It's Flex Time: Using Flexible Demand Appliance Standards to Deliver Peak Load and CO_2 Reductions

Vivian Cox and Matt Malinowski, CLASP
Rachel Margolis and Joanna Mauer, Appliance Standards Awareness Project (ASAP)

ABSTRACT

Demand flexibility is the practice of reducing electricity use during peak demand hours. It can reduce the need to build and run expensive “peaker” plants, improving grid reliability and reducing CO_2 emissions. However, while the potential US peak demand reduction from demand flexibility is estimated at 20% of US demand in 2030, or 200 GW, current programs can only achieve 60 GW (Hledik et al. 2019, 2). One reason for this discrepancy is the lack of smart, demand-flexible appliances. Appliance standards can help realize the full potential of demand flexibility by making demand-flexible appliances ubiquitous.

In this paper we provide an overview of flexible demand appliance standards (FDAS) for residential electric water heaters adopted in three states (Oregon, Washington, and Colorado), discuss how these standards can help overcome barriers to demand flexibility (DF) programs, and consider the consumer impacts of such standards. We also outline potential future actions at the state and federal levels to advance demand flexibility including federal standardization; state-level FDAS for an expanded scope of electric water heaters or for a package of appliances; increasing DF program availability; load management standards for utilities; and stretch building energy codes.

Introduction

We open the paper with a discussion of demand flexibility (DF) and its benefits, and we introduce DF programs, DF communications technology, and demand-flexible electric storage water heaters. We then focus on flexible demand appliance standards (FDAS) for residential electric storage water heaters; how these standards can help overcome barriers to DF programs; and the consumer impacts of FDAS. Finally, we conclude with potential future actions, including alternative approaches to state-level water heater FDAS. To inform this paper, the authors conducted interviews with relevant stakeholders including water heater manufacturers, the Open Automated Demand Response (OpenADR) Alliance, the Air-Conditioning, Heating and Refrigeration Institute (AHRI), utilities, an energy efficiency organization, and a state regulator.

Demand Flexibility 101

DF is the capability of electrical end-use equipment to shift or reduce electricity usage during hours when demand is high, also known as “the peak.” Fossil fuel “peaker plants”—“low-use, high emitting power plants that grid operators call on at times of high demand” (Enel 2023)—are usually required to meet this demand.

DF can also increase use of renewable electricity by shifting demand to hours of high renewable availability. Figure 1 shows the summer average 24-hour electric generation (natural gas, solar, and other) of California Independent System Operator (CAISO) and the net electricity demand.[1] The net demand is lower in the middle of the day when renewable energy production is high. These hours of low net demand, when renewable generation is plentiful, are prime for a DF service provider (ISO, utility, or aggregator) to request demand-flexible appliances to utilize electricity to perform their tasks. In the evening hours, another DF opportunity arises when solar generation plummets and net demand increases sharply. During these hours, a DF service provider may request that appliances curtail their usage to help reduce the height and steepness of the evening peak.

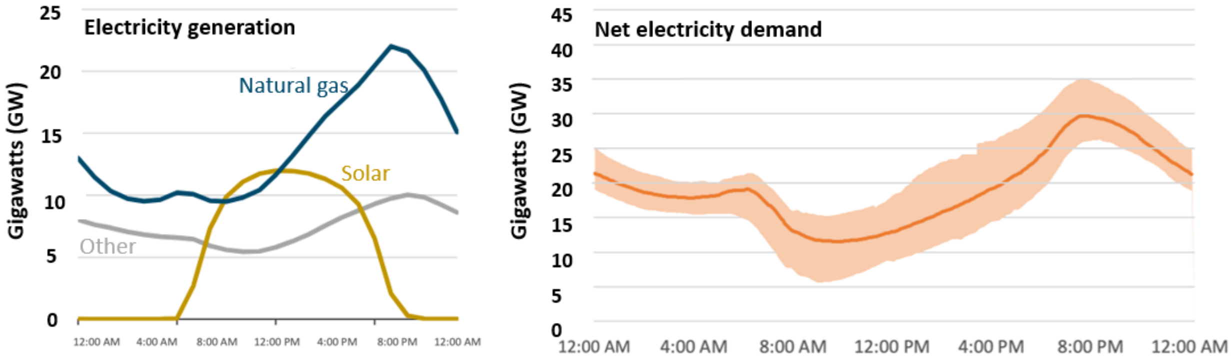

Figure 1. Average of July and August 2020 daily electricity generation in California (left). Net electricity demand in July 2020 in California (right). *Source:* Modified from EIA 2020; Alexander 2020.

Water Heaters 101

This paper focuses on FDAS for residential electric storage water heaters (ESWHs). ESWHs include both electric resistance water heaters (ERWHs), which make up nearly half of the U.S. residential water heater market, (Wachunas 2024), and heat pump water heaters (HPWHs), which are a small, but growing portion of the market (Wachunas 2023). ERWHs usually consist of an insulated steel tank lined with glass and two electric resistance elements that heat water. ERWHs have two electric resistance elements that heat water. HPWHs transfer heat from the ambient air to the stored water using a refrigeration system and are significantly more efficient than ERWHs. HPWHs also usually have backup electric resistance elements. The other roughly half of the market of residential WHs either burn fossil fuels (natural gas or oil) and/or do not store water (i.e., are instantaneous type, also called “tankless”). Since non-electric products do not contribute to the demand of the electric grid, and electric “tankless” WHs do not have potential to shed electric load, these WH types are not discussed in this paper.

Benefits of Demand Flexibility

The benefits of DF can include peak demand reductions, CO_2 emissions reductions, and cost savings for consumers.

