Grid-Responsive Heat Pump Water Heaters

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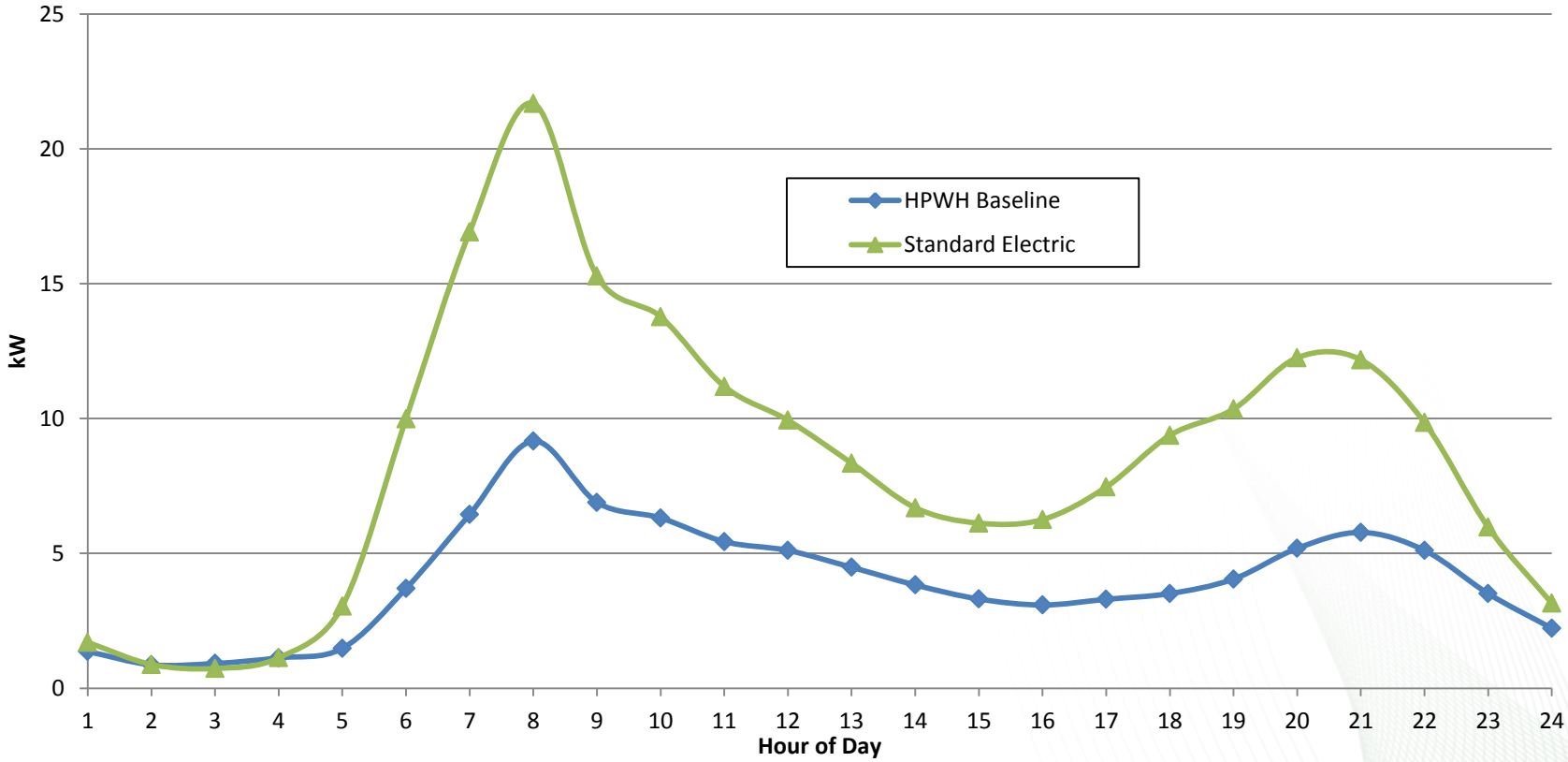
Outline

