GRID TIED WATER HEATERS: CLIMATIC AND SEASONAL EFFECTS ON OPTIMAL ENERGY EFFICIENCY AND LOAD MANAGEMENT POTENTIAL

ACEEE HOT WATER FORUM 2017

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CONTEXT

Although it's well known that Heat Pump Water Heaters(HPWHs) are more efficient than conventional water heaters, they also have significant potential to be leveraged for load management and energy storage by connecting them to the grid.

Questions utility program designers should ask themselves are:

- How to assess the value in controlling these water heaters?
- During what time of day is their value maximized?
- How do climate and different seasons affect their operation and load management/storage capability?

PURPOSE: Help utilities understand the performance of grid-connected HPWHs in two different climates and seasons for a given set of assumptions

GRID INTERACTIVE WATER HEATERS

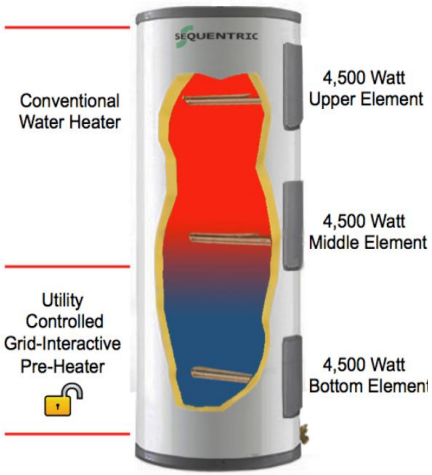
- The technology works by heating and storing water at higher temperature (typically 150 F) than the normal set point (typically 120 F) during *preferred* times ("charging mode"), and then uses that hot water in times of higher draws during the peak period ("discharging mode").

GE GeoSpring

AO Smith Voltex

Whirlpool heat pump water heater

Sequentric (not a HP water heater)



Hubbell Heat Pump Water heater

Sanden SanCO2 (outdoor unit)

Source: Product websites

RESIDENTIAL CONFIGURATION

Most models are available in 50 gallon and 80 gallon tank size, can operate in multiple modes and can have a set point of up to 160 F.

- There are multiple modes:
  - Heat Pump (HP) only,
  - Electric Resistance (ER) only
  - Hybrid – HP with ER backup
  - Vacation
- The setpoint can be as high as 160 F for thermal storage purposes during charging mode.

Model	Available tank sizes (gal)	Rated Energy Factor	Height (inch)*	Diameter (inch)*
GE GeoSpring	50, 80	Up to 3.39	61	22
A.O. Smith Voltex	50,66,80	Up to 3.24	61	22
Whirlpool heat pump water heater	50,80	Up to 2.75	63	22
Hubbell heat pump water heater	40,50,65,80,119	Up to 3.3	66	25
Sanden SanCO2 (includes an outdoor unit 35 x 30)	43,83	Up to 3.5	47	22

Source: Product websites

***Height and Diameter are based on the 50 gallon tank size.**

SIMULATION INPUTS

- **Baseline Domestic hot water (DHW) load profile:**
  - DHW load from BEopt simulation of a typical single family house with a 50 gallon tank and average rated EF of 0.85.
- **Load Offset**: 4.5 kW
  - Baseline technology is standard efficiency 2 element electric resistance water heater with 4.5 kW demand
- **Storage Capacity:** 2.7 kWh
  - Allowable temperature band from 110-140 degrees F
  - Storage capacity is difference in electric resistance energy required to heat tank from 110 - 140 degrees F
- **Charge Rate:** 4.5 kW in electric resistance mode
  - Depends on ambient temperature when in heat pump mode and ranges from 0.2 to 0.4 KW
  - Heat pump mode requires ambient temp of 58.6 degrees F or greater
- **Decay Rate:** 0.74% per hour
  - Corresponds to about 0.02 kWh per hour loss at full charge
- **Location of water heater:** Unconditioned basement or garage

