McGuireWoods LLP
501 Fayetteville Street
Suite 500
PO Box 27507 (27611)
Raleigh, NC 27601
Phone: 919.755.6600
Fax: 919.755.6699
www.mcguirewoods.com

E. Brett Breitschwerdt
Direct: 919.755.6563

bbreitschwerdt@mcguirewoods.com

March 18, 2020

VIA Electronic Filing

Ms. Kimberley A. Campbell, Chief Clerk
North Carolina Utilities Commission
Dobbs Building
430 North Salisbury Street
Raleigh, North Carolina 27603

Re: Docket No. E-100, Sub 157

Dear Ms. Campbell:

Pursuant to the North Carolina Utilities Commission's directive in its July 22, 2019 *Order Accepting Smart Grid Technology Plans* ("SGTP Order") and November 13, 2019 *Order Amending Commission Rule R8-60, Eliminating Rule R8-60.1, and Requiring Compliance Filing*, Virginia Electric and Power Company, d/b/a Dominion Energy North Carolina ("DENC"), respectfully submits this *Supplemental Grid Integrated Water Heater Research Summary* in the above-referenced proceeding.

On December 13, 2019, as required by the SGTP Order, DENC filed a preliminary assessment of Grid Integrated Water Heater ("GIWH") technology and noted that the Company is pursuing additional assessments from consulting firms and implementation contractors that either operate demand response programs using GIWH technology or have knowledge of comparable programs. The Company committed to filing this additional information once received. Attachment A is a "Grid Integrated Water Heater Research Summary" report authored by Advanced Energy that provides a more detailed technology review and assessment of GIWH programs.

Please feel free to contact me with any questions. Thank you for your assistance in this matter.

Very truly yours,

/s/E. Brett Breitschwerdt

EBB:kjg

Enclosure

REPORT
Grid Integrated Water Heater Research Summary

March 6, 2020

advanced energy

PRIMARY INVESTIGATORS / AUTHORS

Jonathan Coulter

CC Maurer

Kristin Riggins

NOTE: REPORTED DATA AND REPUBLICATION

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BACKGROUND

In 2019, the North Carolina Utilities Commission issued an order directing Dominion Energy to address a discussion around grid integrated water heater (GIWH) technology:

"The Commission is interested in additional discussion and analyses of 'Grid Integrated Water Heaters'. The Commission concludes that each of the utilities should include discussion of this technology in the next SGTP ("Smart Grid Technology Plan") Updates. This discussion, at a minimum, should include direct comparisons to existing battery storage technologies."

Dominion Energy submitted a response in a December 2019 compliance filing after conducting a preliminary review of GIWH technology. The review indicated that "(1) there are opportunities to use GIWH for peak shaving and energy storage depending upon the deployment location and other considerations which include cost-effectiveness of the technology, reliability of the technology, and the ability of a deployed system to ensure the comfort and safety of participants, (2) when viewed strictly from a price per kW perspective, GIWH technology generally compares favorably to existing battery technologies, and (3) new technology options exist for remotely controlling water heater load which can be used to enable load-shifting in a more optimized manner than older technologies."[1]

The utility also indicated that it planned to complete an additional investigation to be filed in the first quarter of 2020. As such, Dominion Energy engaged Advanced Energy to provide technical research on GIWH, including a review of the technology, a direct comparison of GIWH to battery storage, a summary of GIWH utility programs and a literature review of GIWH findings from independent sources.

TECHNOLOGY REVIEW

Grid integrated water heating, also known as grid enabled or grid interactive water heating, describes water heaters with bidirectional control that can be turned on or off or ramped up and down as a flexible load on the grid by a utility or third party.[2]

[1] https://starw1.ncuc.net/NCUC/ViewFile.aspx?Id=07dafb74-95cf-4ea7-8def-aaddfab3969e
[2] https://www.aceee.org/files/proceedings/2016/data/papers/6_336.pdf

Grid Applications

There are multiple applications of GIWH that should be outlined before discussing the technology in depth. When evaluating savings or results from field studies and pilot programs, it is important to identify which application is being assessed.