Peak demand reductions. One study projects that in the US, DF could reduce peak demand by 200 GW by 2030, or 20% of projected 2030 peak demand. This equates to a more than 3-fold increase, from 60 GW in 2017 (Hledik et al. 2019, 2), with other studies concurring (Langevin et al. 2021, 2103). This increase would be roughly equivalent to the capacity provided by coal

---

[1] Total demand minus non-dispatchable renewable sources.

generation that is scheduled to retire by 2030 (DOE 2023, 34), providing peak capacity without added emissions and at lower cost, saving $10 billion annually (DOE 2023, 33). Another estimate puts the benefits of DF in buildings at $18 billion annually by 2030 (Schwartz 2021, 6).

CO_2 emissions reductions from DF. Depending on the energy generation mix, DF can have varying levels of impact on CO_2 emissions reductions. Modeling in New York City under a low variable-renewable penetration of 2% showed that DF in buildings could reduce CO_2 emissions by 3%. Assuming a higher 2030 variable-renewable penetration of 36%, CO_2 emissions reductions would grow to 10% (Carmichael et al. 2021, 14). Another study of the effect of DF on the Spanish and Portuguese electricity market found CO_2 emissions reductions of 4.5% (Sousa and Soares 2023).

Economic benefits for customers. In a Department of Energy (DOE)-funded pilot study of residential demand-flexible HPWHs in the Southeastern US, participants saw an average load reduction of 72 W during a single DF event. Study participants were on time-of-use (TOU) rates[2] and saved an average of $40 in annual electricity costs (Davis and Urigwe 2024). A modeling study of four scenarios across different geographies and rate structures estimated that demand-flexible residential air conditioners together with demand-flexible ESWHs could save households 10 to 40% on their electricity bills annually (Bronski et al. 2015, 7).

Managing Appliances

Demand Flexibility Programs

DF programs are the mechanism that allows DF service providers to send DF signals to connected appliances. Establishing and administering DF programs generally involves marketing the program to potential participants, screening participant eligibility (e.g., ensuring the customer has a qualifying device), signing a participation agreement, and installing (if applicable) and enabling the DF communications technology. A DF service provider may then send signals to manage participating appliances under different scenarios, including daily peaks, critical peaks, and grid emergencies. Common types of DF programs include incentive-based direct load control (DLC), demand bidding, interruptible tariffs, and emergency load shedding (Lu et al. 2018).

One example of a utility program to manage new residential HPWHs is Xcel Energy’s Smart Water Heater Program (Xcel Energy 2024); an example of a DF program for managing ERWHs in multifamily housing is Pacific Power’s Optimal Time Rewards program (Pacific Power 2024). DF programs generally compensate qualifying participants with a modest bill credit. However, if TOU rates are available to the customer, larger electric bill savings can be achieved. TOU pricing encourages users to also shift and shed load independent of calls for DF events. Despite identifying several programs through a web search, we discuss later how DF programs for residential ESWHs are not yet widely available. Today, not every consumer with a DF-capable ESWH is be able to enroll in a DF program in their area.

---

[2] Higher prices during peak and lower prices during off-peak times.

Demand Flexibility Communications Technology

For a DF service provider to send DF signals to an appliance, the appliance must have the necessary communications technology. For ERWHs, the technology that enables this communication has historically been a load control switch that is installed as a retrofit to the device. For HPWHs, which are newer to the marketplace, it is more common for manufacturers to offer a proprietary communications interface and mobile application to enable DF and additional "smart" features (Rheem 2024). More recently, due in part to state-level FDAS, standardized communications interfaces have been made available for both ERWHs and HPWHs from major manufacturers.

Each DF communications technology (retrofit switch, proprietary communications interface, and standardized communications interface) can receive (and/or send) signals. One residential water heater retrofit load control switch (of the type required for participation in the previously mentioned Pacific Power Optimal Time Rewards program) is compatible with both Wi-Fi and cellular data (Armada Power, n.d.-b; n.d.-c). Proprietary manufacturer interfaces generally connect through Wi-Fi. Standardized communications technology can receive signals via FM broadcast, cellular data, and/or Wi-Fi (SkyCentrics 2024). For DF signals to be sent and received, the DF communications technology on the appliance must be compatible with the type of signal the DF service provider chooses to transmit.

Demand-Flexible Electric Storage Water Heaters

Many residential appliances have loads that can be shifted to different times of the day or curtailed. However, in this paper, we focus on ESWHs, which provide flexibility as a managed load with little impact on consumer experience. ESWHs make sense as an adopter of DF communications technology because they are "low-hanging-fruit" compared to some other residential appliances. ESWHs are: 1) in nearly half of homes in the US (EIA 2023), 2) are the third-largest home electricity user (EIA 2024), and 3) can shift and shed load with little notice, in part due to their ability to store thermal energy. While these "thermal batteries" are somewhat less flexible as a managed load than an actual battery (Mansouri and Sioshansi 2023), homes already have this equipment, and so the consideration is the incremental cost of enabling DF communications technology (instead of requiring an entirely new piece of equipment, like a lithium-ion battery).

The energy storage capacity of an ESWH depends on both tank size and water storage temperature. Under a DF program (or voluntary operation from price signals), when an ESWH receives a request to load up, if the stored water temperature is below the consumer setpoint, the water heater will turn on and heat the water to the water delivery temperature set by the user; this hot water is stored in the tank, ready for the consumer to draw. When the ESWH receives a load shed request, the water heater is prevented from using energy.

Figure 2 illustrates the average hourly load shape from a field study of about two dozen HPWHs under normal operation and under DF. A load up request is sent mid-day, and a load shed request is sent during the hours of peak demand. Note that an ERWH would operate similarly, but ERWHs offer larger potential demand reductions because they typically consume about 3-4 times as much energy as HPWHs (DOE 2024b, 7–20).

