Northwest **Power** and **Conservation** Council

November 7, 2023

MEMORANDUM

TO: **Power Committee Members**

FROM: **Kevin Smit**

SUBJECT: **Emerging Trends in Energy Efficiency**

BACKGROUND:

Presenter: Ammi Amarnath, Principal Technical Executive, EPRI

Summary: Energy efficiency (EE) continues to be an important part of the Northwest energy landscape. The 2021 Power Plan calls for between 750 and 1000 aMW of EE by 2027, and the plan analysis showed that if loads increase significantly, it is likely even more EE will be required. Some utilities are struggling to meet energy efficiency goals, primarily because many of the lower cost, and easy-to-implement EE measures have been acquired or are now in our baseline due to building codes or appliance efficiency standards. Therefore, the need is great for new EE measures to be brought into the mix. Ammi Amarnath of EPRI will present insights from both national and international research that is happening in the energy efficiency field.

EPRI is an independent non-profit energy research, development, and deployment organization, with three specialized labs. EPRI also maintains an employee presence in more than a dozen countries in Europe/Middle East/Africa, as well as Asia, and the Americas through its subsidiary EPRI International Inc. and its Ireland-based research arm, EPRI Europe DAC. EPRI collaborates with scientists, engineers, government, and experts from academia and industry to shape and drive energy technology

advancement by pushing the frontier of innovation from concept, pilot, operation to end-of-life.

Relevance: The Northwest has a long history of acquiring energy efficiency resources. Like any other generating resource, new resources need to continue to be developed to successfully meet future needs at a reasonable cost. This is the view of the Northwest's energy efficiency emerging technology efforts. Existing energy efficiency technologies need to continue to improve, and new measures need to be developed. Prior to each power plan, Council staff investigate these emerging technologies to determine which ones are ready[1] to be included in the plan's EE supply curves. The 2021 Power Plan includes recommendations for the region to continue investing in emerging technologies: "Continued investment in NEEA and efficiency-related research and development is critical to achieving the long-term goals…we recommend the region's utilities continue to fund research and development on emerging technologies…"[2]

Workplan: Track emerging technologies, both supply and demand side, providing periodic updates to the Council.

[1] The Northwest Power Act requires that energy efficiency measures be "reliable and available" at the time they are needed.
[2] Northwest Power and Conservation Council, *The 2021 Northwest Power Plan*, March 2022, Page 34.

Ammi Amarnath is a Principal Technical Executive in the Electrification & Sustainable Energy Strategy Research Sector at EPRI.

He leads the research, development and deployment efforts in Energy Efficiency, Demand Flexibility, and Load Management technologies and programs. This includes RD&D in smart and efficient grid-edge technologies while ensuring their interoperability with the electric supply system. Some of the technologies demonstrated includes smart space conditioning systems for residential and commercial buildings, heat pump water heaters, high performance/low energy buildings, efficient industrial electrification technologies including high temperature heat pumps, and Energy-Water Nexus technologies for efficiency and load management improvements in water systems.

Ammi also manages RD&D activities focused on flexible demand response technologies, which includes open standard communication protocols such as OpenADR, CTA 2045 & IEEE 2030.5, integration of distributed energy resources, and non-wire alternatives for asset optimization. His focus also includes analytical techniques, such as energy meter data disaggregation, and impact of energy efficiency on emissions.

Amarnath received a Bachelor of Engineering degree in Chemical Engineering from India and a Master of Science degree in Chemical Engineering from the University of California, Santa Barbara. He also holds a Master of Business Administration degree from the University of Houston.

Ammi Amarnath
Principal Technical Executive
Electrification & Sustainable Energy Strategy
EPRI

Energy Efficiency & Efficient Electrification

Presentation to Northwest Power and Conservation Council

Ammi Amarnath
Principal Technical Executive

Portland, OR
November 14, 2023

About me

- Working in the Clean Energy Sector for about 30 years
- Mostly in the Energy Utilization Space
- Led EPRI's Industrial Technology RD&D activities as related to Process Industries
- "Restarted" the Energy Efficiency Program at EPRI in 2007
- Currently a Principal Technical Executive in the Electrification & Sustainable Energy Strategy
  - Involved in EE/DR RD&D as related to Residential, Commercial and Industrial, Ag, Water (IAW) Sectors
- Residential & Commercial Sectors – Good adoption of decarbonization technologies
- IAW Sectors – Widespread adoption of decarbonization technologies has been challenging
- Note: I will not cover "Demand Flexibility" in this presentation

Three Key Aspects of EPRI

Collaborative

Bring together scientists, engineers, academic researchers, and industry experts

Independent

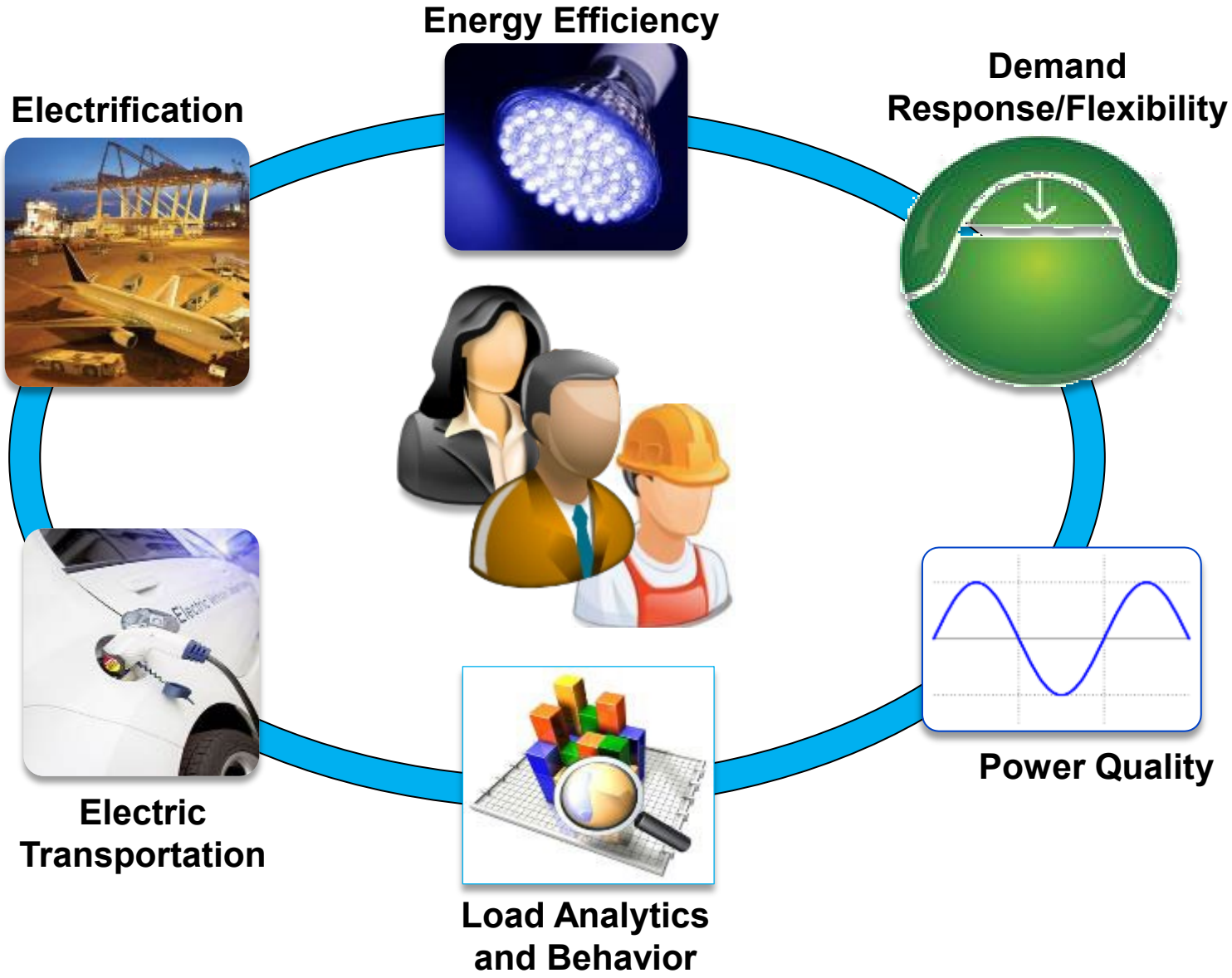
Objective, scientifically based results address reliability, efficiency, affordability, health, safety, and the environment

