rider (2018)
[41] Golden (2016)
[42] Id.
[43] California Energy Commission (2018)
[44] Rider (2018)

reduce greenhouse gas emissions to at least 50 percent below 1990 levels by 2030. Senate Bill 1477, authored by state Sen. Henry Stern, would explicitly allocate funding for the market development of low-emissions space and water heating. That bill also creates a voluntary incentive program for building developers and owners to seek greenhouse gas emission savings in their construction projects. The financial incentives would be based on the amount of greenhouse gas emissions reduced through the installation of "near-zero-emission building technology," according to the bill language. SB 1477 would also offer higher financial incentives to low-income communities to adopt often costly heating technology.

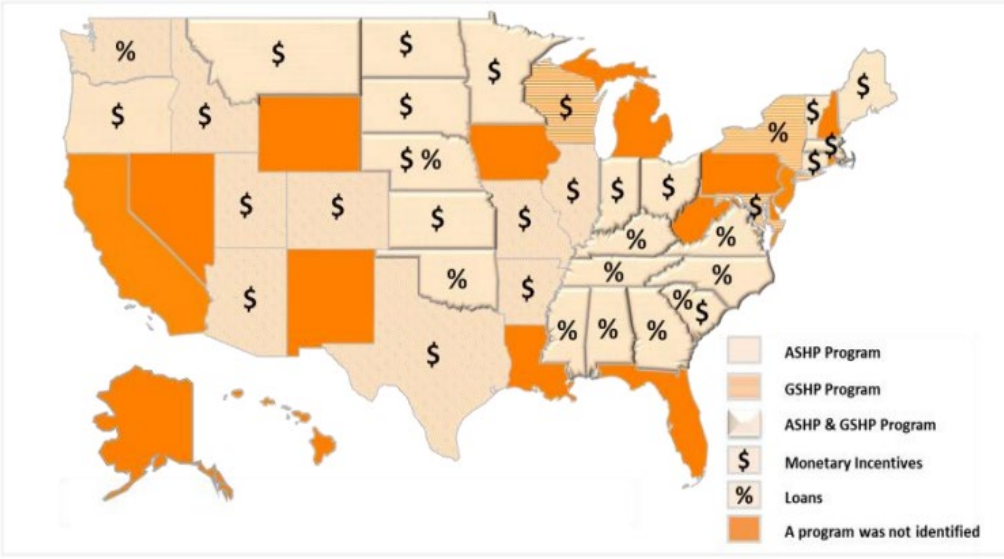
COMPARATIVE ANALYSIS OF OTHER US STATES AND EUROPEAN COUNTRIES

Heat Pumps in US States:

The amount of greenhouse gas reductions achieved by helping households switch to electrified heating depends on the carbon intensity of each state's electricity production. For example, electric water heater replacement is estimated to lead to a 90 percent reduction in household GHG emissions in Washington state compared with a 5 percent reduction in GHG emissions related to household water heating in North Dakota.[45] The Golden report also suggests that replacing gas water heaters with heat pump water heaters will reduce household GHG emissions across the U.S. in 2030.[46] The largest winners from a GHG savings perspective will be more politically progressive states such as Washington, Oregon and Maine because their electricity portfolio mostly consist of renewable energy sources.[47] The health of the housing market also has a major impact on the deployment of heat pumps. Without new housing programs, manufacturers are limited to the add-on and replacement market (roughly 80 percent of total market).[48] Heat pumps steadily increased their share of the new home market in the years leading up to, during, and following the

[45] Golden (2016)
[46] Id.
[47] Id.
[48] Lapsa, M., Khowailed, K., 2011. "The Evolution of the U.S. Heat Pump Market." 10th IEA Heat Pump Conference, Tokyo, Japan.

recession, up to 41 percent in 2015.[49] In the early 2000s, interest in geothermal heat pumps (GSHPs) was relatively low in both the United States and Canada. A geothermal heat pump or ground source heat pump uses the constant temperature of the earth as an exchange medium instead of the outside air temperature.[50] The use of such pumps picked up in the late 2000s due to a 30 percent federal tax credit that was available in the United States for GSHPs placed in service after 2008 until December 31, 2016. To qualify for this tax credit, GSHPs had to meet federal Energy Star criteria set by the Environmental Protection Agency.[51] The tax credit was introduced in 2009 but expired in 2016. In February 2018, these tax credits for heat pumps were extended through December 31, 2021.[52] This extension, coupled with complimentary state government policies, can increase installations leading to a cumulative cut in greenhouse gas emissions.