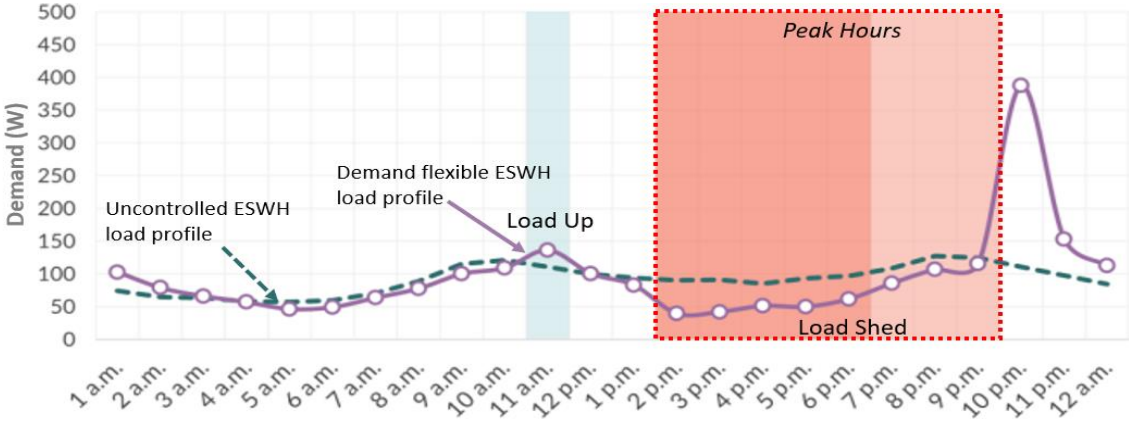

Figure 2. Average 24-hour summer demand profile of a fleet of about two dozen HPWHs in North Carolina. The blue curve is the normal operation, the purple curve is the operation under a DF event where the HPWHs load up, preheating the water earlier in the day, and shed load during peak hours. *Source*: Modified from Davis and Urigwe 2024.

Flexible Demand Appliance Standards

For the DF potential of residential appliances to be realized, two conditions must be met: 1) a significantly greater volume of appliances must include DF communications technology, and 2) DF programs must be more widely available, and consumer participation in those programs must be high. Requiring integrated DF communications technology on appliances at the point of sale (versus retrofit switches) would address the first condition.

States have some authority to regulate attributes of appliances sold within their borders. One way that states have used this authority is in adopting efficiency standards for products for which there are no existing federal energy conservation standards (ECS). As an example, in the absence of ECS, the California Energy Commission (CEC) adopted an energy efficiency regulation for portable electric spas in 2004, with 13 other states adopting spa standards since. Recently, for the first time, several states have adopted regulations for appliances requiring DF communication technology. In the following sections we describe these novel FDAS, the rulemaking processes, and the specified technology required to be compliant with the regulations in each state.

State-Level FDAS for ESWHs

Washington, Oregon, and Colorado have adopted regulations requiring that new residential ESWHs include DF communications technology at the time of sale. These states' regulations include prescriptive requirements for a standardized communication socket for both ERWHs and HPWHs with 40-to-120-gallon storage tanks. The FDAS in each of these states were part of regulatory packages that included new or updated energy efficiency standards for other appliances. The FDAS address the DF communications technology of the product, but do not address energy efficiency.

Table 1 shows the relevant legislation, authorized state agency, regulation, and compliance date for existing and upcoming FDAS for ESWHs. For Washington and Oregon, the compliance date refers to the date of manufacture; existing non-compliant inventory at distributors and retailers can continue to be sold past this date. In California, the CEC is expected to publish a proposal for FDAS for residential ESWHs in 2024.

Table 1. State-level FDAS for ESWHs

	Colorado	Oregon	Washington	California
Legislation (adoption year)	HB 23-1116 (2023)	HB 2062 (2021)	HB 1444 (2019)	SB 49 (2019)
Authorized state agency	Department of Public Health and Environment	Department of Energy	Department of Commerce	California Energy Commission
Regulation (final rule effective/ publication date)	C.R.S 6-7.5-105	OAR 330-092-0020 (June 2022)	WAC 194-24-180 (January 2021)	Forthcoming
Regulation compliance date	Jan 1, 2026	July 1, 2023*	Jan 1, 2023*	No sooner than one year after final rule adoption

* Oregon compliance delayed from January 1, 2022; Washington compliance delayed from January 1, 2021.

Other state actions include a 2021 bill in Nevada granting authority to the Governor's Office of Energy to "adopt by regulation standards for appliances . . . to facilitate the deployment of flexible demand technologies." (A.B. 383 2021, 2). However, no rulemaking has been initiated.

Additionally, in 2023, CEC adopted its first FDAS for pool pumps and heaters (collectively, "pool controls"). Starting in 2025, pool controls sold in the state are required to have a default operating schedule between 9 am and 3 pm (CEC 2023, 12–13). This regulation does not require a specific onboard DF communications technology, but does require pre-programmed controls using the local system clock. The regulation also requires system capability for communicating the operational status and stored schedule.

These first-of-their-kind regulations to get DF technology into more homes have only been in effect for about 1 and 1.5 years in Oregon and Washington, respectively. In these states, where implementation is in early stages, it appears that program effectuation has yet to fully ramp up. As programs and participation increase, a next step for analysts and regulators would be to evaluate the impacts of these FDAS.

Communications Technology Requirements for ESWHs

States have employed two different approaches for regulating communications technology in FDAS for residential ESWHs. As shown in Table 2, Washington and Oregon require compliance with the Consumer Technology Association (CTA)-2045 technical standard,[3] while Colorado requires compliance with the AHRI 1430-2022 technical standard. The AHRI standard was first published in December 2022, after the Oregon and Washington rules became effective.

