Carrots and Sticks in Hot Water:
Role of Codes and Policy in Market Transformation

Smita Gupta, Jim Edelson, Kim Cheslak, Amruta Khanolkar,
New Buildings Institute

ABSTRACT

Codes have traditionally been the final stage along the market transformation curve for energy efficiency measures and technologies. However, this linear portrayal does not capture the role that regulatory policy now plays in driving the market. Codes and standards are increasingly driving markets for technologies that are seeking to overcome barriers like cost, awareness, and accessibility. This paper discusses the role for codes and standards in transforming the market for the 40-year-old hot water technology by examining the heat pump water heater (HPWH) and comparing its path to other recent technologies such as rooftop solar. This paper establishes the importance and value of rapidly transforming the market for HPWH, and describes other policy tools that can supplement codes and standards to speed market adoption of HPWH.

The efficiency and grid connectivity requirements for HPWH are making their way into base and stretch codes. In addition, the adoption of policies for new construction all electric buildings and indoor air quality requirements are also making HPWH a default choice. This parallel path of codes and standards is critical to accelerating market adoption, while driving down unit costs, and supporting supply chain and workforce expansion. The magnitude of the HPWH opportunity is based on the water heater stock of 118 million residential units, of which 27 million are more than 10 years old, 7.5 million are replaced annually, and over 1 million units in new home construction per year. The impact is assessed at 100 million tons of carbon savings every year which is equivalent to closing 18 coal power plants, making the market acceleration more imperative to meet widespread decarbonization goals for the building sector.

Introduction

Traditional market transformation for building technologies begins with technology advancement to meet market requirements, followed by awareness and education to gain market share on its way to becoming cost effective, then, and only then, does it get locked in code as a requirement. This traditional process presents a problem: uncertainty in policy is a barrier to building sufficient market demand. A lack of clarity in policy signals produces uncertainty in the commercial market for manufacturers to assess and in product demand, which in turn poses its own market barrier in the form of product availability. But climate imperatives now are rapidly changing policy objectives that are transforming markets for low or zero emission products.

Heat pump water heaters (HPWH) have been around for over a decade as a commercially available product and only seen minimal market uptake. The current market share nationally stands at 2 percent of all residential water heater sales annually (EnergyStar 2019), accounting for both new construction and retrofits. If market penetration doesn't increase, there is a possibility that major water heater manufacturers will decrease investment in their HPWH product lines and eventually discontinue their HPWH models (Butzbaugh 2017).

An analogy for the HPWH market transformation can be found in both the rooftop solar and the lightweight consumer electric vehicle markets, both recent and relevant examples of how policy has changed its impact on the market transformation curve and continues to shape the growth trajectory for their adoption and increased market share. The Figure 1 below shows a illustrative market adoption curve highlighting the important role policy can play in market transformation.