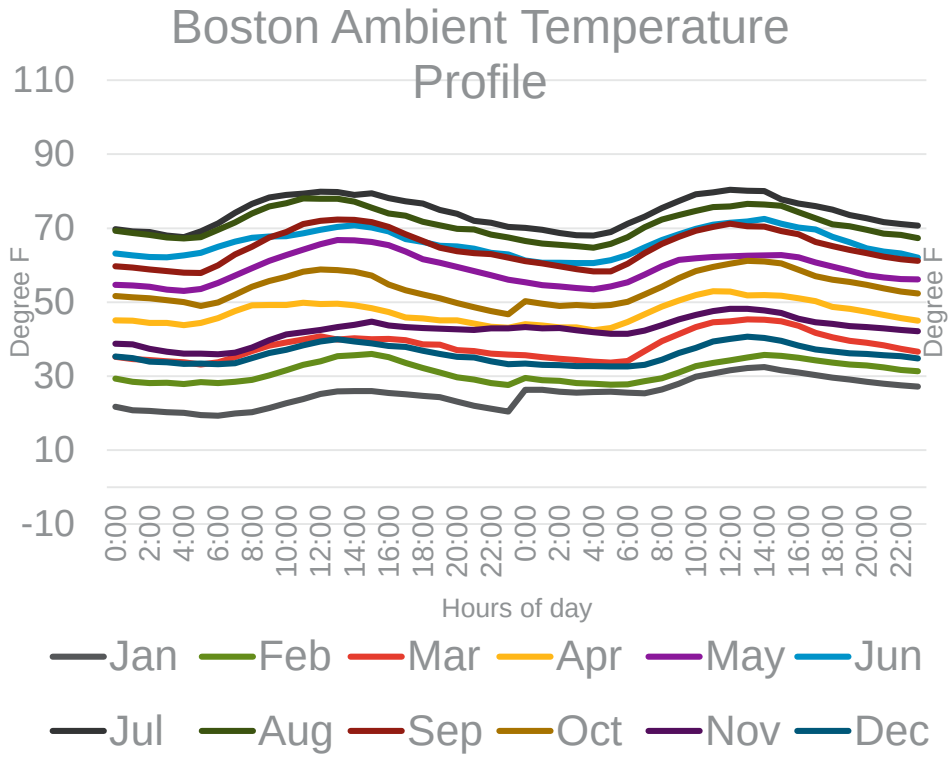
SIMULATION METHODOLOGY – CUSTOMER PERSPECTIVE

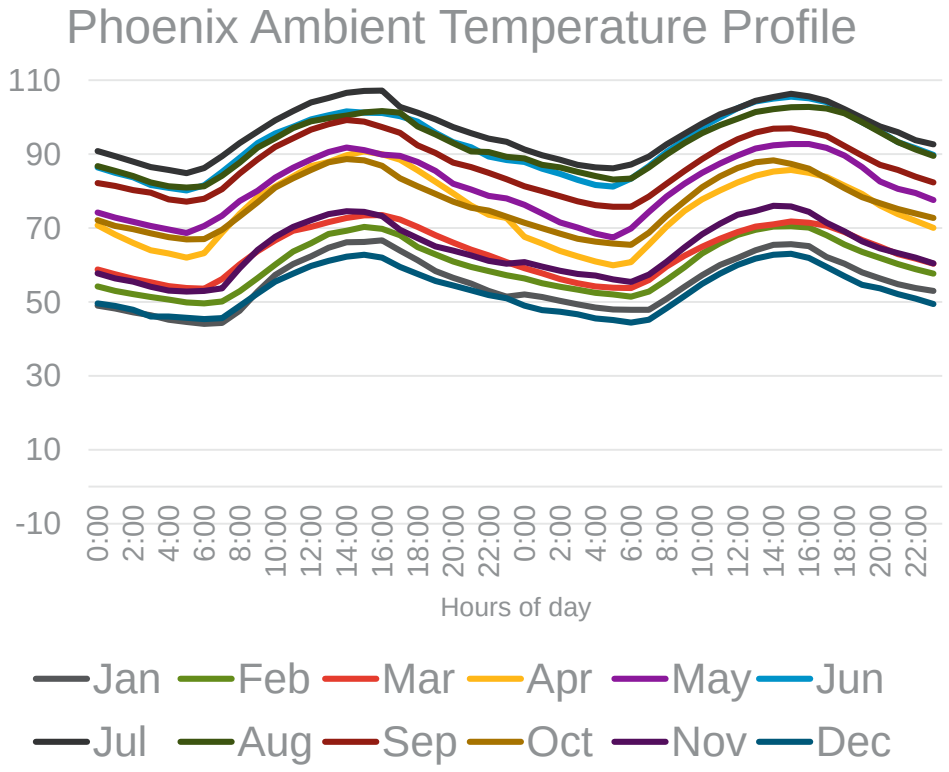
The goal is to minimize the customer's water heating bill subject to retail rates.

- **Optimize**: operation to match hourly baseline equivalent kW
  - Heat pump mode depends on ambient temperature
  - Hourly dry bulb temperature profile for each month used to define hourly heat pump mode's max output
- **Constraints:**
  - For each hour, if heat pump max output is greater than water heating demand, then heat pump mode will be used
  - Otherwise, electric resistance mode is be used
- **Retail Rate Scenario:**
  - Peak Time of Use(TOU) pricing from 3 PM to 8 PM on weekdays only
  - $5/kW-month demand charge, applicable to loads during peak TOU hours only