The CTA-2045 technical standard includes prescriptive requirements for the DF communications interface (socket and plug connections) and describes the basic set of DF signals that can be sent and received. CTA-2045 sockets can be integrated into a variety of

---

[3] The term "technical standard" refers to criteria that the communication interface must meet.

residential and commercial devices. AHRI 1430 incorporates similar requirements, but the scope is limited to residential ESWHs. Importantly, while AHRI 1430 and CTA-2045 can be considered harmonized, AHRI 1430 requires the additional step of testing the equipment to verify that DF signals are sent and received as expected by the CTA-2045 socket and plug.

Table 2. Industry technical standards for ESWHs

	CTA-2045	AHRI 1430
States requiring the technical standard for ESWHs	Washington, Oregon	Colorado
Scope of technical standard	Many residential and commercial appliances	Residential ESWHs
Testing requirement	None	Testing to determine compliance with CTA-2045

As currently structured, the state-level FDAS for ESWHs only regulate the CTA-2045 socket on the equipment, requiring manufacturers of ESWHs to include this socket on products sold in these states. Figure 3 illustrates a typical setup for a compliant ESWH in a home.

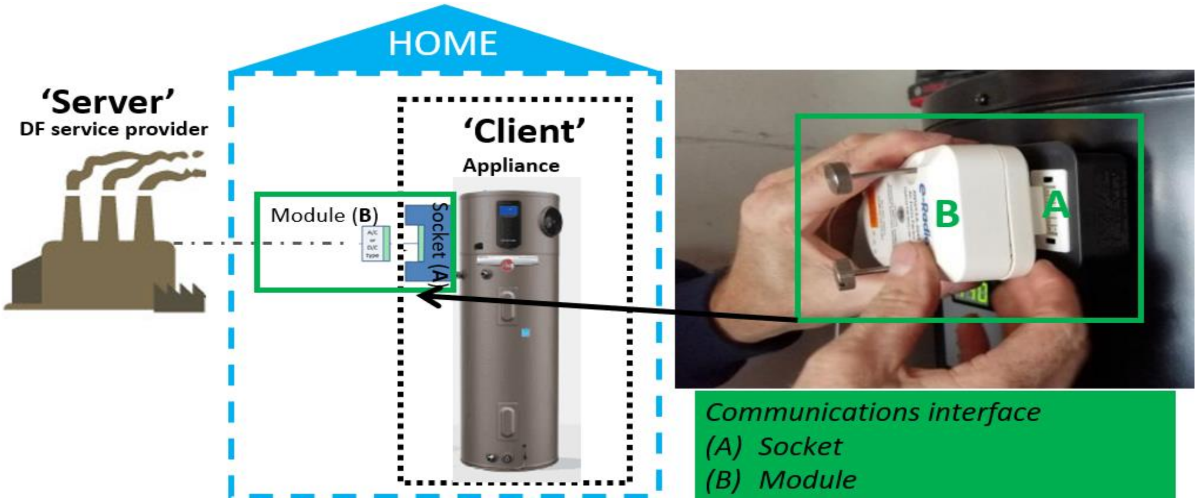

Figure 3. An illustration of a complete DF-enabled ESWH in a home that is receiving and sending DF signals. The FDAS boundary (dotted black line), communications interface (solid green line), and home boundary (dashed blue line) are shown. Inset: the communications interface is comprised of the CTA-2045 socket (A) and CTA-2045 communications module (B). *Source*: Image modified from CTA 2021; inset photo modified from DOE, n.d.-a.

The communications interface (solid green line) is made up of the CTA-2045 socket (*A*), which must be paired with a CTA-2045 compliant communication module (*B*). The current state-level regulations require only the socket at the time of sale. A module, which is typically provided by the utility, must be attached after sale to enable DF communication. Because installation is plug-and-play, it is expected that the consumer will complete this step independently after receiving the module from the utility. Once the complete communications interface is assembled, the utility may send DF signals to the ESWH.

The communication is two-way: once the communications interface receives a signal communicating a DF event request, the internal controls of the water heater determine if the device can participate in the event and send a status back to the utility. The ESWH then participates or declines participation in the event according to the availability of hot water. In addition to the internal logic to prevent cold water events, consumers are able to manually opt out of DF events (a required functionality in CTA-2045). How this manual override is engaged by the consumer varies among ESWH models. One HPWH model user manual instructs the user to disable the connectivity via the user control panel on the tank and specifies that after 72 hours (the maximum time period specified in the technical standards), ESWH participation will automatically resume (A.O. Smith 2022, 24).

Overcoming Barriers to DF Programs with Standards

There are several barriers to the deployment of DF programs including the cost to install and/or enable the DF communications technology on appliances, recruitment of program participants, and program management and scalability. FDAS—which increase the availability of DF-capable appliances—can ease some of the burden associated with the costs/logistics of installation of DF communications technology.

First, policies requiring standardized DF communication technology on ESWHs (i.e., the Washington, Oregon, and Colorado policies), can help reduce the cost of enabling DF communications technology. These regulations ensure that every new ESWH with a tank size of at least 40 gallons is sold with DF communications technology. Alternatively, ESWHs can be retrofitted with DF communications technology. However, these retrofit installations are typically expensive with an estimated cost of about $400 per ESWH (Daken et al. 2020, 34). The higher cost of retrofit installations is partly due to the need for a site visit from an electrician to wire a load control switch onto the existing tank (Armada Power, n.d.-a). In contrast, when an ESWH has an onboard standardized communication port, a consumer can simply plug a communications module into the socket to complete the setup of the communications interface (essentially a zero-cost installation). However, utilities typically bear the cost of the DF communications module, which today is about $150. If programs are scaled and utilities purchase communications modules in large quantities, manufactures of the communications modules (e.g., Skycentrics, e-Radio Inc., Steffes) may be able to achieve economies of scale (Dayem 2018, 8). One module manufacturer anticipates that with volume production, the cost could drop by two-thirds, to as low as $50.