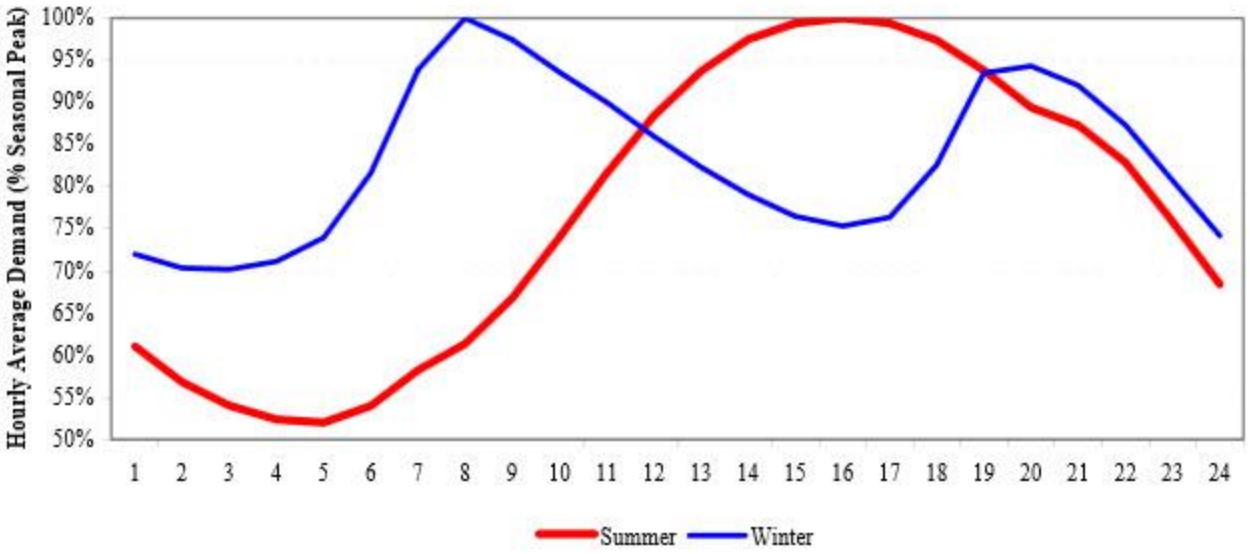
- What Do Water Heating Loads Look Like?
- Load Shifting/Peak Shaving
  - Non-Renewable Generation
  - Renewable Generation
- Conclusions

What do WH Loads Look Like?

- Water use data from 25 homes (1 minute resolution)
- Fed into calibrated model of standard electric and HPWH