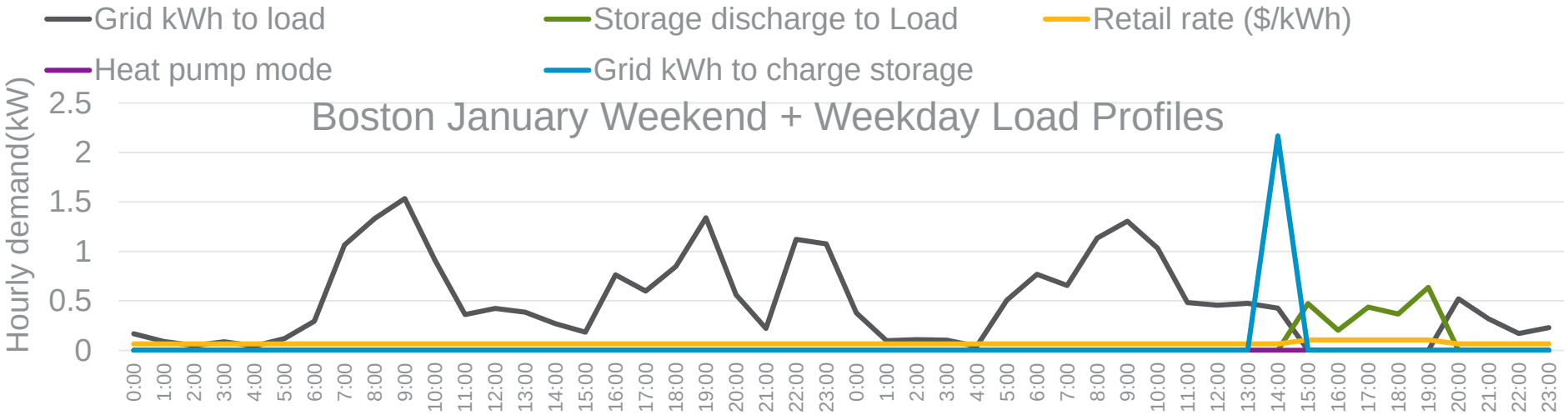
SEASON AND CLIMATE SELECTION

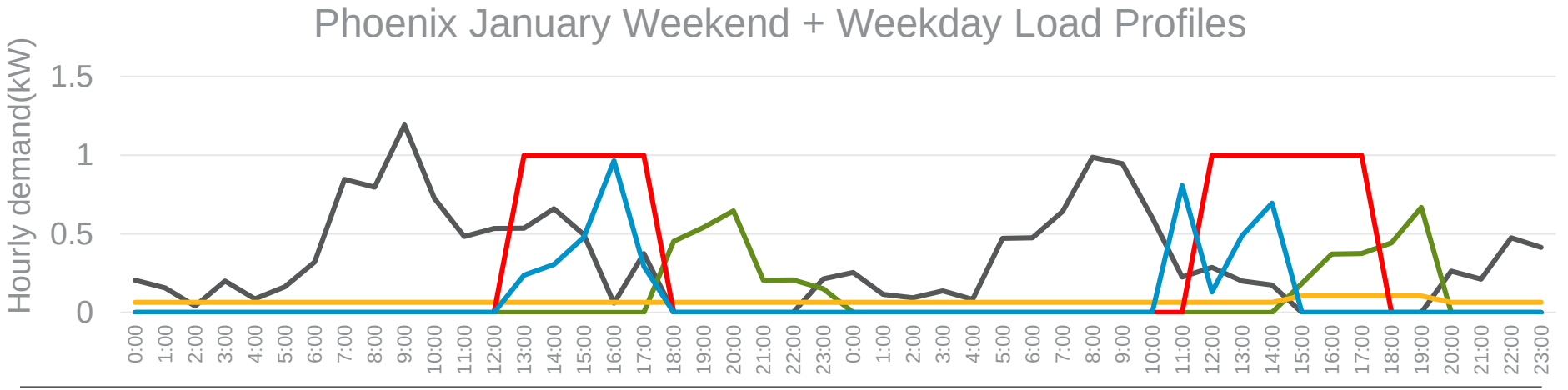
- Simulated the operation of a HPWH in multiple climates and seasons:
  - Winter and summer operation in hot and cold climates.
  - Phoenix represents the hot climate and Boston represents cold climate.