Second, FDAS could help reduce the costs associated with marketing and recruitment of program participants. As with any program, utilities incur the significant cost of recruiting participants; the Bonneville Power Administration (BPA) estimated a marketing cost per customer of $150 for ESWHs. State-level FDAS will drive the market uptake of DF-capable ESWHs, increasing public familiarity and thereby lowering program marketing costs. BPA anticipated program marketing costs would decline quickly to about half the initial cost ($80 per enrollment) once just 4% of electric water heaters are equipped with the DF technology, with the costs further declining to as little as $25 per enrollment in a scenario where 2/3 of electric water heaters have this technology (BPA 2018, 54).

Finally, FDAS can streamline how DF service providers communicate to a fleet of residential appliances. A DF service provider must manage thousands of residential ESWHs to realize meaningful load shifts. The existing state-level FDAS in effect have already required the major water heater manufacturers to redesign model lines to include the CTA-2045 socket. With FDAS, over time, the existing stock of ESWHs will be replaced with new models that include the standardized communication ports, simplifying communications and opening the door to scaled DF programs.

Consumer Impacts of FDAS

Incremental equipment cost. FDAS requiring ESWH communications capability will likely impact appliance purchase prices. While the cost of adding an onboard CTA-2045 communication socket is very low (a few dollars), the cost of adding the necessary internal controls could be much higher depending on the ESWH type.

HPWHs already have sophisticated vapor compression cycle control boards; these units will not incur a significant cost to add communications functionality. However, ERWHs' generally simple operation does not require electronics, and these units are expected to incur a 20 to 30% cost increase to incorporate the electronic controls necessary for CTA-2045 functionality. We found that a large retailer sells a 40-gallon ERWH (4.5 kW elements) without DF functionality for $439 and an equivalent model with the DF functionality for $579 (The Home Depot 2024b; 2024a). In the near future, far fewer consumers will incur this incremental cost as the ESWH market transitions to HPWHs. Recent DOE ECS will drive this market shift beginning in 2029 with requirements that will effectively require all ESWHs with a rated storage volume above 35 gallons to utilize heat pump technology (DOE 2024a, 37798).

The costs described above relate to the onboard DF communications technology only, and not the pluggable communications module. The consumer cost for both ERWHs and HPWHs would likely increase if, in addition to the socket, the communications module was required at the time of sale. In this scenario, a state may consider requiring the utility to subsidize the cost of the communications module so that the additional purchase cost is not borne by the consumer.

Recouping costs through program participation. Consumers who bear the incremental cost of DF communications and control technology can only recoup the cost by enrolling in an available DF program. The economic payback from participation in a DF program is not straightforward since enrolling in a DF program does not necessarily guarantee lower electric bills; electricity consumption is likely to be shifted to different times of the day without decreasing overall. In some cases, electricity consumption could even slightly increase.

Generally, utilities structure a program offering guaranteed compensation or bill credits for program participants. For example, program participants in Xcel Energy's Smart Water Heater Program receive a $100 one-time enrollment incentive and a $25 incentive annually (Xcel Energy 2023). The incentive amounts vary by utility but are small compared to the potential bill savings for consumers that have access to advantageous electricity rates. One study that modeled savings for ERWHs and HPWHs with a TOU rate structure estimated operational cost savings for a managed ERWH of 25%, or $120 annually, relative to an unmanaged ERWH (even with a modest increase in total energy consumption). For HPWHs, the modeled savings were smaller, as expected, because HPWHs have significantly lower operating costs than ERWHs. The study estimated operational cost savings of 15% for HPWHs, or $30 annually, again with a modest increase in annual electricity consumption (Carew et al. 2018, 23).

Consumers who do not enroll in an available DF program may experience indirect benefits—lower electricity rates, or rates that do not rise as quickly as they would have otherwise—due to avoided infrastructure investment by the utility (DOE 2023, 33).

Potential Future Actions

In the previous sections, we discussed the current approach to FDAS for residential ESWHs and how these state-level regulations can be a market transformation tool to increase the uptake of standardized DF communications technology. Here, we consider a range of potential future actions that we consider complementary approaches to achieving broader market transformation and increased consumer savings. First, we discuss alternative approaches to FDAS including federal standardization; state-level FDAS for residential ESWHs with an expanded scope; and state-level FDAS for packages of residential and commercial equipment. Second, we discuss the need for more DF programs to realize the potential of DF-capable devices. Third, we discuss load management standards and alternative rate structures, which could enable greater bill savings for consumers. Lastly, we consider building codes as an alternative pathway to requiring appliances with DF communications technology in new construction and major renovations.

Considering Different Approaches to FDAS

Federal standardization. Like many types of regulations, there could be significant benefits to federalizing FDAS. For example, federal FDAS for residential ESWHs would have a significant impact, resulting in the sale of up to about 5 million DF-ready residential ESWHs each year (DOE 2024b, 9–20).

This path has been forged before; for many appliance energy efficiency standards, states first adopted state-level efficiency standards, with Congress or DOE subsequently establishing a federal standard. Most recently, five states adopted efficiency standards for room air cleaners (between 2020 and 2022); DOE subsequently issued a federal standard for room air cleaners in 2023. These national standards have generally had the support of the regulated industry since manufacturers prefer to avoid a "patchwork" of state standards. For the same reasons, federalization of FDAS would likely appeal to manufacturers. For DF service providers, a national approach would ensure that all regulated ESWHs have DF capability, regardless of where the device is sold.

