The Brattle Study - The Hidden Battery: Opportunities in Electric Water Heating

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The Hidden Battery

Opportunities in Electric Water Heating

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Three DR strategies were modeled for ERWHs

Strategy #1: Peak Shave

- The water heater is curtailed only on a limited number of days of the year (typically 10 to 15) when the system peak is likely to occur, and for a limited number of hours on those days (typically 2 to 4, depending on the duration needed to confidently capture the hour of the system peak)
- The water heater is not controlled on the other days of the year
- This strategy is used largely to capture capacity value

Strategy #2: Thermal Storage

- Every day, the WH heats at night and then is curtailed during highest priced hours of day; the total number of hours curtailed during the day will depend on the size of the tank and the amount of hot water it can store
- This strategy is used to capture energy value through price arbitrage
- We assume that the strategy would also include curtailment of the water heater to provide capacity value, in addition to the energy value

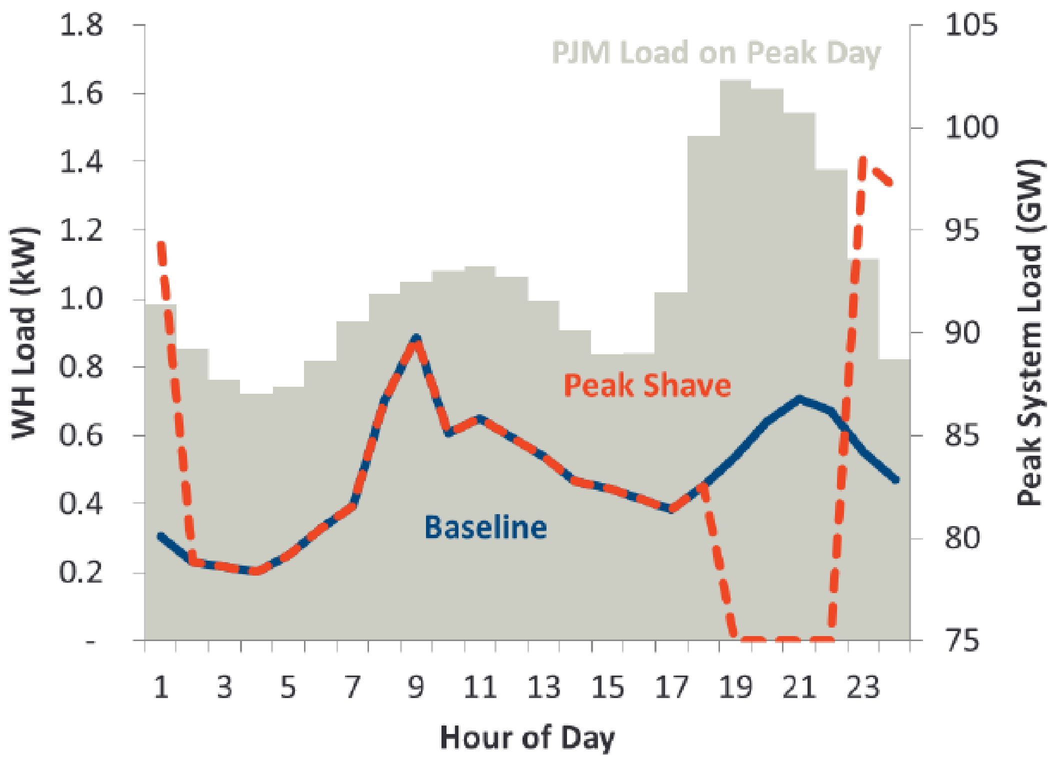
Strategy #3: Fast Response

- The water heater offers frequency regulation into the wholesale ancillary services market when heating water during off-peak hours, on a daily basis
- It responds to a signal from the system operator in a matter of seconds and can increase or decrease load depending on the need, consistent with the requirements of PJM's Dynamic Regulation ("RegD") market
- As it is modeled in our analysis, we also assume that the water heater is controlled to capture additional energy and capacity value, although the dispatch is not perfectly optimized across these three revenue streams