Demand Response or Peak Shaving

With this application, the utility controls the water heater to shed load at certain peak times for shorter periods, around 2-4 hours. This strategy could be considered similar to dispatching peak generation and would be called upon only for limited days of the year.[3] The approach may result in disabling the water heater during peak periods but not necessarily preheating the water or enabling the unit before the peak period.

Utilities have used this setup for years with conventional water heaters and one-way switches; the advantage of GIWH technology is the ability to know how the load performs in the field. In addition, like smart thermostats, this technology gives consumers the ability to interface with the water heater and/or utility. With a demand response control strategy, it is important to mitigate a potential rebound effect — an unintended peak occurring after the event is over.

Load Shifting or Storage

In this application, the water may be heated at night to shift load from on-peak to off-peak times. Alternatively, water heaters could be enabled during the day to store renewable energy when generation is available. This strategy is generally applied for longer periods, such as 4 hours or more. The water can be also be preheated to a higher temperature to “ride through” peak times.

Ancillary Services

Water heaters can be used for “fast response” strategies in which they provide frequency regulation or respond to voltage sags.[4] This control strategy is applied for the shortest period, typically seconds to an hour.[5]

[3] https://www.electric.coop/wp-content/uploads/2016/07/The-Hidden-Battery-01-25-2016.pdf
[4] https://www.electric.coop/wp-content/uploads/2016/07/The-Hidden-Battery-01-25-2016.pdf
[5] https://eta-publications.lbl.gov/sites/default/files/lbnl-2001113.pdf

Water Heater Equipment

Nationwide, there are nearly 55 million water heaters,[6] and around 70% of households in the South Atlantic use electricity as the primary fuel for this equipment.[7]

There are two main types of electric water heaters: electric resistance water heaters (ERWH) and heat pump water heaters (HPWH). Water heaters that lack grid integrated controls are referred to as standard water heaters. However, a subset of ERWH and HPWH have these controls and are referred to as GI-ERWH or GI-HPWH.

A limited number of manufacturers produce models equipped with grid integrated controls built-in, though several offer controls that can be added to existing units. The term GIWH may apply to a new water heater with grid integrated controls built-in or an existing water heater that has been modified with such controls. These controls enable a utility or third party to control the water heater as a flexible electric load. They may allow water temperature sensing, user overrides and performance monitoring through an app.

Electric Resistance Water Heater (ERWH)

Legislation passed in 2015 limited new manufacturing of standard ERWH to a capacity of 55 gallons. However, there is an exception to allow manufacturing of GI-ERWH at higher tank capacities. Initially, specialty companies such as Steffes and Vaughn were the primary manufacturers of GI-ERWH, but water heating market leaders now also have models available off the shelf. For example, Rheem offers the Gladiator model in 40- to 55-gallon capacities and the Marathon in the 85-gallon capacity.[8]

GI-ERWH have the potential to shift and shed significant load when controlled; however, storage potential may be limited for smaller tank capacities (e.g., 50 gallons) if only maintaining the water at a setpoint of 120 degrees Fahrenheit. A 50-gallon storage tank at normal temperature has only 1-2 kilowatt-hours (kWh) of storage available.[9]

Using a higher storage temperature, such as 170 degrees Fahrenheit, produces larger savings and longer storage capabilities. Storing the water at a higher temperature will increase heat loss, referred to as standby loss. A theoretical analysis of a 50-gallon water heater showed that increasing the water temperature by 10 degrees Fahrenheit could

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[6] https://energy.ncsu.edu/storage/wp-content/uploads/sites/2/2019/02/NC-Storage-Study-FINAL.pdf
[7] https://www.eia.gov/consumption/residential/data/2015/hc/php/hc8.8.php
[8] https://www.rheem.com/product/marathon-85-gallon-electric-grid-enabled-water-heater-with-limited-lifetime-warranty-mrg85245c/
[9] https://www.energytrust.org/wp-content/uploads/2017/11/Water_Heater_Energy_Storage_wStaffResponse.pdf

result in an overall increase in energy from standby losses of 21-100 kWh per year.[10] On the other hand, a field demonstration of one 85-gallon water heater showed that total energy use was similar when increasing GI-ERWH storage temperatures from 125 to 170 degrees Fahrenheit for short periods applying the right control strategy.[11]

Higher storage temperatures require integrating mixing valves, which adds expense and complexity. The current report does not include any large demonstration projects or field results from applying the higher temperature storage approach.