[49] Melissa Lapsaa, Gannate Khowailedb, Karen Sikesb, Van Baxtera, The U.S. Residential Heat Pump Market, a Decade after "The Crisis" , http://hpc2017.org/wp-content/uploads/2017/05/O.2.1.2-The-U.S.-Residential-Heat-Pump-Market-a-Decade-after-The-Crisis-and-Regional-Report-North-America.pdf , Accessed on June02, 2018.

[50] Heat Pumps, https://www.energy.gov/energysaver/heat-and-cool/heat-pump-systems/geothermal-heat-pumps, Accessed on June 02, 2018.

[51] U.S. Environmental Protection Agency, 2016, ENERGY STAR – Geothermal Heat Pumps Key Product Criteria.

[52] Residential Renewable Energy Tax Credit, https://www.energy.gov/savings/residential-renewable-energy-tax-credit, Accessed on June 02, 2018.

Image1: Sample of Financial Incentives and Loans Available for Heat Pumps and Ground Source Heat Pumps in the United States[53]

Expansion to colder climates - Maine & Vermont

Commercial deployment of heat pumps has been mainly focused on moderate climates, especially in the southern part of the United States where homeowners rely on HP technologies for both cooling and moderate heating needs. Those residents can opt for heat pumps when their air-conditioning units need replacement, because heat pumps can be used for both cooling and as a secondary source of heating during the coldest months.

Nowadays, deployment of cold climate HPs (CCHP) is growing, along with outreach about the technology, especially in states such as Vermont and Maine. In Vermont, for example, up to $800 in incentives are available for qualifying homeowners at the time of purchase to scale up the deployment of qualified CCHPs. To qualify as a CCHP under the Vermont program, a heat pump must be a variable-speed mini-split[54] or multi-split[55] ductless heat pump with specific cooling capacities. As of December 2015, 1,296 qualified CCHPs were installed as part of Vermont's efforts and the number has increased since then. As of 2017, the installation of these heat pumps has resulted in an average seasonal efficiency of 314 percent.[56] The Vermont program targets homeowners who live in structures with open floor plans, use at least 2,270 liters of oil or propane annually and are interested in controlling future spikes in oil or natural gas prices. In areas where natural gas-fired furnaces are an option, CCHPs are not promoted due to their generally higher energy cost. Similar to Vermont, Maine has deployed 20,000 high-

[53]Melissa Lapsaa , Gannate Khowailedb , Karen Sikesb , Van Baxter, The-U.S.-Residential-Heat pump-Market-a-Decade-after-The-Crisis-and-Regional-Report-North-America.pdf, (2017)

[54] Department of Energy defines variable speed mini-split system heat pump as a heat pump having two main components- an outdoor compressor/condenser and an indoor air-handling unit. Mini-split HPs make good retrofit add-ons to houses with "non-ducted" heating systems. They are small in size and good for zone heating. (https://www.energy.gov/energysaver/heat-pump-systems/ductless-mini-split-heat-pumps, Accessed on May 30, 2018)

[55] A multi-split system connects multiple indoor units to a single outdoor unit resulting in increased efficiency.

[56] John Walczyk, Evaluation of Cold Climate Heat Pumps in Vermont, Vermont Public Service Department, (November 3, 2017)

efficiency ductless heat pumps in homes and businesses over the past years. In Maine, $500 in rebates are available toward the installation of ductless HPs that provide a single or first zone of heating for a home. An additional rebate of $250 is available for ductless heat pump installations that provide a second zone of heating.[57] Direct incentives to homeowners have played a major role in the adoption of these heat pumps. In a survey conducted in 2017, none of the owners expressed dissatisfaction with their choice to install a heat pump.[58]

Role of incentives by utilities and states:

The incentives structures are largely driven by utilities' cost-effectiveness tests and other policies that vary from one program to another. Some programs opt for financing aid while others prefer offering monetary incentives to homeowners or directly to mid-stream market actors such as retailers. Financing programs include either on-bill financing (where utilities offer loans to customers so they can pay for energy efficiency improvements through regular monthly payments) or a subsidized interest rate. Monetary incentives, in comparison, seem to be more widely deployed. Some programs, such as MASS SAVE[59] in Massachusetts, set aggressive efficiency targets where a homeowner qualifies for the $500 incentive if the heat pump has a SEER rating (Seasonal Energy Efficiency Ratio) of ≥18. Incentives under this program range between $500 to $750.[60] MassCEC Rebate is also offering up to $10,000[61] until December 2020 for the installation of residential ground-source heat pumps in Massachusetts. Other programs, such as those offered by PP&L in Pennsylvania, assign a sliding range of incentives based on the efficiency

[57] Ductless heat pumps, https://www.efficiencymaine.com/at-home/home-energy-savings-program, Accessed on March25, 2018.
[58] Id.
[59] Mass save is a collaborative of Massachusetts' natural gas and electric utilities and energy efficiency service providers.
[60] Residential Rebates and Incentives, https://www.masssave.com/en/saving/residential-rebates, Accessed on March25, 2018.
[61] Learn About Ground-Source Heat Pumps, http://www.masscec.com/learn-about-ground-source-heat-pumps Accessed on May 30, 2018.

and cooling capacity of the unit.[62] These are available in the form of rebates ranging from $75 to $400. All residential customers of PPL Electric are eligible for the incentives.[63]

Ground-source, or geothermal heat pumps (GSHP), are also eligible for incentives to encourage their widespread deployment. The U.S. federal government offers a GSHP tax credit that covers up to 30 percent of the cost, including for installation, available through December 31, 2021.[64] In addition, many states, utilities and local programs provide loans, state tax credits or financial incentives as already shown for both residential and commercial purposes. Finally, some programs encourage consumers to purchase heat pumps over air conditioners. For example, Connecticut's Energize CT program provides a $500 incentive for heat pumps compared to only a $200 incentive for AC units.[65] Such scenarios are making the cost differential between heat pumps and ACs negligible. For geothermal heat pumps in Hawaii the federal incentive covers 30 percent of the expenditures in the year the incentive is taken, up to a cap of $2,000 if the system was installed prior to January 1, 2009.[66] A qualifying geothermal heat pump property installed after December 31, 2008, is eligible for 30 percent of the installed cost without a cap, as provided under the American Recovery and Reinvestment Act of 2009 (ARRA).[67] The incentive, which was available until December 2016, helped taxpayers install qualifying equipment at their primary residence or a second home, but not for a rental property.

Over 25,000 efficient air-source heat pumps have received incentives in the Northeastern U.S. just in the last reported program year. Some of the programs are

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[62] https://pplelectricsavings.com/HomeEquipment/Products?utm_source=heatpump&utm_medium=allrebates&utm_campaign=pplwebsite, Accessed on May 30, 2018.

[63] https://www.energy.gov/savings/ppl-electric-utilities-residential-energy-efficiency-rebate-program, Accessed on May 30, 2018.

[64] Database of Incentives for Renewables & Efficiency, 2016. Database of Incentives for Renewables & Efficiency. North Carolina Clean Energy Technology Center.

[65] ENERGY STAR Central Air Conditioner or Heat Pump Rebate, https://www.energizect.com/your-home/solutions-list/high-efficiency-heating-cooling, Accessed on May 30, 2018.

[66] Geothermal heat and cool with dirt, http://www.geothermalgenius.org/states/hawaii.html, Accessed on March 28, 2018.

[67] Martha S. McRee of the Office of Associate Chief Counsel, Credit for Residential Energy Efficient Property, https://www.irs.gov/pub/irs-drop/n-09-41.pdf, (2009).

listed below.