The strategies are modeled for both 50- and 80-gallon water heaters, to explore the economic impacts of increasing the storage capability of the water heater

The peak shave strategy reduces water heating load during peak hours of the year

The Peak Shave Load Control Strategy (50-gallon)



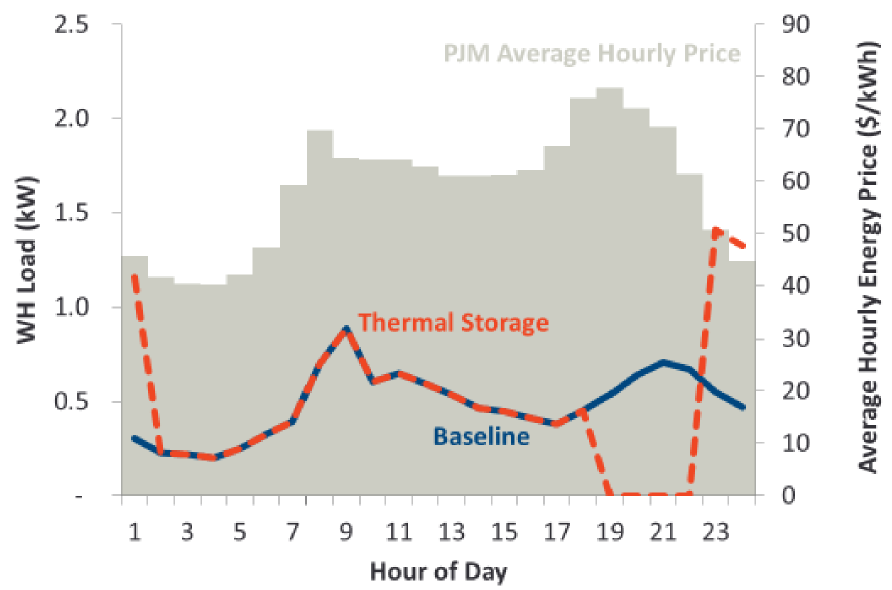
Source: Hourly load data for PJM RTO from Ventyx Energy Velocity Suite.

Comments

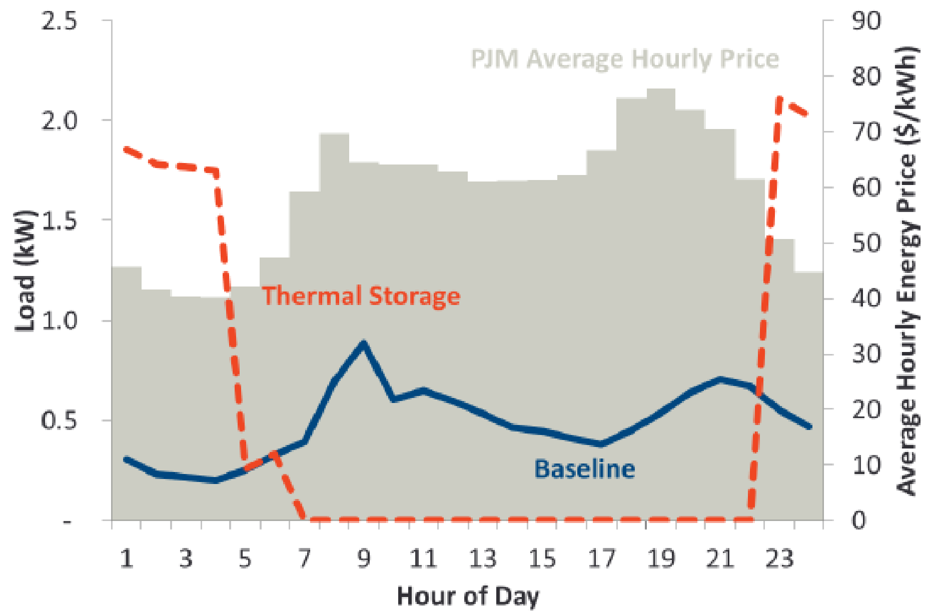
- A 50-gallon tank can be interrupted for up to 4 hours with little risk of hot water runouts across a range of customers with diverse hot water needs
- This requires the installation of a mixing valve and heating the water in the tank to 160 degrees
- System peaks are typically in the afternoon; however this strategy interrupts charging during peaks, regardless of time of day they occur
- System coincident peak demand reduction associated with this strategy is 0.5 kW per water heater
- This is the average load of the baseline water heater during the peak hours when the load is curtailed

