Stor4Build

Panel 1: Pioneering Visions for the Future of Thermal Energy Storage

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Chair: Kyle Gluesenkamp

Panelists: Sven Mumme, Paul Steffes, Doug Poffinbarger, Yu Hou, Tom Sottile

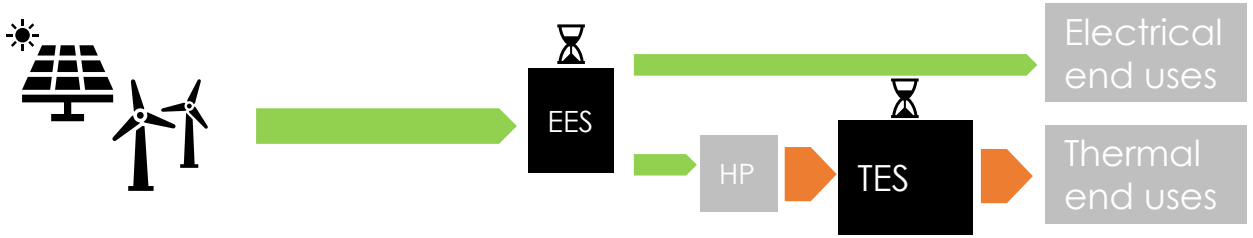
Stor4Build Annual Meeting
August 26–27, 2024
Oak Ridge National Laboratory

National scale of storage

Scenario using only electrical storage

24 TWh: 24 hours of 1 TW grid
0.14 TWh: 3.5 million EVs @ 40 kWh each

Scenario using both electrical and thermal storage



National scale of thermal storage

back-of-the-envelope calculations!

Number of existing TES, controlled to shape load	TWh today
20k electric storage water heaters	0.000 06
PCM in refrigerated warehouses (1B tons product)	?
100M gal Chilled water storage	0.01
10M gal Ice storage	0.005
20k electric thermal storage AHUs	0.005

National scale of thermal storage

back-of-the-envelope calculations!

Number of existing TES, controlled to shape load	TWh today	Potential number (100% market pen.)	TWh @ 100% market penetration
20k electric storage water heaters	0.000 06	100M	0.4
PCM in refrigerated warehouses (1B tons product)	?	50M tons (<5%)	3
100M gal Chilled water storage	0.01	100x	1
10M gal Ice storage	0.005	100x	0.5
20k electric thermal storage AHUs	0.005	100M	25

National scale of thermal storage

back-of-the-envelope calculations!

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Existing TE, lacking load-shaping controls	TWh today	Potential number (100%)	TWh @ 100% market penetration
50M electric storage water heaters	0.2	100M	0.4
PCM in refrigerated warehouses (1B tons of product, assume 2 K allowable swing)	1	50M tons (<5%)	3
Passive shallow thermal mass of buildings within thermostat deadband	3	140M buildings	3
1.7M GSHPs (diurnal storage)	0.1	50M	2.5
1.7M GSHPs (seasonal)	33	50M	1000

TES: Enables building electrification and decarbonization

Objective

Design higher performing thermal storage solutions that directly support the electrification and decarbonization of space heating and cooling and water heating. To this end, BTO seeks advances in the development of next-generation equipment and envelope integrated TES systems that are cost-effective and easy to integrate, install, and maintain.

If it works, will it matter?

Thermal energy storage in buildings can play a significant role shifting building loads to reduce emissions, lower utility bills for homeowners and businesses, provide superior resilience during grid outages and extreme weather events, and minimize the impact on the grid by enabling significant demand flexibility/load shifting capacity.

Limitation of current technology

Existing TES applications are mostly limited to cooling and to large commercial or district spaces such as university campuses. Building owners may find retrofits with current TES-integrated equipment cost prohibitive.

New approach needed

Widespread adoption of TES systems in buildings will require lower upfront capital costs, improved annual utilization, and easier integration. R&D projects should target lower-cost, higher performing materials and components to reduce system size and weight, high utilization system designs to reduce the levelized cost of storage, and modular or packaged TES systems with simpler HVAC and envelope integration and installation.

Priorities for equipment integrated thermal energy storage

Residential central air source heat pumps (heating and cooling), commercial rooftop units, and residential water heaters are the priority equipment types for TES integration and deployment.

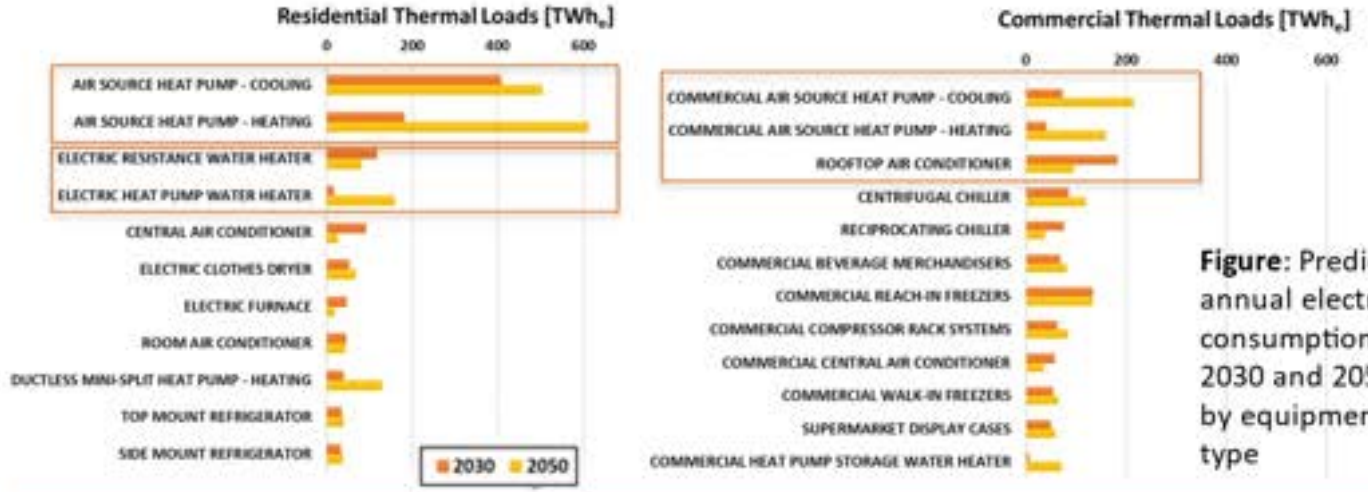

Figure: Predicted annual electricity consumption in 2030 and 2050 by equipment type

Thermal energy storage can be more cost effective for buildings than Li-ion batteries

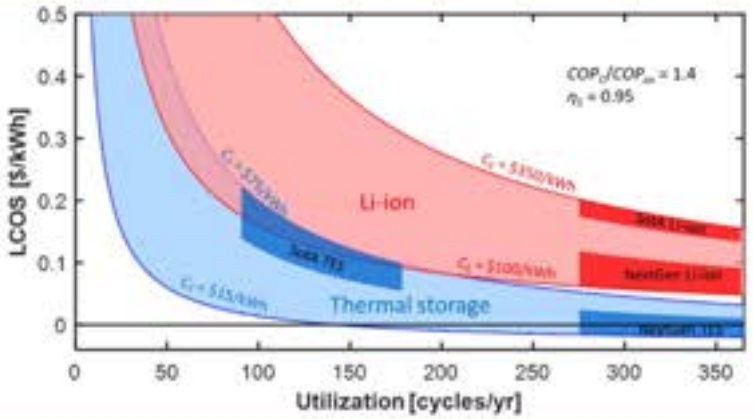

Figure: LCOS projections for TES + heat pump and EES + heat pump with varying capital costs, and utilization assumptions

Paul Steffes *Founder & Innovation Advisor*
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What is Electric Thermal Storage (ETS)?