Nonprofit

Chartered to serve the public benefit

Electrification & Customer Solutions Research Area

Revolving Around the Customer – Focus on Decarbonization



EE/Electrification in Residential & Commercial

Some Examples

Heat Pumps

For Space Conditioning & Water Heating

Next-Gen Heat Pumps

- Large scale field test of advanced heat pump from multiple manufacturers

Cold Climate Heat Pumps are Entering the Market

Single-Room Heat Pumps

- Benefits:
  - Efficient heating and AC
  - Functional windows
  - Simple installation
  - Some have low-GWP refrigerants
- Concerns:
  - Window compatibility
  - Single room only
  - Still higher cost than window ACs ($2-3,000)

EPRI Demo projects with120V Inverter Driven Window Heat Pumps

Gradient

(100 units installed in 2 cities, 2023)

- Installation bracket for easy setup
- R-32 refrigerant with water glycol loop
- Reduced noise levels
- Mobile app control and schedule

https://www.gradientcomfort.com/

Innova

(60 units installed in 1 city, 2021)

- Monobloc form factor for easy install
- R-32 refrigerant
- Aesthetically appealing design
- Requires 2 small holes in wall (~6 in)

https://www.innovaenergie.com/en/products/air-conditioning-without-outdoor-unit/2.0-verticale/

Gradient Heat Pump Field Deployment Key Findings

- **Usability Validated For Primary (Heating/Cooling) & Secondary (Mobile App) Benefits**
  - Validated usability of the Gradient unit among LMI community through surveying and conversations.
  - Users enjoyed App control. Some had feedback for how to improve, but many positive experiences with the advanced features
  - Instances where the user had health or mobility challenges, being able to control the Gradient from their phone was very valuable
- **Modular HVAC System Enables Energy Saving Behavior**
  - Many LMI residents want control and flexibility to save money
  - Prefer to heat or cool each room as needed
  - 9x the number of surveyed participants used their Gradients in a modular way, compared with using all units at once

New Efficient and Flexible Water Heating Solutions

- Primary Focus Areas:
  - What are the targeted applications for new HPWH products and how do they perform?
    - 120 VAC residential HPWHs
    - Propane HPWH from Europe
    - HPWHs with improved communications and TOU scheduling
  - What EE, DR and decarbonization benefits can be gained?

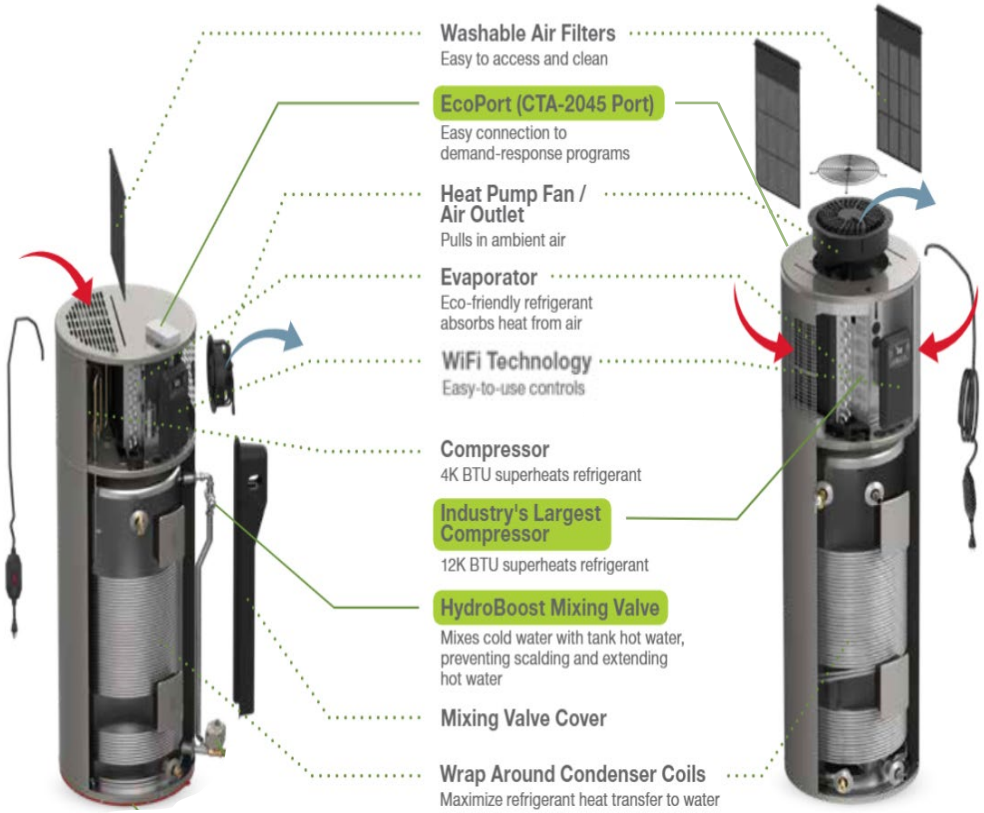
Emerging HPWH Product Specifications

Nominal Capacity	40 gallon (Shared)	40 gallon (Dedicated)
	15 Amp Breaker	
UEF	2.8	3.0
FHR	45	51
Recovery (for 60°F rise)	12 gal/hr	28 gal/hr
Dimensions	H: 63” D: $20\frac{1}{4}$”	H: $65\frac{5}{8}$” D: $20\frac{1}{4}$”
Features	• Internal mixing valve • EcoPort: port for DR • 4 kBTU Compressor • Wifi connectivity	• EcoPort: port for DR • 12 kBTU Compressor • Wifi connectivity

Operation Modes	Definition
Heat Pump	Default
Vacation Mode	2-28 Days or Indefinitely

Shared Unit

Dedicated Unit

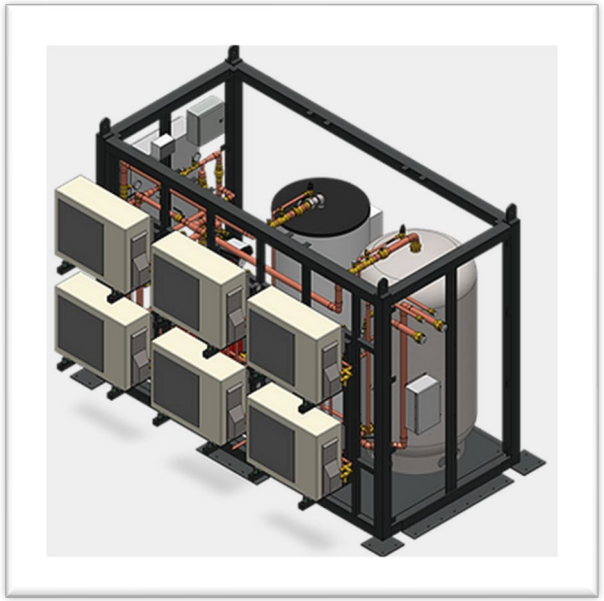


No Resistance Heat

Multifamily Water Heating HPWH

Advanced Water Heater Initiative

- Plug-and-Play packaged systems
- AWHS v9.0 in development
- QPL with 4 products
- UES measure for Multifamily in development