Hourly Demand without Renewables



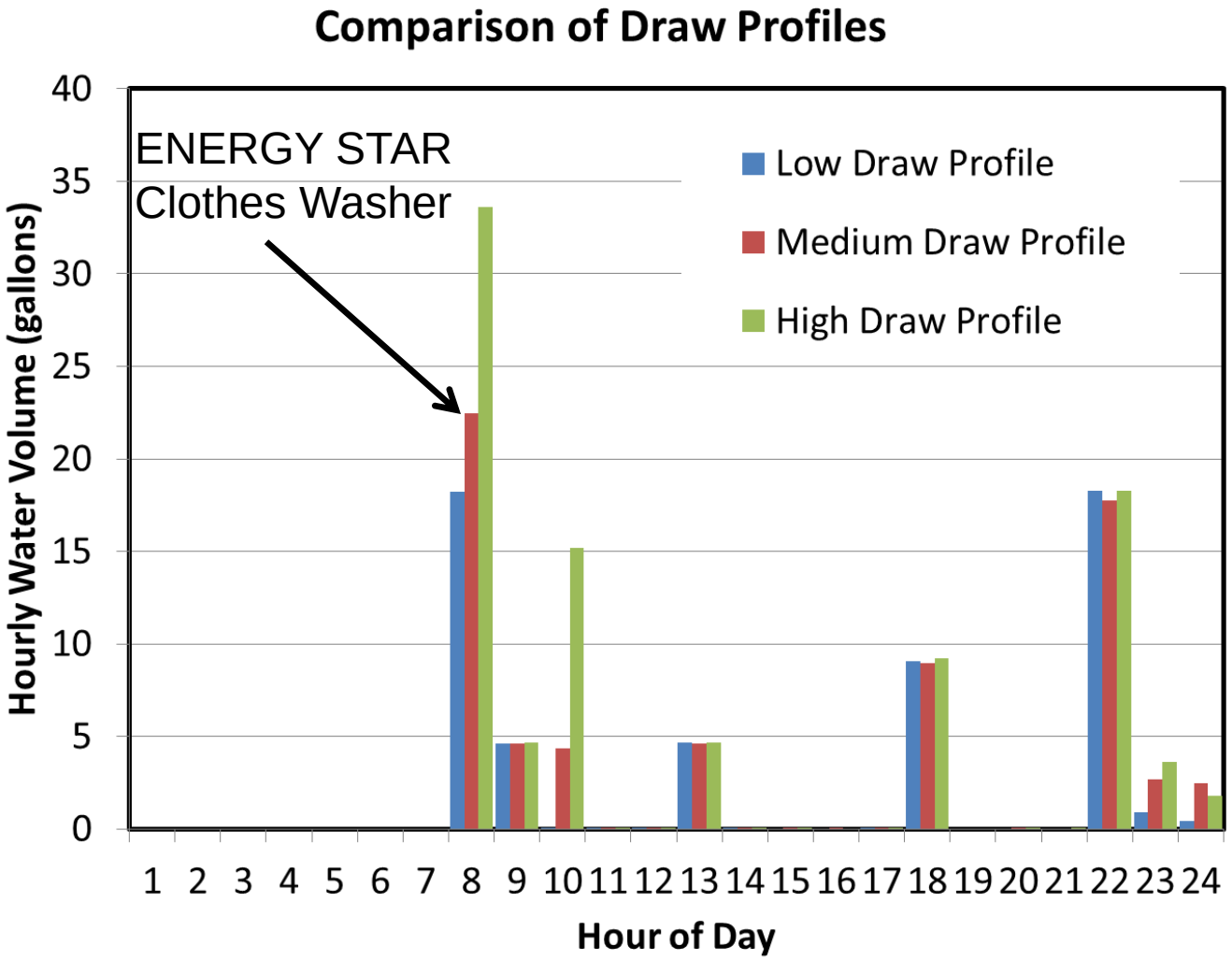
Source: http://energymag.net/daily-energy-demand-curve/

- HPWH set point schedule can be adjusted to shave peak and fill valley

Load Shifting - Methodology

- 3 – distinct water draw profiles for HPWH
- 4 – Temperature set point schedules were investigated
- Compared to a baseline schedule (120°F – Hybrid, strip heat enabled)
- Peak Energy, Total Energy, and Hot Water Delivery Quality