However, FDAS are a prescriptive requirement not directly related to the energy consumption of the appliance, and, therefore, likely not within DOE's authority. The Energy Policy and Conservation Act (EPCA) would likely have to be amended to grant DOE the authority to consider DF communications technology requirements. In 2022, the bipartisan legislation H.R. 7962 would have given DOE the authority to consider "demand response capabilities" for residential ESWHs (H. R. 7962 2022). While the bill was supported by industry and energy efficiency advocates, it did not progress beyond initial introduction.

State-level ESWH standards with an expanded scope. Additional states considering the adoption of FDAS for ESWHs could choose to harmonize with existing FDAS or could elect to change the scope of the regulation in at least two ways.

First, a state could consider an expanded scope to include smaller ESWH tank sizes to future-proof the regulation—ensuring that most new ESWHs continue to be sold with DF communications technology after the updated DOE energy efficiency standards for residential water heaters take effect in 2029. The three existing state regulations exclude tanks below 40 gallons. However, DOE estimates that when the new water heater standards take effect in 2029, about 40% of the ESWH market will be below this capacity (DOE 2024b, 9–23). To capture the DF potential from smaller units, the scope of FDAS could be expanded to include smaller tank sizes.

Second, the existing state FDAS require that ESWHs must include the DF communications socket, but do not specify that the DF communications module must be present at the time of sale. Requiring inclusion of the module would represent an important step towards DF-readiness. However, this potential benefit would need to be balanced against the additional cost that would be incurred by consumers, including for consumers who do not have a DF program available to them or do not enroll in one.

Including additional appliances. Potential state-level FDAS could also include a suite of residential and/or commercial products; this bundling could unlock greater demand shifting potential. This paper has primarily focused on FDAS for ESWHs because of the success in establishing standards for these products. However, many other residential products have the potential to be included in FDAS. When considering other products for regulation, it could be useful to examine the existing voluntary specifications or technical standards relating to DF capability. For example, the ENERGY STAR program has established “connected criteria” for many types of equipment including connected thermostats (and air conditioning equipment), clothes washers and dryers, and dishwashers.

AHRI 1380-2019 and 1530-202X are additional technical standards that could be referenced in state-level FDAS. AHRI 1380 covers DF for variable-capacity residential and small commercial HVAC equipment. This standard is referenced in the Consortium for Energy Efficiency (CEE) specification for variable-capacity central air conditioning and heat pump systems and in the ENERGY STAR v6.1 specification for central ACs and heat pumps. However, to date, no AHRI 1380 certified equipment is available on the market. AHRI recently initiated the development of AHRI 1530-202X, the technical standard for DF of commercial ESWHs, which will likely resemble AHRI 1430 for residential ESWHs.

Increasing DF Program Availability

The first-ever state-level FDAS for ESWHs are early in their implementation. However, water heater manufacturers have observed that many of the CTA-2045-compliant water heaters in these states are not engaging in DF activities. From a web search, we found that some of the largest electric utilities in the region are not currently advertising DF programs to customers. As the purpose of FDAS is to make devices available for utilities to manage at scale, it will be critical for state policymakers and public utility commissions to work with utilities to increase the availability of DF programs. In addition, policymakers should work with demand-side resource aggregators to identify barriers that may prevent the scaled deployment of demand-flexible residential appliances.

Adopting Load Management Standards for Utilities and Alternative Rate Structures

Adopting load management standards would be a way to complement FDAS and successfully achieve load shifting from appliances. For example, California's Load Management Standards (LMS) provide directives to utilities to make DF programs available to commercial and residential customers. LMS involve maintaining publicly available time-varying rates and may require utilities to conduct consumer education and outreach.

Using price signals, which is a more passive way to shift the load, can also be a tool for load shifting. Price signals can potentially save consumers money by incentivizing load shifting away from peak—effective even for those consumers who lack a DF program in their area. Furthermore, consumers with DF programs may find them more appealing with the addition of price signals. Examples of price signals include TOU; critical peak pricing (similar to TOU pricing, but based around a handful of peak days and events yearly, rather than peak hours daily); demand charges (where customers pay a monthly or yearly fee based on their maximum power demand[4]); and real-time pricing (where customers are not insulated from wholesale electricity price variation, and the price of power depends on supply and demand) (GridFabric 2020).

Considering Building Codes as an Alternative Pathway

Building codes could serve as an alternative pathway to promote market transformation to appliances with DF communications technology. For instance, California's Title 24 building code's Joint Appendix 13 (JA13), "Qualifications for Heat Pump Water Heater Demand Management Systems," defines the DF requirements that must be met for a HPWH to receive credit to demonstrate compliance with the building code (CEC 2022). The CEC maintains a list of HPWHs that have been declared by the manufacturer to meet the specifications in JA13. California's Title 24 energy code also includes DF requirements for lighting and zonal HVAC controls such as smart thermostats.

To inform the development of "stretch codes," DOE has developed a series of technical briefs, some of which relate to DF of water heaters and thermostats (DOE, n.d.). Stretch codes are alternative compliance pathways that are more ambitious than base codes; they can be included in existing building energy codes, such as state and local codes, the International Energy Conservation Code (IECC), and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1.

---

[4] This approach is common for commercial and industrial customers but has the potential to negatively impact residential customers.

Conclusion

DF has the potential to reduce US peak demand by 20% in 2030, or 200 GW. However, current programs can only achieve reductions of 60 GW due to the lack of demand-flexible appliances in homes, businesses, and other buildings. The significant electricity use of ESWHs and their ability to store thermal energy makes these appliances a desirable managed load for a utility, with little impact on the consumer's experience with the device.