WaterDrop

Steffes Origin

Large Focus in the Pacific Northwest

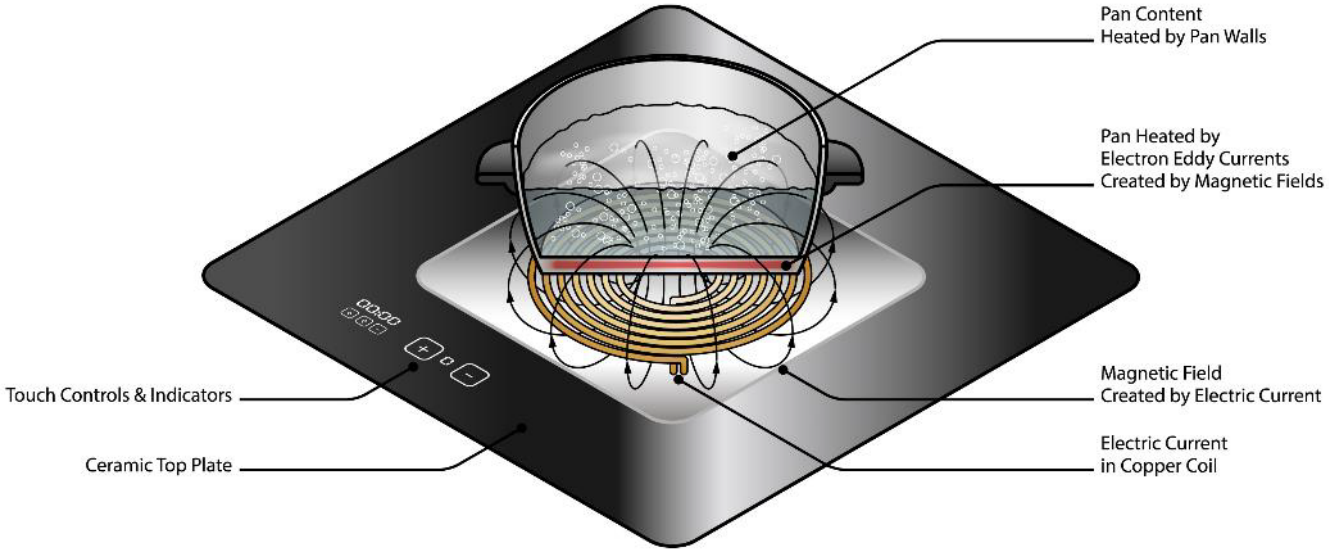
Heat Pump for Large Commercial Buildings

1. The Problem – Hydronic Heating in U.S. Buildings
2. A Solution in Heat Pumps?
    1. High-lift heat pump varieties
    2. Off the shelf vs. Engineered Solutions
3. New Construction
4. Retrofit
    1. Design Process
5. Ongoing Research

High Lift HPs for Hydronic Heating

Other EE Technologies

Induction Cooking



Induction requires ferrite-based cookware in most cases

Key Induction takeaways

Advantages

- Highest energy efficiency of conventional cooking methods (gas, electric, induction)
  - 5-10% more efficient than electric, 3 times more efficient than gas
- Faster heating times = cook faster.
- Lower surface temperature = safer operation for cooks
- Easy to clean surface.
- Advanced systems like pot detection and flexible cooking surfaces
- Precise temperature control via its defined number settings

Challenges

- Higher initial cost
- Potential electrical service install or expansion requirement
- Compatible cookware – requires ferrous cookware
- Learning curve
- Cooking method adjustment – cannot remove cookware from surface
- Fragility of glass surface
- Lack of knowledge and information among the general public

In 2021, DOE stated if all cooktops sold in the US in 2021 were induction cooktops that met the Energy Star criteria, the energy cost savings would exceed $125 million and the energy savings would exceed 1,000 GWh

Flexible space induction cooking surfaces are emerging

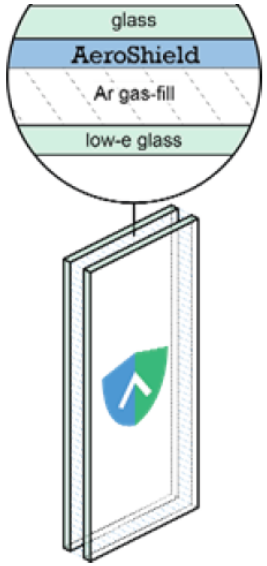
Aerogel Based Materials Window Insulation

Description

- AeroShield is a transparent aerogel used in double pane windows
- Triple-pane performance without impacts to weight, thickness, or transparency
- NREL modeling shows avg home would save $10.25/yr per 15 sqft window: 7 year payback w/o incentives
- LBNL testing showed 30% reduction in heat loss compared with typical double-pane window

Maturity (preliminary scores)

- **Technology Readiness Level (TRL) Score:** 6-7
- **Adoption Readiness Level Score:** 4-5
- **Years to Market:** 2-3 years



Modeled Thermal Performance

All values modeled in Berkeley Lab WINDOW v7.8 based on measurements done at LBNL

Description	Airspace	Total Thickness	U-Value Center-of-glass (Btu/h·ft2·F)	U-Value Center-of-glass (W/m2·K)
AeroShield Double Pane *(3mm glass, 2 LoE)*	11mm argon + 4mm aerogel	21mm	0.14	0.79
Double Pane *(3mm glass, 2 LoE)*	15mm argon	21mm	0.20	1.14
Triple Pane *(3mm glass, 2 LoE)*	8mm argon / 8mm argon	25mm	0.17	0.97

Building Controls

Description

- Solis dimmer for guest room automation and management
- Maps room using radar from multiple sensors for superior occupancy sensing
- Connects with thermostat for HVAC control
- Reduced energy consumption of HVAC, lighting, & plug loads

Benefits

- Integrated virtual assistant for enhanced guest experience
- Easy install & retrofit into existing building
- Demand Response practical
- Zero programming