ERWH are quieter and smaller than HPWH and require less maintenance, but a challenge is the limited number of manufacturers and models available in grid integrated versions.

Heat Pump Water Heater (HPWH)

HPWH do not need to be controlled to achieve energy and demand savings; on their own they provide significant energy savings and are up to 63% more efficient than ERWH. Experimental tests on 80-gallon models have shown that they can be used effectively in demand response programs and that they are available for peak reduction. However, the power demand for an 80-gallon HPWH is only 25% of an ERWH.[12] Therefore, if used in a demand response application, the unit may not shift or shed as much load.

HPWH have an air filter, require more maintenance than ERWH and are perceived as noisier. They are also larger in physical size and either cool the surrounding air or need to be ducted, restricting where they can be installed. In addition, there is limited ability to preheat hot water, and recovery time could take longer in heat pump mode.[13]

External Controls

A number of manufacturers of external grid integrated controls (to modify existing water heaters) exist, including Carina Technology, Aquanta, Emerson and Shifted Energy. An advantage of this approach is that customers do not have to replace their whole water heater, so equipment costs are reduced.

The North Carolina Electric Membership Corporation used Carina Technology controllers on existing water heaters in a pilot program starting in 2017. The co-op

[10] https://www.energytrust.org/wp-content/uploads/2017/11/Water_Heater_Energy_Storage_wStaffResponse.pdf
[11] Electric Power Research Institute. (2014). Field Evaluation of Grid Interactive Water Heaters.
[12] https://labhomes.pnnl.gov/documents/PNNL_23527_Eval_Demand_Response_Performance_Electric_Water_Heaters.pdf
[13] https://www1.eere.energy.gov/buildings/pdfs/75473.pdf

found average savings of 0.45 kilowatts (kW) per water heater in the summer and 0.90 kW in the winter, though there was significant variation across households.[14]

Battery Storage

Like GIWH, there are multiple approaches and use cases for battery storage. Certain battery types (or chemical makeups) might be better suited for one application or another, such as ancillary services vs. load shifting.[15]

This review concentrated on behind-the-meter applications of lithium-ion technology. The industry has largely focused on lithium-ion batteries due to rapid declines in price, and they hold the majority of the market share for grid-scale batteries, electric vehicle batteries and storage paired with solar photovoltaic (PV) systems.[16]

All residential batteries discussed in this section have native or built-in battery management systems (BMS) that may be used to control charge and discharge cycles to shift load and respond to variations in demand. There are, however, two broad categories of residential battery systems.

The first category is capable of serving as a standalone source of backup power, though it can store power generated by on-site renewable energy sources with additional equipment. For example, the Tesla Powerwall 2 is an AC battery (AC in/AC out) that includes a built-in AC-DC inverter/charger.[17] Because the Powerwall 2 is an AC battery, it requires a solar inverter to function together with a solar array, but this inverter can be almost any model because it operates independently of the Powerwall.

The LG Chem RESU (Residential Energy Storage Unit) is another example of this type of battery. Unlike the Tesla Powerwall 2, the LG Chem RESU does not have a built-in AC-DC inverter or charger. Its batteries are compatible with both new and existing solar arrays. If a new installation involves a solar array and battery storage, a hybrid inverter is expected to be used instead of installing individual inverters for the battery and solar array. For homes with existing solar arrays, the batteries will require an inverter in addition to the existing solar inverter.[18]

[14] https://www.advancedenergy.org/2018/08/09/ncemcandcarina/
[15] https://www.utilitydive.com/news/batteries-for-electric-vehicles-and-stationary-storage-are-showing-signs-of/528848/
[16] https://energy.ncsu.edu/storage/wp-content/uploads/sites/2/2019/02/NC-Storage-Study-FINAL.pdf
[17] https://www.cleanenergyreviews.info/blog/tesla-powerwall-2-solar-battery-review
[18] https://www.infiniteenergy.com.au/products/solar-batteries/lg-chem-resu-faqs/

Another type of battery system provides an integrated solution to solar PV and battery storage, such as the SolarEdge StorEdge[19,20] storage systems. These systems automatically provide homeowners with backup power during grid interruption and maximize self-consumption. Unused PV power is stored in a battery and deployed during an outage or when PV production is insufficient. When there is an outage, a combination of PV and battery powers important loads, such as refrigerators, lights and AC outlets.