- Stores heat energy in high-density ceramic bricks during off-peak, low-emission, or low-cost periods to balance grid load.
- Optimized performance when combined with an air source heat pump to reduce peak grid demand.
- Advanced control system enables grid-edge aggregation, maximizing renewable energy integration.

Steffes ETS pairs with heat pumps in cold weather

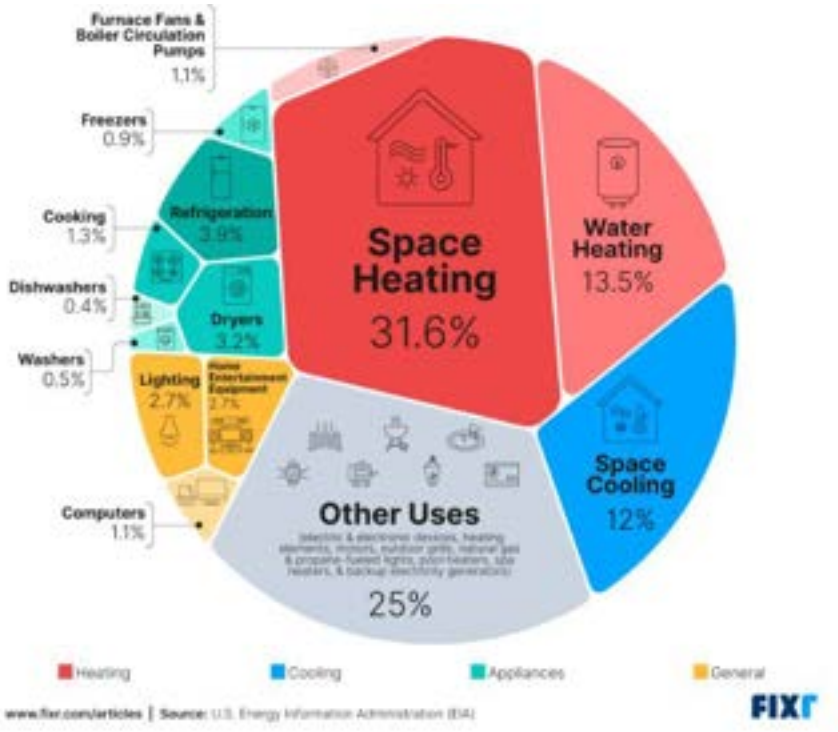
Why Space Heating?

As the Nation Electrifies, Most Utilities **will be Winter Peaking**. The winter peaks can be **DOUBLE the summer peaks.**

If we electrify US space heating with heat pumps, we would need **70%** more generation capacity to meet the peaks.

TES is one way to reduce that burden.

Heat pumps are great, heat pumps + thermal storage is better



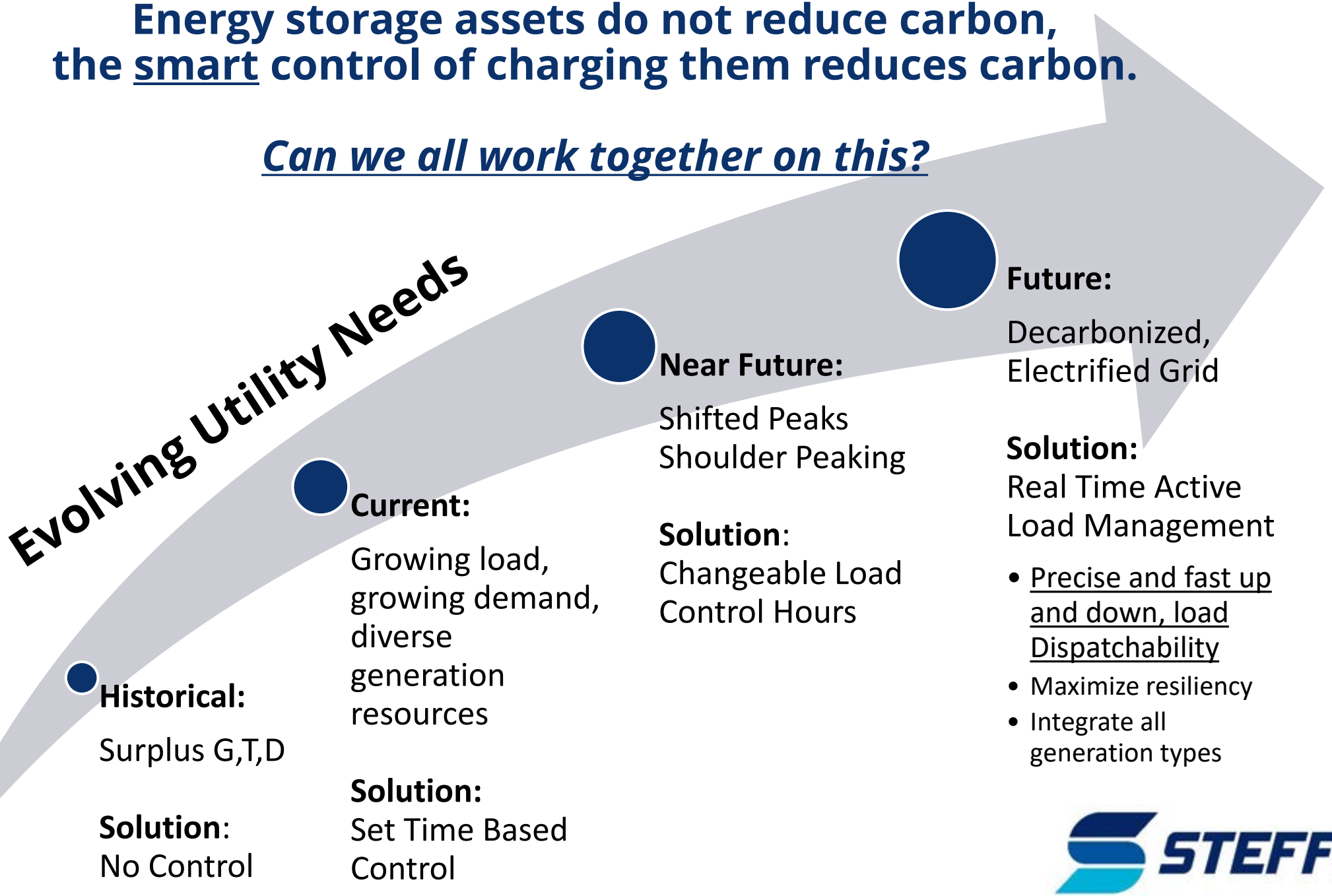
- Residential and Commercial Applications
- No on-peak backup heat required
- Serenity 4210 unit: 80 kWh of storage, only 22” wide!
- Thousands already operating today

Photo: Serenity 4210 80 kWh heat storage with 3-ton HP.

