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Advancing Decarbonization: Efficient Electric Water Heating for the other half

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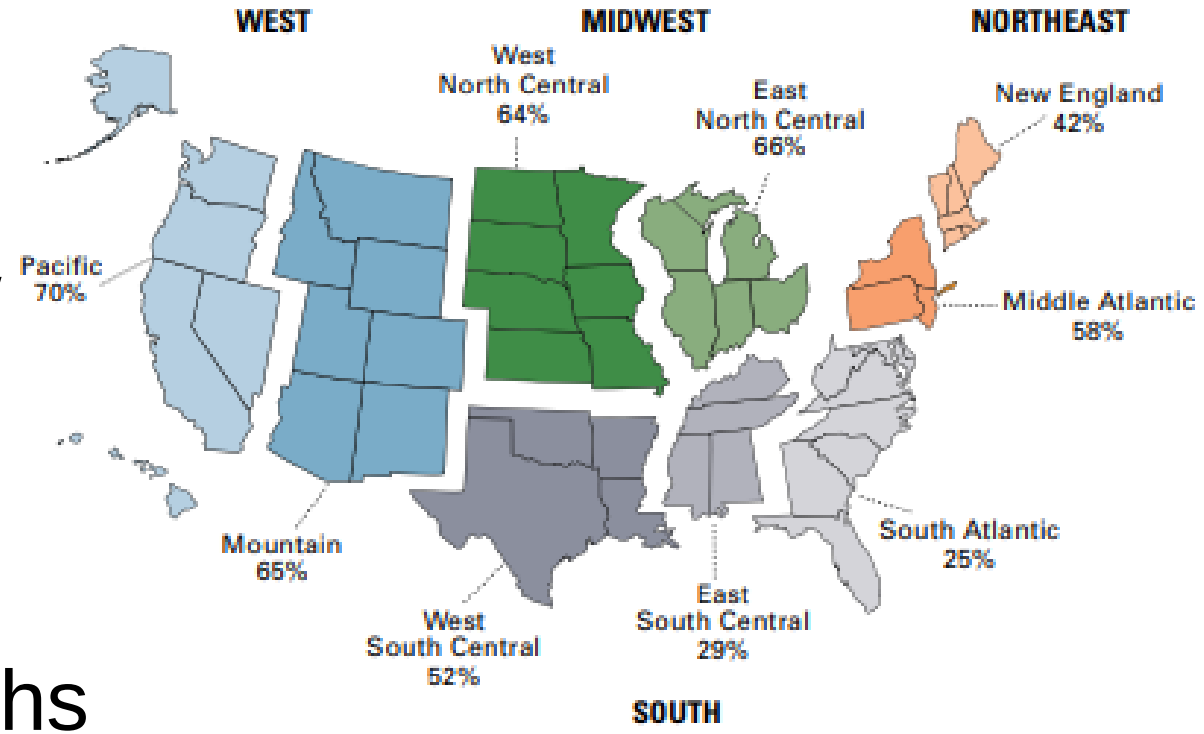
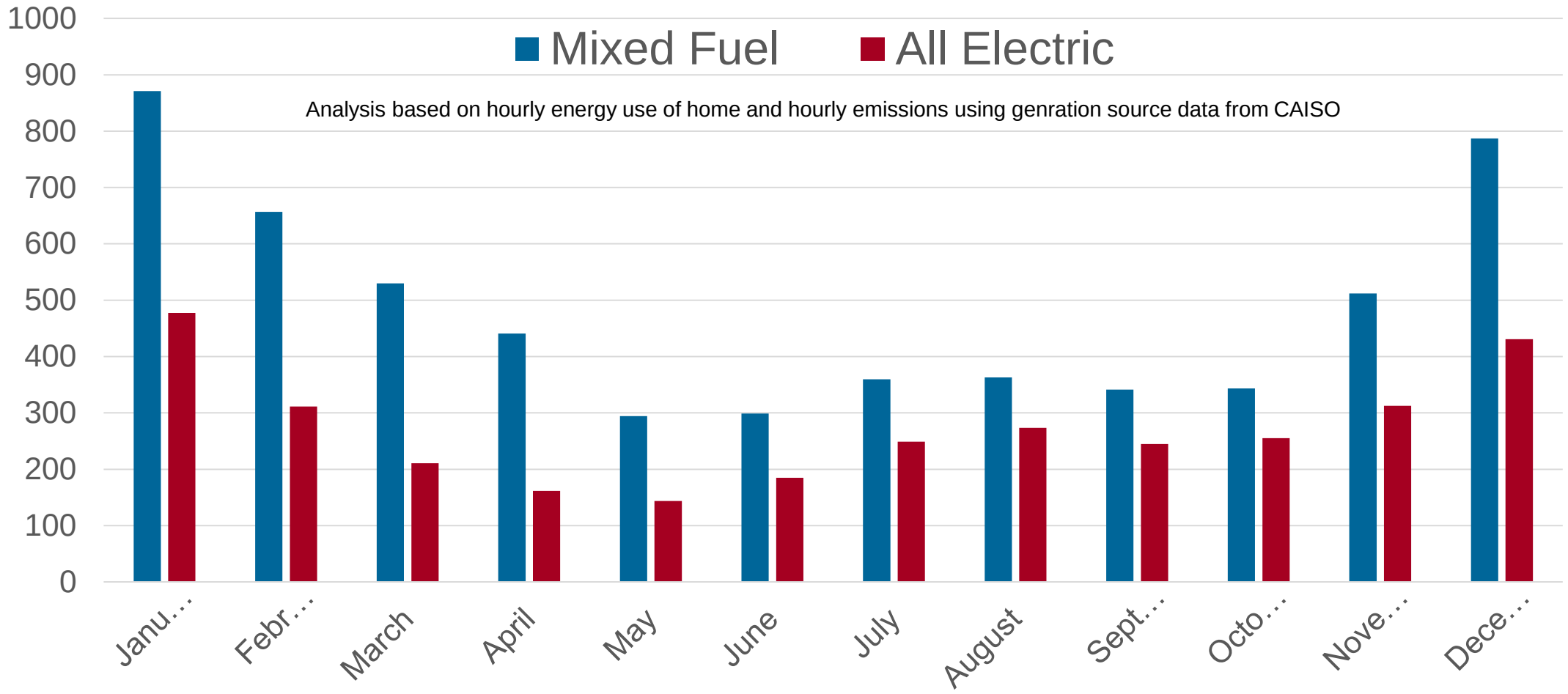
Discussion topics