Load Shifting - Methodology

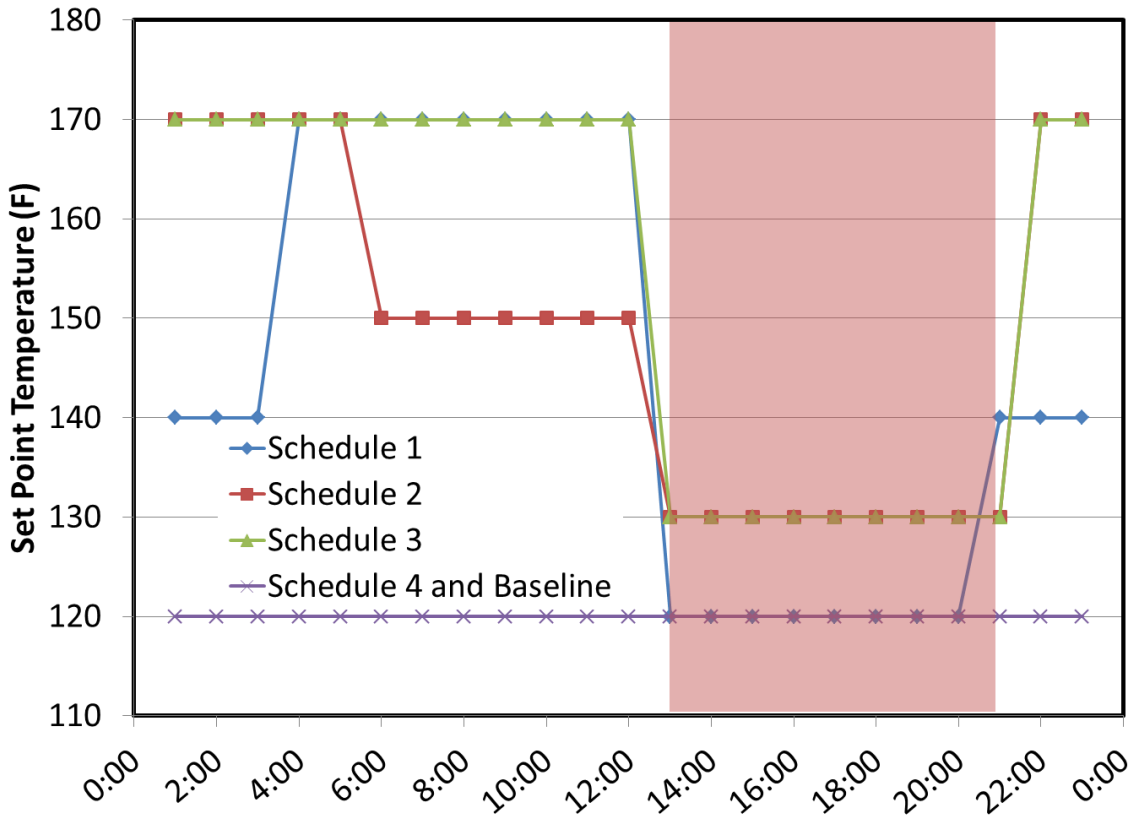


Draw Profile Name	Daily Volume (gal)
Low	57
Medium	69
High	91

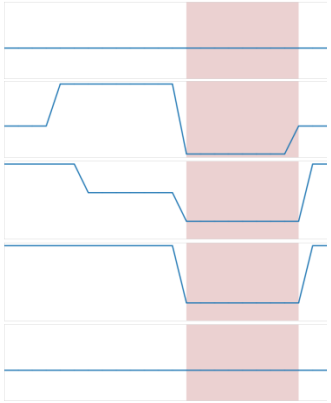
- Metrics: Peak load shifting, energy consumption, and ability to meet hot water demands

Load Shifting - Methodology

- Main goal - Minimize peak energy consumption (1-9 PM)