State-level FDAS for residential ESWHs in Washington, Oregon, and Colorado will increase the number of appliances that have DF communications technology. The standards should reduce barriers to DF programs through the standardization and simplification of DF communications technology installation. However, the availability of DF programs that manage ESWHs is still inadequate. Achieving broader market transformation could involve a range of complementary approaches including federal standardization; state-level regulations of residential ESWHs with an expanded scope; state-level regulations of packages of residential and commercial equipment; increasing DF program availability; load management standards for utilities; and building codes.

References

AB383. 2021. "Assembly Bill No. 383–Assemblymen Watts, Brown-May; and C.H. Miller." 2021. https://www.leg.state.nv.us/App/NELIS/REL/81st2021/Bill/7985/Text.

Alexander, Brentan. 2020. "California Blackouts Show Natural Gas Is Needed For A Stable Grid (For Now)." Forbes. August 22, 2020. https://www.forbes.com/sites/brentanalexander/2020/08/22/california-blackouts-show-natural-gas-is-needed-for-a-stable-grid-for-now/.

A.O. Smith. 2022. "Installation Instructions and Use & Care Guide - Hybrid Electric Heat Pump Water Heater." https://pdf.lowes.com/productdocuments/556a6016-a457-4d4a-b5d3-fec64f10b937/61067632.pdf.

Armada Power. n.d.-a. "ELECTRIC WATER HEATER INSTALLATION MANUAL." https://www.ed3online.org/home/showpublisheddocument/240/638151665296070000.

———. n.d.-b. "LCS2400 (Wifi + Cellular)." Accessed May 30, 2024. https://www.armadapower.com/lcs2400-wifi-cellular/.

———. n.d.-c. "Pacific Power - Optimal Time Rewards." Accessed May 30, 2024. https://www.armadapower.com/pacific-power/optimal-time-rewards/.

BPA (Bonneville Power Administration). 2018. "CTA-2045 Water Heater Demonstration Report Including A Business Case for CTA-2045 Market Transformation." November 9, 2018. https://www.bpa.gov/-/media/Aep/energy-efficiency/demand-response/20181118-cta-2045-final-report.pdf.

Bronski, Peter, Mark Dyson, Matt Lehrman, James Mandrel, Jesse Morris, Titiaan Palazzi, Sam Ramirez, and Herve Touati. 2015. “The Economics of Demand Flexibility.” RMI. August 2015. https://rmi.org/insight/the-economics-of-demand-flexibility/.

Carew, Nick, Ben Larson, Logan Piepmeier, and Michael Logsdon. 2018. “Heat Pump Water Heater Electric Load Shifting: A Modeling Study.” Ecotope, Inc. https://ecotope-publications-database.ecotope.com/2018_001_HPWHLoadShiftingModelingStudy.pdf.

Carmichael, Cara, James Mandel, Henry Richardson, Edie Taylor, and Connor Usry. 2021. “The Carbon Emissions Impact of Demand Flexibility.” Rocky Mountain Institute. https://rmi.org/insight/the-carbon-emissions-impact-of-demand-flexibility/.

CEC (California Energy Commission). 2022. “Appendix JA13 – Qualification Requirements for Heat Pump Water Heater Demand Management Systems.” https://www.energy.ca.gov/sites/default/files/2022-12/JA13_2022_Qualification_Requirement_HPWH_DM_ADA.pdf.

———. 2023. “Pool Controls Rulemaking - Final Proposed Regulatory Language.” https://efiling.energy.ca.gov/GetDocument.aspx?tn=252510&DocumentContentId=87582.

CTA (Consumer Technology Association). 2021. “Modular Communications Interface for Energy Management (ANSI/CTA-2045-B).” Consumer Technology Association®. February 2021. https://shop.cta.tech/products/https-cdn-cta-tech-cta-media-media-ansi-cta-2045-b-final-2022-pdf.

Daken, Abigail, Pierre Delforge, Ashley Armstrong, and Tony Koch. 2020. “Load Shifting with ENERGY STAR Connected Water Heaters.” October 28. https://www.energystar.gov/sites/default/files/asset/document/Load%20Shifting%20with%20ENERGY%20STAR%20Connected%20Water%20Heaters.pdf.

Davis, Helen, and Daniela Urigwe. 2024. “Connected Heat Pump Water Heaters for Low-Income Homes in North Carolina.” Presented at the American Council for an Energy Efficient Economy Hot Air and Hot Water Forums, Atlanta, GA, March 14. https://drive.google.com/file/u/0/d/1-FBUo0LlnwdTwR-1ANe_-VDAPNMdvhmr.

Dayem, Katherine. 2018. “Standardized Communications for Demand Response - An Overview of the CTA-2045 Standard and Early Field Demonstrations.” Xergy Consulting. https://www.cooperative.com/programs-services/bts/Documents/Reports/Standardized-Communications-for-Demand-Response-Report-June-2018.pdf.

DOE (Department of Energy). 2023. “Pathways to Commercial Liftoff: Virtual Power Plants.” https://liftoff.energy.gov/wp-content/uploads/2023/09/20230911-Pathways-to-Commercial-Liftoff-Virtual-Power-Plants_update.pdf.

———. 2024a. “Energy Conservation Program: Energy Conservation Standards for Consumer Water Heaters.” https://www.govinfo.gov/content/pkg/FR-2024-05-06/pdf/2024-09209.pdf.

———. 2024b. “Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Consumer Water Heaters.” Regulations.Gov. April 30, 2024. https://www.regulations.gov/document/EERE-2017-BT-STD-0019-1416.