- The importance of HPWH for building decarbonization
  - Market requirements for decarbonization and electrification are different from traditional electric water heating market requirements
- Market Barriers to implementation
  - Residential & Commercial, New Construction & Existing Construction
- Grid integration
- Technology Development Paths

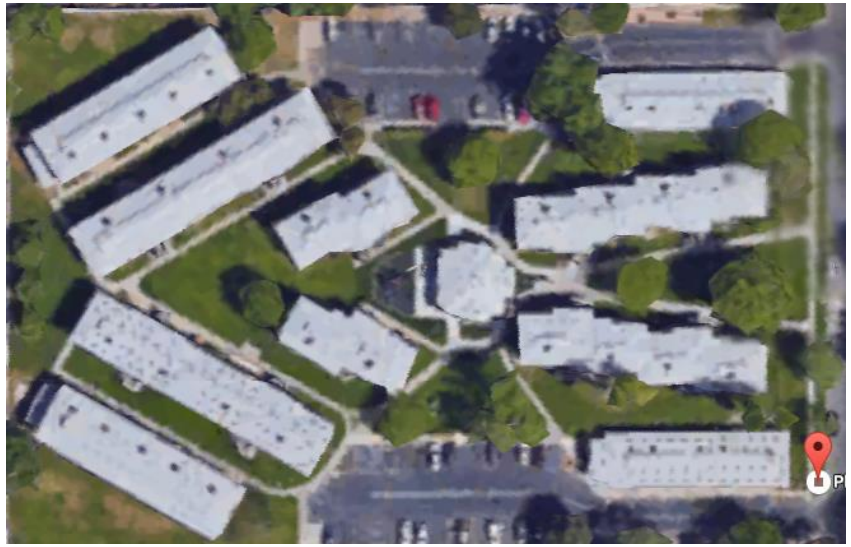


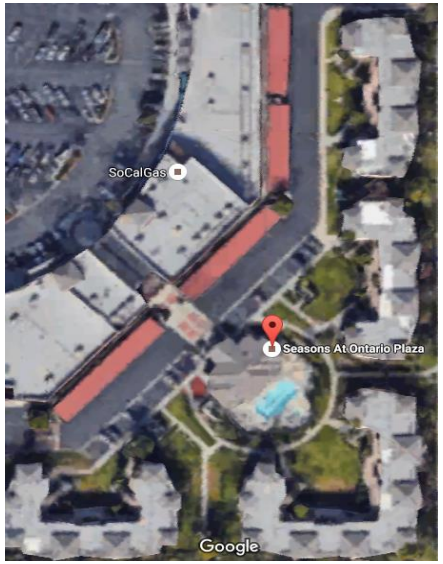
Energy emissions from new homes in California



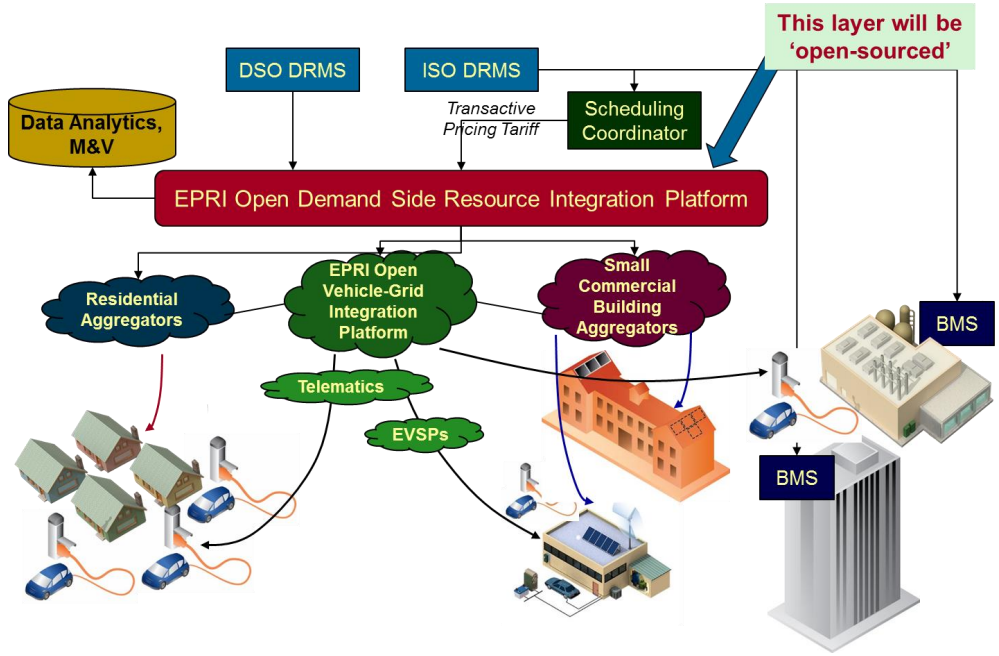
The GHG benefit accrues mainly from heat pumps and heat pump water heaters