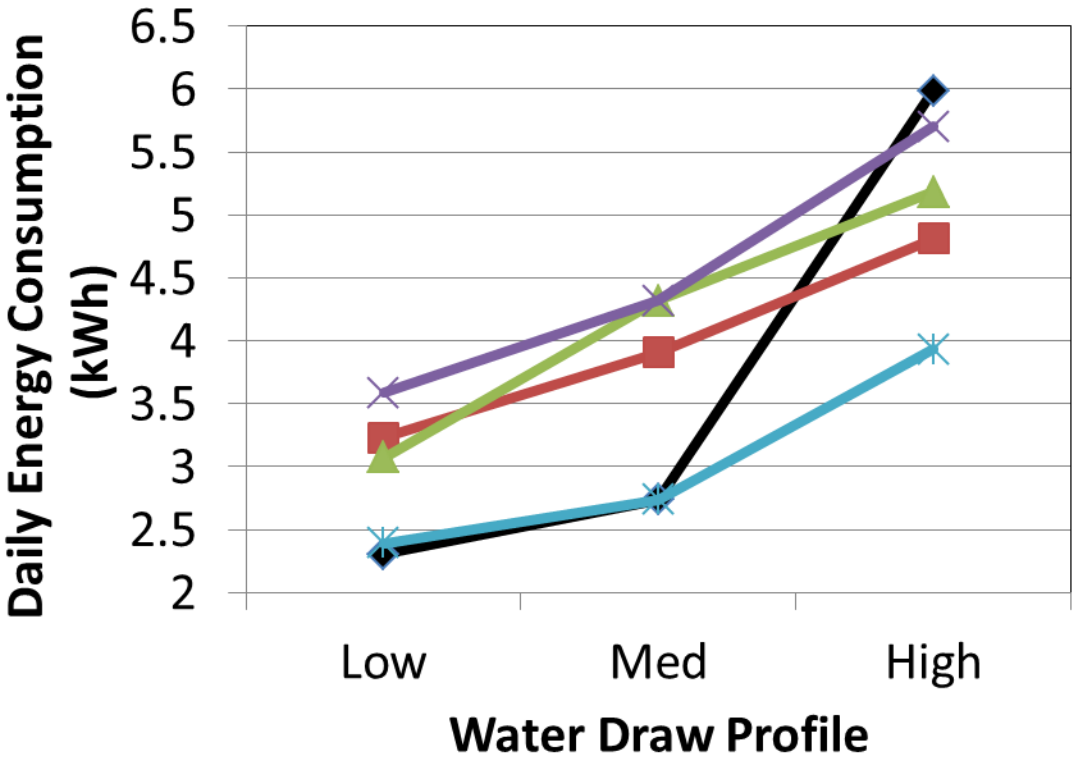


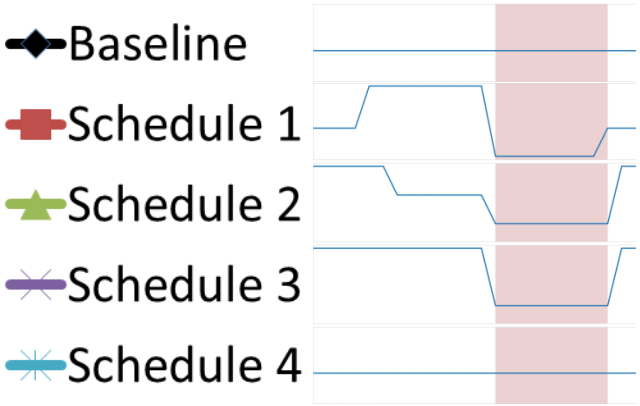
Load Shifting – Results



Energy Use During Peak Hours For Different Tank Set Point Schedules and Water Draw Profiles			
	Low Water Consumption (kWh)	Medium Water Consumption (kWh)	High Water Consumption (kWh)
Baseline	0.6	0.5	0.6
Schedule 1	0	0	0
Schedule 2	0	0	1.5
Schedule 3	0	0	0
Schedule 4 (HP only)	0.5	0.4	0.6