STEFFES

Energy storage assets do not reduce carbon, the smart control of charging them reduces carbon.

Can we all work together on this?



STEFFES

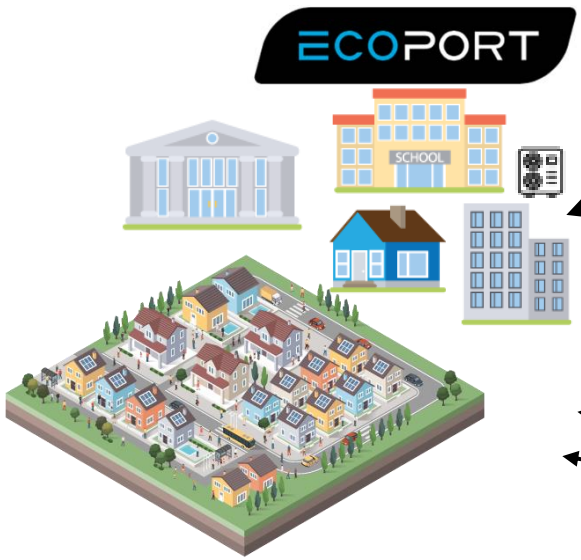
One Example of a Scalable Communication system Not using homeowner Internet

3,000 electric utilities broadcasting their unique grid needs

Open-standard DER signaling, e.g., Open ADR or Other

ATSC 3.0 Television Broadcast Platform

Billions of devices in building/home



ATSC 3.0

Broadcast can be as frequent as a few seconds

Return path provides verification to each utility

Low-cost light-weight cellular transmission, daily or as needed for visibility of load shifting capacity

Various clouds

STEFFES

NOSTROMO
COOLING GLOBAL WARMING

A vision for Thermal Energy Storage

The pathway to transform the industry

Nostromo Energy

August 2024

1.3 MWh System at the Beverly Hilton

Deploying 80-160 GW of virtual power plants (VPPs) by 2030 could expand the US grid's capacity to reliably support rapid electrification while redirecting grid spending from peaker plants to participants and reducing overall grid costs.