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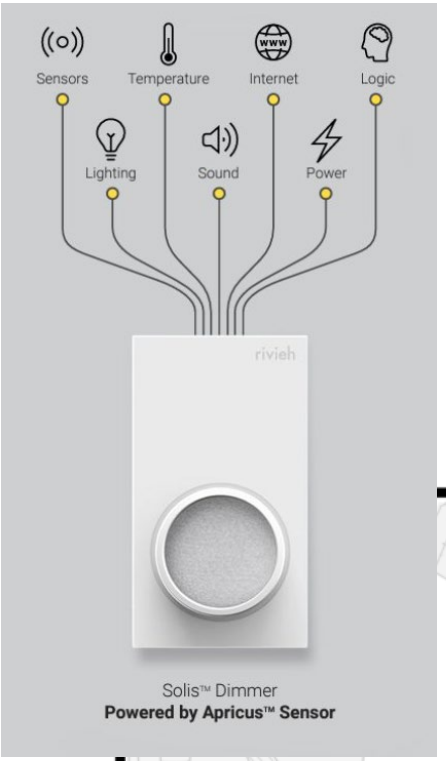
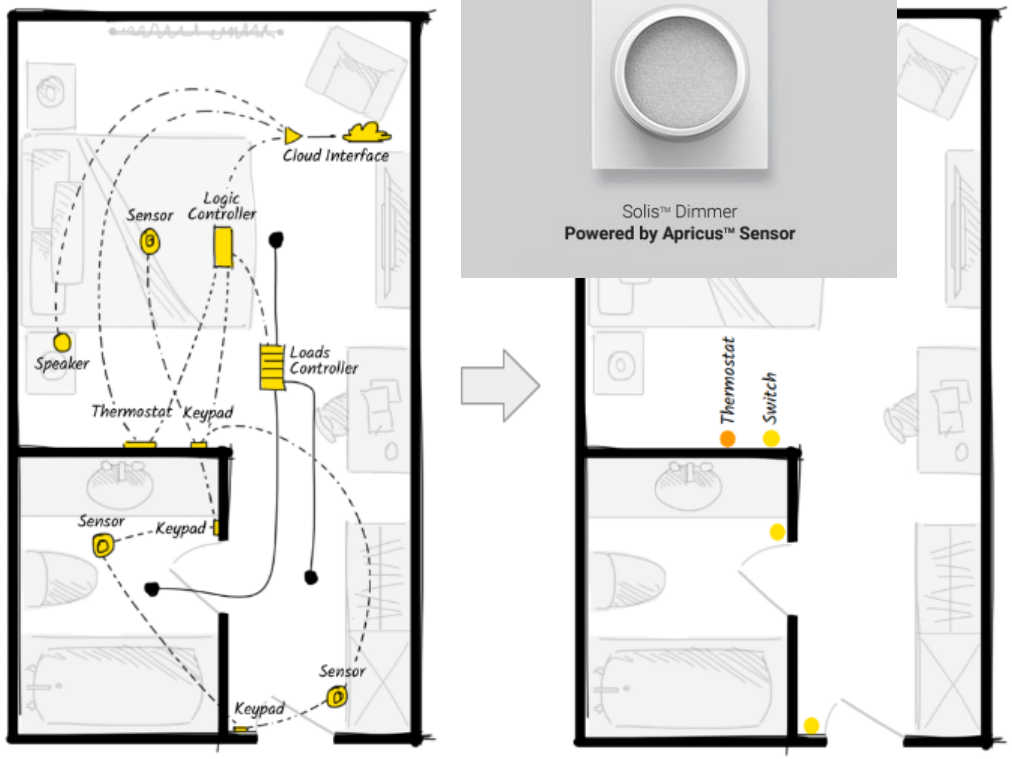


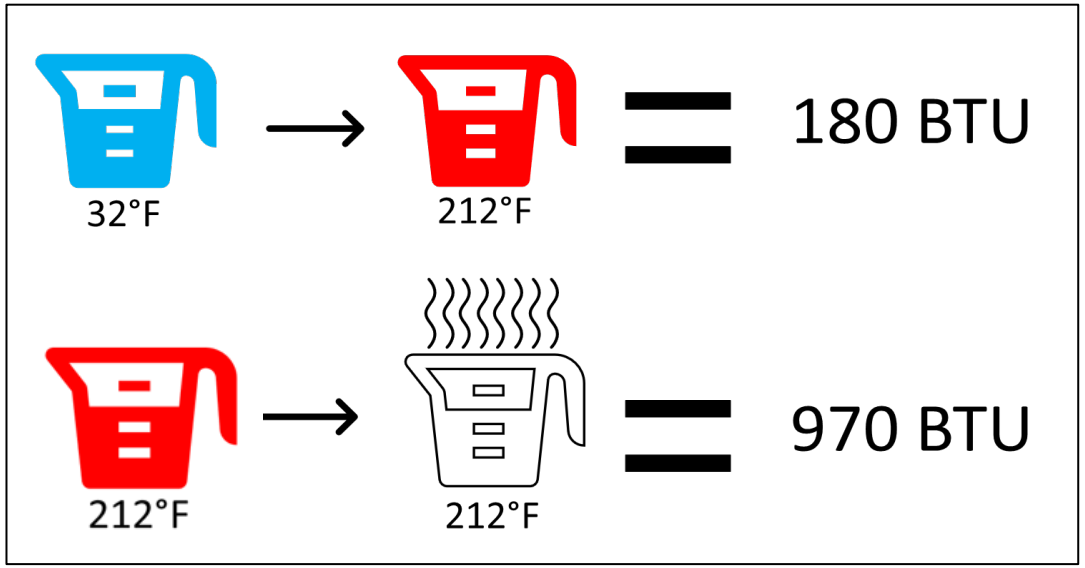


Dehumidification with Vapor Compression

- Dehumidification with vapor compression machines is energy intensive because of water's high latent heat of vaporization
  - Air must be cooled below dew point
  - Requires reheat with fossil fuels or electric resistance heaters

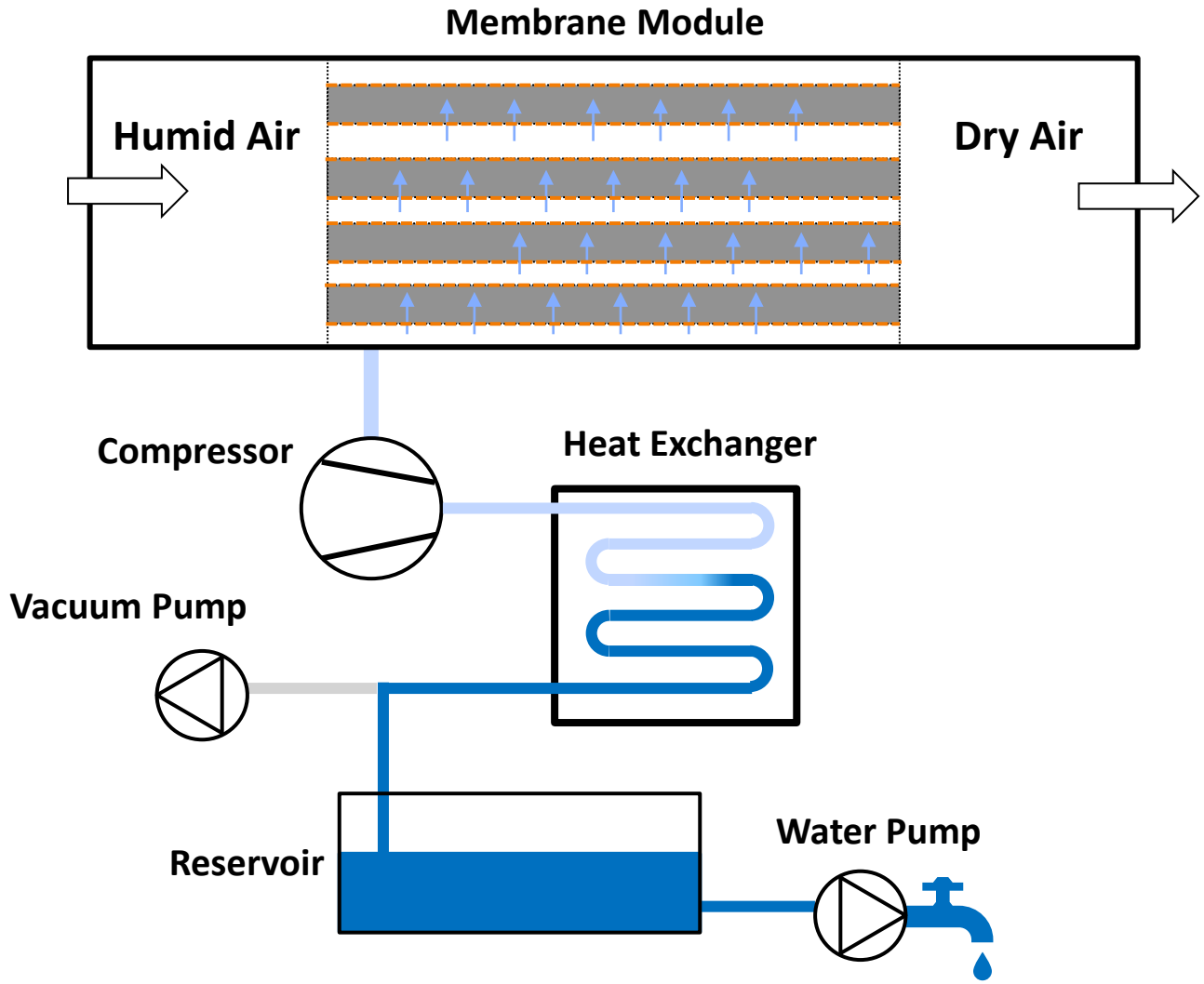
- There can be significant savings if latent load can be met *without* condensing water vapor