The Thermal Storage strategy captures energy benefits in addition to capacity

50-gallon Tank



80-gallon Tank

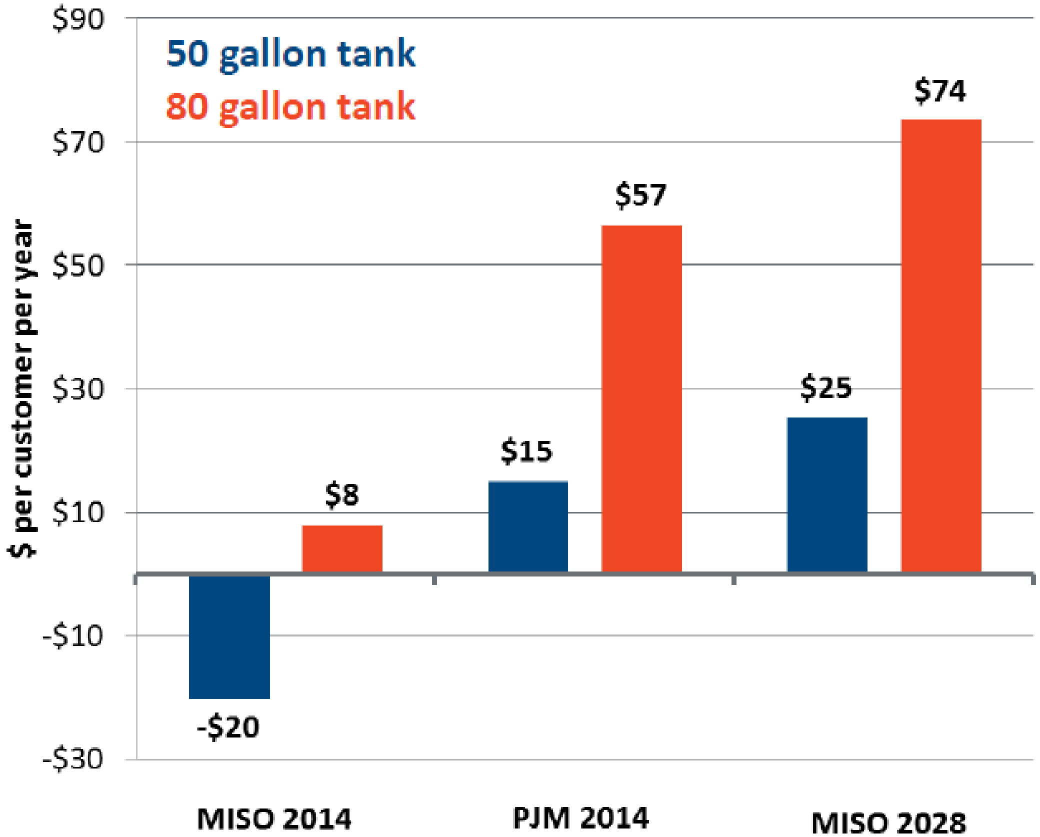


Source: Hourly day ahead wholesale price data for PJM East Hub from Velocity Suite.