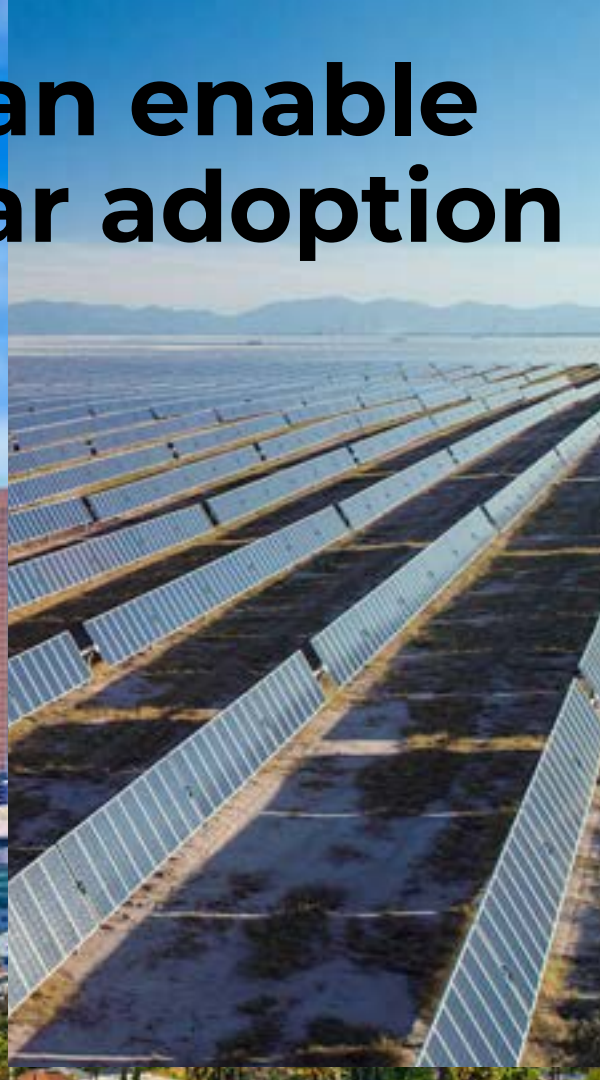
740 GW
US peak demand

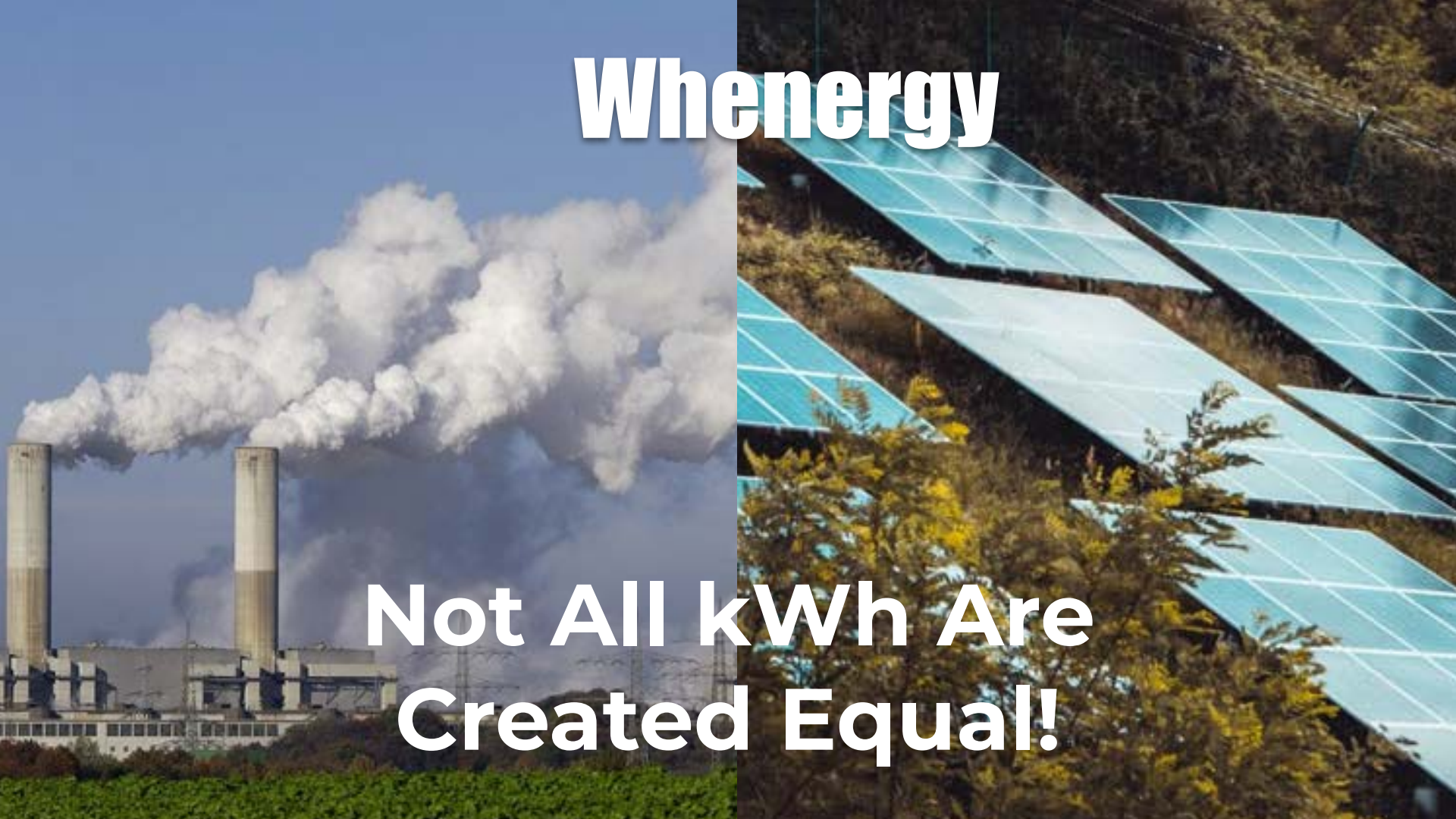
200 GW
shortfall by 2030

160 GW
VPP by 2030

How do we make sure every building has TES?

A daily shift program can enable buildings to increase solar adoption




Whenergy
Not All kWh Are
Created Equal!

Storage is the ultimate manifestation of VPPs

NOSTROMO


Storage is a buildings best decarbonization strategy


Thank You

California Energy Commission

Title: California’s Vision on TES in Buildings

Presenter: Yu Hou, Supervisor, Building Decarbonization Research

Date: 8/26/2024

Moving California to 100% Clean Energy

CEC'S R&D Grant Programs: Fostering Innovation Across the Energy Sector

Core mission: strategically invest funds to catalyze change and accelerate achievement of policy goals

- ✓ **Electric Program Investment Charge (EPIC)**
  Over $130 million annually

- ✓ **Gas Research and Development Program**
  $24 million annually

https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program
https://www.energy.ca.gov/programs-and-topics/programs/natural-gas-program

California's Climate Goals

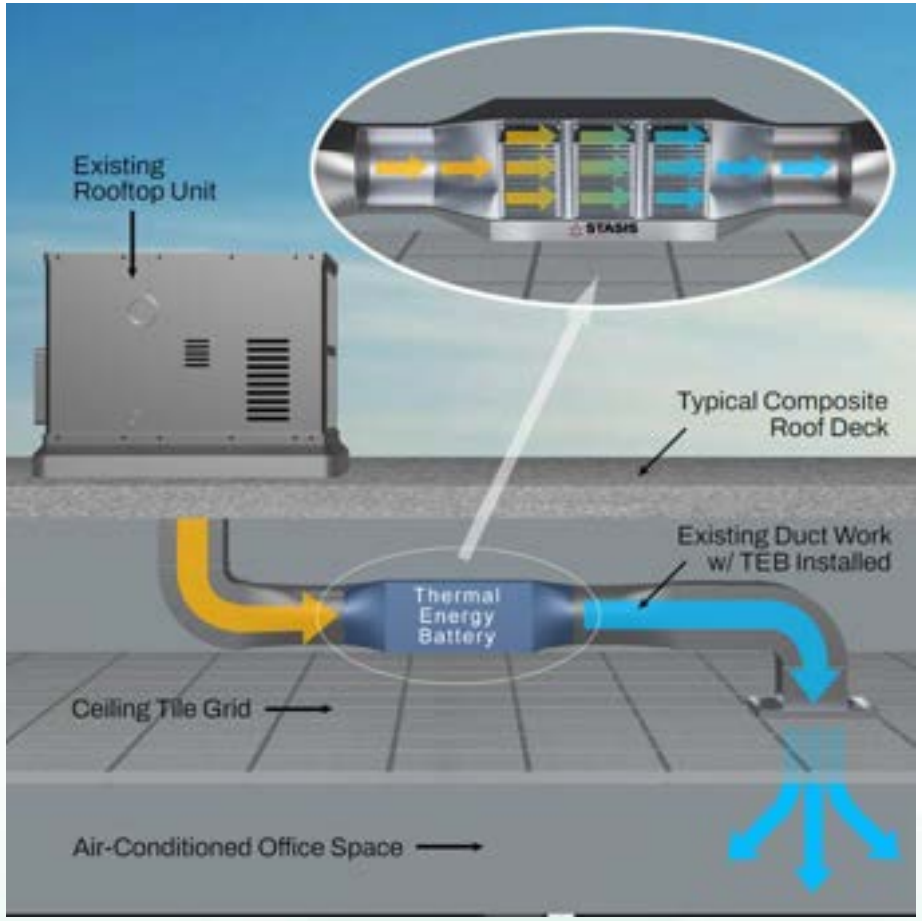
- By 2030
  - Load Shifting 7 GW
  - 3 million climate-ready and climate-friendly homes, supplemented by 6 million heat pumps
  - Reduce statewide GHG emissions to 40% below 1990 levels.
  - Double cumulative energy efficiency
- By 2035
  - 100% of new passenger vehicles are zero emission
  - 7 million climate-ready and climate-friendly homes
- By 2045
  - Carbon Neutrality in all sectors, including buildings
  - 100% of electricity retail sales are renewable and zero-carbon
  - 100% of medium and heavy-duty on-road vehicles are zero-emission

TES in building

- Building Decarbonization
  - Load Flexibility
  - TES-integrated HVAC
  - Heat pump water heaters with controls
  - TES in commercial refrigeration
  - Improve Energy Efficiency
  - Support new solar deployment
- Climate Resiliency
  - Distributed solar utilization
  - TES in the envelope
  - Microgrid

Stasis Energy Group Thermal Energy Storage System (TESS) for Packaged HVAC Systems

- Installed their Thermal Energy Storage System (TESS) at 10 small to medium-sized commercial sites statewide
- Components include a phase change material inside ducts of packaged rooftop systems under 10 tons and a programmable thermostat controller
- Avg 46% kWh load shift from peak to off-peak
- Avg 57% peak kW reduction
- RAMP grant to design and build pilot line for the TES system
  - 50 panels per hour while exceeding 95 percent yield.



https://www.energizeinnovation.fund/projects/stasis-energy-group-thermal-energy-storage-system-tess-packaged-hvac-systems

DC HVAC Nanogrid Module Development and Demonstration

- Demonstrate a combined DC HVAC, solar-PV, and energy storage module for use in commercial and residential buildings.
- Eliminate or reduce building HVAC grid load during peak hours in summer months.
- Streamline installation by using a factory-built module that does not require interconnection and does not export electricity to the grid.
- Reduce installation costs and barriers for under-resourced and other communities from installing solar PV and storage.
- Demonstrate efficiency from onsite DC-coupled HVAC.

https://www.energy.ca.gov/solicitations/2024-03/gfo-23-308-dc-hvac-nanogrid-module-development-and-demonstration

R&D Resources

- CEC R&D Website:
  - https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program
  - https://www.energy.ca.gov/programs-and-topics/programs/gas-research-and-development-program
- Energize Innovation: https://www.energizeinnovation.fund/
- Empower Innovation: https://www.empowerinnovation.net/
- EPIC Symposium (10/28/2024): https://www.energy.ca.gov/event/outreach/2024-10/2024-electric-program-investment-charge-epic-symposium
- Solicitations: https://www.energy.ca.gov/funding-opportunities/solicitations

Thank You!