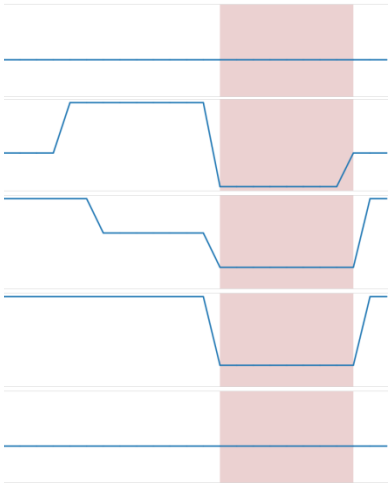
Load Shifting – Results





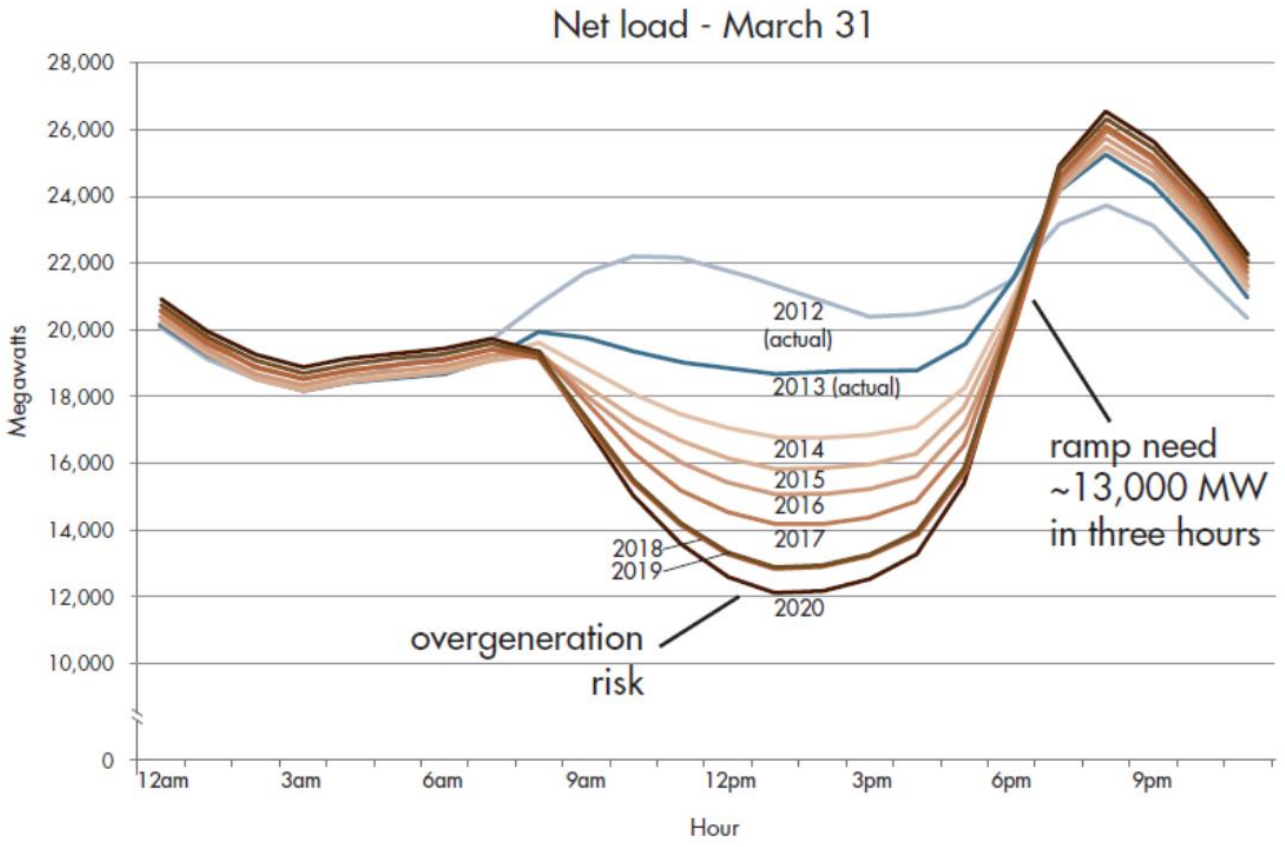
Load Shifting – Results

- % of time tank water < 115°F



	Low Water Consumption (kWh)	Medium Water Consumption (kWh)	High Water Consumption (kWh)
Baseline	5%	9%	5%
Schedule 1	0%	0%	1%
Schedule 2	0%	5%	1%
Schedule 3	0%	0%	0%
Schedule 4	6%	9%	18%

