WATER HEATERS AS MULTIPLE GRID RESOURCES

Country/region	**Hawaii (U.S.)**
Type of E1st approach	C – Behind / General 1 – Allowing E1st
Energy carrier(s) targeted	Electricity
Sector(s) / energy system(s) or end-uses targeted	Residential and distribution
Implementing bodies	HECO (utility) and Shifted Energy (third-party service provider)
Decision makers involved	Hawaii Public Utilities Commission (energy regulator)
Main objective(s)	2.5 MW demand response and other grid services provided by Grid Interactive Water Heaters (GIWHs) to a Hawaiian utility
Implementation period	2018

Tanks equipped with electric resistance water heaters are widely used domestic appliances. Apart from supplying hot water, they can offer various power system benefits as well. Traditionally, they are used as thermal storage devices by delinking the time of demand for and generation of hot water: heating up water in the tank in periods of low overall power demand (e.g., at night). However, with a minor upgrade, these appliances can provide further grid services as well as save money for consumers. The recent programme initiated in Hawaii is a prime example of stacking benefits from water heaters as demand-side resources and a showcase of how a third-party service provider startup can come up with solutions for efficient grid operation.

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1. Background

Electric resistance water heaters are important demand response resources and are expected to remain so. Smart water heating is estimated to provide more cost-effective flexibility than dynamic tariffs in the U.S. in 2030 (Figure 13).

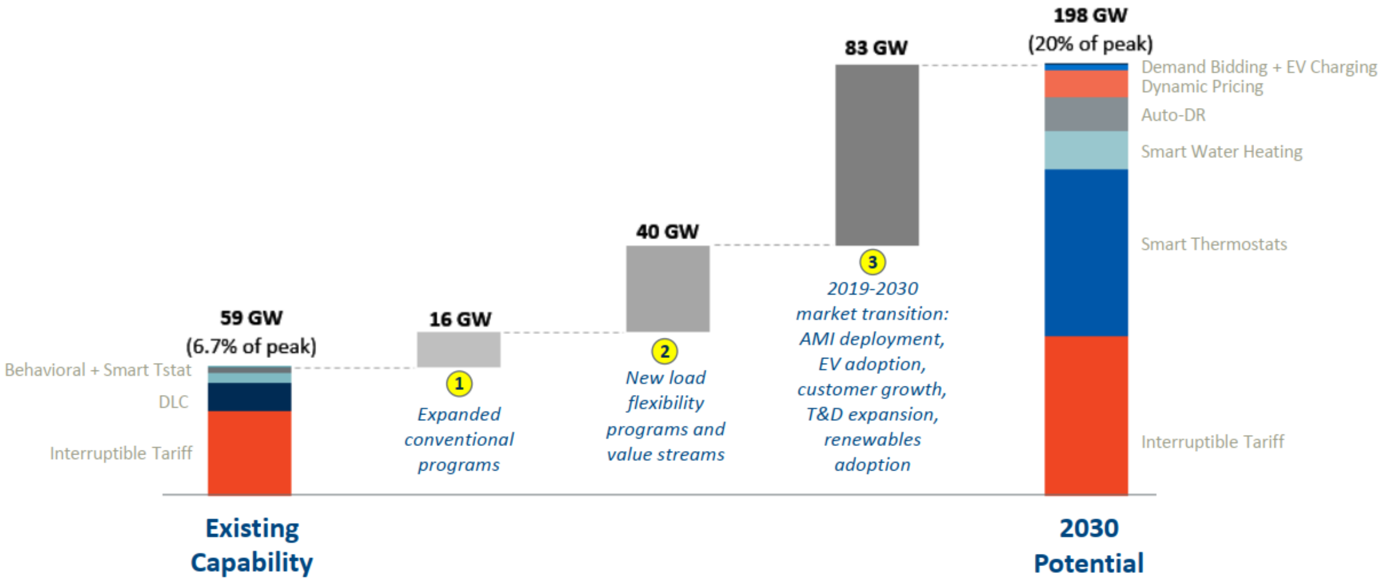

Figure 1 – Cost effective load flexibility potential in the U.S.
(Source: Hledik et al., 2019)

Water heaters are traditionally used in many countries to shift demand from peak periods to periods of abundant supply. This is increasingly important because of the increasing share of weather-dependent renewables in the supply. The thermal storage property of water heaters makes them very similar to batteries. Technically, they are directly controlled by utilities that turn them off as needed in a peak period without the consumers experiencing any disturbances in hot water supply. The associated system benefits are that of avoided generation, avoided transmission and distribution network reinforcement, and the curtailment of wholesale prices in these hours.