- With the Thermal Storage strategy, water is heated to a maximum acceptable temperature at night and then heating is still curtailed to reduce load during hours with high energy and capacity prices
- The storage capability of the 50-gallon tank allows for curtailments of up to 4 hours per day; longer curtailments would either lead to an unacceptable risk of hot water runouts or require that the water in the tank be pre-heated to unacceptable levels
- The larger storage capability of the 80-gallon tank allows it to be curtailed up to 16 hours per day without violating the constraints described above; for more information about these assumptions around WH operations, see accompanying analysis by Dr. Carl Hiller
- Note that, with the larger tank, in some select cases customers would need to be equipped with a ~100-gallon tank in order to achieve the full 16 hours of curtailment with minimal risk of hot water run outs. Both tank sizes also require a mixing value, which allows the max temperature of the water in the tank to be increased, therefore reducing the possibility of hot water runouts when curtailing on a daily basis

A larger tank dramatically improves the economics of the Thermal Storage strategy

Net Benefit of Thermal Storage: 50-gal vs 80-gal



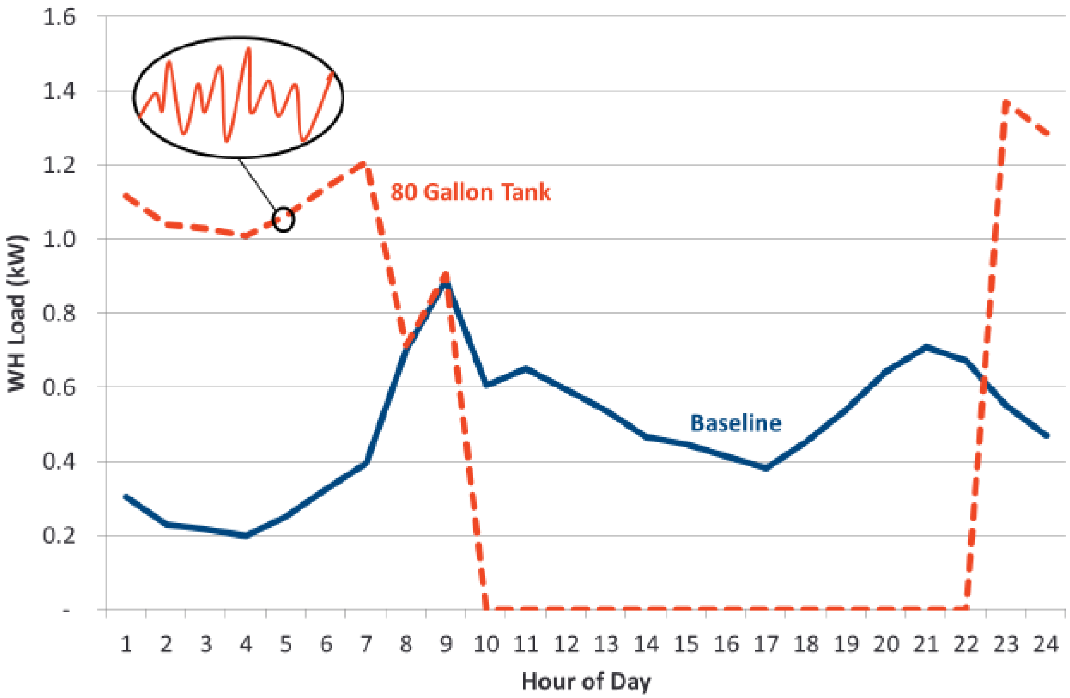
Note: MISO 2028 includes a CO_2 charge, the direct impact of which is not reflected in the results shown here. Net benefits would decrease by about $10 in the that scenario for the 80-gal tank and $2 for the 50-gal tank due to a slight increase in associated emissions.

Comments

- The larger tank can be curtailed for many more consecutive hours without risking running out of hot water
- With a significant number of hours with high energy prices and a large price differential between peak and off-peak prices, the benefits of increasing the tank size justify the incremental cost of the larger tank
- The ability of the larger tank to store more hot water can significantly improve the avoided energy cost
- With a larger tank, the economics of water heating load control are cost-effective even at the low capacity and energy prices of the MISO 2014 scenario