Learnings from HPWH deployment





Grid Integration of Zero Net Energy Communities

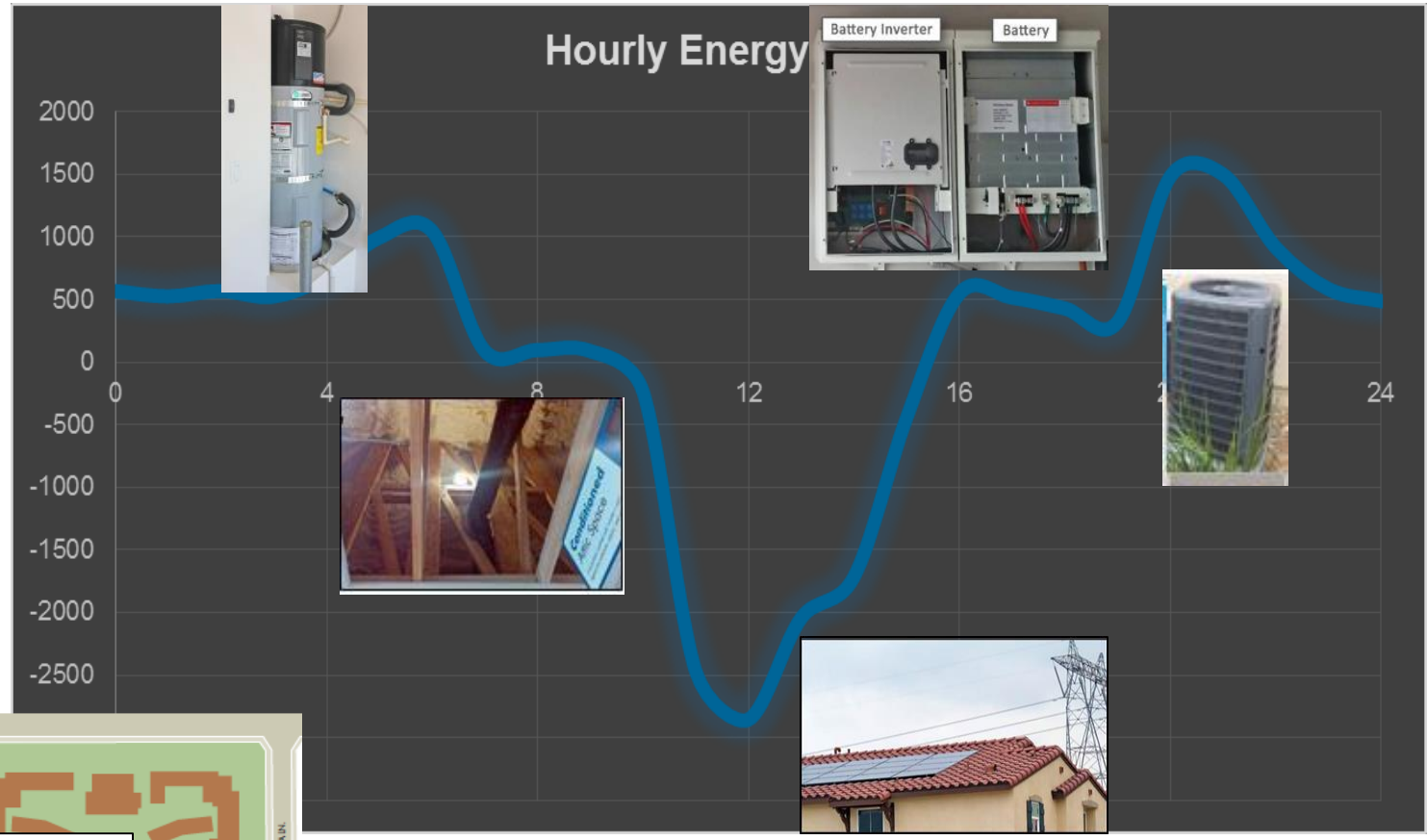


Open Demand Side Resource Integration Platform

IDSM in low income communities

Grid Integration of ZNE communities

- California's first ZNE neighborhood with national production builder
- 20 homes on 2 transformers
- Electrified Heating loads for renewables balancing



Load Shape for example home in community – excess generation in the evening followed by late evening peaks