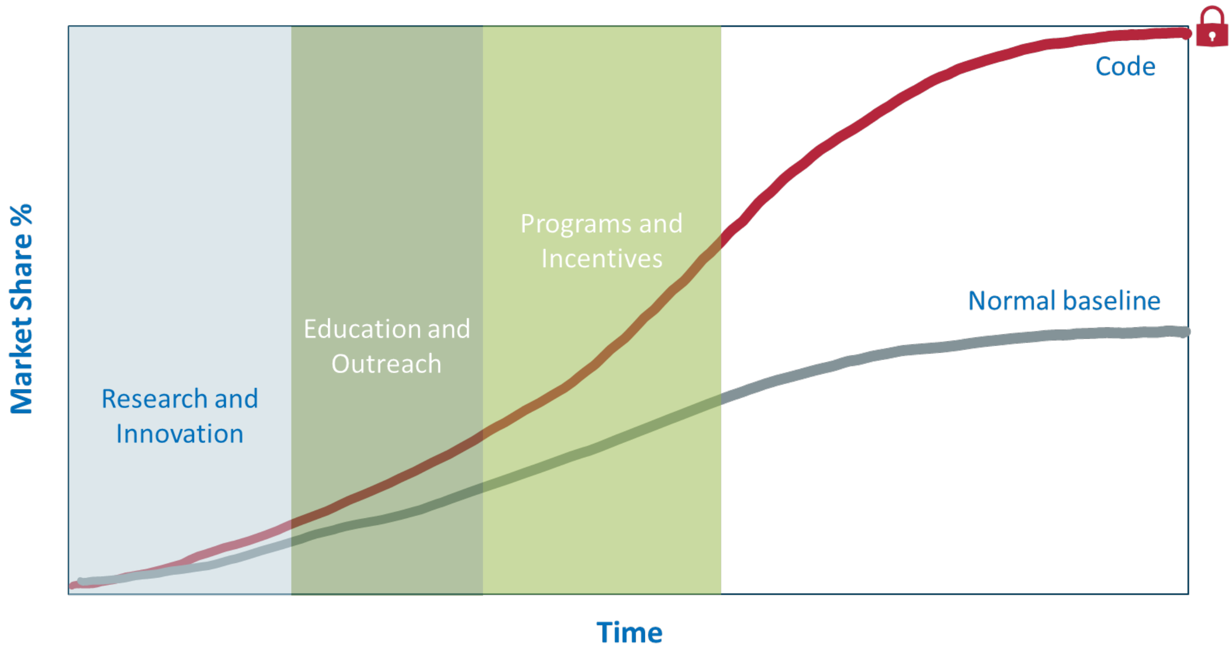

Figure 1: Illustrative market share curve for increased adoption of technology over time. Source: NBI

The rooftop solar market grew exponentially from 2006 through 2016 in California due to a rich policy landscape initiated by the Senate Bill 1, also known as the million solar roofs legislation (SB 1, Murray 2006: Electricity: solar energy: net metering). This, combined with the net energy metering policy (NEM 2016), which credited excess export to the grid, made it cost effective. Coupled with upfront and ongoing performance incentives, as well as time of use rate structures, this suite of policies completed the setup for successful market growth. As a result, the distributed solar market in CA saw 200 percent growth over 10 years and significant cost per watt reduction associated with the maturity of the market (Figure 2).

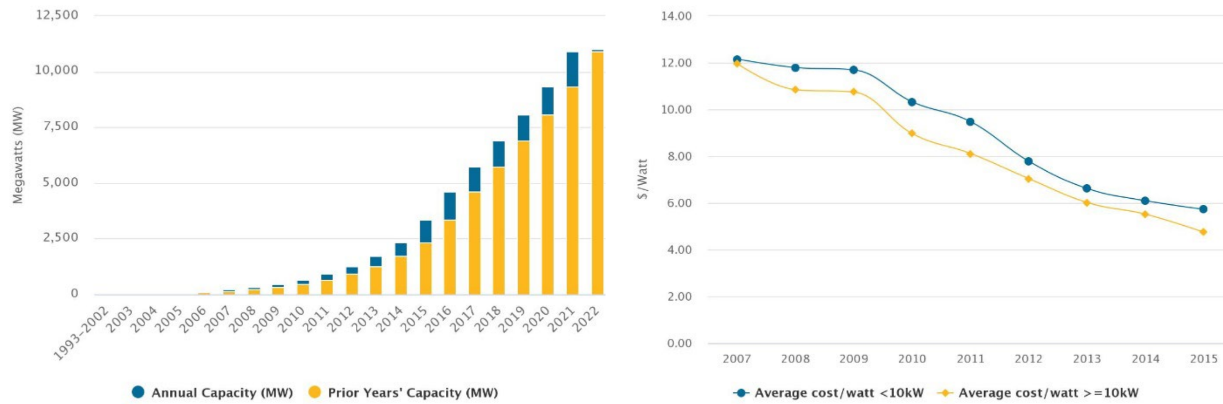

Figure 2: California DG solar growth and associated cost per watt reduction
Source: https://www.californiadgstats.ca.gov/

Some of the key codes and policies that triggered this growth include NEM tariffs and incentives as carrots which were rounded up with rooftop solar requirements in reach and stretch codes adopted by local jurisdictions, followed by solar readiness criteria in the State's Title 24 energy standards, to compliance credit and eventual requirements over successive update cycles of the code from 2008 to 2022.

Similarly, policies around zero emission vehicles have catalyzed the market share for electric vehicles. The California Governor issued an executive order requiring sales of all new passenger vehicles to be zero-emission by 2035[1,] This policy has been followed by similar government and private commitments around the country to phase out internal combustion engines, thus giving manufacturers the vision towards projected market demand and adequate time to scale up production to meet a zero-emissions standard. These policies are reinforced by increasing consumer demand. The technology which advances has resulted in major U.S. auto manufacturers setting their own dates for ending production of fossil fuel power vehicles. Policies such as these are repeatedly demonstrated to be significant drivers for signaling market trajectories and thus accelerating the transformation.