The Fast Response strategy provides real-time response to fluctuations in supply

Illustration of the Fast Response Strategy



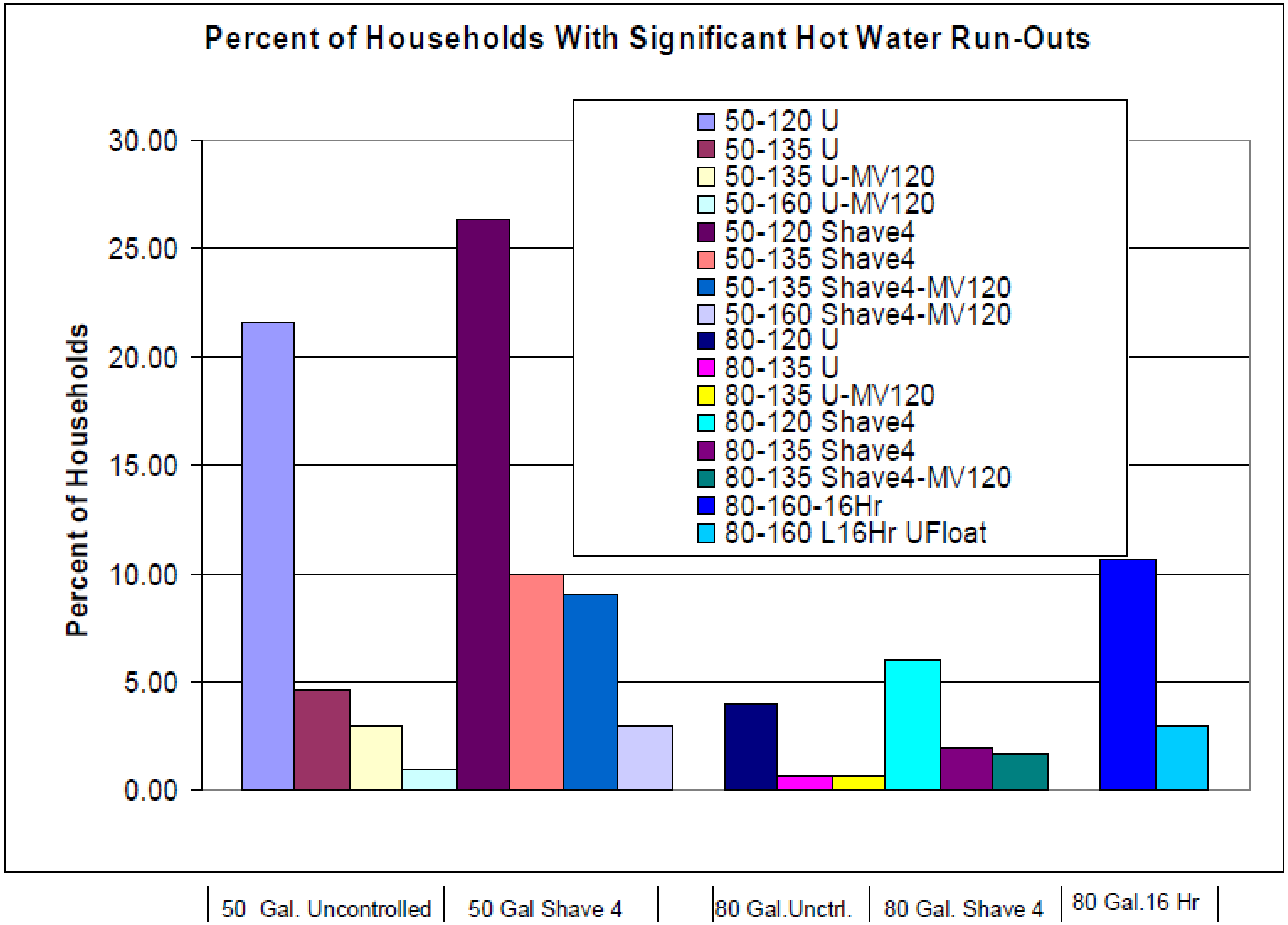
Note: Regulation line is illustrative, not real data.