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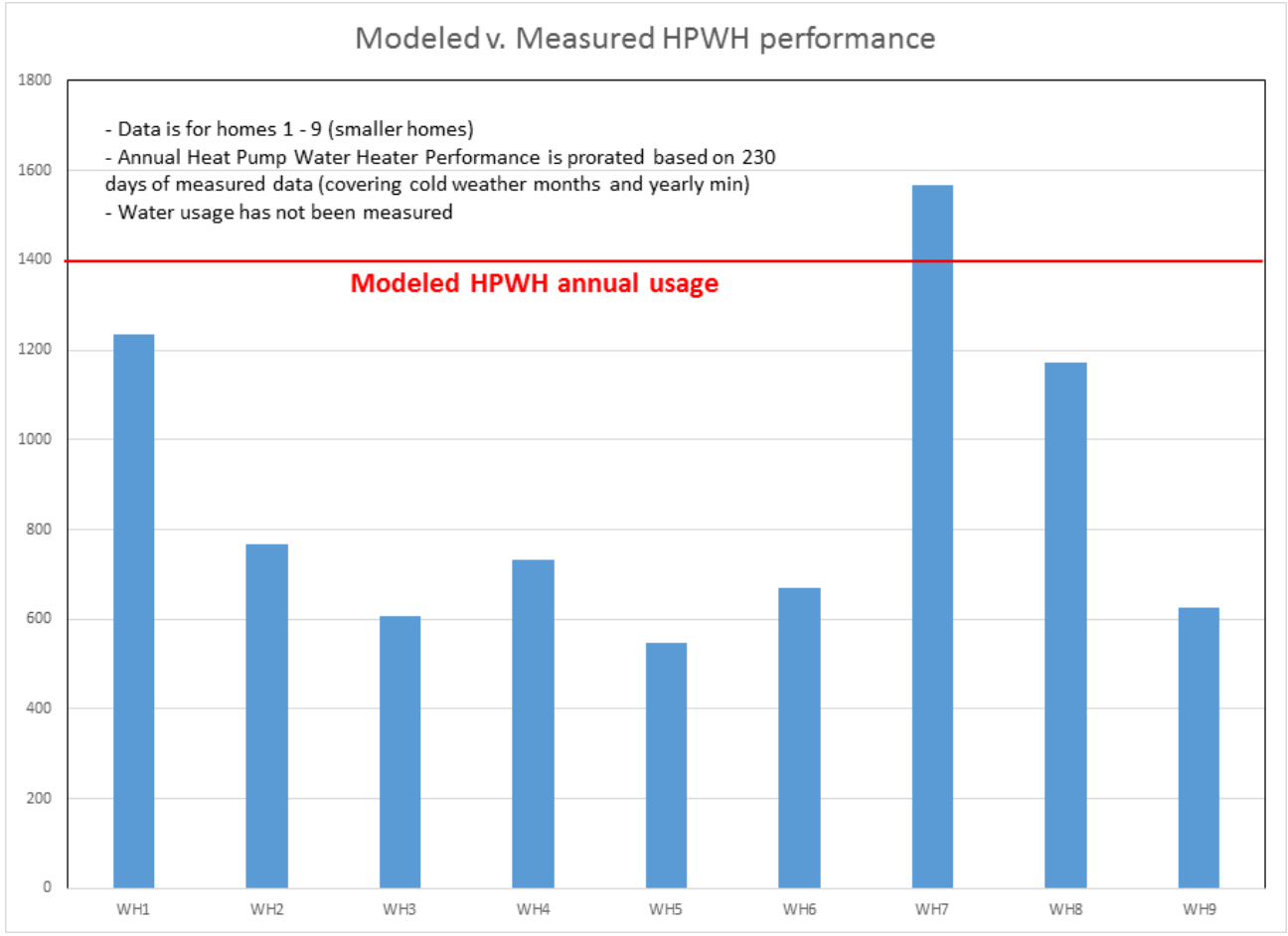
HPWH learnings - ZNE community

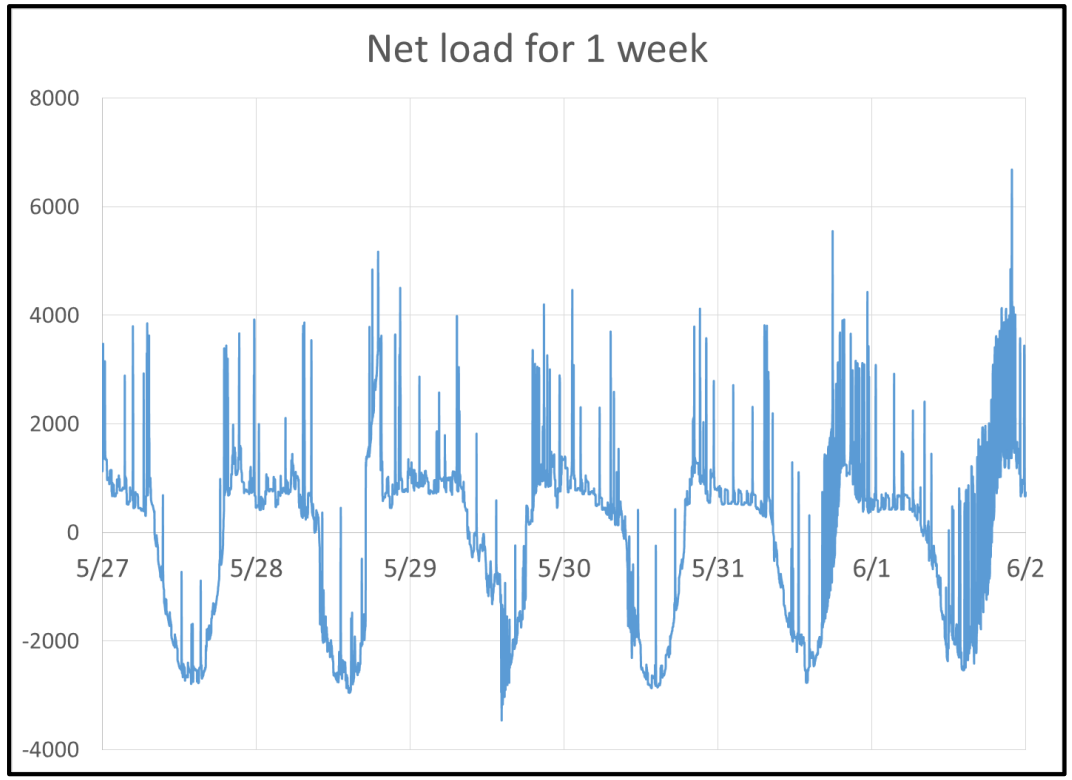
- Heat Pump water heaters are cost neutral to tankless gas water heaters in general and lower first cost sometimes
- Electric resistance element operation has significant energy impacts, due to built-in control algorithms for recovery
- Water efficiency measures improves energy performance of HPWH