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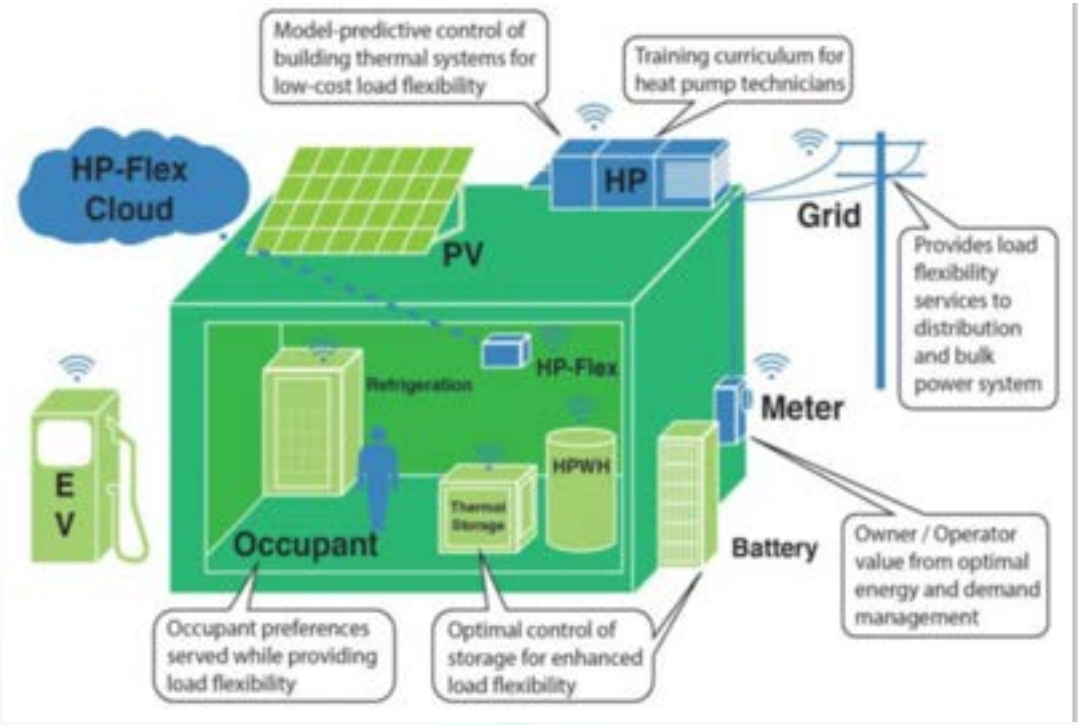
HP-Flex: Next Generation Heat Pump Load Flexibility (LBNL)

Summary

- The system optimizes energy use based on building owner/occupant preferences and responds to hourly or sub-hourly price and demand response (DR) signals.

- The HP-Flex system, includes new optimization software and equipment interfaces that collectively optimize heat pump operation in small/medium commercial (SMC) buildings while being extensible to manage equipment such as refrigeration, water heaters, batteries, and thermal storage.

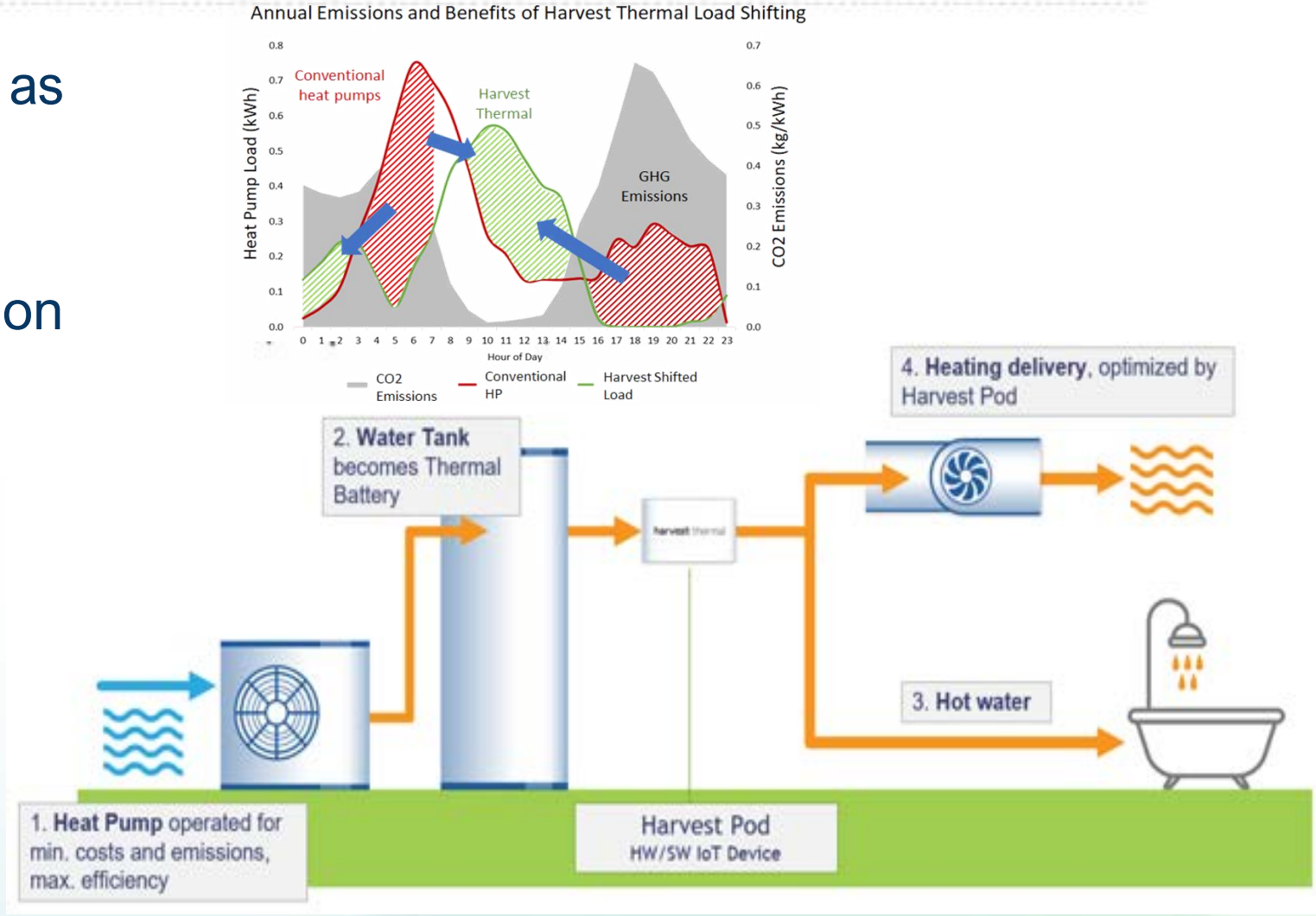
- Initial results show up to 40% reduction in morning warm-up load during the heating season.