The solution in this integrated system is based on a single inverter for PV, storage and backup power. Various third-party battery subsystems (including the Tesla Powerwall 2 and LG Chem RESU) can be connected to the StorEdge system, and all can provide emergency backup power. The duration of backup depends on the size of the battery and the amount of available solar irradiance to recharge it.

Sunverge and Sonnen developed other popular battery systems that have been used in residential energy storage programs. The Sunverge Solar Integration System (SIS) is an example of a solar-integrated battery system, whereas the sonnenBatterie eco is similar to the Tesla Powerwall 2.[21] It is an AC battery with a built-in AC-DC inverter, but it still requires an additional solar inverter to function with a solar array.

GIWH and Battery Storage Direct Comparison

A GIWH can cost from $640 (GI-ERWH) to $2,000 (GI-HPWH) for the equipment plus installation. A 50-gallon water heater has up to two electric elements rated at 4.5 kW. If the water is at 125 degrees Fahrenheit, it theoretically stores up to 8 kWh.[22] However, based on typical usage patterns and results from demonstration projects, the demand shifted is closer to ~0.5 kW per water heater.[22,23,24] The storage available per event without impacting hot water is closer to 1-2 kWh.[25]

The table below illustrates the features of popular battery systems available on the market.

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19 https://www.solaredge.com/us/solutions/grid-backup#/
20 https://www.greentechmedia.com/articles/read/enphase-storage-storedge-solar-and-energy-storage-system-review#gs.kzWyFus
21 https://www.cleanenergyreviews.info/blog/2015/11/19/complete-battery-storage-comparison-and-review
22 Electric Power Research Institute. (2011) Peak Load Shifting by Thermal Energy Storage Assessment of a Smart Electric Water Heater.
23 https://www.advancedenergy.org/2018/08/09/ncemcandcarina/
24 https://www.bpa.gov/EE/Technology/demand-response/Pages/CTA2045-DataShare.aspx
25 https://www.energytrust.org/wp-content/uploads/2017/11/Water_Heater_Energy_Storage_wStaffResponse.pdf