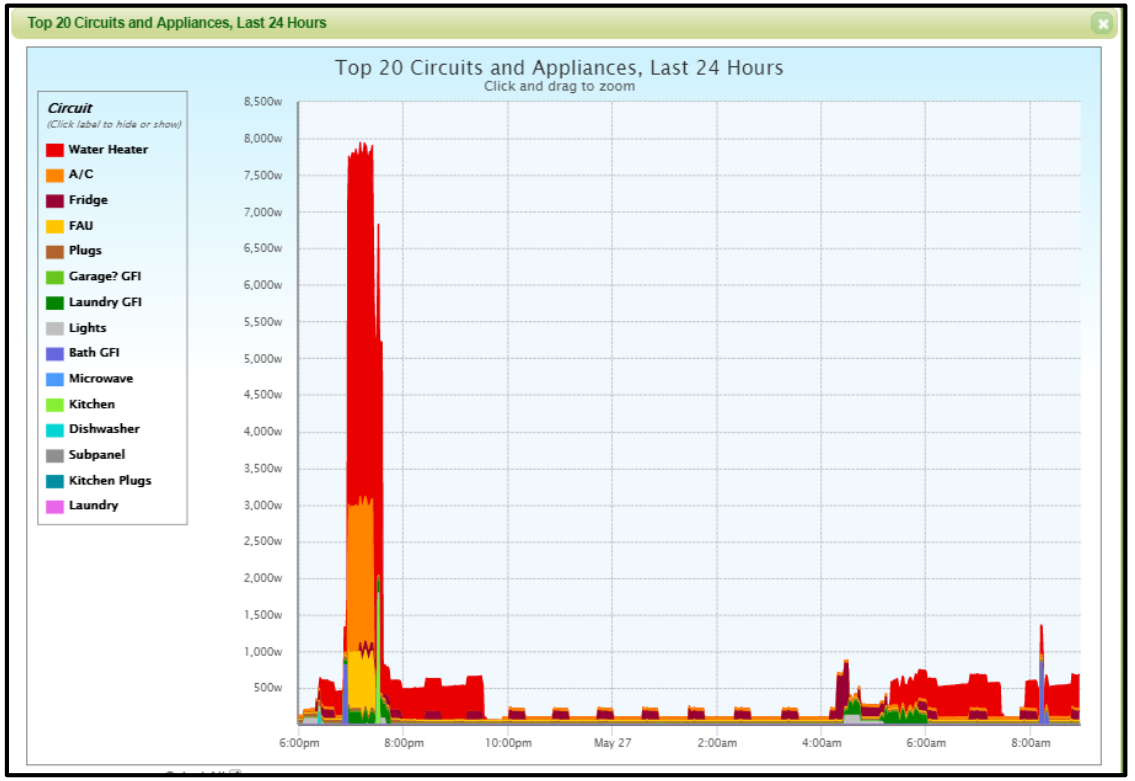
System	Purchased Cost	Net Installed Cost
Heat Pump Water Heater	$1000	- $200 reduction (eliminate gas venting and piping, run 240V)
Gas Tankless	$950	



HPWH Operational Performance

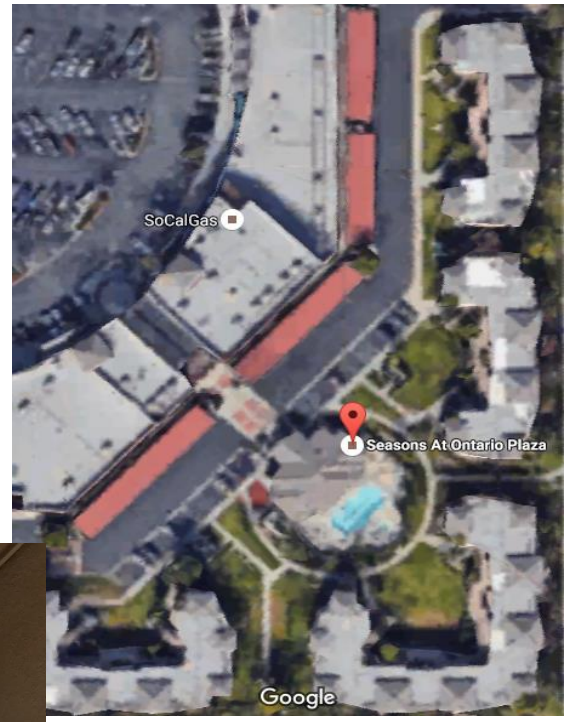
- Average energy use of HPWH 30% less than modeled over 1 year
- However, HPWH operation set the peaks for individual homes
- No complaints from 2 homeowners who ran in “Heat Pump” mode (18 homes were in hybrid mode)
- Front panel temp setting by plumber limited capability for load management and grid support