HPWH Market Transformation

Given the urgency of impending climate change and the need to reduce carbon emissions associated with all aspects of buildings, water heating as an end-use is a significant tool in the arsenal. The challenge in front of us is to increase market adoption for high efficiency, low emissions water heaters, or in other words, heat pump water heaters (HPWH). The technology has been around for over four decades yet still has low market adoption. The HPWH are a technology that are unmatched in their higher efficiency and lower emissions compared to their counterparts that use relatively outdated technology, either electric resistance or burning of gas or other fossil fuel to heat water. The key challenges have been around education and awareness for the technology and therefore market demand, which has resulted in limited availability, feeding into the cycle of lower visibility and awareness.

[1] https://www.gov.ca.gov/2020/09/23/governor-newsom-announces-california-will-phase-out-gasoline-powered-cars-drastically-reduce-demand-for-fossil-fuel-in-californias-fight-against-climate-change/

Water heating accounts for twenty to thirty percent of residential energy use typically (Figure 3). And water heating shares of building energy are only increasing as energy codes make large strides in lighting and other building systems (Figure 4).

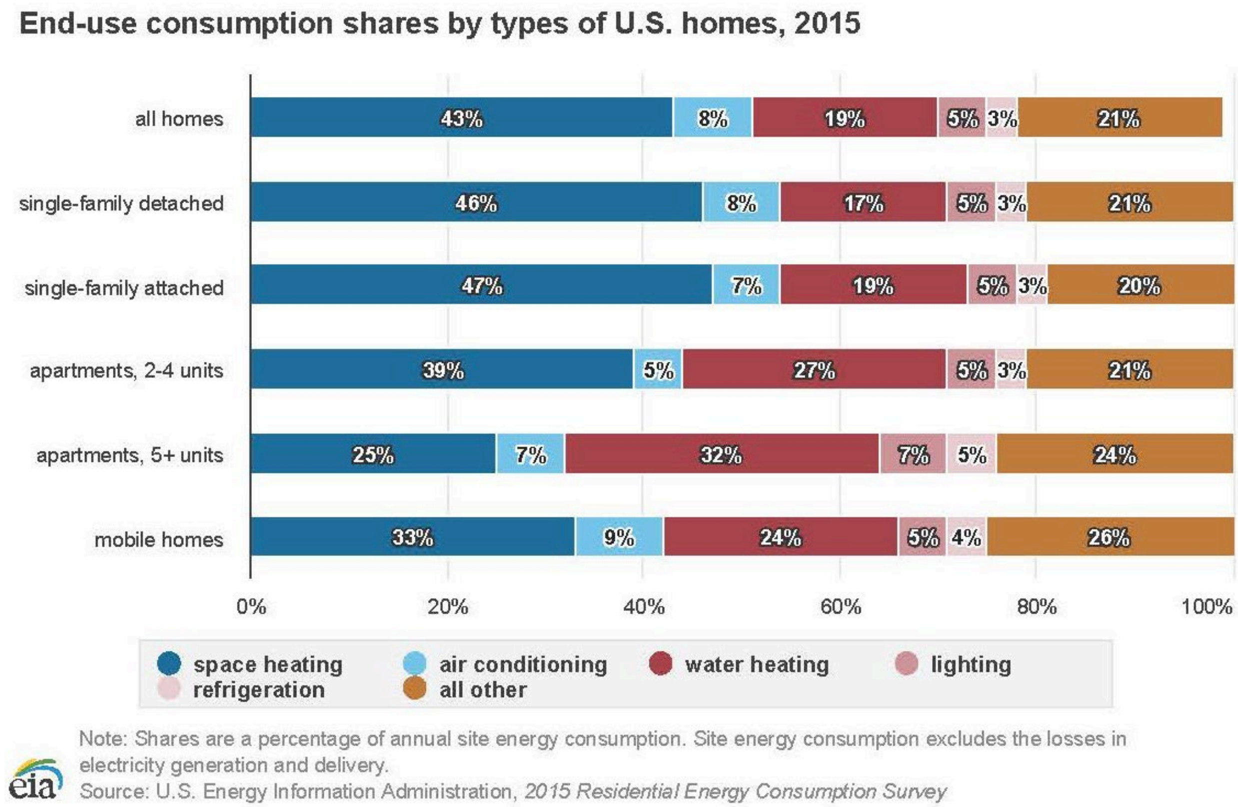

Figure 3. Energy Use for Water Heating in Residential Occupancies Built to Current Codes *Source:* EIA

The residential water heater stock is estimated at 118 million residential units, of which 27 million (22.9 precent) are more than 10 years old. Of these, 7.5 million (6.4 percent) are replaced annually, and over 1 million units are placed in new home construction every year[2]. If all new water heaters and all replacement water heaters were HPWH, the impact would be 100 million tons of carbon savings every year, equivalent to closing 18 coal power plants. Knowing the scale of potential impact, the widespread and growing demand on the building sector to decarbonize and meet climate goals, makes the market acceleration for HPWH that much more imperative.