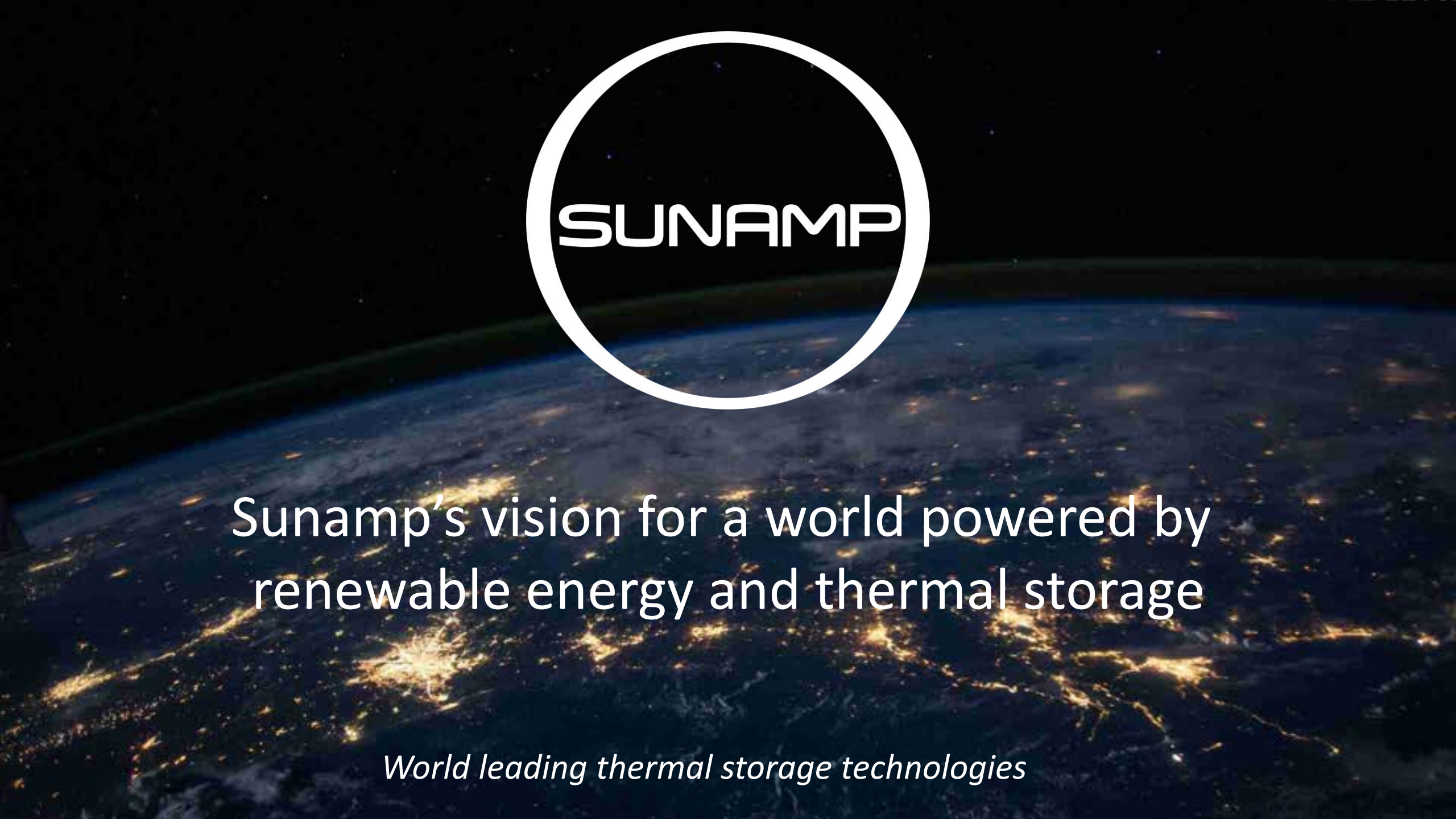
https://www.energizeinnovation.fund/projects/hp-flex-next-generation-heat-pump-load-flexibility

EPC-19-012: Affordable Space Conditioning and Domestic Hot Water Systems with Low Emissions and High Performance (Franklin Energy)

- Domestic Hot Water Tank as a thermal battery
- 90% Emissions reduction
- 30% Energy Cost Reduction
- Compatible with most vendors
- 150+ systems sold in CA



https://www.energizeinnovation.fund/projects/affordable-space-conditioning-and-domestic-hot-water-systems-low-emissions-and-high



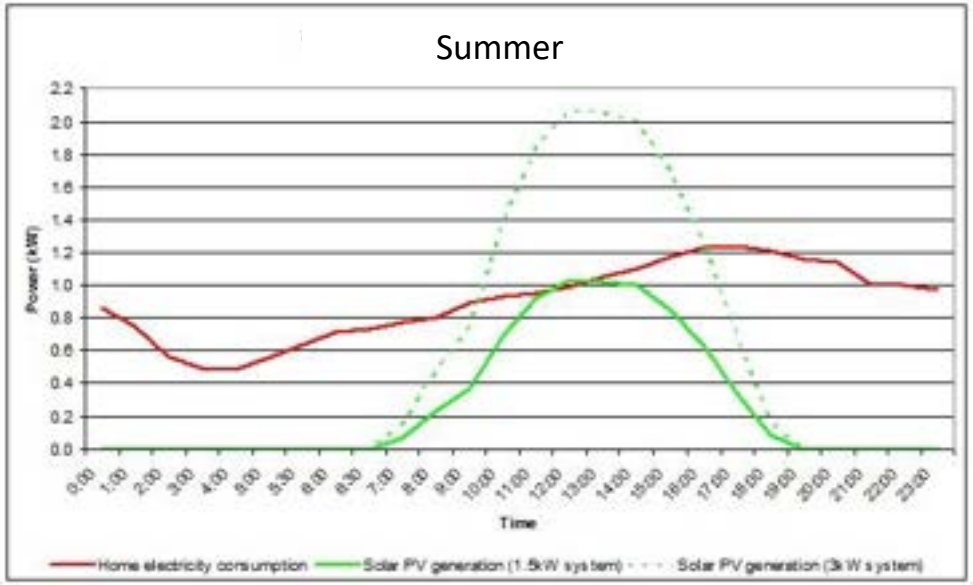
Sunamp’s vision for a world powered by renewable energy and thermal storage