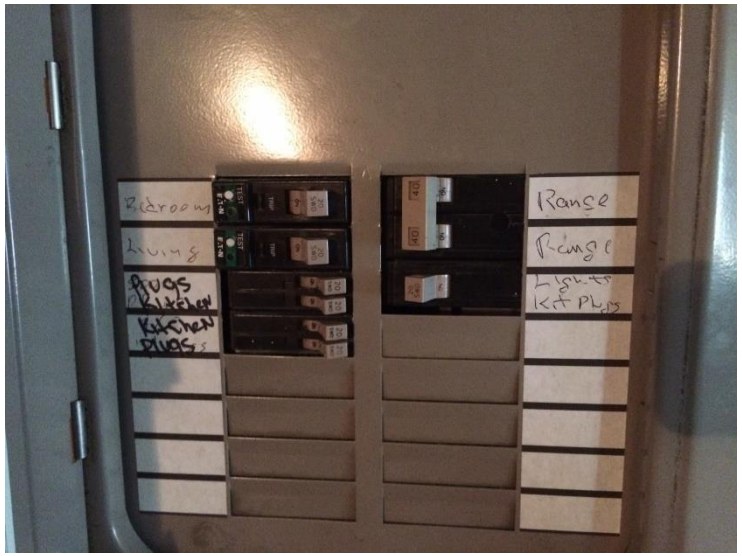


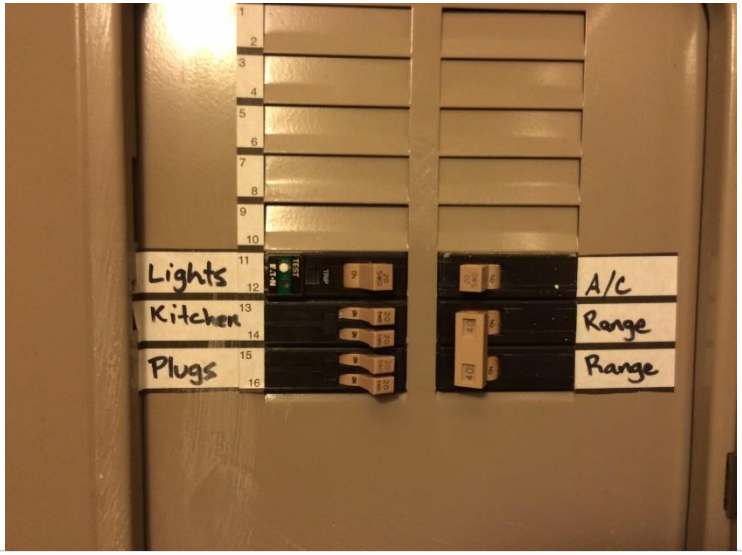
Retrofitting Challenges in non-electric markets

- Targeted Near Zero Energy multifamily whole building retrofits
- Solar PV Net Energy Metering drives electrification
- Electrification offsets solar production and reduces GHG substantially
- However, significant costs due to gaps in product offering



Current State of community





What were the barriers to implementation and adoption?

Heat Pump water heaters and gas tankless water heaters are cost neutral, however:

1. Costs Add up for retrofits:
   - Panel Upgrades ~ $2000
   - Running 208 V electrical to HPWH location ~ $1500 - $ 2500
2. Form factor not appropriate
   - Many retrofits are in closets designed for 30 or 40 gallon units with 18 – 20” diameter
   - Current HPWH form factors do not fit in these tight dimensions
   - Need air for evaporator – so need to open up slots on doors, etc.
3. Constraints on utility distribution circuits
   - Adding 4.5 kW of connected load per home could overload transformers and wiring, especially in areas where distribution systems are designed for gas heating
   - Timeline and cost for distribution planning with utilities can delay or defer HPWH upgrades
4. Options for community water heating in multifamily buildings
   - No clear options exist for efficient electric options to replace boilers

GHG reduction is not just efficiency – it is also new refrigerants

- Need to select refrigerants for cycle efficiency, low GHG and low flammability/toxicity
- Carbon di-oxide has both efficiency and low GHG benefits on the heating side
- Challenge remains with finding the right refrigerant to combine HVAC and WH