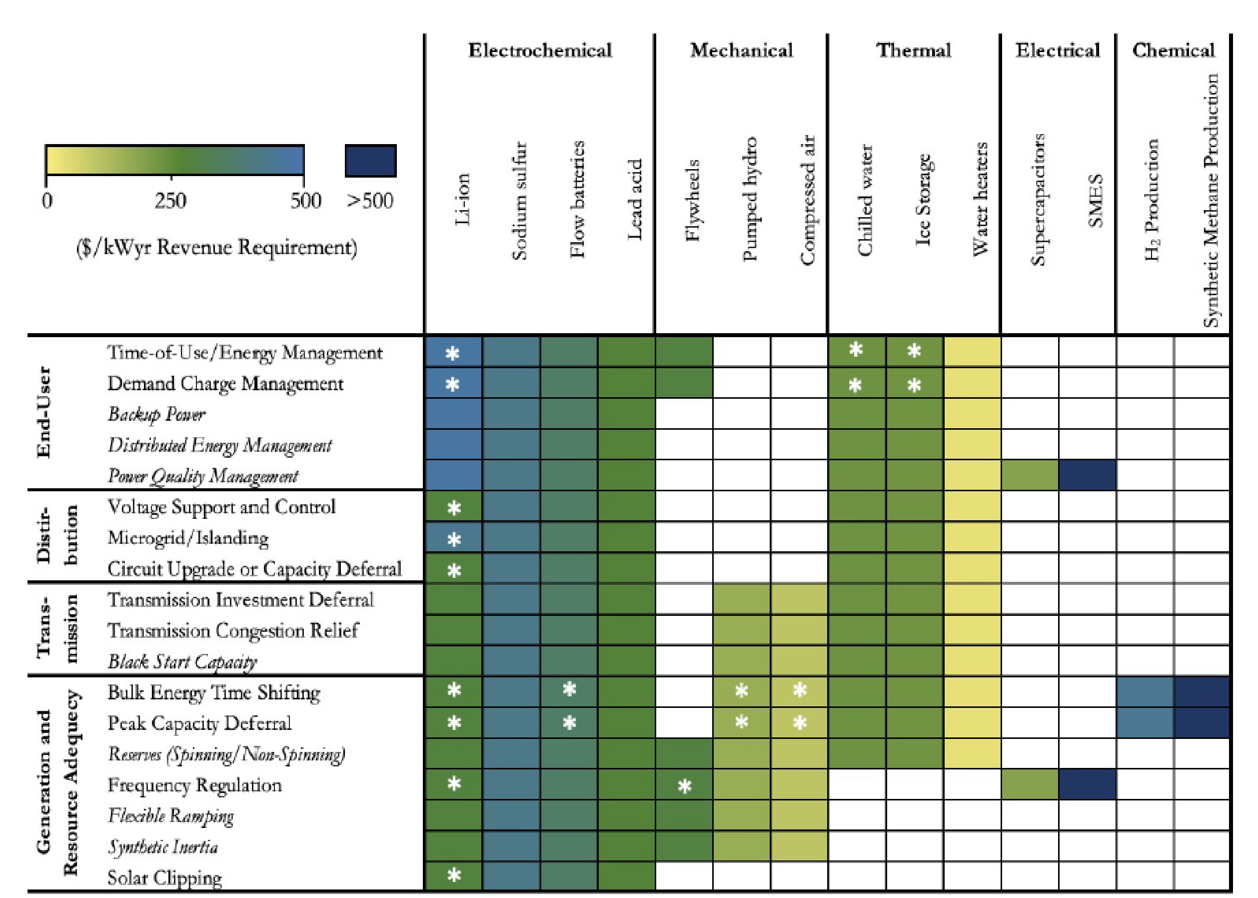
System	Capacity	Power Rating (continuous)	Roundtrip Efficiency*	Equipment Price
Tesla Powerwall 2	14 kWh	5 kW	90%	$7,600
sonnenBatterie eco	10 kWh	7 kW	86%	$16,000
LG Chem RESU	9.8 kWh	5 kW	94.5%	$5,000-$6,000**

*Roundtrip efficiency is a measure of the electrical losses involved with charging and discharging a battery; **Does not come with integrated inverter

When viewed in terms of cost, water heater technology used as storage is preferred to lithium-ion batteries in residential applications. Data from a study by the NC State Energy Storage Team is presented for comparison.[26] The water heater was estimated at $100 per kWh for a 4-hour duration, whereas a residential lithium-ion battery for the same duration was projected to be $748 per kWh. The water heater also had favorable ratings for lifetime (12 years vs. 10 years), fixed operations and maintenance ($15.80/kW per year vs. $71/kW per year) and roundtrip efficiency (92% vs. 85%). However, although there are significant cost differences today, this pattern may shift in the future as battery costs decline and technology improves.

[26] https://energy.ncsu.edu/storage/wp-content/uploads/sites/2/2019/02/NC-Storage-Study-FINAL.pdf

The NC State Energy Storage Team also analyzed the performance of battery storage and water heaters under different grid service scenarios. The following table from its report illustrates various applications that storage technologies can serve.



Intersection between storage technologies and grid-related services. The colors indicate the magnitude of the revenue requirement, which represents the fixed costs associated with the storage technology: capital cost amortized over the technology lifetime at a 10% rate plus annual fixed operations and maintenance costs. Higher revenue requirements do not necessarily imply lower cost-effectiveness, as more costly options may be able to capture greater benefits.