Comparison of latent and sensible capacity of water



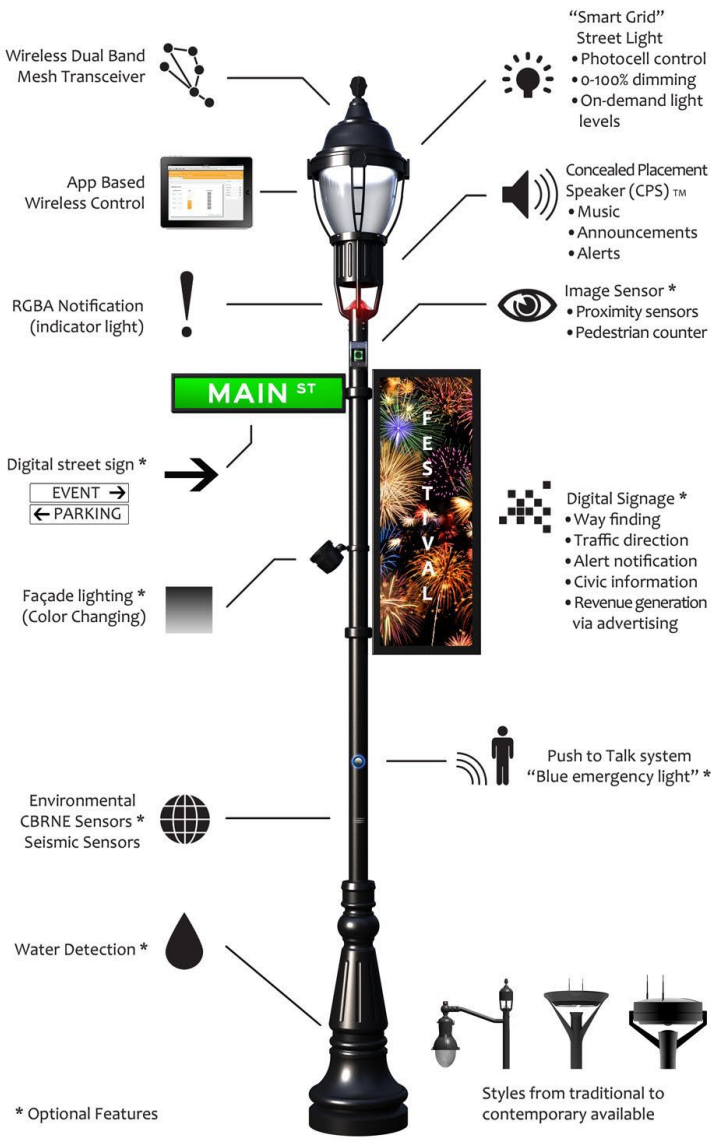
Novel Method in Membrane Dehumidification

- Claridge-Culp-Liu Dehumidification Process
  - Compress extracted water vapor to sub-atmospheric pressure
  - Requires specialized compressors and pumps
  - Provides pure water



Modeling results show 34%-64% savings for moisture removal

Collaborative Smart Pole Project Summary

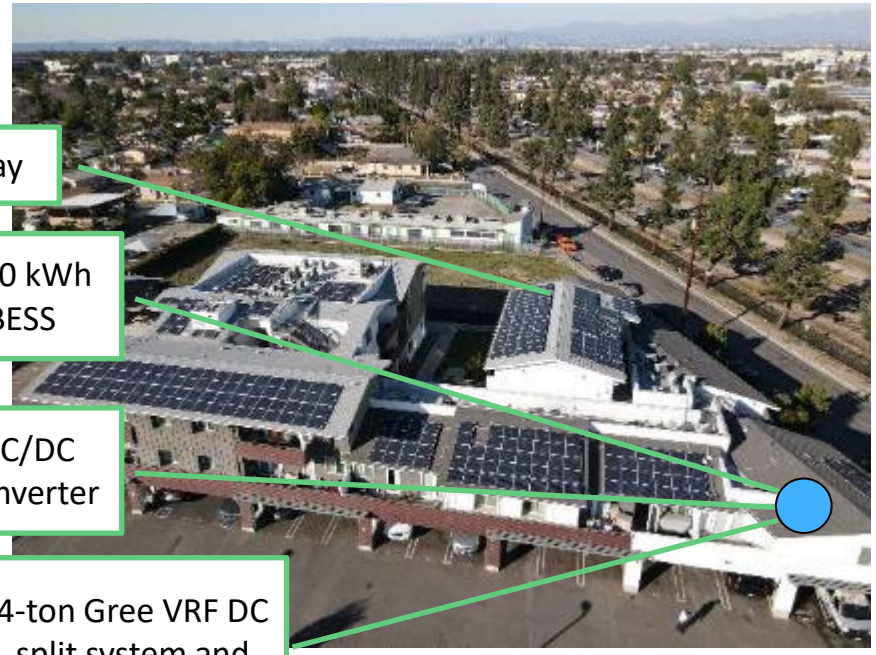


- Smart poles are different from smart streetlights.
  - Smart streetlights use connectivity to control and monitor lighting
  - Smart poles use connectivity to communicate with, control, and monitor lighting and additional equipment
  - **Smart Poles are *an emerging concept* that provides the potential integration of a wider range of technologies in a range of forms**
- Smart Poles enhance cities and spaces with features such as *dynamic lighting, emergency communications, Wi-Fi / cellular hotspots, and security cameras*
- Additional smart pole features include (but are not limited to):
  - Electronic Signage
  - Smart Meter Integration
  - Asset Tracking
  - Parking Management
  - Controllable Outlets
  - Speakers / Music
  - Dynamic Wayfair Signage
  - Environmental Sensing (Climate, Air Quality, Earthquake, Flooding, etc.)
  - IoT Data Collection

Solar+: Enabling Clean Energy in Disadvantaged Communities w/ Integrated PV + Storage (Willowbrook, CA)

Project Scope:

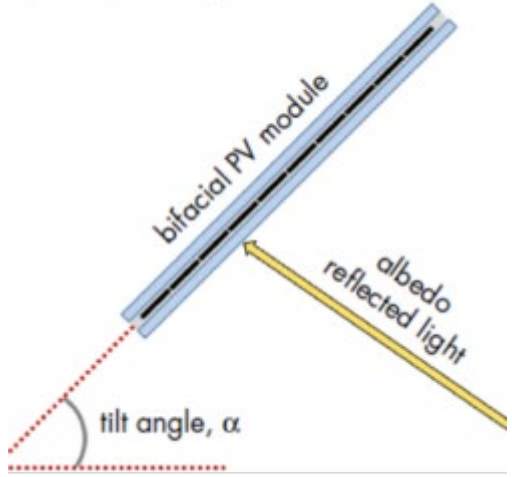
Demonstration of community-level resource integration and controls at an affordable housing property in a low-income, disadvantaged neighborhood