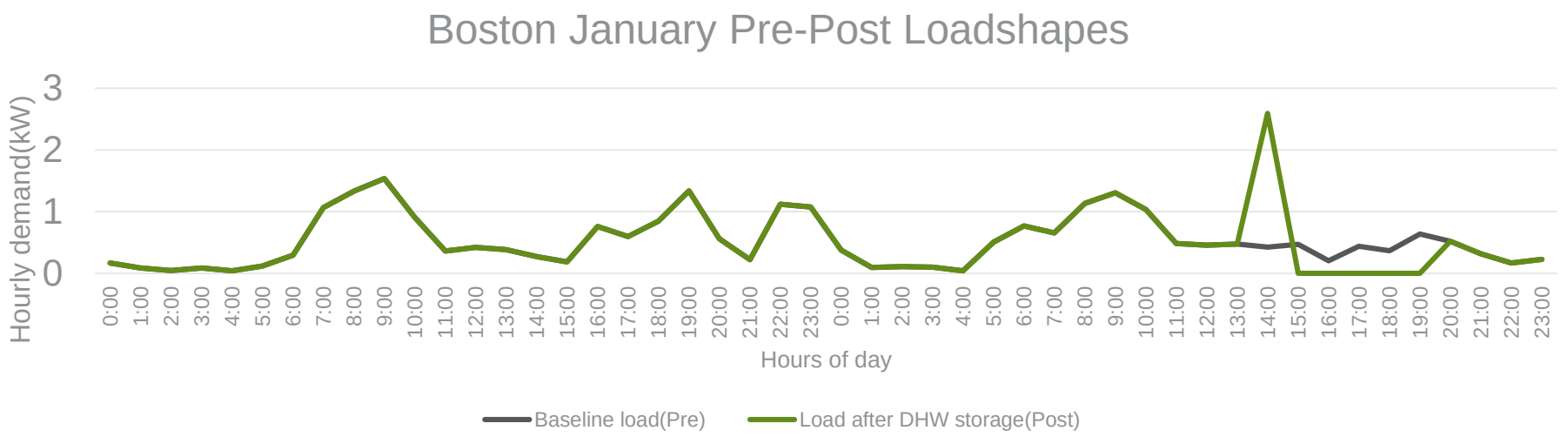


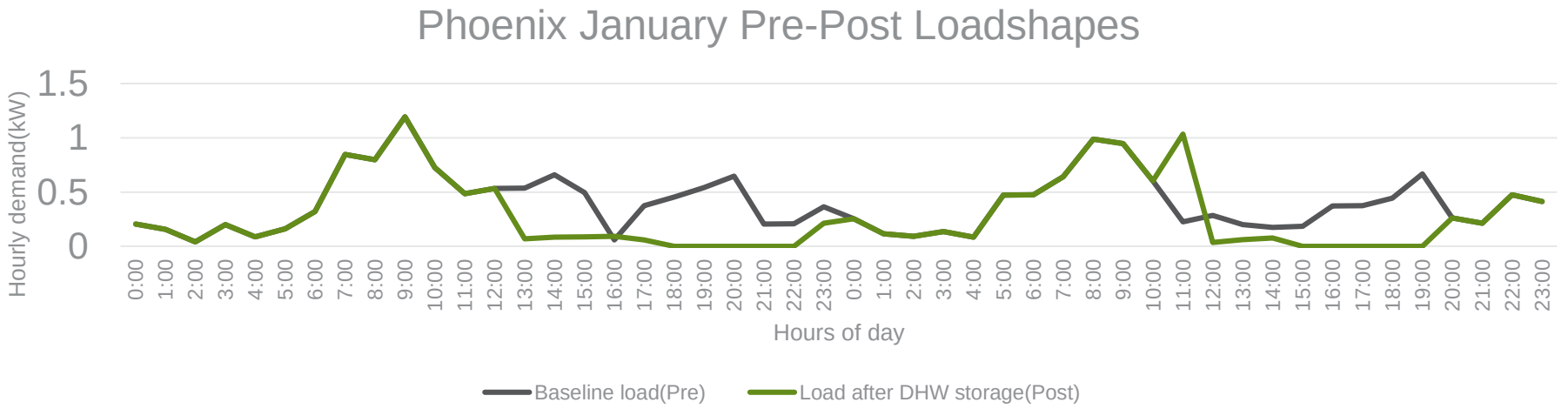
LOAD PATTERN FOR DIFFERENT CLIMATES IN JANUARY



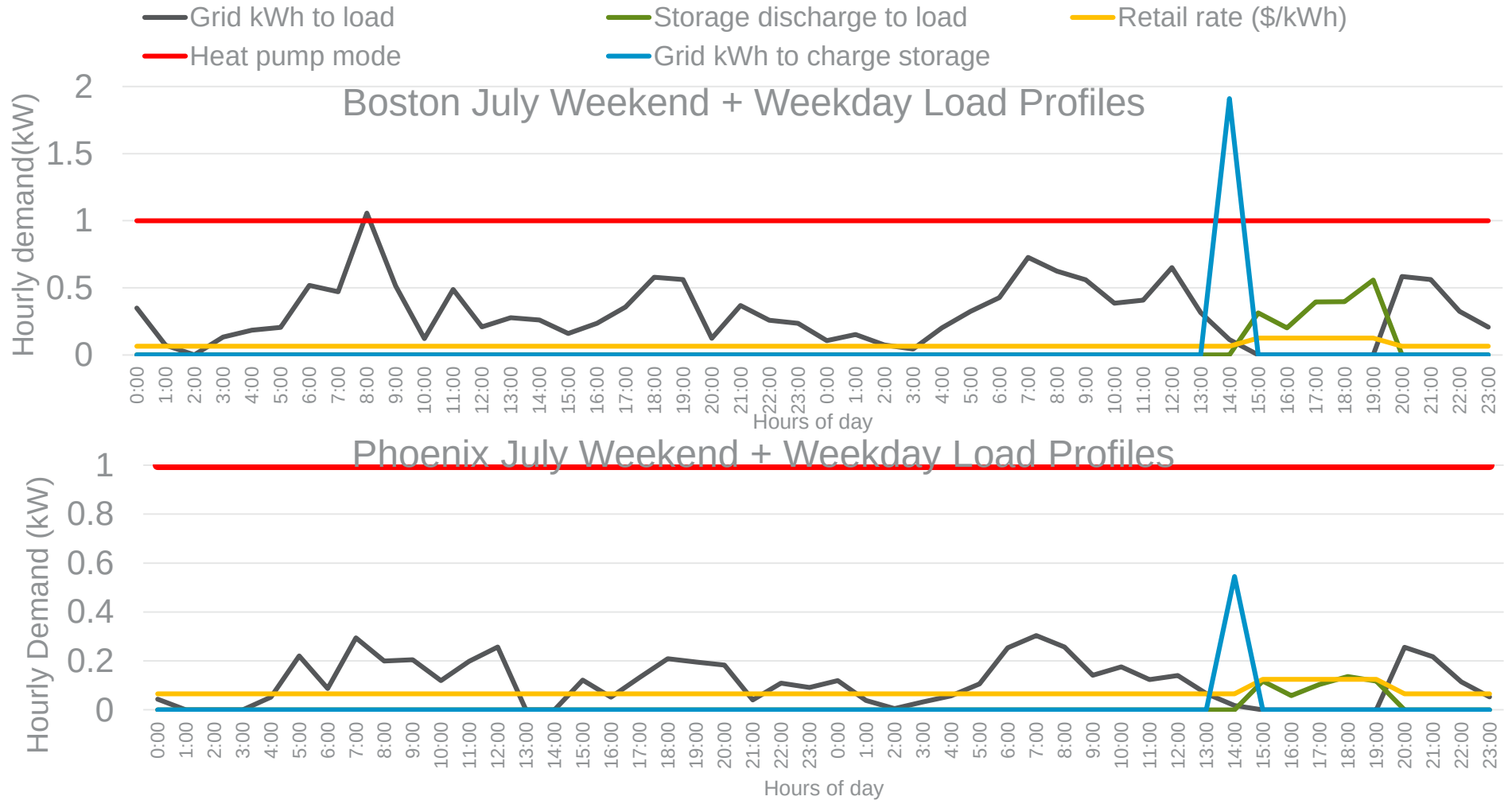