Comments

- The Fast Response strategy has a charging profile that is somewhat similar to the Thermal Storage strategy, but with short-duration, high-frequency fluctuations in load around the average charging profile
- As defined by the PJM RegD product, these fluctuations are "energy neutral" on an hourly basis, so there is no significant additional concern about over- or under-heating the water in the tank
- These fast response services would be provided on a daily basis

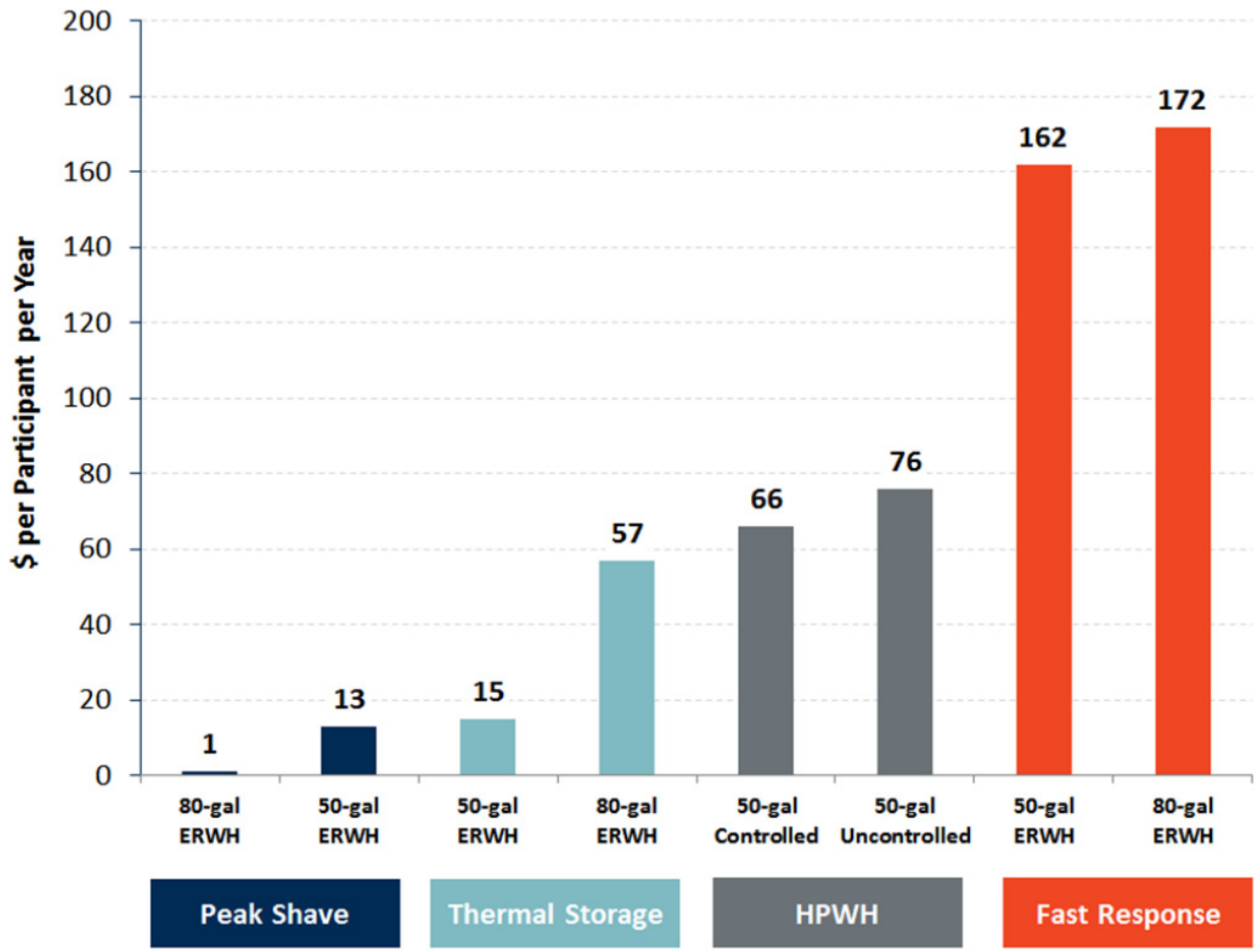
As with the Thermal Storage strategy, water heating load is also curtailed to reduce the system peak on the limited number of days when it is likely to occur

