Technology Sector
Electric Water Heating

Product Category
Grid-Enabled Water Heater

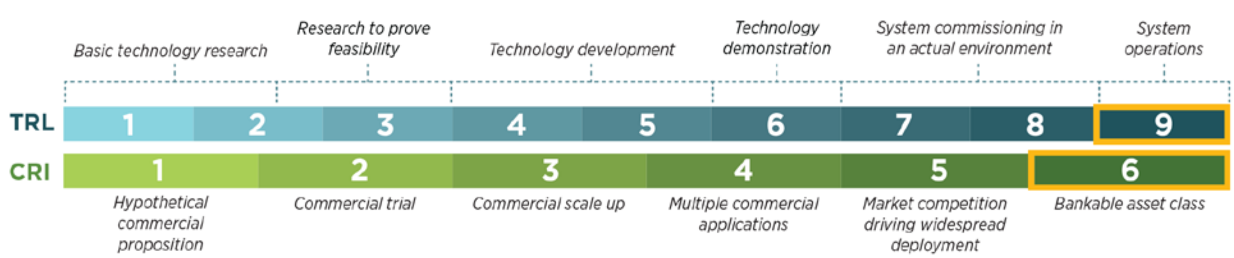
Last Updated
12/13/2018

Figure 1: Westinghouse commercial electric grid enabled water heater

Product Category Overview

Grid-enabled water heaters (GEWH) allow utilities to control electric storage water heaters in order to manage electricity demand and optimize supply. For example, utilities can turn off GEWH when demand for electricity is high and power them back on when demand is low. Since these water heaters are still able to deliver hot water to the customer at any time, the design benefits the utility without impacting the consumer, enabling the utility to generate more electricity from intermittent sources like wind and solar. In exchange for these benefits, utilities offer rebates to compensate customers for this service.

Characterization at a Glance



Product Category Characterization

Energy Benefits

GEWH allow utilities to reduce electricity demand at peak hours by shifting some water heating load to off-peak hours. For these units, water in the tanks can be pre-heated and/or recovered to the desired temperature outside of peak times, substantially decreasing energy costs by making use of available resources. At large scale, GEWH can provide a relatively cheap form of energy storage. They do not save any site energy but may be responsible for downstream savings by allowing utilities to best use existing supply, potentially enabling renewables and reducing greenhouse gas emissions from electricity generation.

Non-Energy Benefits

GEWH are valuable to the utility. Utilities pass this value on to the customer in the form of rebates or similar financial incentive. GEWH are also valuable to the utility by helping with grid stability and frequency regulation.

Product Category Differentiation

This product is different from solar and heat pump water heaters as it refers only to the controls of the water heater. A commercial water heating system could incorporate any electric water heating technology with grid-enabled controls.

Installation Pathway and Dependencies

GEWH are available as new construction or plug-in and do not necessarily require any additional hardware or installation compared to an equivalent non grid-enabled water heater—other than a connection to the utility. This connection can be achieved via Wi-Fi, cellular, or landline service and is generally minimally invasive. Some grid-enabled solutions include an additional heating element, temperature probes, or external controls, while others are sold as-is and require no modifications.

List of Products

Table 1: Summary of manufacturers and products for the product category.

Manufacturer	**Model**	**Type**	**Differentiating Feature***
Westinghouse	Everlast WEG115C2X055H	Integrated unit	UEF 0.9
Sunnovations	Aquanta	Controller	
Steffes	GETS Hydro Plus	Integrated unit	
Vaughn	V-Grid	Integrated unit	EF 0.95

*Uniform Energy Factor (UEF) is the measure of water heater overall efficiency, per 10 CFR Appendix E to subpart B of Part 430, part 1.15. Energy Factor (EF) is a more general efficiency descriptor, previously used in water heaters and still used for other appliances. As UEF is the current efficiency descriptor, it is typically used by manufacturers. In cases where manufacturers only list the EF, that is provided in the above table.