Other Considerations

Distributed Energy Resource Management System (DERMS) Platform

Advanced Energy recommends considering how GIWH technology may interface with other technologies in homes and buildings. A DERMS aggregates multiple devices through open standard communication. The features may include device enrollment, dispatch, forecasting, settlement, measurement and verification, and demand response. It can integrate battery storage, solar and electric vehicle charging equipment. Vendors include EnergyHub, AutoGrid, Whisker Labs and Open Access Technology International (OATI), and they can provide solutions with varying capabilities.

Device Communications

Grid integrated appliances must be able to receive and send information or communicate with the utility or third-party aggregator. Example communication methods include Wi-Fi, Zigbee, 4G-LTE, Z-Wave, Bluetooth and FM broadcast. Some of these methods (Wi-Fi, Zigbee) rely on the customer's internet connection, while others (cellular) do not. Demand response languages include OpenADR, SEP 2.0 and BACnet.

There are limitations to certain communications, such as Wi-Fi, in that customers may not have service available or have a weak signal at the location of the appliance. A field demonstration by Bonneville Power Administration (BPA) primarily used FM broadcast for control events but also connected through Wi-Fi, providing boosters as needed. Of the 280 participants, 15 had problems with their Wi-Fi connection.[27]

There is ongoing work on standard communication protocols for devices in the home for energy management. For example, the ANSI/CTA-2045 Modular Communications Interface Standard was first published in 2013. CTA-2045 defines a standard hardware interface between a product and a communications module — essentially a port built into an appliance. The module hardware can then be replaced if it becomes obsolete.

The communications module enables a connection to the preferred system by utility (Wi-Fi, Zigbee, cellular, etc.). However, there is not a single open standard currently adopted in the market. This can be perceived as a barrier and is discussed extensively in the pilot program results and market transformation plan for BPA.

User Satisfaction

One of the most important aspects of any water heater program is customer satisfaction. Users should not notice any change in hot water temperature during control events. One

[27] https://www.bpa.gov/EE/Technology/demand-response/Pages/CTA2045-DataShare.aspx

field demonstration measured the water temperature at the tank and found that 120 degrees Fahrenheit water was always available during hot water draw periods.[28] Other programs may survey their customers. For example, the North Carolina Electric Membership Corporation found that 85% of customers participating in their pilot program never ran out of hot water, and those that did tended to have the same problem before the pilot.[29]

The field study by BPA also looked at customer satisfaction through surveys, and it monitored customer overrides as well.[30] An override may be used proactively if the participant is expecting high hot water usage or in response to low water temperature; however, BPA found that only 10% of participants used the feature. The surveys also asked whether participants had problems with hot water availability in the previous week, and they were randomized to include weeks where there was no curtailment. While in some cases participants did report issues, there was no correlation between curtailment events and hot water availability problems.

Other factors that may affect user satisfaction include noise and ease of maintenance.

Environmental Benefits

Storage and load shifting are critical to being able to utilize the increasing amount of renewable energy on the grid. It is important to use the appropriate strategies in a water heater program to reduce carbon dioxide emissions. The environmental benefits may be impacted by both energy and peak demand.

The Brattle Group analyzed several scenarios for environmental impact.[31] The researchers noted that there may be a different curtailment or dispatch strategy to maximize environmental benefits. GI-HPWH provided consistent reductions in carbon dioxide emissions in all scenarios evaluated.

Installing a new water heater may save energy thanks to increased efficiency levels of the appliance; however, if water heater capacity is higher than the existing unit, energy usage and emissions will rise.

[28] Electric Power Research Institute. (2014). Field Evaluation of Grid Interactive Water Heaters.
[29] https://www.advancedenergy.org/2018/08/09/ncemcandcarina/
[30] https://www.bpa.gov/EE/Technology/demand-response/Pages/CTA2045-DataShare.aspx
[31] https://www.electric.coop/wp-content/uploads/2016/07/The-Hidden-Battery-01-25-2016.pdf

UTILITY PROGRAMS

The 2019 Utility Demand Response Snapshot showed that 27.9% of utility respondents are offering water heater programs.[32] There was a total of 585.6 megawatts (MW) of enrolled capacity and 202.7 MW of dispatched capacity. Of the utilities that have a program, 51.7% utilize it to defer or replace generation and transmission or distribution capacity. Eleven states have GIWH pilot programs: Arizona, California, Florida, Georgia, Hawaii, Minnesota, North Carolina, Oregon, South Dakota, Washington and Wisconsin.