Dr. Carl Hiller's Work Incorporated



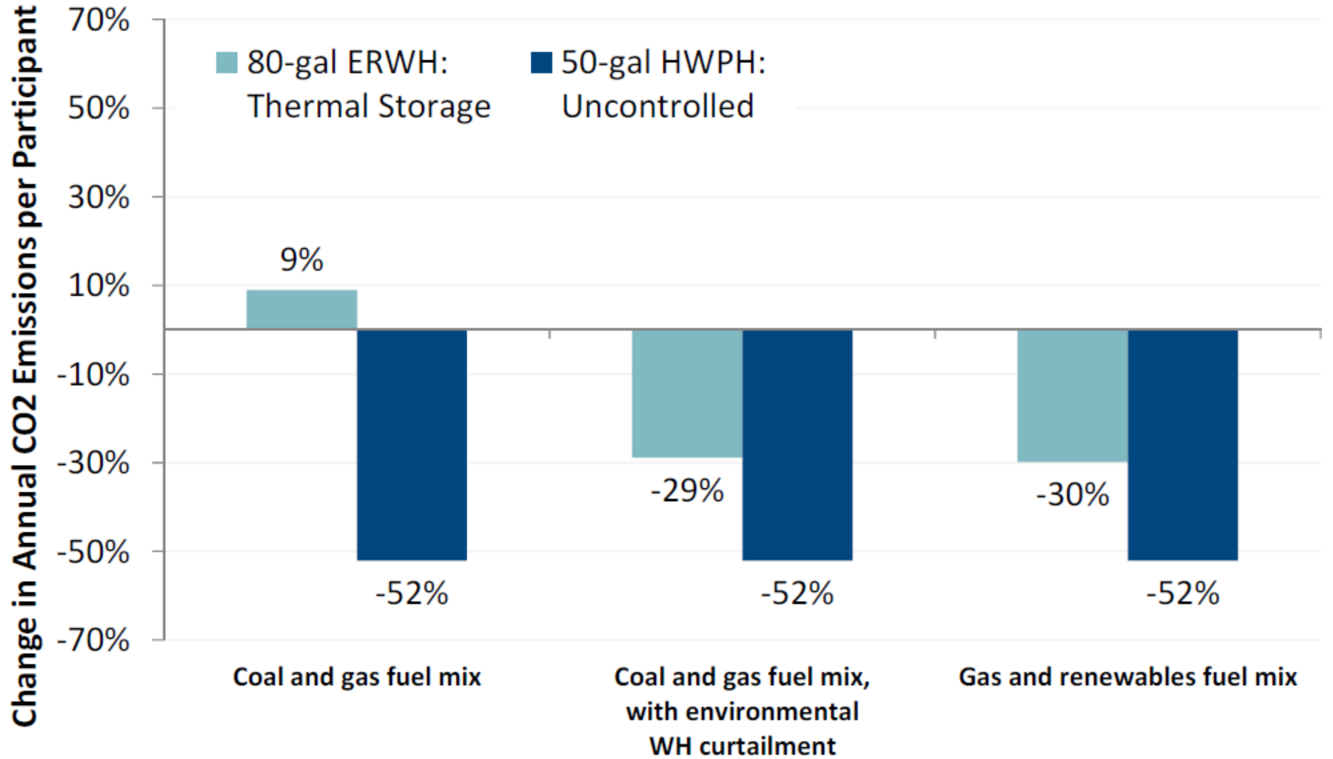
Conclusion– Lots of Options to Save $

Figure ES-1: Annualized Net Benefits of Water Heating Strategies (PJM 2014)



Potential for CO2 Reductions Load Control

Figure ES-2: Change in Water Heater CO_2 Emissions (Relative to Baseline Uncontrolled 50-gallon ERWH)



Electric Water Heating is an Important Part of our Future!

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