State	Program/ Utility	Incentives	Incremental Electric Savings (kWh/unit/year)		Fuel Savings (MMBtu/unit/year)
			Heating	Cooling	
CT[4]	Energize CT	$300 SEER 20+	136 kWh	74 kWh	None
MA[5]	Mass Save (utility programs)	$100 SEER 18+ $300 SEER 20+	SEER 18: 286 kWh SEER 20: 330 kWh		None
	Mass. Clean Energy Center	$625 per unit Up to $1000 for income-qualified customers	NA		None
ME	Efficiency Maine	$500 first unit	1,815 kWh	88 kWh	None
NH[6]	NHSaves (utility programs)	$375 SEER 15+ $750 SEER 18+	328 kWh	103 kWh	None
NY[7]	NYSERDA	$500 per unit	260 kWh	144 kWh	None
	Utility programs	$100-$300			
RI[8]	National Grid	$100 SEER 18+ $300 SEER 20+	SEER 18: 270 kWh SEER 20: 248 kWh	SEER 18: 76 kWh SEER 20: 70 kWh	17.43 for fuel oil retrofit[9]
VT	Efficiency Vermont	$600-$800 per unit	SEER 20: 668 kWh		21.98/year for blended mix of fuels
	Utility RES Compliance	VEC $150 WEC $250 BED $375	NA		NA

Image 2: Residential Ductless Mini-Split Incentives and Savings[68]

Heat pumps in Europe:

Overview:

An important factor that has played a key role in the European market is the price of electricity. That price in comparison with costs for other energy sources varies as does the electricity prices from one country to another and from one customer category to another. In general, large electricity users pay a lower price than those using less electricity. The rate of electricity for business/ industrial

[68] Emily Levin & Merrian Borgeson, Driving the heat pump market, lessons learnt from the northeast, Feb 20, 2018.

consumers[69] is much less than residential customer[70]. The cost competitiveness of heat pumps is dependent on the electricity price in comparison with other energy sources such as natural gas, oil or biofuels.

Directives 2003/54/EC and 2003/55/EC of the European Parliament and of the Council set out common rules for internal markets in electricity and natural gas, respectively, requiring markets to be fully open to industrial customers by June 1, 2004, and to domestic customers by July 1, 2007.[71] However, despite ongoing harmonization, substantial differences remain between European countries today in these respects.[72]

District heating and district cooling are some of the alternatives for heating and cooling, which has been widely tried across in Europe. District energy systems produce hot water/air or chilled water/air at a central plant and then distribute the energy through underground pipes to buildings connected to the system.[73] Heat pumps are used in both types of systems on the supply side: those supplying cooling often, in fact, use the district heating system as their heat sink. European countries such as Denmark, Sweden, Finland, Germany, Poland and France have substantial district heating systems. Almost 40 percent of total heating supplies in Sweden, for example, are met by district heating.[74]

Heating of buildings is needed in all European countries. According to the EHPA, 53 percent of dwellings have a central heating system, 11 percent are heated by electricity and 10 percent are heated by gas.[75] Cooling is common in southern Europe, particularly in southern France, Greece, Italy and Spain, and air is the most common medium for distributing the cooling. In some countries such as Norway, Finland and Sweden, for example, a substantial proportion of residential buildings have direct electric heating, presenting an obstacle to the installation of heat pumps,

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[69] https://britishbusinessenergy.co.uk/electricity/#page4
[70] Tatsuya Yamada, International Comparison of Electric Service Tariffs, August 2002.
[71] Article 21 of 2003/54/EC; Article 23 of 2003/55/EC.
[72] Axell Monica & Karlsson Fredrik, Europe: Heat Pumps—Status And Trends, 2008. Proceedings of 9th IEA Heat Pump Conference, 2008.
[73] District Energy & Combined Heat & Power, https://energyandsustainability.fs.cornell.edu/util/districtenergy.cfm, Accessed on June 03, 2018.
[74] Håkan Sköldberg and Bo Rydén, The heating market in Sweden, May 2014.
[75] European Heat Pump Association, Strategy Plan 2000.

as it is not as easy to distribute the heat from them when the house has no heat distribution system to start with. Some countries, such as Holland, the United Kingdom and Germany, have an extensive natural gas distribution network. Europe has a large stock of older buildings with hydronic heating systems that use water as the principal medium for heating and cooling, with high-temperature systems predominating. [76]This has been recognized by several countries, including Germany and Switzerland, as constituting a technical obstacle in the way of using heat pumps that needs to be overcome.[77] The high temperature requirements of many existing buildings have meant that, in most European countries, heat pumps are installed mainly in new buildings.