With a High Penetration of Renewables

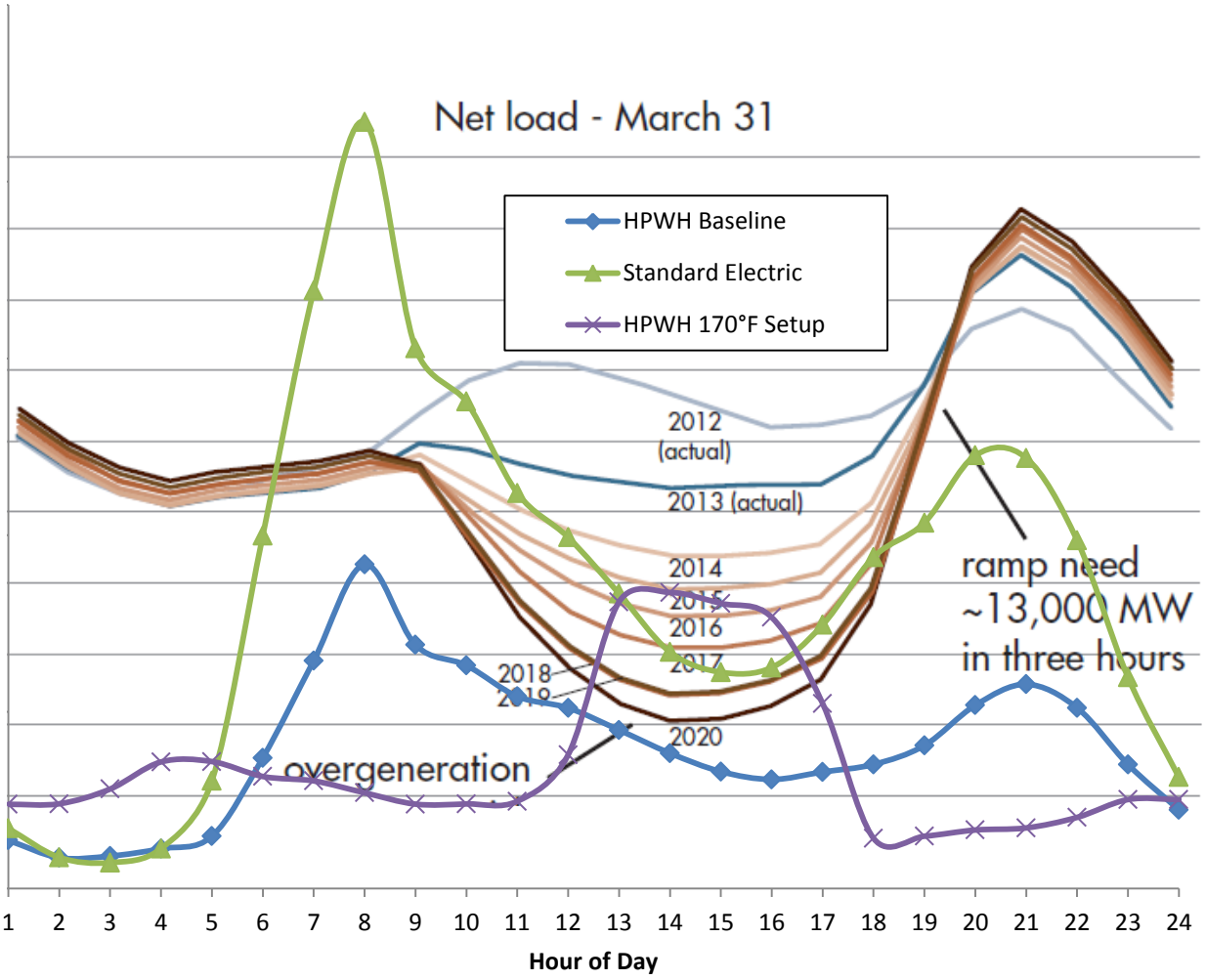


https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

Load Shifting Strategy for HPWH

- Fill the valley by setting the HPWH up to 170°F from 11-4 pm
- All other times set down to 120°F
- HP Only mode
- Simulated data for 25 homes using calibrated model

Impact of Renewable Energy Generation



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Comfort and Energy Use

	Annual Energy Use (kWh)	Annual deg-hours Tank Top Below 115°F (1k °F-h)	Annual deg-hours Tank Top Below 115°F During Flow (1k °F-h)
Standard Electric	74571	110.5	9.0
HPWH Baseline	35117	120.5	43.3
HPWH 170°F Setup (HP Only)	31213	201.9	32.7

- Reduced energy use
- Potentially improved water quality

Conclusions

- Long time scale
  - HPWHs can use set point schedules to shift loads as needed by the grid
- Short time scale
  - Increase HPWH set point to use excess generation
  - Potential to use learning algorithm on HPWHs to determine which can participate in load shed events with low risk and delay recharge until after load shed event

Discussion

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