Innovations

- High-Efficiency Bifacial Solar PV
- Battery Energy Storage
- DC-coupled Bi-directional Smart Inverter
- Energy Efficient Direct Current Loads
- Multi-Level Controls Integration through Cloud-Based Platform
- Innovative Community-Sharing Business Model (VNEM)

Rear-side irradiance $\propto (1 - \cos(180^\circ - \alpha)) \cdot albedo \cdot GHI$



Decarbonization Retrofit for Multifamily Apartments (Fresno, CA)

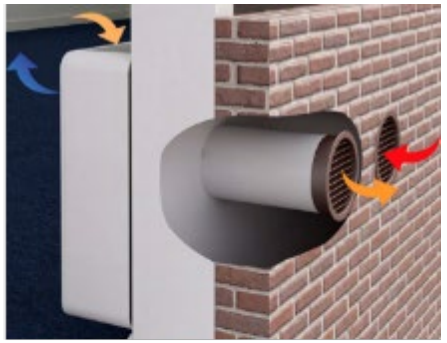
3-year journey for comprehensive retrofit

CEC EPC-15-053

- Insulated, replaced lighting & appliances, installed heat pumps, added community solar
- Implemented measures: 150 kW PV, insulation, some appliances, some lighting
- Circuit metering in each unit

- 60 units in 10 buildings plus common area (multifamily)
- Built in 1969, Fresno CA
- 1 – 4 bedroom apartment units, 4-10 units per building
- Master metered on gas, electric and water
- 200 A panel for each building and 125 A panel in each apartment

Key New Electrification Technologies Implemented

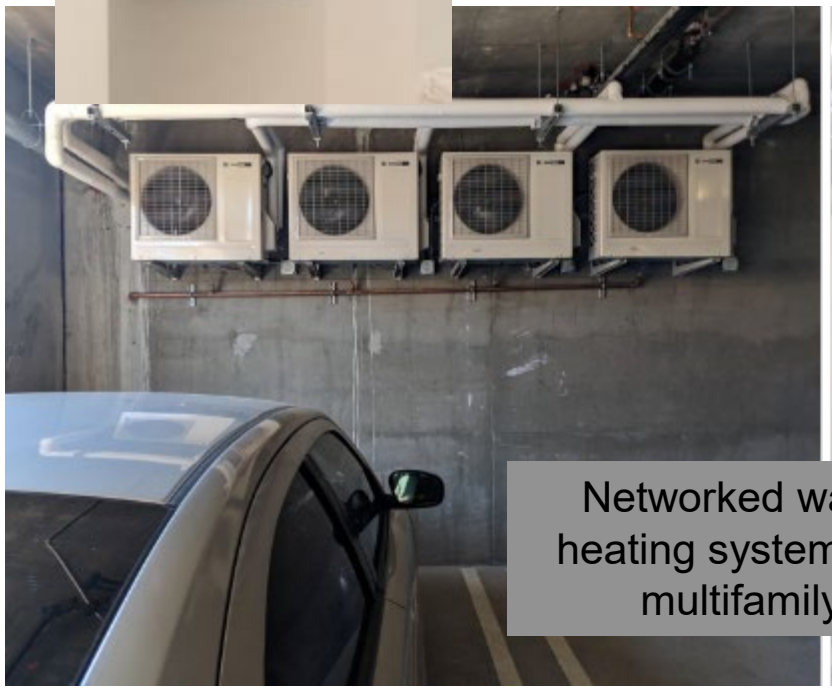


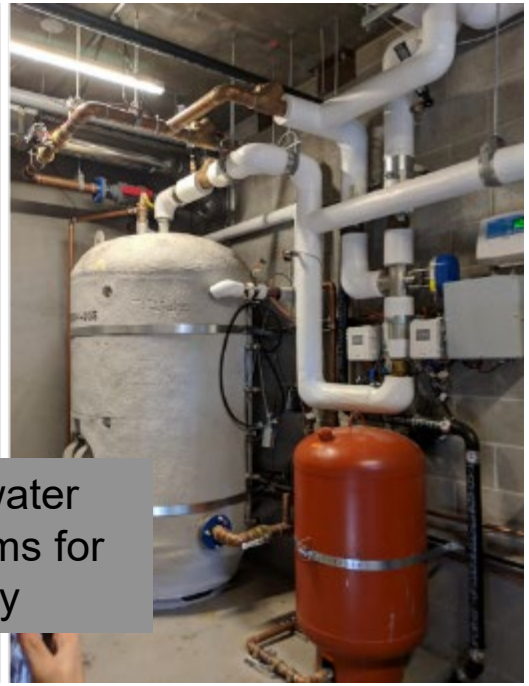
110 V Heat Pumps with asbestos mitigation

Low cost/ low draw cooktops

Wall mount HPWH with potential for 110 V retrofit

Smart Panels for retrofits



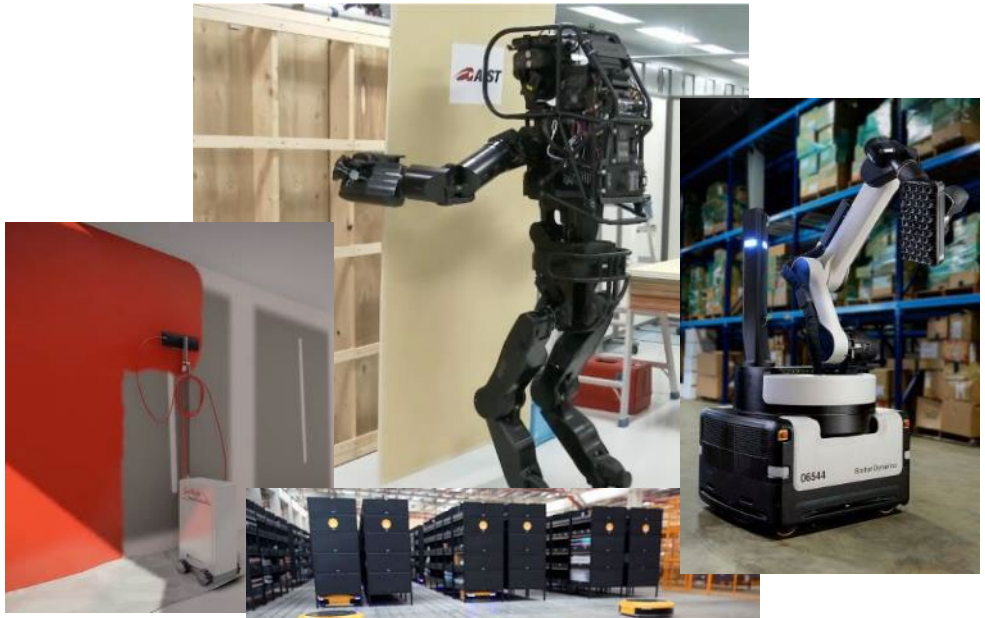


Networked water heating systems for multifamily

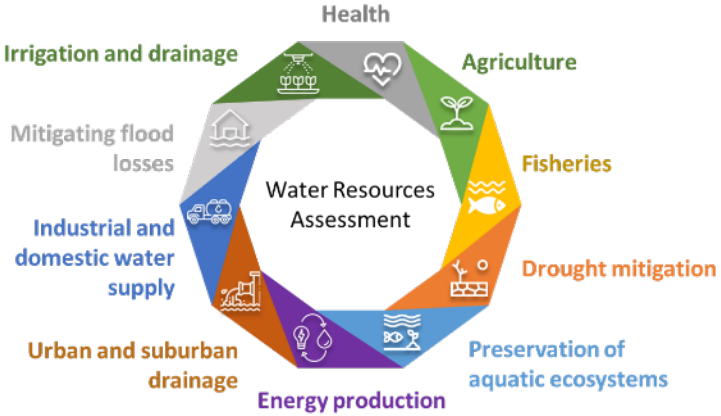
What is on your horizon?