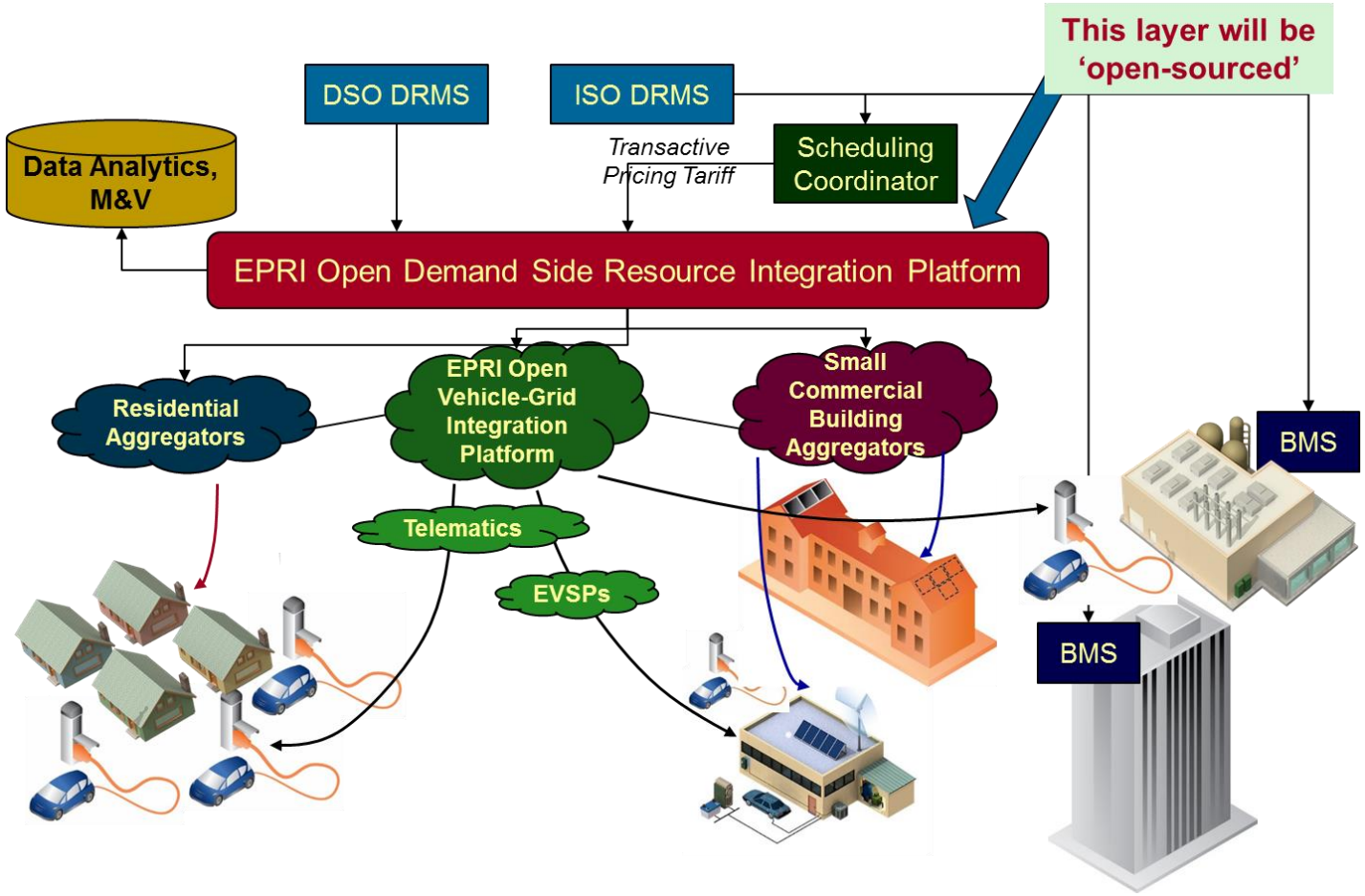
Example R-134a replacement refrigerants

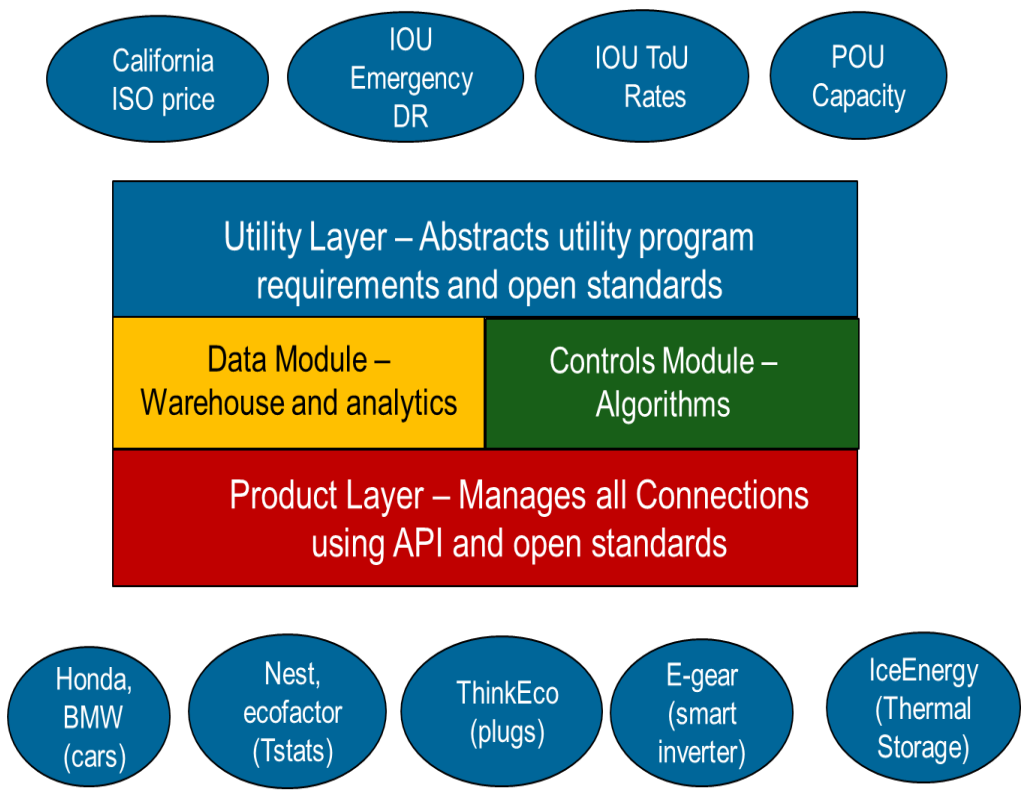
Refrigerant Name(s)	GWP	Blend?	ASHRAE Safety Designation	Capacity	Efficiency	Critical Pressure	Critical Temp.	Molecular Mass	Normal Boiling Point (or bubble point)
R134a	1370	N	A1	-	-	588.8	213.9	102	-14.9
R1234yf	4	N	A2L			490.6	202.5	114	-20.9
R1234ze(E)	6	N	A2L			527.29	228.87	114	-2.2
R-450A	547	Y	A1			554	219.9	108.7	-10.1
ARM-42a	143	Y	A2L			502.6*	199.6*	107.9*	-23.1*
D4Y	551	Y	A1			514.0*	195.0*	109.2*	-25.2*