Ownership, Third-Party Aggregation and Bring Your Own Device (BYOD)

In considering a GIWH or battery storage program, there are numerous ownership models, opportunities for partnerships with third-party aggregators and device preferences. Utilities may prefer not to own any equipment that will be inside customer homes. In this case, they can provide a rebate or incentive to customers that covers part or all of the system. Several utilities hired a contractor to administer the program, such as working through their DERMS vendor. Some pilot programs are utilizing only one technology or manufacturer, while others are considering BYOD programs — where the customer gets to choose the equipment as long as it is compatible with program specifications.

Pilot Programs

Lab, field and modeling demonstrations have been conducted over the last 8-10 years; however, many utility pilot programs have launched only recently (within the last 1-3 years). Therefore, there may be limited measurement and verification or published results available at this time. For this review, a few programs were selected to illustrate deployment considerations, costs and reported savings.

New Water Heater Programs

The largest of these pilots was recently completed by BPA, Portland General Electric and the Northwest Energy Efficiency Alliance.[33] The three-year pilot was designed to develop a business case for a market transformation plan that would create widespread adoption of GIWH equipped with a standard communication protocol.

The demonstration included 277 participants across eight retail utilities. It evaluated the ability of both GI-ERWH and GI-HPWH equipped with the ANSI/CTA-2045 interface

[32] https://sepapower.org/resource/2019-utility-demand-response-market-snapshot/
[33] https://www.bpa.gov/EE/Technology/demand-response/Documents/20181118_CTA-2045_Final_Report.pdf

to shed load during peak demand and to shift usage to periods with excess renewable generation. The study concluded that a participation rate of 26.5% would result in a demand response potential of over 300 MW in Oregon and Washington, and that having a standardized physical communication port installed during manufacturing is the most cost-effective solution. Retrofitting and aftermarket solutions raise installation costs for demand response of water heaters by a factor of at least 2 in the near term and by 8 after 2039.

A summary of savings results from the peak demand and grid emergency scenarios is presented in the table below. One takeaway is that there are differences in reported savings depending on the season, time of day and length of event.

Water Heater Type	Time	Peak Demand Shed		Emergency (1-2-Hour Events)	
		3-Hour Event Winter Savings (Watts)	4-Hour Event Summer Savings (Watts)	Winter/Spring Savings (Watts)	Summer Savings (Watts)
HPWH	AM	223	N/A	244	122
	PM	165	85	167	96
ERWH	AM	374	N/A	562	393
	PM	321	347	563	389

In 2019, United Illuminating (UI) broadened its partnership with EnergyHub to include the integration of Rheem's intelligent GI-HPWH. As part of its income-eligible program, UI will install the Wi-Fi-enabled Rheem GI-HPWH at no cost to qualifying customers. The GI-HPWH will then be added to available devices that can be controlled through EnergyHub's Mercury DERMS. UI is already using DERMS to manage its Bring Your Own Thermostat demand response program.[34]

Arizona Public Service (APS) uses EnergyHub's Mercury DERMS to manage its portfolio of grid devices, which includes GI-HPWH.[35] APS offered a Ruud connected HPWH from Rheem to approximately 200 eligible customers in targeted areas.[36] The utility provided an instant rebate covering the cost of the equipment and installation in exchange for

[34] https://www.energyhub.com/blog/united-illuminating-der-program
[35] https://www.energyhub.com/blog/arizona-public-service-energyhub-mercury-derms
[36] https://www.marketwatch.com/press-release/aps-offers-three-new-programs-to-help-customers-use-more-solar-energy-2018-09-10

managing the timing of the water heater for the life of the unit. Customers retain ownership of the equipment.[37]

Water Heater Switch Installations and Programs

OATI will incorporate Shifted Energy's GIWH systems into its grid services platform for Hawaiian Electric beginning in 2020.[38] Up to 2,400 systems will be installed and used for frequency response as well as load shedding and shifting. The system includes an off-tank controller that can be installed without plumbing modifications or tank-connected sensors to retrofit existing water heaters into GIWH. The controllers utilize a cellular communications platform.