Quantification of Performance

A literature search was conducted and a sample of published study results are summarized in Table 2.

Table 2: Summary of results from literature review

Location	Application	Results	Reference
Blacksburg, Virginia, USA	University implementing demand response (for the purpose of offsetting future electric vehicle demand) on a portion of their load. Baseline was without demand response.	No effect on water heating load in the morning or summer, roughly 20% reduction in the winter evening peak.	[1]
Richland, Washington, USA	Lab exercise comparing using large electric resistance and heat pump water heaters for demand response over seven days.	Under demand response conditions currently in practice, the electric resistance heater was available 22% of the time for demand response for peak load reductions. The heat pump was available 29% of the time. The resistance water heater's power use was 4 kw, and the heat pump's was 1 kw.	[2]
N/A	In response to DOE's request for information, typical demand reduction reported in multiple comments was 0.7-1.1 kw per water heater.	0.7 – 1.1 kW demand reduction per tank.	[3]
Minnesota, USA	Studied demand response and snapback at the utility level, gathering aggregated system load and demand response data from two large Minnesota utilities during demand control days. Also used energy modeling to analyze typical residential and commercial buildings.	kW saving (peak load, summer): 0.6 kW. kW saving (peak load, winter): 0.8 kW. Utility load relief per event: 454 MW (IOU) and 184 MW (G&T Co-op).	[4]

References

[1] S. Shao, M. Pipattanasomporn and S. Rahman, "Grid Integration of Electric Vehicles and Demand Response with Customer Choice," *IEEE TRANSACTIONS ON SMART GRID,* vol. 3, no. 1, pp. 543-550, 2012.

[2] E. Mayhorn, S. Parker, F. Chassin, S. Widder and R. Pratt, "Evaluation of the Demand Response Performance of Large Capacity Electric Water Heaters," Pacific Northwest National Laboratory, 2015.

[3] A. Cooke, R. Carmichael, D. Anderson, E. Mayhorn, D. Winiarski and A. Fisher, "Analysis of Large-Capacity Water Heaters in Electric Thermal Storage Programs.," Pacific Northwest National Laboratory, 2015.

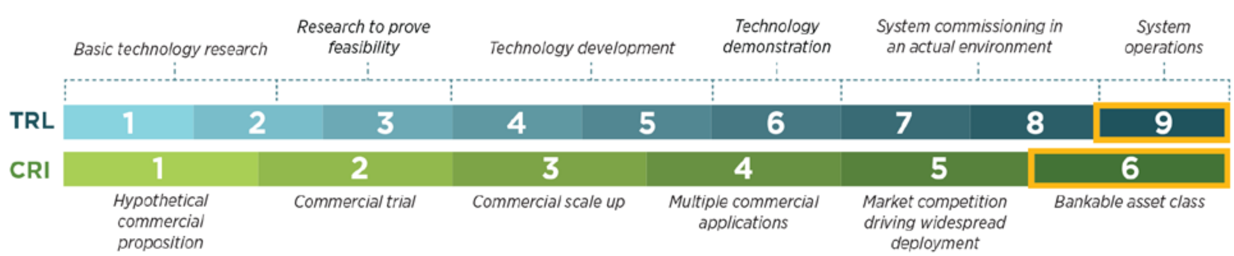
[4] R. Parker and R. Dickerson, "Demand Response and Snapback Impact Study," Michaels Energy, 2013.

Technology Sector Electric Water Heating Product Category Heat Pump Water Heater Last Updated 11/30/2018	 *Figure 1: AO Smith AWH (left) and Rheem HPLD (right)*

Product Category Overview

Heat pump water heaters (HPWHs) extract heat from a source and transfer it to potable water via a refrigeration cycle. Air-source HPWHs extract heat from ambient air. These typically will have an energy factor (EF) of approximately 2.5, whereas electric resistance water heaters will have an EF of 0.9. Water-source or ground-source HPWHs are similar to air-source HPWHs except they extract heat from water or the ground. They are more efficient than air-source HPWHs but typically also more expensive to install and require drilling into the ground or access to a body of water. In the commercial/institutional context, the largest HPWHs will be the “add-on” type, designed to be used with either a storage-type electric resistance water heater or a storage tank. In this configuration, the heat pump apparatus stands alone, and a heat exchanger transfers heat to a water tank. An “integrated” HPWH includes the tank; these units are generally more suited to light commercial duty.