The low temperatures at which a floor heating system operates (supply temperatures in the range of 30-40 °C) are very suitable for use with heat pumps. In the case of new energy efficient buildings, heating requirements are reduced and cooling and ventilation requirements increase. The trend favors reversible heat pumps that can supply low temperatures for heating and reject heat during high temperature for cooling. Lower heat demand for space heating also means that domestic hot water production will stand for a larger part of the total heat demand in the future in low-energy buildings. In warmer European countries, where heat pumps are also used for cooling, national regulations to phase out the use of ozone-destroying refrigerants have been implemented at different rates. The European Commission plans a 35 percent reduction in HCFCs in 2004, 60 percent in 2007, 80 percent in 2010 and 100 percent in 2015.

The phase-out of CFC and HCFC refrigerants has led to the introduction of new refrigerants, which are also used in these heat pumps. The most common refrigerant used in heat pumps produced in Europe today is R407C, although R404A, R134a and R290 (propane) are also used.[78] R410A is the most common refrigerant for air-to-air heat pumps, although R417A is also used. Although the refrigerant R410A is a non-ozone depleting substance, it has the same greenhouse

[76] Supra note 71.
[77] Laue, H.-J., 2004, Retrofit heat pumps for buildings, IEA HPP Expert Meeting, Hannover, Germany.
[78] Supra note 71.

impact as two tons of carbon dioxide, which is the equivalent of running a car for six months.[79] The global warming impact of R417A is much smaller.[80] However, by way of comparison, in the U.S. the most common refrigerant choice has been R-22, which is a HCFC, for residential heat pump and air-conditioning systems for more than four decades.[81] Releases of R-22 from system leaks and its manufacturing processes both significantly contribute to global warming. The production and import of R-22 will completely stop in the U.S. by 2020[82] but the use of recycled refrigerant will still be allowed. Since, the existing systems cannot use a substitute refrigerant without making changes to the system component, the use of recycled R-22 is expected to continue in existing heat pump systems.[83]

Legislative Action by EU:

The Directive EC/2002/91[84] of the European Parliament and the European Council on the Energy Performance of Buildings was published in December 2002. The objective is to improve the energy performance of buildings within the European Community, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost efficiency. Incorporation of the Directive into national law was required by January 2006[85], although member states had some flexibility concerning the exact manner in which it was to be implemented. In 2010, the EU came up with a recast Directive 2010/31/EU[86], in which many features of the original Directive were strengthened and new

[79] Refrigeration and air-conditioning Consumers, http://www.environment.gov.au/protection/ozone/rac/consumers, Accessed on May 30, 2018.
[80] Neil A. Roberts, Rhodia Organique Fine Ltd, Use of R417A (ISCEON® 59) in Refrigeration and Air Conditioning Applications, http://www.eurocooling.com/public_html/articlerhodia.htm, Accessed on May 30, 2018.
[81] Guide to Air Conditioning & Heat Pump Refrigerant Gases, https://inspectapedia.com/aircond/Refrigerant_Gas_Guide.php, Accessed on May 30, 2018.
[82] Air Conditioning, https://www.energy.gov/energysaver/home-cooling-systems/air-conditioning
[83] Supra note 77.
[84]Directive 2002/91/EC Of The European Parliament And Of The Council on the energy performance of buildings, of Dec 16, 2002, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32002L0091&from=EN, Accessed on April 20, 2018.
[85] Directive EC/2002/91, Article 15 (2002).
[86]Directive 2010/31/EU Of The European Parliament And Of The Council on the energy performance of buildings (recast) May 2010, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0031&from=EN, Accessed on April 20, 2018.

requirements were introduced. The directive emphasized making new buildings nearly zero energy by ensuring the use of high efficiency alternative systems including heat pumps. It also created a timeline of four years for full application of the requirements for boiler inspection, air conditioning system inspection and building certification.[87] The Directive also aimed to reduce energy use in renovated buildings, excluding industrial properties, and included certification schemes for new and existing buildings, together with requirements for the recurrent inspection of boilers and heating/cooling installations[88].