The magnitude of this relatively untapped resource is significant: it is the third single largest source of residential electricity consumption (9%), behind space cooling and lighting, in more than 40% of U.S. households (Hledik et al., 2016).

Water heaters, if equipped with modern control devices, can participate in frequency regulation and grid balancing services for the power system as well (Figure 2). These grid interactive water heaters can be controlled with near instantaneous response from the operator, and these additional benefits are increasingly valuable in markets with rapid fluctuations in supply due to the large share of renewable sources.

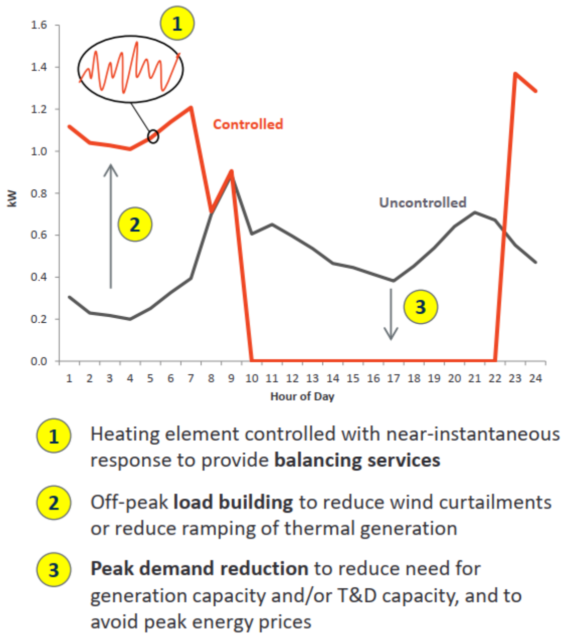

Figure 2 – Water heating load profile

(Source: Hledik et al., 2016)

If an 80-gallon tank electric resistance water heater is able to interact with the grid beyond simply shaving peak and building load within the day, then the net benefits (considering the extra cost of upgrading the heater) triples, mainly due to the benefit provided for frequency control (Figure 3). This, however, can only materialise if market rules allow demand-side resources to participate in ancillary services markets.

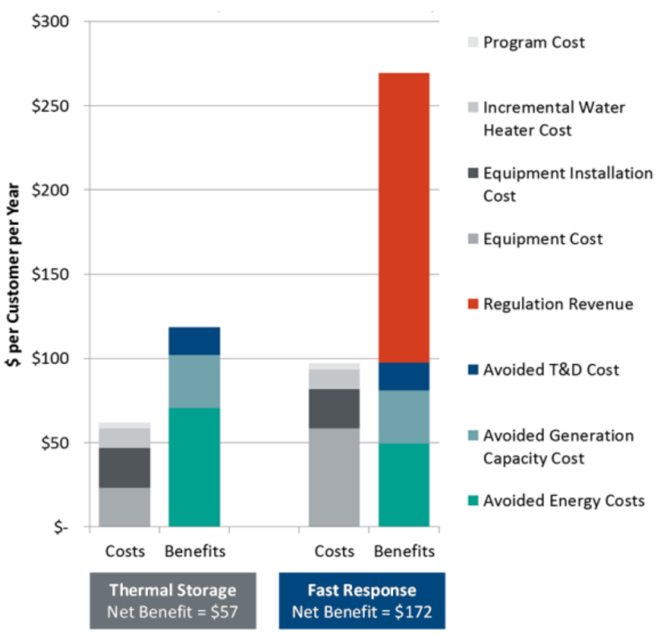

Figure 3 – Costs and benefits for 80-gallon tank

(Source: Hledik et al., 2016)

In sum, electric water heaters can provide various demand response services. In the taxonomy developed by the Lawrence Berkeley National Lab and increasingly used to differentiate between DR services, they do not only "Shift" but also "Shimmy" as well (Alstone et al., 2017): not only to move energy consumption from peak times to times of day when there is a surplus of renewable generation, but also to use loads to dynamically adjust system demand to alleviate short-run ramps and disturbances at timescales ranging from seconds up to an hour.[1]