Characterization at a Glance



Product Category Characterization

Energy Benefits

The energy benefits come from switching from electric resistance to heat pump technology. Heat pumps employ the refrigeration cycle to move heat from a source to a sink. In the case of water heaters, the sink is the hot water, and the source is typically air, although other sources are possible. Resistance heaters, on the other hand, generate heat directly by running a current through a resistor. Instead of using the electricity for heat directly, heat pumps use electricity to operate a compressor to "pump" heat from a cooler source to a warmer sink. The cycle starts with compressing a working fluid (e.g. refrigerant or less commonly CO_2) at ambient temperature and pressure and raising it to a high temperature. At this high temperature the working fluid naturally exchanges heat to the sink via a heat exchanger, which is referred to as a condenser or coil. The working fluid is then allowed to return to atmospheric pressure, where, since it has lost some heat, it cools to below ambient temperature. In the evaporator, the working fluid is warmed by the source ambient air and the cycle starts over. This process allows HPWHs to be three times as efficient as resistance heaters or even up to EFs of 3.7, which would be more than four times as efficient as typical resistance heaters at EFs of 0.9.

Another energy benefit is spot cooling, which refers to cooling in a specific space. Since HPWHs extract heat from the air and transfer it to the water, they are constantly venting cool air. This means when building space predominately requires cooling, which is common in commercial buildings in California due to ambient temperatures or high internal gains (e.g. data center or server room), a well-placed HPWH could address part of the cooling load. Another benefit is electrification, which refers to using electricity as the energy source for a process that has historically used fossil fuels. Electric HPWHs are cost competitive with natural gas high efficiency water heaters, and heat water exclusively with electricity instead of fossil fuels.

Non-Energy Benefits

Not Applicable

Product Category Differentiation

This category is different from grid-enabled water heaters because heat pump technology refers to the actual mechanism of heating water, as opposed to the grid connectivity features. Any electric water heater could be grid enabled. This category is different from solar water heaters as there is no solar component. However, solar water heaters all have gas or electric backups, and it is possible to have an electric heat pump as a backup system to a solar water heater.

Installation Pathway and Dependencies

Electric HPWHs are currently marketed primarily as replacements for traditional electric resistance storage water heaters. They are appropriate for both new construction and replacement installations. For many replacement installations, HPWHs do not require a major renovation or retrofit. This is particularly true for the add-on type, as the name suggests, where the heat pump system is located separately from the tank. In general, HPWHs are slightly larger than typical water heaters, which may cause difficulties if the original water heater was installed in a very tight space. Since air-source HPWHs require some amount of airflow, this also may require some installation considerations, although much less than for a fossil fuel water heater. These systems do not typically require expensive maintenance or dedicated personnel, but manufacturers typically recommend annual air filter cleaning and refrigeration system checks, and normal tank maintenance policies apply.

List of Products

Table 1: Summary of manufacturers and products for the product category.

Manufacturer	Model	Type	Differentiating Feature*
AO Smith	AWH-35 – AWH-170	Add-on	Installation profile/form factor is shorter and more boxlike, where typically HPWHs are taller and more cylindrical.
Rheem	HPLD 80	Integrated	High UEF of 3.7, looks more similar to a normal water heater.
Hubbell	PBX	Integrated	UEF 2.2, residential and commercial.
SANCO2	SAN-83SSAQA	Add-on with tank	CO2 refrigerant, UEF 2.73. HPWH sold with tank.
Hubbell	RFHP	Add-on	EF 2.0, residential and small commercial.