The European Commission also developed a draft proposal for a new Directive "Eco-design of End-Use Equipment,"[89] which, among other measures, gives the Commission the right to establish mandatory minimum energy performance standards for end-use equipment. The annex of the Directive stipulates that the level of energy efficiency used in the standard will minimize life cycle cost for end users, on the basis of a real interest rate of 5 percent and with realistic assumptions of product lifetimes.[90]

Austria, Sweden and Switzerland are defined by the EHPA as mature markets, a common feature being that various types of national incentives have been used to advance the technology.[91] The Swiss government started a program "Energy 2000"[92] in 1991, with the aim of reducing the country's use of fossil fuels through the greater use of heat pumps. New research projects were started to increase the number of heat pumps in the country's existing building stock under the Swiss Energy Plan.[93] In Sweden, the government conducted a technology

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[87] Article 14 of Directive 2010/31/EU (recast).

[88] https://lms.i-know.com/pluginfile.php/28688/mod_resource/content/57/Energypercent20Efficiencypercent20andpercent20Certificationpercent20ofpercent20Centralpercent20Airpercent20Conditioners.pdf, Accessed on Apr 05, 2018.

[89] Ecodesign, http://ec.europa.eu/growth/industry/sustainability/ecodesign_en

[90] Supra note 47.

[91] Supra note 71.

[92] https://www.iea.org/policiesandmeasures/pams/switzerland/name-21739-en.php, Accessed on April 18, 2018.

[93] Renewable energy technology deployment implementing agreement and the renewable energy working party of the international energy agency, renewables for heating and cooling, July 2007, https://www.iea.org/publications/freepublications/publication/Renewable_Heating_Cooling_Final_WEB.pdf, Accessed on May 31,2018.

procurement project for heat pumps to encourage development of efficient, economically competitive heat pumps.[94] Sales of ground source heat pumps have increased steadily since 1995.[95] In parallel with this, Sweden is also running a national research program[96] for heat pump technology, which shows that effort put into R&D can benefit the market.

Heat Pump Market in Europe:

In southern Europe, the need for air conditioning is driving the growth of the heat pump market, and so the most common types of heat pumps are reversible air/air or air/water units. However, investigation of energy requirements during the year show that, even in these countries, heating requirements dominate. Still, the air conditioning requirement has been driving sales.[97]

Air conditioning is also becoming more common in central and northern Europe. In Europe most heat pumps are installed in new buildings and are of reversible air/water types that can be used for both heating and cooling. Cooling is usually distributed by fan coils, operating at a temperature above the dew point.[98] On the heating side, it is common to have direct expansion floor heating systems. Indirect systems are a new product and are installed only in new buildings.

The heat pump market is also growing rapidly in Norway, Finland and Sweden. The Nordic countries have in common a fast-growing market for air/air heat pumps. As per the Swedish Heat Pump Association, sales increased from 2,625 units in 2000, 21,307 units 2002 to about 55,000 units in 2003[99]. The Norwegian market is another example of where sales of heat pumps increased dramatically.

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[94] NUTEK, Swedish Refrigerator Procurement (appliance market transformation program), https://www.iiec.org/2015-11-12-07-41-32/results-center/profiles-by-number/298-results-center/profiles/278-nutek-swedish-refrigerator-procurement-appliance-market-transformation-program-profile-108, Accessed on May 31, 2018.
[95] Supra note 71.
[96] RISE Research Institutes of Sweden, is performing extensive research on performance and technical evaluation of heat pumps under the Swedish Ministry of Enterprise, Energy and Communications (https://www.sp.se/en/index/services/heatpump/Sidor/default.aspx).
[97] Supra note 71.
[98] Id.
[99] Baardsen, B. (Norwegian Heat Pump Association), Development Of Heat Pumps in Norway.