Green Mountain Power began offering the Aquanta Wi-Fi-enabled smart water heater controllers in 2017 to retrofit existing units for grid services.[39] It recently launched a new BYOD program that allows customers who purchase and install compatible batteries, GI-ERWH and Level 2 electric vehicle home charging stations to enroll their devices to be managed by Green Mountain Power in exchange for monthly credits.[40] Rheem is currently the only eligible water heater.[41]

A pilot program by the North Carolina Electric Membership Corporation installed Carina Technology controllers on 136 existing water heaters.[42] The pilot utilized both 4G-LTE and Wi-Fi technology. The co-op can see which units are on or off at any given time and can examine daily and hourly history for each individual unit. Participating members can find out how much energy their water heater has been using through an app.

The controller has a sensor at the top of the tank, and if the tank's water temperature drops below a certain threshold during a demand response period, the controller automatically overrides the event until the water temperature returns to a preset temperature. The North Carolina Electric Membership Corporation reported an average savings of 0.45 kW per water heater in the summer and 0.90 kW in the winter.

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[37] https://www.aps.com/en/About/Sustainability-and-Innovation/Technology-and-Innovation/Reserve-Rewards
[38] https://www.globenewswire.com/news-release/2019/10/01/1923461/0/en/Shifted-Energy-to-Equip-2-400-Water-Heaters-in-Hawaii-with-Grid-Interactive-Technology-to-Create-Virtual-Power-Plant.html
[39] https://www.globenewswire.com/news-release/2017/05/23/995222/0/en/Green-Mountain-Power-Launches-Smart-Water-Heater-Program-to-Help-Customers-Save-Money.html
[40] https://greenmountainpower.com/wp-content/uploads/2019/03/BYOD-Terms-and-Conditions-3-11-19.pdf
[41] https://greenmountainpower.com/bring-your-own-device/
[42] https://www.advancedenergy.org/2018/08/09/ncemcandcarina/

CONCLUSION

Based on this research and literature review of lab, field and demonstration studies, GIWH technology has displayed value for multiple grid service applications. It allows flexibility beyond traditional one-way water heating controls used for peak shaving to include load shifting and storage, optimization of excess generation as well as frequency regulation with fast response through advanced controls that can enable when the water heater runs, preheating and water temperature adjustments.

This market is still emerging, however, with a relatively small number of available products. Limitations with the technology exist, such as communication standards and network constraints. While more utilities are actively implementing GIWH technology, most efforts are in a pilot phase and continue to be evaluated.

Battery storage is another emerging market with its own set of limitations, such as price. With cost in mind, water heater technology used as storage is preferred to lithium-ion batteries in residential applications; however, the price of lithium-ion battery technology has already fallen 87% between 2010 and 2019 (from $1,100/kWh to $156/kWh) and is projected to drop to around $100/kWh by 2023.[43]

It is difficult to draw a direct comparison between GIWH and battery storage without a specifically defined use case and objective. Both technologies have the potential to be solutions for grid services based on application and implementation. It is likely that a combination of the two, in addition to other grid service technologies, can provide added value when managed in coordination through a DERMS. Though even without a DERMS, it is possible to leverage multiple technologies simultaneously to achieve desired results.

[43] https://about.bnef.com/blog/battery-pack-prices-fall-as-market-ramps-up-with-market-average-at-156-kwh-in-2019/

CERTIFICATE OF SERVICE

I hereby certify that a copy of the foregoing *Supplemental Grid Integrated Water Heater Research Summary*, filed in Docket No. E-100, Sub 157, was served electronically or via U.S. mail, first-class postage prepaid, upon all parties of record.

This the 18th day of March, 2020.

/s/E. Brett Breitschwerdt

E. Brett Breitschwerdt
McGuireWoods LLP
501 Fayetteville Street, Suite 500
PO Box 27507 (27611)
Raleigh, North Carolina 27601
(919) 755-6563 (Direct)
bbreitschwerdt@mcguirewoods.com

Attorney for Virginia Electric and Power Company, d/b/a Dominion Energy North Carolina