PRE-POST LOADSHAPES IN JANUARY





LOAD PATTERN FOR DIFFERENT CLIMATES IN JULY



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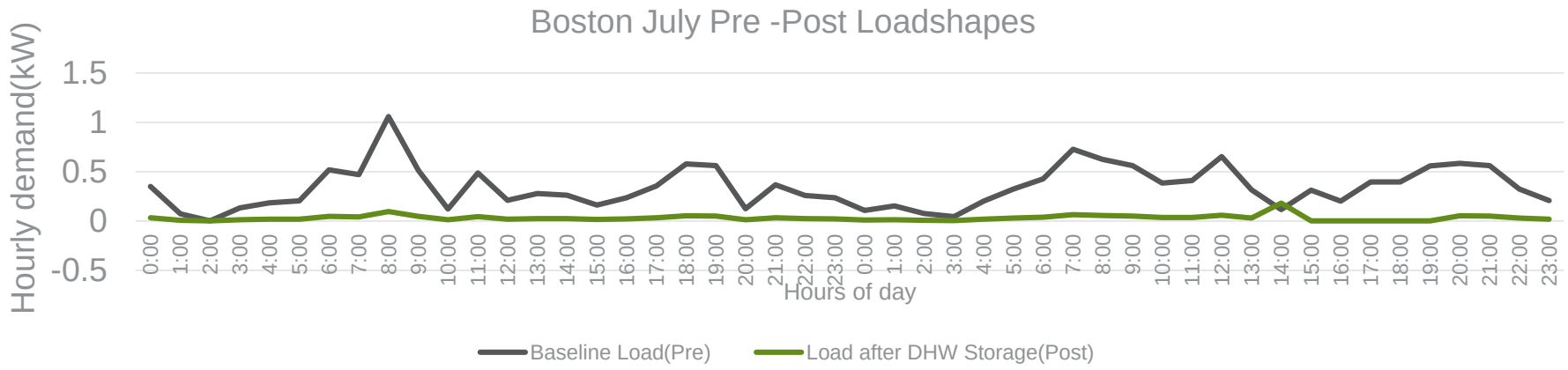
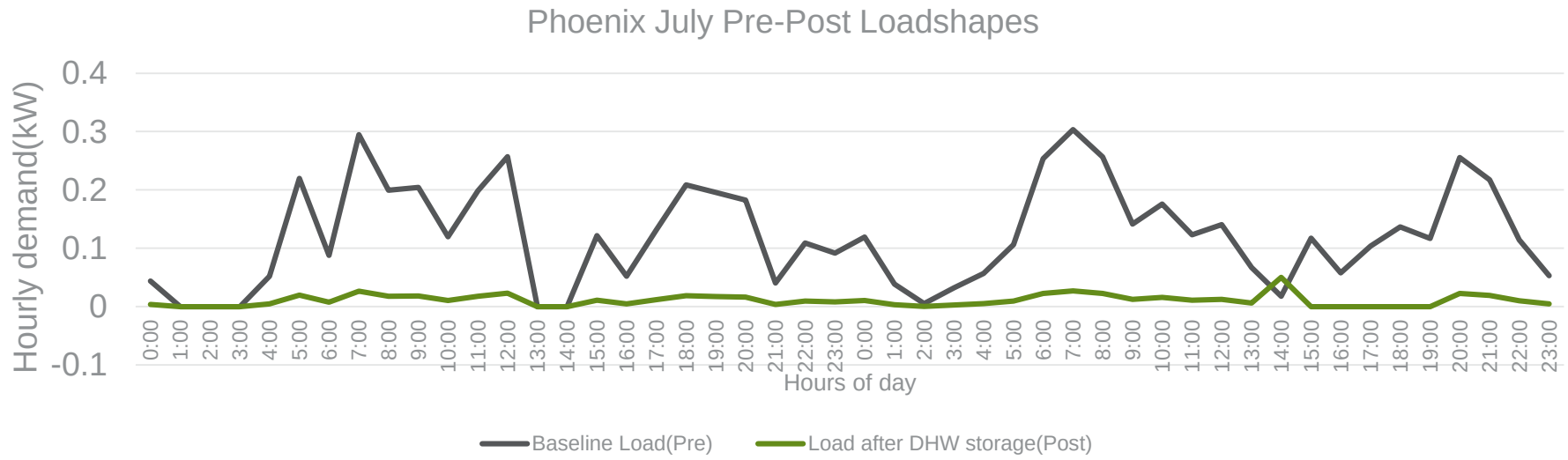
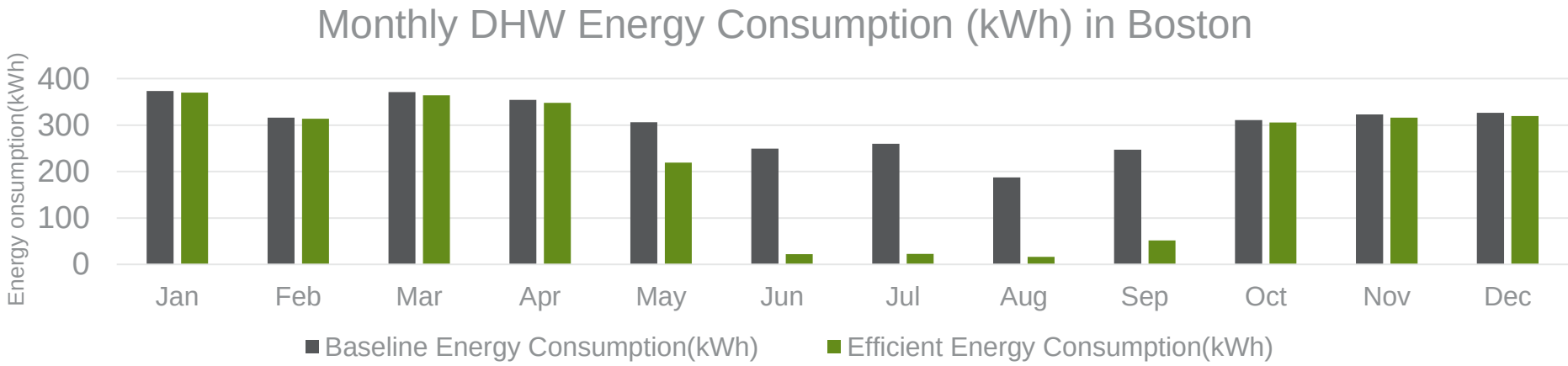
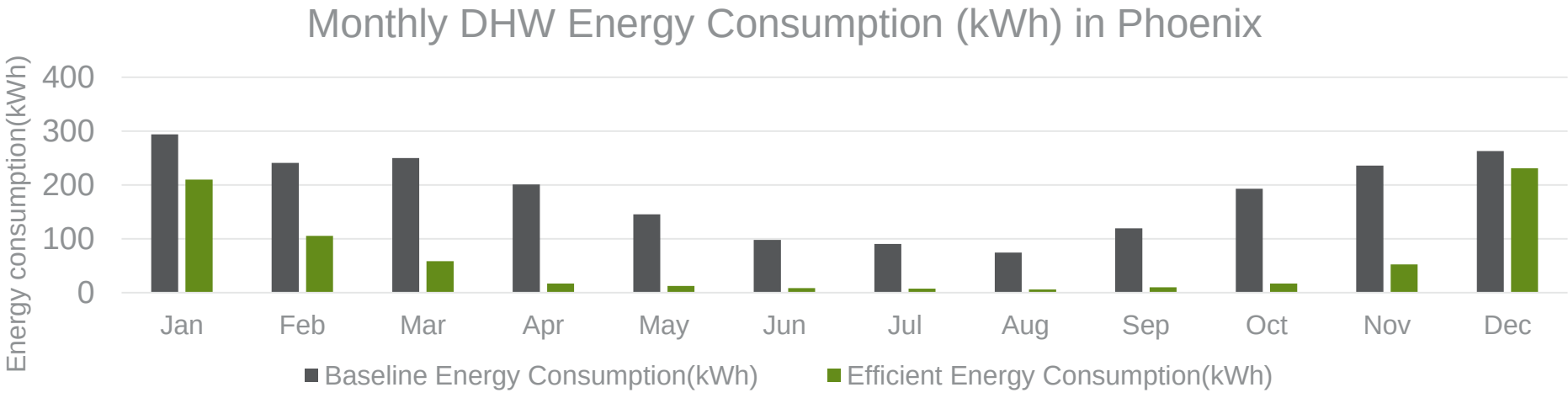