The New Construction Market

The new construction market is the most conducive to adoption of the technology since it does not face the same physical and cost barriers as a retrofit. Key design and construction criteria for the inclusion of HPWH include:

---

[2] Building stock from 2015 RECS and 2018 CBECS, annual construction from US. Census Bureau, market potential from ENERGY STAR Water Heater Market Profile (2010), and savings calculated by New Buildings Institute

1. Electric panel capacity in terms of amps available
2. 240-volt circuit
3. Appropriate location for venting (needs about 700 cubic feet space to draw air and ideally an unconditioned space to vent cool air, from manufacturer installation instructions)
4. Physical space requirements (typical units need 3'x3'x7', similar to most 30-80-gallon storage models, from manufacturer installation instructions)
5. Ability to drain condensate

Being able to design for these in new construction leaves only the incremental cost as a potential barrier. If done at scale, this cost can also be mitigated through volume purchases. In new construction we recognize two primary drivers for equipment selection: market demand and code requirements. This makes the code a powerful lever to influence the new construction market adoption.

The Replacement Market

The other ripe market sector is that of the electric resistance change outs, since they have already overcome many of the primary barriers for retrofits: the existence of electric panel capacity, 240-volt circuits, and physical size. The HPWH technology is at least three times more efficient than electric resistance water heaters, making the return on invest a favorable proposition, especially so in regions like the South, where 68% of water heaters are already electric (Figure 5).

The replacement market can be highly influenced by installer or plumber education and awareness and ready availability of equipment. Options to influence this market can be driven by utility incentive programs, the traditional carrot, but also by changing codes around replacements. Since water heater replacements require permits, there is an opportunity to drive towards HPWH equipment through codes at state and local level. At the federal level, EnergyStar labeling of high efficiency equipment plays a role in recognizing HPWH, but the market could also be driven by other appliance standards for efficiency which may exclude being able to replace electric resistance models with like.