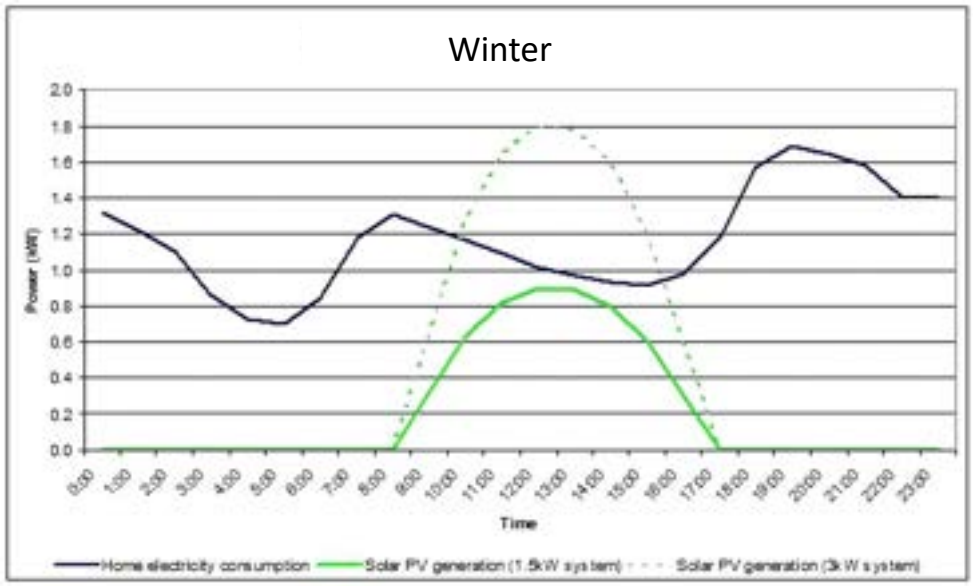
World leading thermal storage technologies


In a world powered by renewables,
energy storage is key

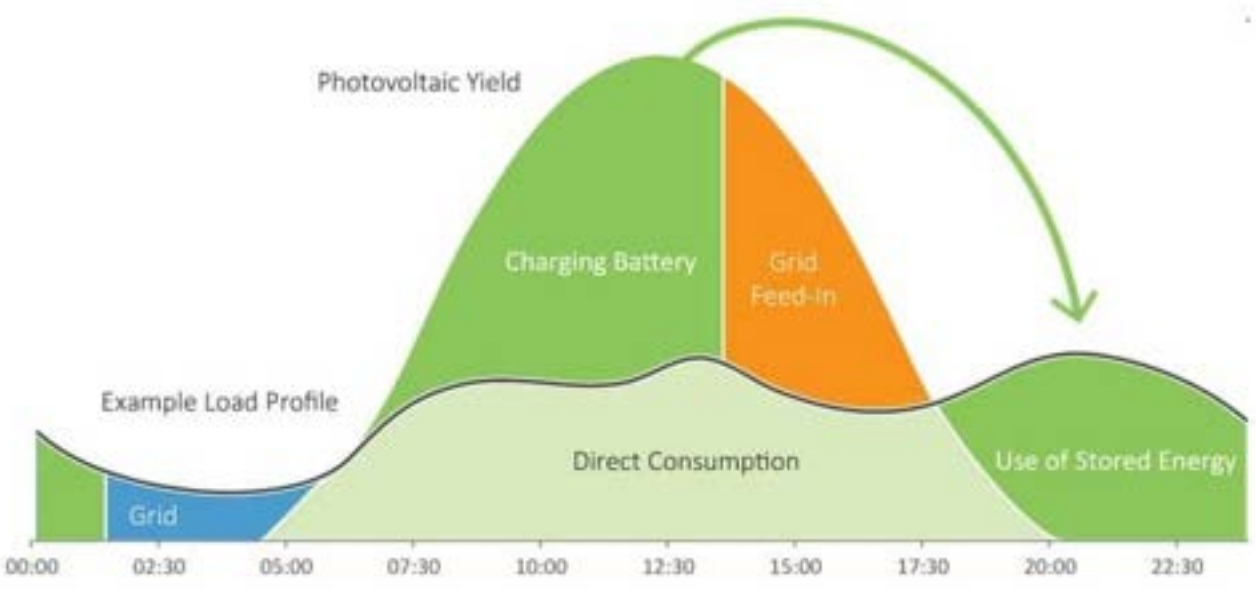
Energy storage solves the challenge of grid balancing

Energy Consumption per hour X PV Generation per hour:





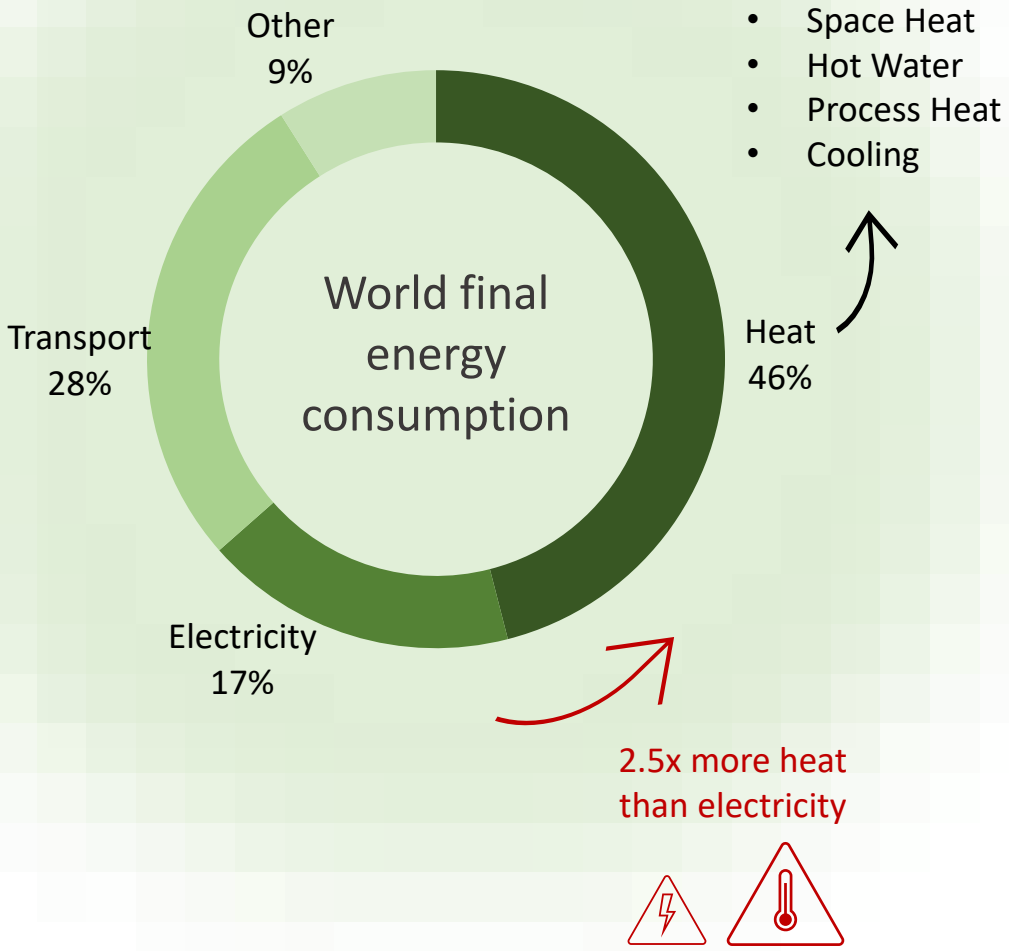
How to balance the curve?