———. n.d.-a. “Heat Pump Water Heater - Load Shifting.” Accessed May 31, 2024. https://bsesc.energy.gov/training-modules/heat-pump-water-heater-load-shifting.

———. n.d.-b. “Stretch Codes - Building Energy Codes Program.” Energy.Gov. Accessed May 6, 2024. https://www.energycodes.gov/stretch-codes.

EIA (Energy Information Administration). 2020. “In California, Natural Gas Helps Balance Changes in Electricity Demand and Solar Output.” December 11, 2020. https://www.eia.gov/todayinenergy/detail.php?id=46236.

———. 2023. “Table HC8.1 Water Heating in U.S. Homes, by Housing Unit Type, 2020.” https://www.eia.gov/consumption/residential/data/2020/hc/xls/HC%208.1.xlsx.

———. 2024. “Table CE4.1 Annual Household Site End-Use Consumption by Fuel in the United States—Totals, 2020.” https://www.eia.gov/consumption/residential/data/2020/c&e/xls/ce4.1.xlsx.

Enel. 2023. “What Is a Peaking Power Plant?” May 11, 2023. https://www.enelnorthamerica.com/insights/blogs/what-is-a-peaking-power-plant.

GridFabric. 2020. “Demand Response: 101.” April 22, 2020. https://www.gridfabric.io/blog/introduction-to-demand-response.

H. R. 7962. 2022. “A Bill To Amend the Energy Policy and Conservation Act to Modify the Definition of Water Heater under Energy Conservation Standards, and for Other Purposes.” House of Representatives. https://www.congress.gov/117/meeting/house/114932/documents/BILLS-117HR7962ih.pdf.

Hledik, Ryan, Ahmad Faruqui, Tony Lee, and John Higham. 2019. “The National Potential for Load Flexibility: Value and Market Potential Through 2030.” Brattle Group. https://www.brattle.com/wp-content/uploads/2021/05/16639_national_potential_for_load_flexibility_-_final.pdf.

Langevin, Jared, Chioke B. Harris, Aven Satre-Meloy, Handi Chandra-Putra, Andrew Speake, Elaina Present, Rajendra Adhikari, Eric J. H. Wilson, and Andrew J. Satchwell. 2021. “US Building Energy Efficiency and Flexibility as an Electric Grid Resource.” Joule 5 (8): 2102–28. https://doi.org/10.1016/j.joule.2021.06.002.

Lisa Schwartz. 2021. “State Indicators for Advancing Demand Flexibility and Energy Efficiency in Buildings – Part I: Demand Response and Energy Efficiency Targeted to Reduce Peak Electricity Demand.” State Energy Efficiency Action Network (SEE Action). https://emp.lbl.gov/publications/state-indicators-advancing-demand.

Lu, Xinhui, Kaile Zhou, Xiaoling Zhang, and Shanlin Yang. 2018. “A Systematic Review of Supply and Demand Side Optimal Load Scheduling in a Smart Grid Environment.” Journal of Cleaner Production 203 (December):757–68. https://doi.org/10.1016/j.jclepro.2018.08.301.

Mansouri, Mahan, and Ramteen Sioshansi. 2023. “Comparing Electric Water Heaters and Batteries as Energy-Storage Resources for Energy Shifting and Frequency Regulation.” February 2023. https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=10006357.

Pacific Power. 2024. “Optimal Time Rewards for Tank Electric Resistance Water Heaters and Heat Pump Water Heaters.” 2024. https://www.pacificpower.net/working-with-us/landlords-property-managers/optimal-time-rewards.html.

Rheem. 2024. “Rheem EcoNet Connection Steps.” 2024. https://www.rheem.com/rheem-econet-connection-steps/.

SkyCentrics. 2024. “SkyCentrics Store.” 2024. https://store.skycentrics.com/.

The Home Depot. 2024a. “Performance 40 Gal. 4500-Watt Elements Medium Electric Water Heater - WA or Version w/6-Year Tank Warranty and 240-Volt.” 2024. https://www.homedepot.com/p/Rheem-Performance-40-Gal-4500-Watt-Elements-Medium-Electric-Water-Heater-WA-or-Version-w-6-Year-Tank-Warranty-and-240-Volt-XE40M06CG45U0/326406290.

———. 2024b. “Performance 40 Gal. 4500-Watt Elements Medium Electric Water Heater with 6-Year Tank Warranty and 240-Volt.” 2024. https://www.homedepot.com/p/Rheem-Performance-40-Gal-4500-Watt-Elements-Medium-Electric-Water-Heater-with-6-Year-Tank-Warranty-and-240-Volt-XE40M06ST45U1/326434008.

Wachunas, Joseph. 2024. “The US Saw Record Percentages Of Heat Pump & Electric Water Heater Sales In 2023”. March 4, 2024. https://cleantechnica.com/2024/03/04/the-us-saw-record-percentages-of-heat-pump-electric-water-heater-sales-in-2023/.

Wachunas, Joseph. 2023. “Heat Pump Water Heater sales in 2022 signal a decisive shift in water heating trends.” October 12, 2023. New Buildings Institute. https://newbuildings.org/heat-pump-water-heater-sales-in-2022-signal-a-decisive-shift-in-water-heating-trends/.

Xcel Energy. 2023. “2023 Xcel Energy Smart Water Heater Program Terms & Conditions for Residential Customers.” https://www.xcelenergy.com/staticfiles/xe-responsive/Working%20With%20Us/Renewable%20Developers/2020-Terms-and-Conditions.pdf.

———. 2024. “State Selector - Residential Home Rebate for Water Heaters.” 2024. https://co.my.xcelenergy.com/s/state-selector?return=%2Fs%2Fresidential%2Fhome-rebates%2Fsmart-water-heaters.