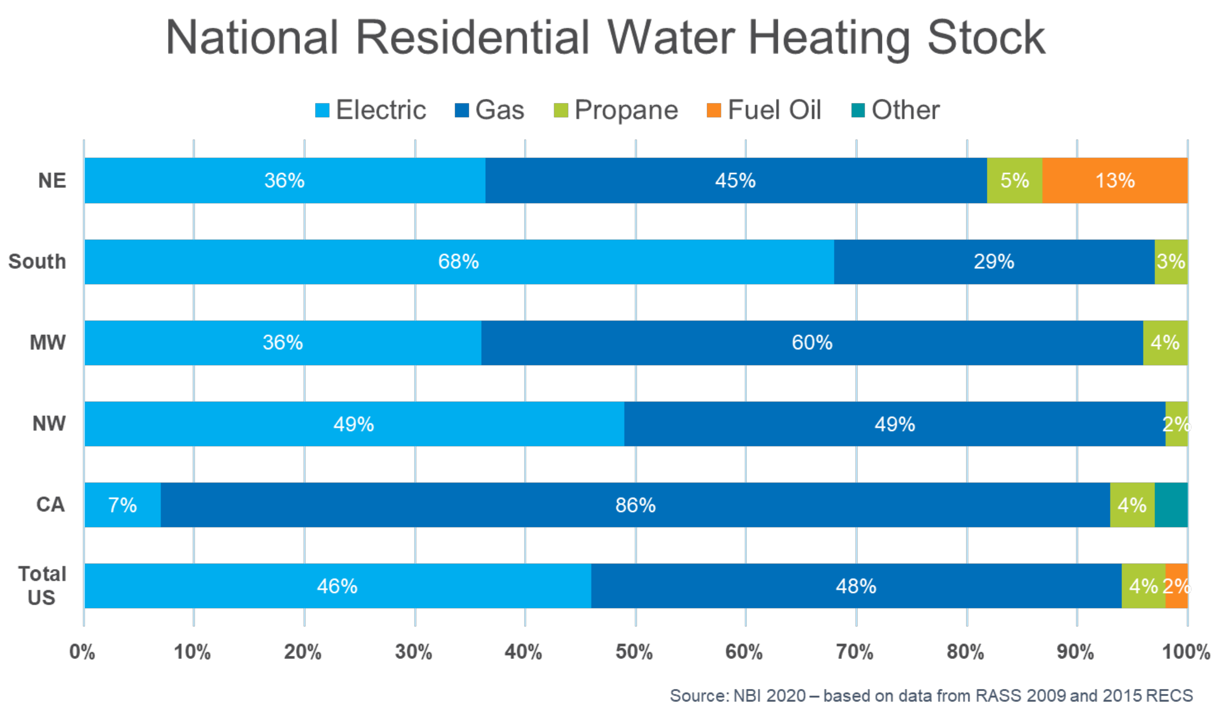

Figure 5: National Residential Water Heating Stock by Fuel type

The gas and fossil fuel stock replacement are the more challenging market and fraught with additional challenges like electric panel constraints and the need for new electrical wiring among others. Having policies and tariffs to support fuel switching will be needed to make the market more conducive, hence making a lagging stock. On the incentive level, there is a substantial policy barrier when, in the case of switching from gas hot water to HPWH, most utility incentives cannot be applied to a switch from inefficient gas heating to efficient HPWH.

The market share projections based on prioritized market sectors are illustrated in Figure 6 which leads with the new construction and electric resistance change out markets in the near term to build market demand and get more awareness around the technology, with an end goal for 100 percent market share by 2030. These projections will need significant intervention since the business-as-usual adoption which has been the historic trend is very low. The projections for HPWH adoption in new construction are based on the increasing adoption of stretch codes, which require higher overall energy efficiency, and all-electric codes. This at full adoption could mean over 1 million HPWH a year in new construction alone. The electric resistance changeouts are the next low barrier market sector with existing electrical infrastructure and much higher efficiency available in HPWH compared to electric resistance water heaters. This market sector does not have a fuel switch challenge in code or operation and the value proposition and benefit to end customer is directly in bill savings. The upfront cost buydown and policy to drive the ready availability of HPWH for emergency replacement situations can be a big factor to drive the market adoption. Electric resistance is at least half of the national water heater stock as a fuel type which makes the replacement potential critical. The southeast as a region has the highest electric resistance stock (over 10 million) which can be impacted by policies that can buy down first cost and by requiring utility programs to support the changeouts. Similarly, New York and

California with climate favorable policies have another 10 million between them to drive the sector. Building performance standards for existing buildings as a policy will also drive this changeout market. With the zero-emission regulation for all appliances making the final cut to all gas appliances.