New Refrigerants?

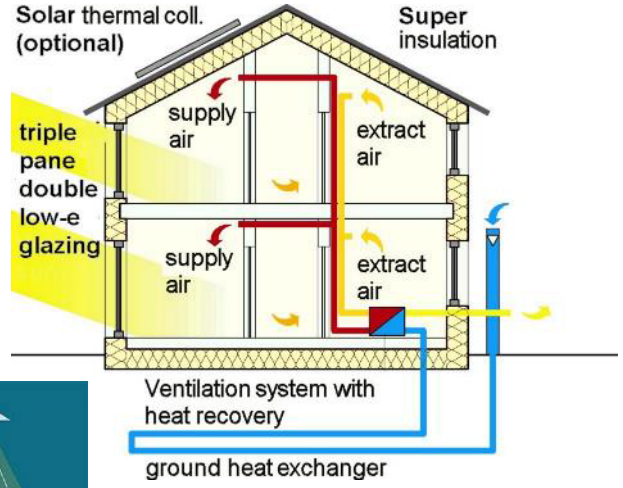
Robotic Workforces?



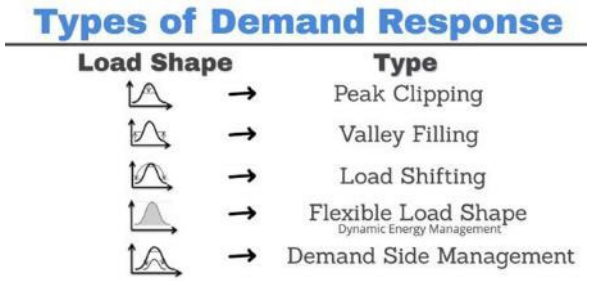
Water Management?



Advanced Heat Recovery and Storage?



Enhanced DR?



Li-Fi?

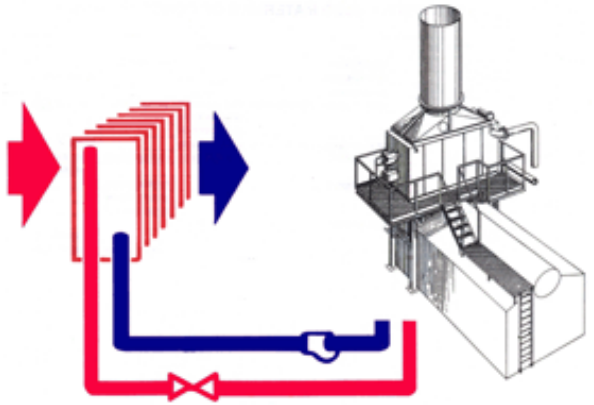
EE/Electrification in Industrial

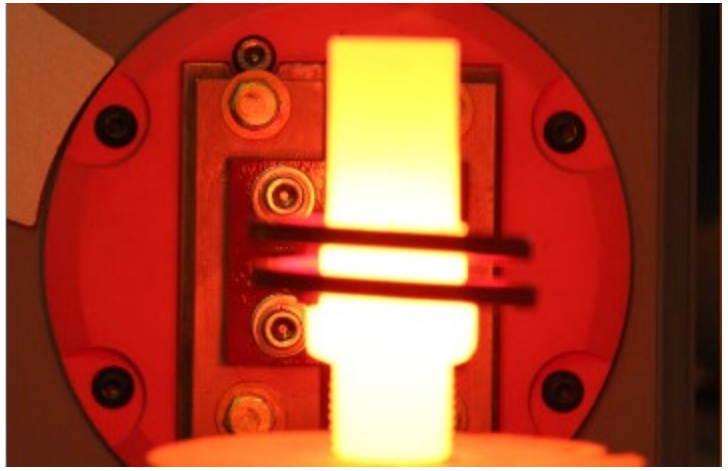
Examples

Opportunities for Decarbonization in Industry

Efficiency, Electrification, Low Carbon Fuels, Carbon Capture

- Process Integration
  - Pinch Technology
- Waste Heat Recovery and Reuse
  - Industrial Heat Pumps
- Electric-Driven Process Heating
  - MW, RF, IR, Acoustic, Ohmic etc.
- Low Carbon Fuels
  - Hydrogen, Ammonia etc.
- Carbon Capture & Utilization

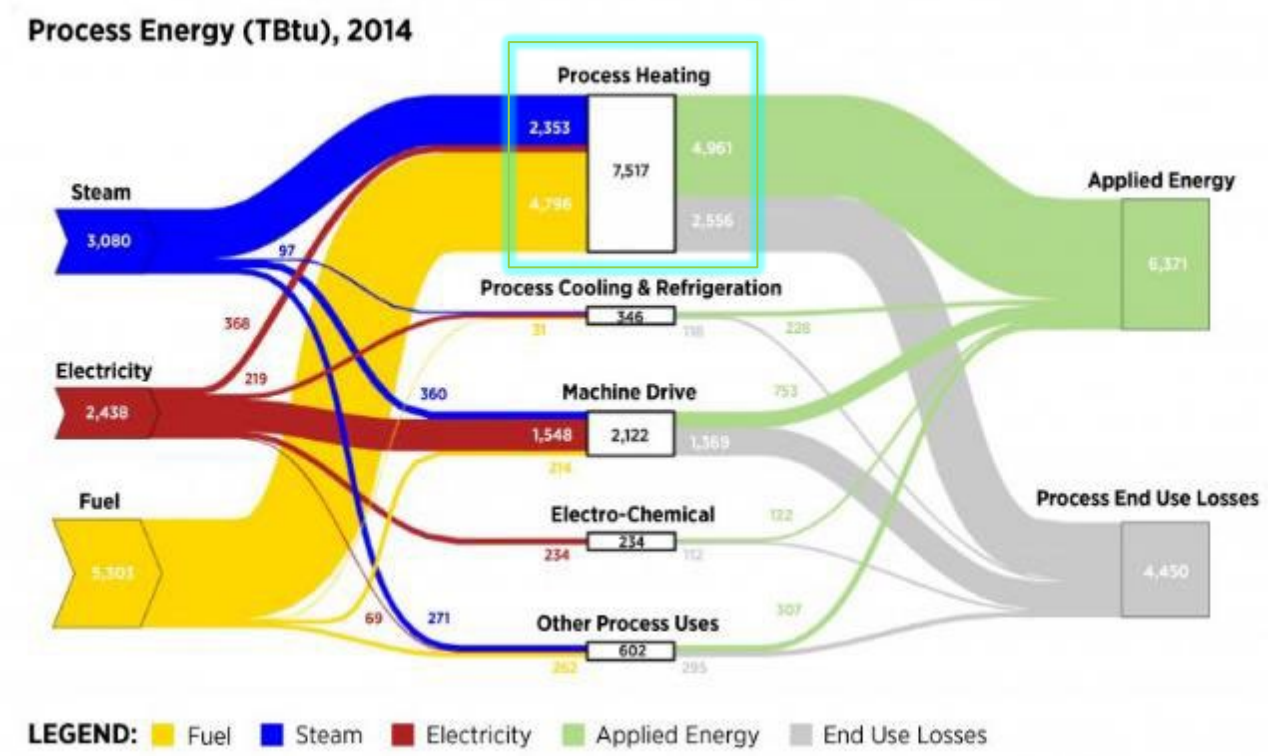




Heat Recovery HP/Chiller

Industrial Process Heating Uses Most Fossil Energy

- Total process heat (PH) energy use for U.S. manufacturing sector is 7,517 TBtu
  - Accounts for ~70% of the total process energy consumed in the manufacturing sector.
- Direct fossil fuel use for process heating is 4,796 TBtu/yr
- Direct and indirect (e.g., fuel used to generate steam) energy use for PH is 7,149 TBtu/yr
  - ~95% of all the process heating energy demand.
- About 35% of fossil energy is lost as waste heat