The main reason was that ENOVA[100] provided grants to encourage installation of air/air heat pumps in 2003. About 18,000 units were sold with the help of these grants, and a further 30,000 without grants as a result of increased awareness of air/air heat pumps, lower heat pump prices and higher electricity prices due to a dry summer. By 2013, the annual sales of heat pumps in Sweden increased by a total of 4 percent.[101]

It should also be noted in this context that only 14 percent of Norwegian properties have hydronic heating systems.[102] However, 45 percent of new houses are now being fitted with hydronic heating systems, and properties with floor areas over 1000 square meters are required to have them[103].

Sweden tops the statistics in Europe for heat pumps intended primarily for heating. In Sweden after its technology procurement project[104] for heat pumps, sales have risen steadily, both for new buildings and for existing buildings. Over 90 percent of new houses incorporate an exhaust air heat pump in combination with floor heating. In existing buildings, primarily vertical ground source heat pumps have been installed. There has also been a noticeable increase in the sales of air/air heat pumps in Sweden, which can be explained by the fact that few buildings have hydronic heating systems, and therefore it's considerably more difficult to convert the housing stock from direct electric heating.[105] Sales of these heat pumps are reported to be running at about 40,000 units per year.[106]

With improved insulation and heating systems, energy demand from new homes in Netherlands is steadily falling, although the demand for cooling is increasing. The decreasing demand for heat makes it very expensive to provide

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[100] Enova SF is a public enterprise owned by the Norwegian Ministry of Climate and Environment and contributes to reduced greenhouse gas emissions, development of energy and climate technology. See http://enova.no/?itemid=425, Accessed on May 30, 2018.

[101] Swedish heat pump sales increased by 4% in 2013, EHPA, Jan 2014, http://www.ehpa.org/about/news/article/swedish-heat-pump-sales-increased-by-4-in-2013/, Accessed on May 31, 2018.

[102] Rose, R., 2004, God varmepumpeutvikling i Europa – og i Norge, p. 22-24, Kulde Skandinavia6/2004, Norway. Translation- good heat pump development in Europe).

[103] Stene J. 2004. IEA HPP Annex 29, Ground-Source heat pumps overcoming technical and market barriers, Status Report Norway, Sintef Energy Research, Norway.

[104] Supra note 93.

[105] Supra note 71.

[106] IEA Heat Pump Centre Newsletter, No 1/2005

natural gas infrastructure in new buildings sites, which helps the market for electrically-driven heat pumps in new houses.[107] In the next two years at least 10,000 houses will be renovated in the Netherlands with gas driven heat pump systems.[108] In Norway, it is expected that the Energy Directive will increase the competitiveness of ground source heat pump systems for energy-efficient heating and cooling in nonresidential buildings. Interest is also growing in small-scale and large-scale district heating and cooling systems. These factors facilitate the installation of ground source heat pump systems.[109]

The principal market barriers are cost efficiency and purchaser confidence – itself reflecting the absence of an established, well-regulated supply and installation structure. Many potential purchasers are wary of the technology, having memories of inadequate systems installed in the 1970s. The cost-efficiency gap is generally smaller than for some other high-profile low-carbon and renewable alternatives. The gap is nevertheless real, especially in competition with fossil fuel heating.

The UK is a relatively small market, with sales of only about 500 reversible air/air heat pumps in 200.[110] It is clear that the technical potential is predominantly in housing, although the existing market is overwhelmingly in commercial buildings. Only a very small proportion of this potential is being tapped in UK.

Two key market barriers in UK are:

- Capital costs are high. For geothermal heat pumps, the high-cost item is the ground loop, typically representing 35 percent to 40 percent of the total cost. UK costs appear to be higher than those elsewhere, so increasing market size and the consequently more efficient use of resources and increasing skill levels could lead to cost reductions.

[107] National position papers HPC-AR7, 1999, International heat pump status and policy review 1993-1996, Heat Pump Centre, The Netherlands.
[108] Kleefkens, O.2004, Oral communication, NOVEM, The Netherlands.
[109] Ibid.
[110] Hitchins, R., 2004, The UK Heat Pump Market, IEA Heat Pump Centre Newsletter 4/2004, IEA Heat Pump Centre, Sweden.