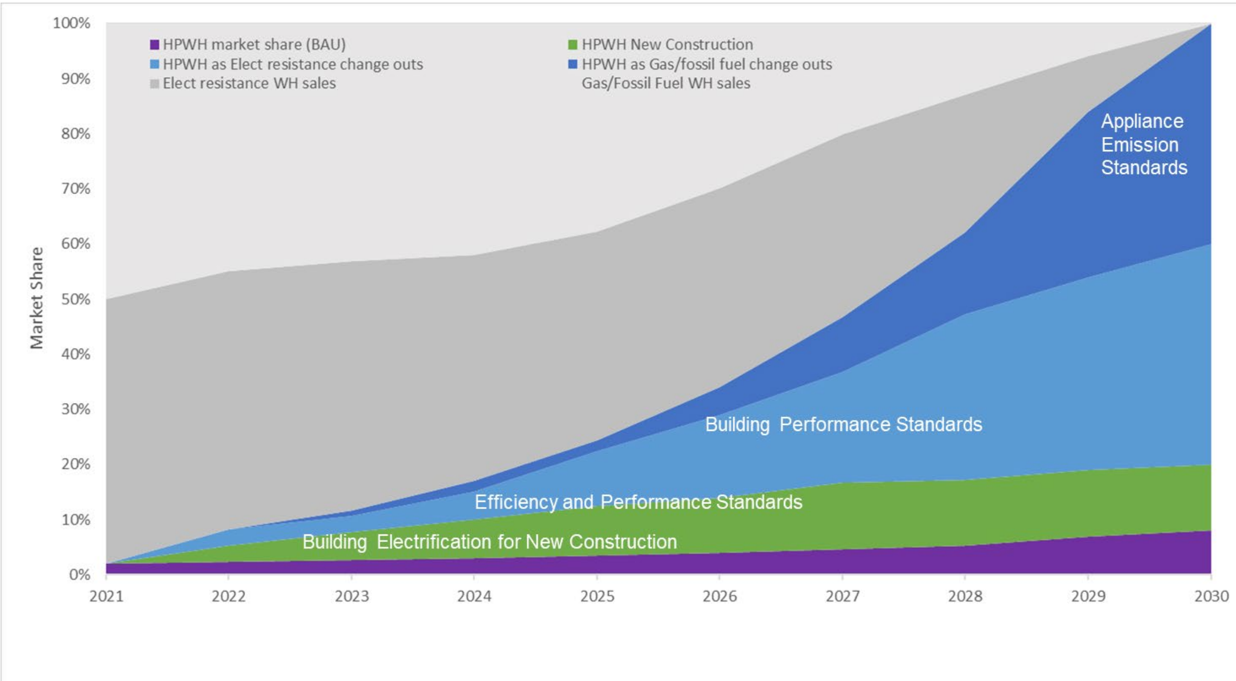

Figure 6: Illustrative market share projection with policy interventions for residential heat pump water heaters, *Source:* NBI 2021

Key Policy Drivers for HPWH

Building decarbonatization plans around the world conclude that electrification of building energy loads is a necessary step to meet climate goals, and cite the need to plan to reduce and eliminate fossil fuel combustion for thermal load in water and space heating. This will take advantage of rapidly increasing proportion of low-emission electricity generation sources without a corresponding drop in the carbon intensity of natural gas and other fuels delivered to buildings. Policy objectives for water heating to support electrification thus are oriented towards two key drivers:

1. Energy Efficiency to reduce overall demand
2. Grid Flexibility to tap a water heater's ability to shift electric demand

The primary driver behind HPWHs is the higher efficiency, which is typically three to four times more than that of electric resistance counterparts. Efficiency contributes to lower energy use, and a reduction in demand on a static basis. The secondary driver is grid flexibility, with HPWH being able to receive and respond to grid signals, they can be responsive to time of use carbon data, and act as thermal batteries, heating water when grid carbon is low, and storing it until there is a demand.

Codes and Standards to Transform the HPWH Market

It has long been recognized that a codes-driven approach to market transformation was necessary to meet the Big Bold Goals for energy codes in California (Brown, 2012). These end goals for code were necessary to meet the efficiency goals contemplated by Assembly Bill 32, a California State Law that fights global warming by establishing a comprehensive program to reduce greenhouse gas emissions from all sources throughout the state. Higa, et al. (2014) described traditional market transformation as such:

"Under this traditional market transformation model some implementers see Codes & Standards as an "exit strategy" to remove public support of efficient technologies during the latter part of the commercial maturity phase. Once energy efficient technologies are broadly accepted (low net to gross ratio) and cost effective they are determined to be "code ready" and should be adopted into energy codes. This traditional bottom-up approach to code updates assumes that measures become 'code ready' due to incremental improvements technologies or building practices over time. Thus, code readiness is passively dependent on the success of other efforts by the regulatory, programmatic and market forces."

In contrast, the top-down approach was described as necessary to achieve the goals and timelines in state statute. The tactical plans to accelerate market transformation were thus described as such. Unlike the goals for many energy efficiency programs, the commercialization phase is not as focused on short term cost-effectiveness and resource acquisition but information acquisition for preparation for code. As described in Eilert et al. (2012), the savings from a new construction program that influences a portion of the market pale beside the savings from an energy code change that impacts the entire new construction market and reduces first costs through commoditization. This past case in California is parallel to the case for rapidly transforming the current heat pump water heater market to achieve energy and emissions reduction goals while being able to support the newly created demands on the electricity grid.

Efficiency and Performance

Code stringency improvements will encourage the utilization of above-code efficiency equipment in high hot water using building types, especially residential. Starting in January 2023, the CA Title 24 2022 standards will require a performance threshold that in effect will require the use of heat pump space and water heating technologies due to their overall much higher efficiency levels than any fossil fuel or electric resistance counterpart. At the national model code and standards level, some of the most cost-effective paths to meet package or credits-based prescriptive requirements (such as Sections C406 and R408 in the IECC, or 90.1-2019 Addendum) are oriented around HPWH. And there is a growing number of code requirements for buildings to be electric-ready, so that the future changeouts are enabled with electric panels and wiring in place - this will further drive new construction towards heat pump solutions.

Appliance standards leadership like the EnergyStar labeling draft version 5.0, raises the bar on water heating efficiency, which makes HPWH a more prominent choice and limits the gas and fossil fuel options for those seeking the market-dominating EnergyStar label.