Benefits:

- Peak Shaving – by storing heat energy when there is less demand and releasing when there is high demand.
- Grid Reliability - reduce cost of reinforcing the distribution grid in order to accommodate the increase in peak demand.
- No exposure to on peak tariff - Increase the overall building energy efficiency.
- Reduce gas emissions - Compliance with local laws and regulations

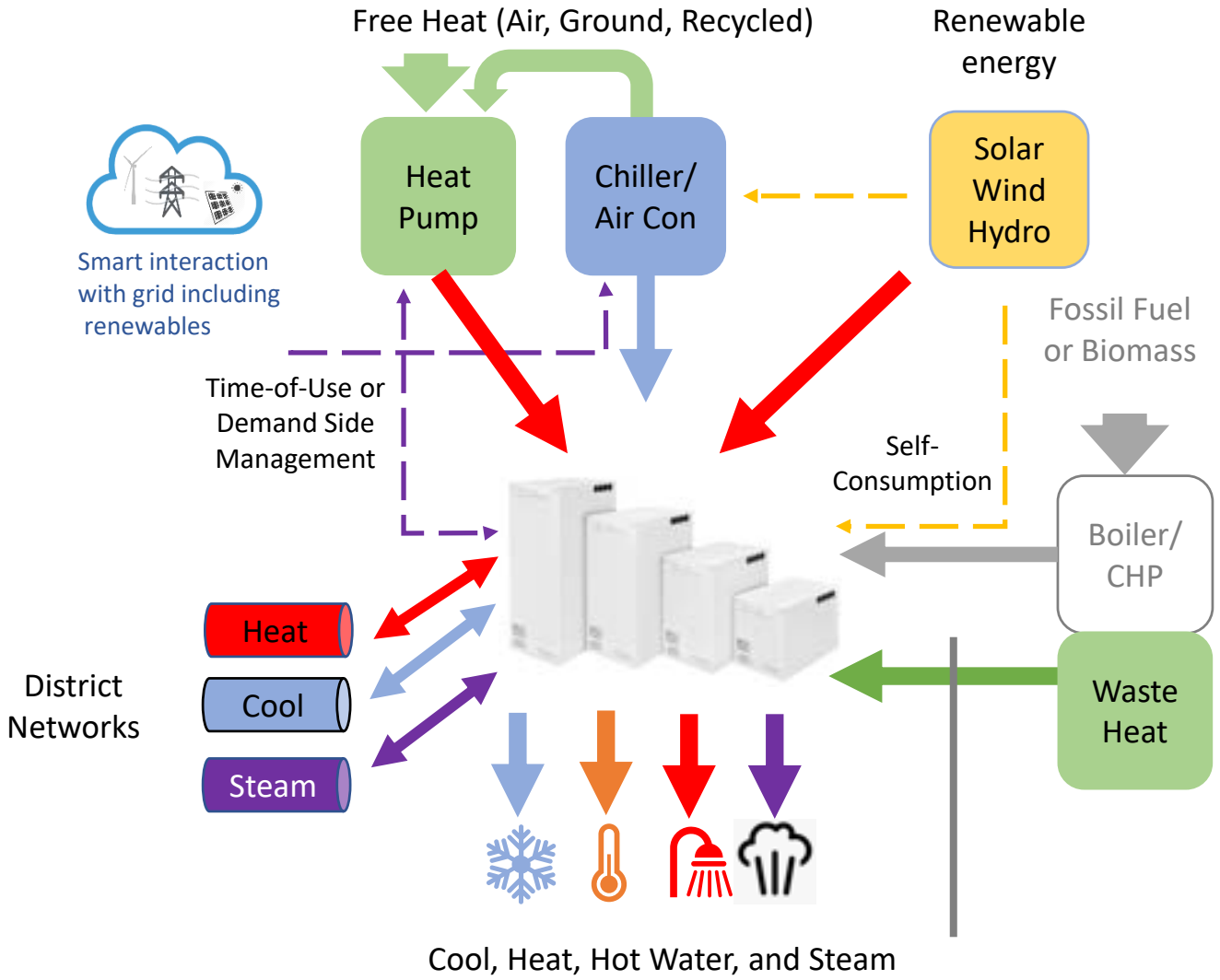
Thermal storage has significant advantages over electric energy storage



	THERMAL	ELECTRIC
	RESIDENTIAL	RESIDENTIAL
	14 KWH	13.5 KWH
	$ 3,230	$ 8,500
	10 YEARS (tested 43k cycles)	10 YEARS
	22.6in/14.3in/41.3in	29.9in/6.3in/62.8in
	513 lbs	343.9 lbs
	MULTIPLE SOURCES	SOLAR/GRID
	NON FLAMABLE	FLAMABLE
	NON-TOXIC	TOXIC*

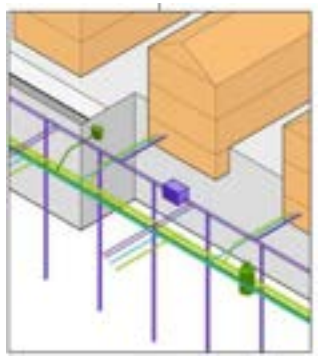
2.7x more expensive (proportionally)

Thermal storage as an integrator technology for the future world



Geothermal district energy with thermal storage for peak shaving & time shifting

PV electricity or



Geothermal Network

Heat Pump

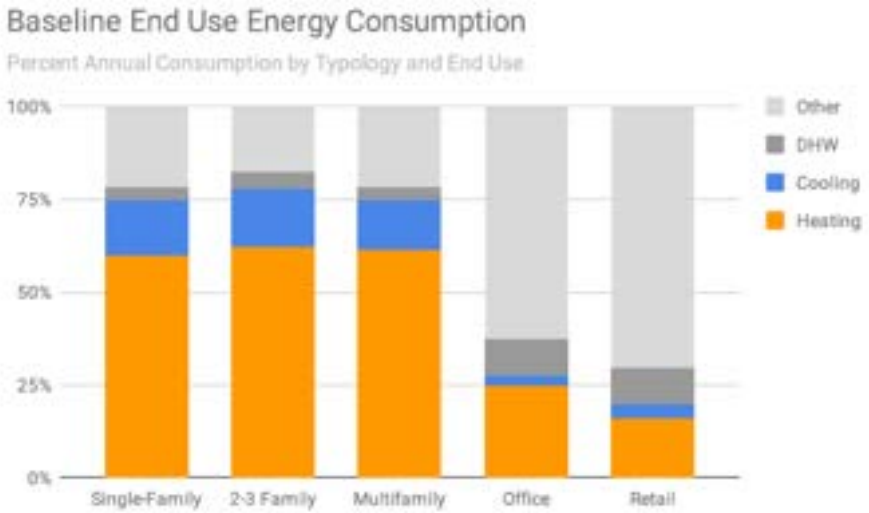
Battery 1 - 60°C (140°F) for charging
Battery 2 - 8°C (46°F) for charging

Heat Pump

Battery 1 - 60°C (140°F) for charging
Battery 2 - 8°C (46°F) for charging

15°C (59°F) cold main water

+ as many houses as possible in the same street



Hot water
Heating/Cooling

Battery 1 - DHW:
46°C (114°F) out from TES (60gal)
Battery 2 - Heating:
46°C (114°F) out from TES (10kWh)
Battery 2 - Cooling:
12°C (54°F) out from TES (5kWh)

Hot water
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Thermal storage will help us balance the grid and achieve resilience.

Phase change materials make this possible by allowing us to create compact systems suitable for every home.