- Consumer barriers include unfamiliar technology and uncertainty about continuing maintenance and service availability. Successful (but relatively costly) strategies for reducing these barriers have been demonstrated in other countries, but the relatively small companies trying to develop the UK market do not have the resources to set up support infrastructure on a comparable scale.

What We Learned

Some of the major recommendations based on the programs discussed above include the following:

- **Direct engagement with the installers and distributors** of heat pumps so that the products are available and installers are primed to offer them to customers.
- **Significant incentives** (at least $500 incentive per unit) for installers, distributors and customers. Direct incentives to homeowners are one of the most effect ways promote the technology and encourage installation. A focus on direct incentives has proven to be a make-or-break point in adoption of these technologies.
- **Ability to both heat and cool** is a driving factor for people to switch to heat pumps - a condition perfect for California. Air-source heat pumps are best for such conditions and are already very popular in Southern Europe.
- **Building codes, especially applicable on new buildings**. Floor heating coupled with heat pumps or reversible heat pumps can find a place in building codes. These codes can include provisions that makes it mandatory to include this technology in the building plans for new buildings. Currently in California, under Title 24, a utility will pay rebates or incentives for the purchase or installation of central air-conditioning, heat pumps or related fans.

Future implementation

The future of residential electrification will depend on both the financial merits of switching from natural gas- to electric-powered heaters from the

consumer standpoint, and the degree of nudging versus mandating that state regulators deploy. On the first point, time is on the side of residential electrification, especially with continually falling prices for solar and wind energy across the country. The question is whether retail electricity prices will approach or fall below natural gas rates, and also in California, when will retail electricity rates more closely match wholesale prices, especially with the addition of fixed and social costs of electricity factored in.[111] On the other hand, as more consumers leave natural gas infrastructure in favor of residential electrification, prices for natural gas could rise as fewer consumers are left to pay for the remaining infrastructure, whose costs will likely be reflected in gas rates. That's where the type of city or state incentives discussed earlier could play a significant role. "It's about how to plan for that over 30 years, people coming off the gas pipeline slowly versus a more planned exit," Borgeson said. A planned exit, she said, would involve "not putting new pipelines in and restructuring of pipeline that there is."

Much of the progress now being made toward residential electrification is happening at the city level. In February 2018, the Los Angeles City Council directed city water and power departments to examine ways to reduce natural gas use in the wake of a CPUC moratorium on new natural gas connections for industrial and commercial properties in Los Angeles County due to the Aliso Canyon leak. That follows moves by governments in San Francisco, Portland and other U.S. cities to encourage or even mandate the switch to electric residential heating.

The recent updates to Title 24 provide the clearest indication yet that California policymakers intend to push residential electrification as a key greenhouse gas solution. Rider said the Energy Commission, in its recent updates to Title 24, all but stopped short of mandating heat pump space and water heaters. A 2017 UC Berkeley study by Imran Sheikh, now an environmental sciences professor at Western Washington University, found much higher adoption of heat pump heating systems when laws require new buildings use electricity-based heat - so much so that charging a natural gas installation fee made little difference in the

[111] Borenstein et al. (2018)

uptake of heat pump heating technology.[112] Such a mandate approach could prove unpopular, however, compared to financial nudges such as tax breaks and rebates that have been employed by other U.S. states and in Europe. Using carbon pricing and other measures to bake greenhouse gas effects into energy costs would help narrow the difference between natural gas and electricity prices and provide the kind of nudge that would spur adoption of electrified heating and cooking. Finally, more efforts should be made to increase awareness among contractors, city officials and consumers about both the heat pump technology and the incentives being offered by cities and utilities to help more households adopt the heaters.

Piette said her group at the Lawrence Berkeley National Laboratory will be joining private and public researchers over the next six months to examine the infrastructure implications of shifting resources to space and water heating. One of the first test beds for such whole building electricity-based heating could be rolled out in the public sector, in state and municipal buildings, before it is expanded to the residential sector.

"The state is certainly looking at the implications of this switch," Piette said. "It'll come and the question is how quickly."[113]

[112] Sheikh (2017)
[113] Piette (2018)