2. How has the E1st principle (or similar concept) been implemented?

Across 53 U.S. utilities, electric water heater DR programmes have a total enrolled capacity of 585.6 MW, representing 2% of the total enrolled DR capacity, and 11 states are running pilots on grid interactive water heaters (SEPA, 2019).[2]

Hawaii is a nice illustration of how a traditional utility DR programme can be upscaled to provide a much larger rollout and more services with the involvement of third-party actors. Hawaiian Electric (the utility) has relied on electric water heaters as demand response devices for years. Its EnergyScout programme uses a one-way paging network to control about 34,000 water heaters, which deliver approximately 10 MW of controllable peak demand.[3] The installed device turns off the water heaters during system peak usage, typically for no more than one hour at a time.

As a response to the request of the Hawaii Public Utilities Commission, Hawaiian Electric (HECO) launched its Grid Services Purchase Agreement in 2018 to competitively procure approximately 16 MW of capacity. This is the framework in which Shifted Energy — partnering with Open Access Technology International (OATI) – committed to deliver 2.5 MW of grid-interactive water heating.

OATI is a Minnesota-based smart-grid solution provider that was awarded the 2018 GSPA contract to deliver aggregated capacity from a combination of residential, commercial and industrial customer-sited assets, including the 2.5 MW of GIWH from Shifted Energy. OATI aggregates these resources to provide capacity and fast frequency response services to Hawaiian Electric.

Shifted Energy – based on its troublesome experience with installing tank-mounted controllers that impacted appliance warranties and troubleshooting controller internet connections – developed a technology that would allow GIWH to be deployed at large enough scale to have a real grid impact. The system is made of the following elements:[4]

- Off-tank controller ("Tempo") that requires a maximum of 20 minutes to install anywhere on the electric line between the breaker panel and the water heater; no sensors touch the tank (does not affect warranties) and no plumbing.

[1] This analytic framework groups DR services into four core categories: Shape, Shift, Shed and Shimmy.
[2] Arizona, California, Florida, Georgia, Hawaii, Minnesota, North Carolina, Oregon, South Dakota, Washington and Wisconsin.
[3] https://sepapower.org/knowledge/two-birds-one-water-heater-how-shifted-energy-and-hawaiian-electric-are-helping-hawaii-meet-its-clean-energy-goals/
[4] http://www.shiftedenergy.com/technology/

- Integrated cellular chip and antenna operate independently of the customer internet network and include end-to-end cyber security.
- A software-as-a-service platform ("Grid Maestro") that monitors, analyses 5-minute, revenue-grade data and optimises smart water heaters through machine learning.[5] Grid Maestro aggregates each heater's forecasts and load shift potential into a virtual power plant of grid interactive water heaters (Figure 4). Automated reporting and integrated ticketing simplify performance measurement and verification.

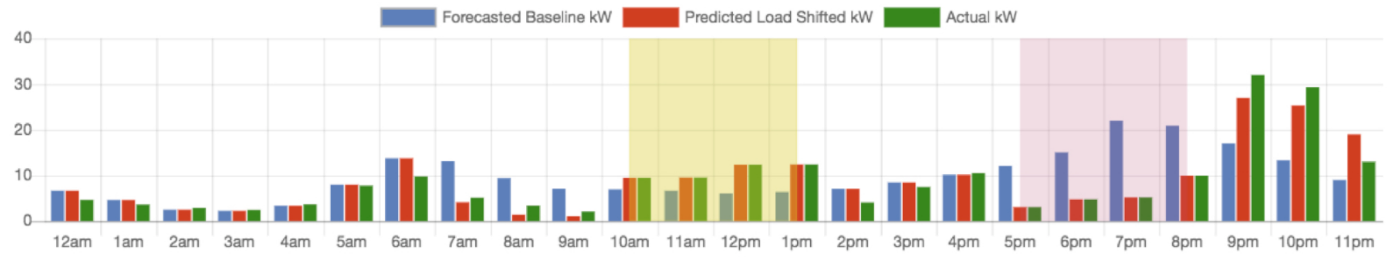

Figure 4 – Scheduling load shifts
(Source: http://www.shiftedenergy.com/technololgy/gridmaestro/)

Heaters provide the following grid services:

- Multi-hour load shifts by storing energy during periods of high renewable generation and reducing consumption during peak demand. In Hawaii, peak demand time (5–9 PM on weekdays) is a time when the grid is strained and when the energy with the highest emissions (oil) is being used.
- Frequency and voltage regulation: 12-cycle or less response time to frequency or voltage deviations, as well as randomised return-to-load.
- Emergency DR: Full fleet shut down to quickly shed maximum kW.