*Uniform Energy Factor (UEF) is the measure of water heater overall efficiency, per 10 CFR Appendix E to subpart B of Part 430, part 1.15. Energy Factor (EF) is a more general efficiency descriptor, previously used in water heaters, and still used for other appliances. As UEF is the current efficiency descriptor, it is typically used by manufacturers. In cases where manufacturers only list the EF, that is provided in the above table.

Quantification of Performance

A literature search was conducted and a sample of published study results are summarized in Table 2.

Table 2: Summary of results from literature review.

Location	Application	Results	Reference
Georgia, USA	Coin laundry, 120 kbtuh water heater, baseline was a gas water heater.	Lifetime Energy Cost Savings per unit: $45,764 (Georgia).	[1]
N/A	Theoretical analysis, baseline was electric resistance.	20% of electric resistance switching would reduce energy consumption of the sector in the US by 13%. HPWH energy factor of 2.3 vs baseline of 0.9.	[1]
N/A	Baseline is electric resistance	Energy Savings of 65%. EF of 2-3 vs electric resistance baseline of 0.9.	[2]

Location	**Application**	**Results**	**Reference**
N/A	Baseline is electric resistance, residential installations	Lifetime Operating Cost Savings of $1,131-$1,148 for typical US household. Energy savings of 2.51 quads from switching to 100% HPWHs. EF of 2-2.51 vs baseline electric resistance of 0.9-0.95.	[3]

References

[1] E. Tawil, "Commercial Heat Pump Water," US Department of Energy, Oak Ridge National Laboratory, 2000.

[2] A. Hepbasli and Y. Kalinci, "A review of heat pump water heating systems," *Renewable and Sustainable Energy Reviews,* vol. 13, pp. 1211-1229, 2009.

[3] V. Franco, A. B. Lekov, S. Meyers and V. Letschert, "Heat Pump Water Heaters and American Homes: A Good Fit?," in *ACEEE Summer Study on Energy Efficiency in Buildings*, 2010.

Technology Sector
Electric Water Heating

Product Category
Solar Water Heaters

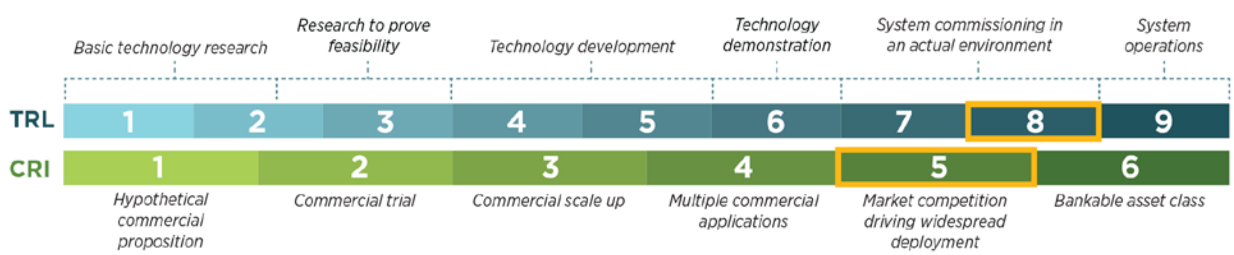
Last Updated
12/13/2018

Figure 1: Thermosiphon Solar Water Heater

Product Category Overview

Solar water heaters (SWHs) collect energy from sunlight and convert it into heat for water heating. Typically solar energy constitutes 50% to 75% of the total energy used to heat water. To provide heating when solar is not available, these systems work with either an electric or gas backup. Since the full solar spectrum is used, these systems tend to not be constrained by available roof space, but they do incur a significant first cost when compared to typical water heater options.

Characterization at a Glance



Product Category Characterization

Energy Benefits

SWHs convert energy from the sun for use in water heating. A collector collects energy from the sun and transfers it to a water tank via a working fluid. This transfer can be done using an active system (pumps) or a passive system. SWHs work in conjunction with traditional gas/propane or electric water heaters. Energy savings come from the fraction of the water heating load that is met with solar energy. The ratio of total energy used for water heating to gas or electric energy used for water heating is the solar energy factor (SEF). The SEF is the typical metric used to quantify system performance, and an SEF of greater than 1.5 is standard. An alternative metric is the solar fraction (SF), which is the ratio of solar energy to gas or electric energy used for water heating.