Grid connectivity

The grid connectivity for HPWH is important to support the all-electric future of buildings and end-uses. The demand response potential in the U.S. through a complete transition to HPWHs is major—on the order of 20-40 Gigawatts. That estimate is without the added value and impact that can occur driven by time-of-use rates (AWHI Progress Report 2020).

States are adopting and considering requirements for grid integration requirements for water heaters in their energy codes, particularly CTA-2045, an industry standard for grid connectivity that requires universal port. As the market for CTA-2045 compliant water heaters are currently all HPWHs, this is effectively a requirement for HPWHs. Washington already has an appliance standard requiring CTA-2045-A and is currently in the process of approving an energy code requirement moving to "near"- B. California has seen a lot of movement in grid integration including policy proceedings for Load Management Standards. Many utilities are looking to water heating loads for grid demand management. As a result, tightening Renewable Portfolio Standards (RPS) incentivize HPWH programs and policies.

Table 1. Policies related to grid connectivity:

Geography	Regulation	Date of Implementation	Details
Washington	SB 5115 HB 1444	January 1, 2021	All new electric water heaters CTA (Heat pump 1/21, Electric resistance 1/22)
Oregon	EO 2020-04	January 1, 2022	All new electric water heaters requires CTA 2045 similar to WA (Heat pump & Electric resistance 1/22)
Energy Star Version 4.0	ENERGY STAR® Version 4.0	Final Draft to be released Q1 2021	ENERGY STAR® Version 4.0 Specification and Connected Criteria— CTA 2045 or Open ADR
California	Title 24, JA13	July 8, 2020	Requires NEEA Tier 3 v7, which requires a CTA-2045 port (New Construction)
National for Water Heating	AHRI 1430	In Progress	Proposing CTA 2045 B with optional OEM path customer via (Wifi, Bluetooth or others). Good alignment at this point
Northwest Energy Efficiency Alliance (NEEA)	Version 7	July 1st, 2020	Requires Tier 3 V7 and Tier 4 have CTA 2045

Building Electrification

Dozens of cities and states are considering code provisions that require or heavily incentivize electrification of water heating loads. This decreases barriers to going to HPWHs, particularly when combined with increased code efficiency requirements. Variations include mandatory electrification in new construction, electrification readiness and HPWH readiness requirements with electrical panel and wiring upgrades in place. Over 50 cities in California have adopted some form of electrification mandates which make HPWH adoption inevitable. The mandates are primarily directed to new construction thus setting the stage to increase market share while also establishing a stock for the future. States like New York are working on aggressive roadmaps towards building electrification which layout a path to electrifying most end uses, including water heating, in all building types and vintages by 2030.

Building Performance Standards

Building performance standards (BPS) for existing buildings are another lever to regulate the performance of buildings. BPS set targets for existing building energy or carbon performance and are emerging as the leading tool for jurisdictions to achieve deep energy savings and emissions reductions in existing buildings. No matter which metric a jurisdiction chooses - energy or carbon - HPWH will become an attractive choice for upgrades and replacements due to their much higher efficiency than their traditional counterparts, removal of direct combustion from the building, and ability to respond to cost and carbon signals from the grid.

While BPS are continuing to emerge, understanding how much impact water heating through HPWH can provide to an individual building's overall compliance target achievement will be an important consideration for continuing to gain market penetration, and may vary from jurisdiction to jurisdiction. The most directly favorable metrics to HPWH will be site EUI, given the technology's three to four times increased efficiency, or carbon, given that HPWH are not reliant on gas. As additional metrics around grid flexibility surface for BPS, they present another area where HPWH can excel to aid in the achievement of the building scale performance goal.

Emission Standards

Given the urgency of climate change, there is a race to curb emissions from all aspects of the economy and life on this planet. Increasingly the emissions associated with gas appliances are making headlines with associated on-site health and wellness concerns. Several air quality management districts are adopting regulations to ban gas appliances through limiting the on-site emissions. The NOx and CO levels permissible make gas fueled options non-compliant, thus making the HPWH an attractive and natural choice. The California Air Resources Board (CARB) is proposing zero-emission standards for space and water heaters to go into effect in 2030 (CARB, 2022) as an implementation strategy to meet the state's decarbonization goals. These types of emission regulations can make a significant difference and impact to increase the adoption of HPWH ahead of all other code and policy levers.