Heaters offer several benefits to the participating GIWH users:

- Optimises onsite PV self-consumption: coordinating GIWHs as thermal storages to optimise grid-injected and grid-supplied power exchange for prosumers.
- Automatically shifts load for off-peak if the consumer is enrolled in ToU and real-time pricing tariffs.
- Fault detection and alert.

The off-tank controller device is free for the participants; in return for allowing their water heaters to support the grid, they receive a monthly bill credit between $3 and $5 over the first 5 years.

[5] When a new water heater is added, Grid Maestro begins monitoring that heater's energy consumption patterns. After about two weeks, the system's advanced machine learning algorithms generate highly accurate forecasts of future consumption at 15-minute intervals for four days in advance. Grid Maestro uses these forecasts to estimate how much electricity consumption can be shifted from one time of day to another without impacting consumer access to hot water.

3. Effects / impacts

As the agreement between the utility and the service provider was only signed recently (fall 2019), there is no information available about the programme's performance yet.

4. Changes over time, if any

As this is a new programme, no change has been proposed yet.

5. Barriers and success factors

The only barrier that has been identified prior to the programme has been turned into a success factor of the Shifted Energy approach: the use of a control device that can be installed very quickly without touching the tank. The drive behind the utility opening a competitive tender to procure grid services that are becoming increasingly valuable with high renewable penetration is motivated by the wider policy goal that Hawaii set in 2015 to reach 100% renewable use by 2045. This is coupled with the fact that Hawaii, like many islands, is largely powered by petroleum-based generators, which makes the cost of electricity very high and thus attracts the attention of cleantech startups. Shifted Energy has been involved with solar panel and battery deployment for years and already had strong community experience with Hawaiian residents.

6. Replicability and scalability potential

It is difficult to see why this solution could not be replicated in other regions and countries. There are 600 million electric water heaters worldwide, and the expected growth in emerging markets (e.g., China and India) offers an enormous networked grid resource.[6] The need for increased power system flexibility and hence frequency regulation requires the involvement of demand-side resources that are cheap and abundant and can be aggregated at low cost. Water heaters are in place in many households and further electrification and the potential phase-out of gas heat supply at the distribution level will increase the penetration of electric water heaters in Europe. The future share of tank-equipped water heaters (versus tankless/on-demand heaters) is yet to be seen, however. There is an option to move beyond considering them simply as power thermal storages and make them to provide further valuable grid benefits at low cost. The regulatory environment should be supportive to third-party aggregators and solution providers in general, and markets should be designed to reflect the real value of flexibility.

[6] https://sepapower.org/knowledge/two-birds-one-water-heater-how-shifted-energy-and-hawaiian-electric-are-helping-hawaii-meet-its-clean-energy-goals/

7. Sources and references

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ABOUT ENEFIRST

ENEFIRST is a 3-year project funded under the Horizon2020 programme, which gathers a consortium of partners from across sectors and regions: IEECP, BPIE, Fraunhofer ISI, CEU, RAP, IREES, TU Wien.

From definition to implementation, ENEFIRST aims at making the “Efficiency First” (E1st) principle more concrete and operational, better understand its relevance for decision processes related to energy demand and supply, its broader impacts across sectors and markets, focusing on the building sector and related energy systems in EU Member States.

> ***E1st gives priority to demand-side resources whenever they are more cost-effective from a societal perspective than investments in energy infrastructure in meeting policy objectives. It is a decision principle that is applied systematically at any level to energy-related investment planning and enabled by an “equal opportunity” policy design.***

ENEFIRST combines policy analysis and quantitative assessments of E1st impacts to develop policy guidelines and recommendations, following a process with continuous exchanges with stakeholders.

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