Non-Energy Benefits

In addition to the energy benefits, SWHs allow a portion of a building's load to not require connection to the electric or natural gas grid, especially when paired with solar photovoltaic (PV) plus storage or propane to provide an off-grid backup energy source. This flexibility may be useful in remote installations or other scenarios where grid connection would be costly or otherwise undesirable. Depending on the installation specifics, there may be significant life cycle savings, particularly in warm climates. Additionally, since commercial water heating demand tends to be more evenly spread over a day compared to demand from residential applications, and since electricity costs tend to be higher during the day to early evening, solar energy can be used to meet the most costly water heating energy demand.

Product Category Differentiation

In this product category solar energy is used to heat water. Heat pump water heaters and grid-enabled water heaters do not necessarily include this feature.

Installation Pathway and Dependencies

SWHs can be installed in new construction or as a retrofit. They do not require as much roof space as solar PV installations, but typically do require mounting a tank on the roof. If necessary, some systems may avoid the mounted tank but at a penalty to the system's overall energy performance due to pumping losses. It's also important to ensure the structural integrity of the roof. Additionally, the roof or other installation space must get adequate sunlight, and the building must have a typical water distribution system. Integration with the existing distribution system typically happens upstream of the existing system (if present) and may be non-trivial depending on building specifics. The backup water heating system will require either electric or gas power. Maintenance costs depend on system specifics, but are typically low.

List of Products

Table 1: Summary of manufacturers and products for the product category.

Manufacturer	**Model**	**Type**	**Differentiating Feature**
AO Smith		Solar with electric backup or gas backup	Savings of 70% or more.[1]
AO Smith/American Solar	SSX62 ACI350-120	Solar with electric backup	SEF 20, larger residential/small commercial, indirect.
Sun Bandit	SBES-119EU-400	Solar with electric backup	SEF 2.5, larger residential/small commercial, direct.
Rheem	SOLPAK : RS120-64BP-TG	Solar with gas backup	SEF: 1.2, larger residential/small commercial, indirect.

[1] https://www.hotwater.com/Water-Heaters/Commercial/Water-Heaters/Solar/Custom-Commercial-Solar-Water-Heating-Systems/

Manufacturer	Model	Type	Differentiating Feature
American Water Heater		Solar with gas backup	2-4 solar collectors, high efficiency condensing gas backup.

Quantification of Performance

A literature search was conducted and a sample of published study results are summarized in Table 1.

Table 2: Summary of results from literature review

Location	Application	Results	Reference
National	Baseline is minimum standards (traditional water heater). Analytical comparison.	70-90% Energy Savings.	[1]
Florida, USA	Baseline is standard electric 50 gallon water heater. Laboratory environment.	COP increase from 0.85 to 3.41 (savings of approximately 75%).	[2]
Thessaloniki, Greece	Baseline is conventional water heater with 2909 kWh total annual load, similar climate to California.	Solar contribution (energy savings) of 58.5%.	[3]
India	Baseline is conventional water heater.	Energy savings of 70-80%.	[4]

References

[1] A. Hepbasli and Y. Kalinci, "A review of heat pump water heating systems," *Renewable and Sustainable Energy Reviews,* vol. 13, pp. 1211-1229, 2009.

[2] M. Raisul Islam, K. Sumathy and S. Ullah Khan, "Solar water heating systems and their market trends," *Renewable and Sustainable Energy Reviews,* vol. 17, pp. 1-25, 2013.

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[4] S. Sadhishkumar and T. Balusamy, "Performance improvement in solar water heating systems—A review," *Renewable and Sustainable Energy Reviews,* vol. 37, pp. 191-198, 2014.