EPRI Membership Report: Near-Term Alternative and Replacement Refrigerant Options for HVAC&R Equipment, Report No. 3002003825, November 2016.

Open Enabling Platform for Connected Devices (water heaters included)

- Focus on data exchange to leverage full grid balancing capability of water heaters
- OpenDSRIP platform is agnostic of connectivity method





There are new products but gaps still exist ….

- Smaller Form Factor with 18” tanks
  - Design for multifamily – lower HW needs require smaller tanks
  - Account for lower water use fixtures
- Eliminate or reduce electric element
  - Reduce element below 1.5 kW, but increase size of compressor
- Move to natural refrigerants like CO2
  - This can also increase COP and efficiency at high water heating temperatures
- Thermal Storage for grid balancing
  - Build in capability to “superheat” to 160 F efficiently and incorporate mixing valves
- Some products available in Europe and China, but not yet UL certified
- And yes, there are tradeoffs like lower 1st hr recovery – can we absorb them?

Heat Pump Water Heater Needs

- We've had pretty good heat pump water heater systems for a while now…
  - *Why aren't they everywhere?*
- In many end-uses, there are major barriers
  - *Multifamily*
  - *Small spaces & apartments*
  - *Low income*
- *How can we bridge the gap?*
  - *Working group*
  - *Alternative products to evaluate?*

https://s3.amazonaws.com/bradfordwhitecorp/wp-content/uploads/brochure_residential_selection_guide_rpsg.pdf

HPWH Product Needs (courtesy of Peter T)

Overview of Heat Pump Water Heater Product Needs and Availability

Product Needs	Rationale	Market Issues	New Construction	Retrofit/Replacement
Small unit (~30 gallon) without large resistance strips)	1. "Low Boy" unit needed suitable for small apartment spaces. 2. Need to reduce customer bill.	Small apartments with low hot water requirements but very restricted space need an efficient electric WH. Need to minimize customer bills	Would be relatively easy to incorporate with known product that fits in small spaces.	Large variety of conditions, difficult to generalize a replacement that would work. Important to mitigate need to upgrade panel. Issue of cold exhaust needs attention
110 volt small unit (~30 gallon) (Would have small resistance strips)	1. Need to minimize electrical costs within dwelling unit (panel, wiring) 2. Need to reduce customer bill	For small units, a 110 V service should be adequate.	110 V less essential in NC, but no real need for 220 without heat strips	110 V very important for retrofit; need for panel upgrade will be a problem for economics
Large unit without large resistance strips (50-80 gallon)	1. Need to reduce customer bill. 2. Need to avoid potential grid issues with multiple units creating coincident demand spikes	Any regular or substantial us of resistance strips will significantly increase customer bills.		Replacement of gas with electric HPWH with strip heat at the neighborhood level could create grid problems costly to mitigate.
Unit capable of boiler replacement (multi-family)	Current practice appears to be "stacking" smaller units (arranging in series)--there does not appear to be a large unit built to handle hundreds of gallon requirements	A boiler style unit would, in a mature market, almost certainly have cost advantages over multiple smaller units	For larger units, dealing with cool "exhaust" would have to be accounted for but should be doable	
Thermal Storage and Load Management System	Could apply to most units; issue involves decrease in efficiency as tank temp increases, Also, there may be code issues around whether or not mixing valves are allowed and what the max temperature can be			
Small tanks in closets – single outdoor unit	Especially in milder climates, could help with interior space requirements and electrical upgrades		Easier in NC	May be problematic sometime in retrofit but generally should be acceptable
Units with DR capability (all sizes)	Units well controlled could mitigate grid issues as well as customer bill issues. Product-integrated controls would need to work "out of the box" without significant attention	Reliance on controls/communication by way of customer wifi will not meet utility reliabilty expectations and will be subject to substantial outages	In new subdivisions, a consistent product choice would likely function more predictably than with individual custom homes	

We need more (new) products…. Some thoughts for market acceleration….

- Stakeholder working group to develop product requirements and test new product choices
  - Manufacturers
  - Utilities
  - Researchers with R&D and testing organizations
  - Government and quasi-government entities
  - Enhance collaboration to identify and bring new products to market
- Enhance availability of international products
  - Identify and work with manufacturers to process new products through safety certifications
- Work with GOV agencies to invest research $$ to develop new concepts with low GHG, small form factor, 110 V capability, grid management and storage, etc.
- Create field test beds for rapid evaluation of new solutions

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