Innovative Policy Levers

The traditional policy levers all have the potential to impact and increase the adoption of HPWH as described above, however there are some innovative approaches that can move the needle faster and address issues around equity for new technology adoption. One such lever is the federal opportunity to make bulk purchases of equipment to install as part of weatherization, and other such plans aimed at disadvantaged communities. Residents of these communities will have the highest operational benefit but lack the resources and mechanism to make the initial changes. The additional benefit of bulk purchases is that it will also spur the market with higher production and availability to motivate and enable manufacturers. This will enable more access and availability of the product that can have a snowball effect on the market.

Yet another lever available to government agencies is to lead by example and adopt HPWH in their procurement practices for their buildings and drive-up market share for the technology, including showcasing the impacts and operational benefits.

Another innovative policy can be a drive to exchange inefficient and gas or fossil fueled water heaters for cash that can be put towards the purchase of high efficiency HPWH. This approach has been tried as the popularly known “cash for clunkers” program by the Obama administration in 2008, aimed at getting low mileage vehicles off the streets. The aim was to stimulate the economy, helping the environment, and also reducing inequality by offering the cash incentive toward high efficiency new purchases. All of these outcomes are also achievable for a program aimed at water heaters.

Conclusions

Using the carrots and stick approach to market transformation is not new, but with the rapidly increasing application of ‘sticks’ to the HPWH market, it is essential that the ‘carrots and sticks’ be addressed comprehensively rather in isolation. The end goals for complete electrification of water heating are being set state-by-state and city-by-city. Energy Star and other voluntary programs, including utility incentives, are targeting the switch to heat pump water heaters, as they offer both better energy efficiency, lower GHG emissions and grid management benefits. First in new construction codes, then in building performance and appliance emission standards, the market for HPWH will be more rapidly transformed through introduction of policy goals and mandates. Including innovative policy levers which can make significant transformation possible. Though we want to acknowledge that policy can be a driver, it is also a deterrent, like in the cases where fuel switching is prohibited or disincentivized. In conclusion, early adoption of codes and policies requiring adoption of HPWH can speed the pace of market adoption of HPWH and catalyze the market towards total transformation.

To summarize:

1. Electrification of water heating with high efficiency HPWH should be a high priority policy objective given its potential to reduce GHGs, lower costs for customers, improve indoor air quality and offer grid management benefits. “Business as usual” will not meet the adoption and market share goals in the time frame needed for the decarbonization of the building sector.

2. Adopting codes in states and cities that mandate adoption of HPWH in both the retrofit and new construction markets will accelerate market transformation. These codes should be coupled with financial incentives that reduce fuel switching costs, with EnergyStar labeling that no longer recognizes gas water heaters, and with bulk purchasing plans – all of which supports this urgently needed market transformation to HPWH.

References

AWHI 2020 Progress Report and Playbook, Bringing Heat Pump Water Heaters into the Mainstream, 2021

Butzbaugh, Joshua B., Sandahl, Linda J., and Baechler, Michael C. 2017, *US HPWH Market Transformation: Where We've Been and Where to Go Next*

CEC (California Energy Commission). 2019. *Residential Appliance Saturation Survey (RASS).* Sacramento, CA: CEC. www.energy.ca.gov/data-reports/surveys/2019-residential-appliance-saturation-study.

https://www.californiadgstats.ca.gov/

https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency

California Public Utility Commission. 2008. California Long Term Energy Efficiency Strategic Plan, September 2008, San Francisco. http://www.cpuc.ca.gov/NR/rdonlyres/D4321448-208C-48F9- 9F62-1BBB14A8D717/0/EEStrategicPlan.pdf

California Air Resources Board (CARB), 2022. Draft 2022 State Strategy for the State Implementation Plan, Jan 2022,

Eilert, P., Naff, D., McHugh, J., Chase, A., & Zhang, Y. 2012. Code Driven Portfolios. Proceedings of the 2012 Summer Study on Energy Efficiency in Buildings. Washington, D.C.: American Council for an Energy-Efficient Economy. http://www.aceee.org/files/proceedings/2012/data/papers/0193- 000177.pdf

Higa R, A Pande, C Chappell, J McHugh, C Worth, D Suyeyasu, J Edelson, P Eilert, 2014. A Top-Down Framework for Managing Energy Code Development, ACEEE Summer Study 2014, https://www.aceee.org/files/proceedings/2014/data/papers/4-1261.pdf

SB-1 Electricity: solar energy: net metering.(2005-2006) https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200520060SB1

Assembly Bill 32: Global Warming Solutions act of 2006 https://ww2.arb.ca.gov/resources/fact-sheets/ab-32-global-warming-solutions-act-2006