MONTHLY ENERGY SAVINGS

HPWHs provide year round energy savings in hot climates, but they are valuable only in summer months in cold climates.





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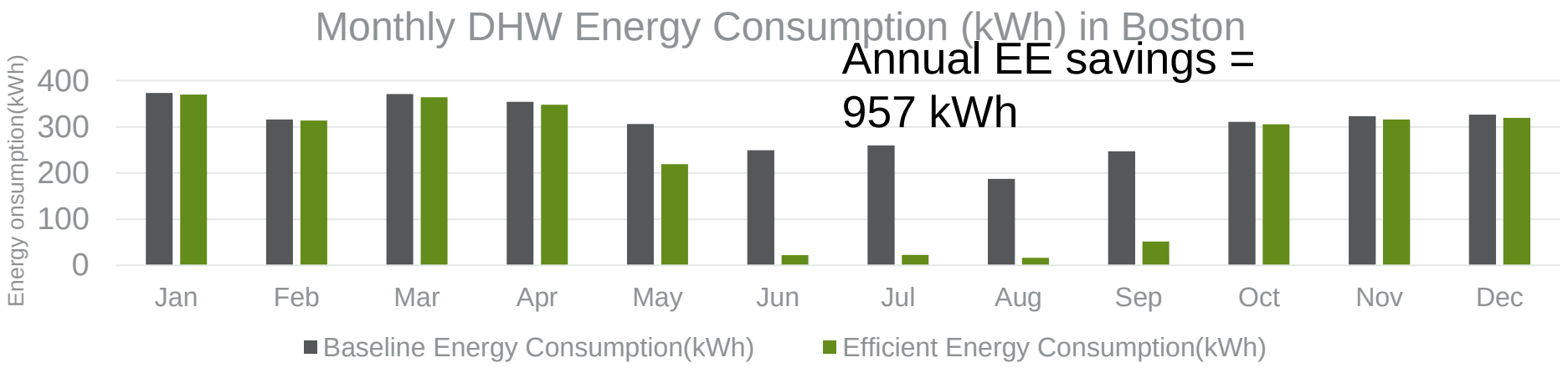
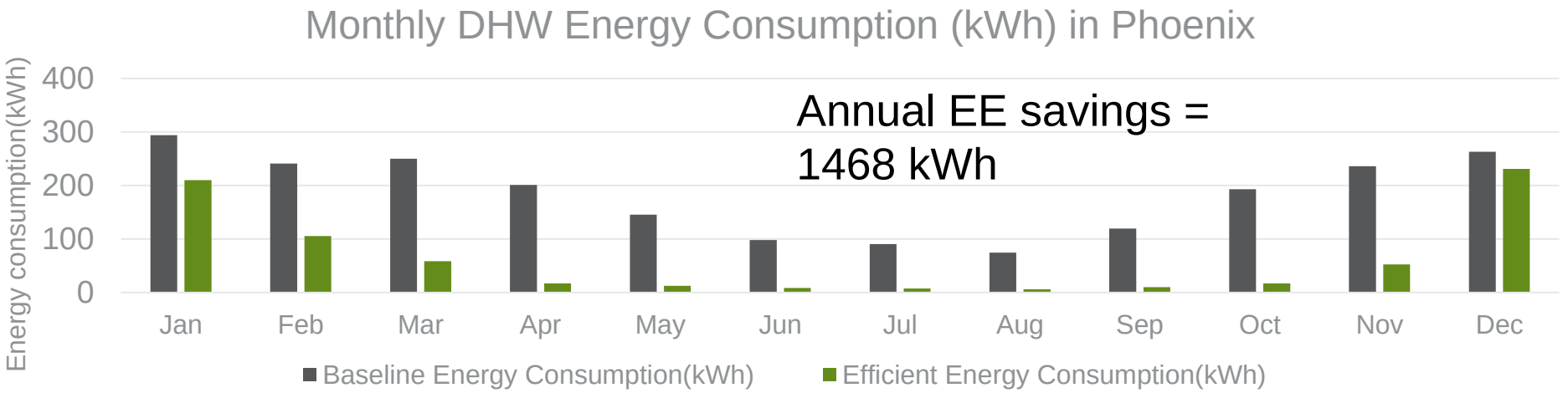
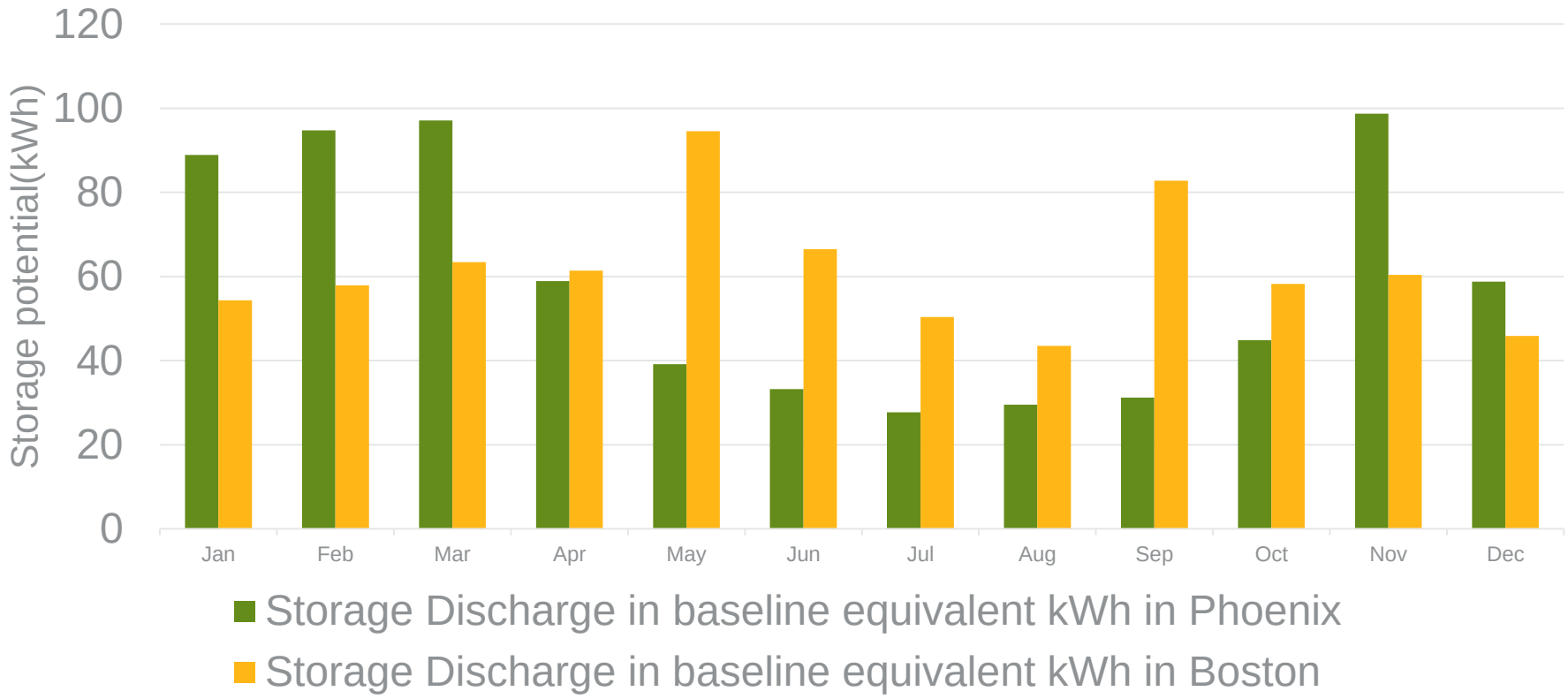




STORAGE DISCHARGE

The storage discharge potential is determined by how often the HPWH goes in the heat pump mode and can generate more energy than the DHW demand.



FUTURE WORK

- Although we match the DHW load, we want to make sure that hot water is delivered at the tap.

THANK YOU !

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