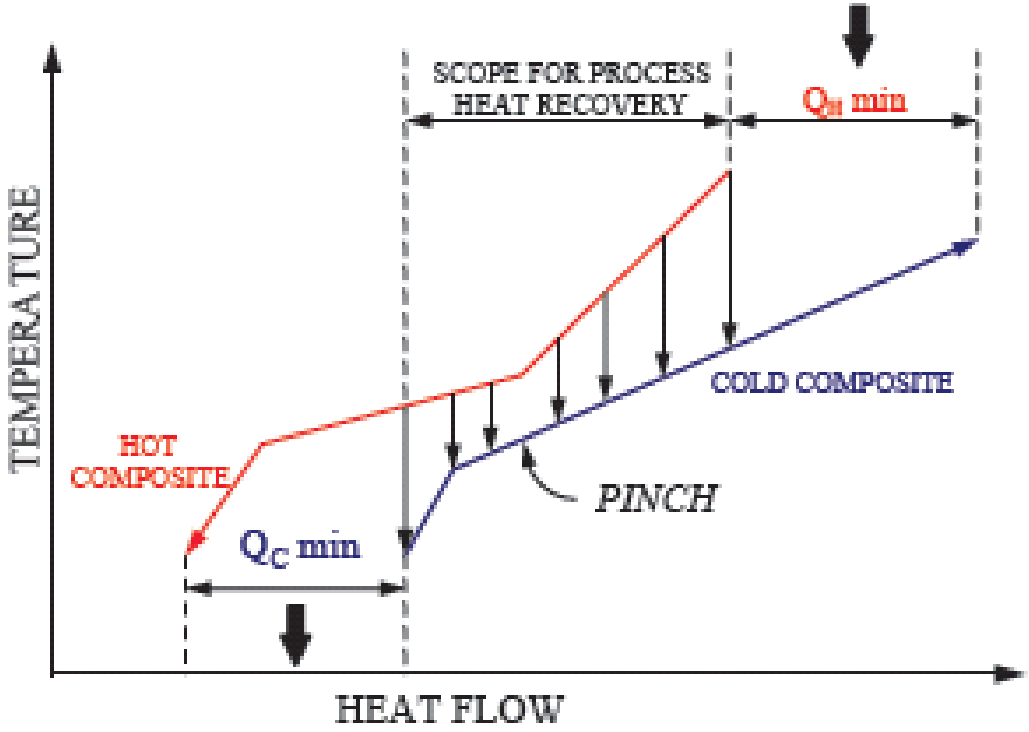


Source: https://www.energy.gov/eere/amo/static-sankey-diagram-process-energy-us-manufacturing-sector-2014-mecs

Only about 5% of energy used by Industrial Process Heating is Electric Energy

Pinch Analysis – Efficiency is the Lowest Hanging Fruit!

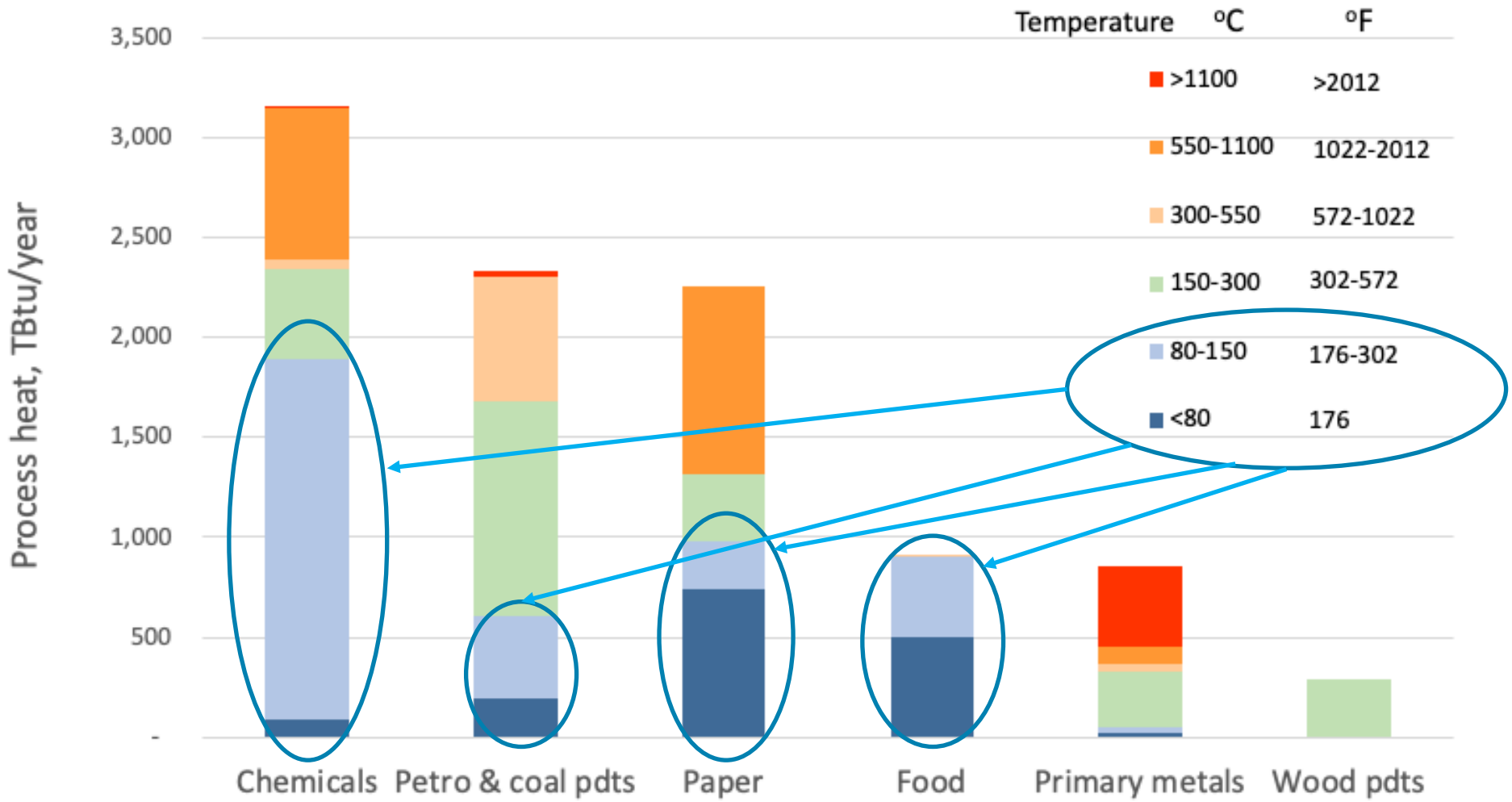
- Minimize heat loss by thermal energy optimization technique
- Matching hot streams with cold streams via optimum heat recovery
- Minimize reliance on external energy inputs
- Pinch temperature (where heating and cooling curves come close together) defines an industrial site's unique heat distribution
- **Pinch Analysis also provides amount of waste heat that can be recovered by Industrial Heat Pumps**



Source: EPRI Report CU-6775

EPRI and US DOE Championed "Pinch Technology" in 1990s

Significant Industrial Process Heat is Below 150°C



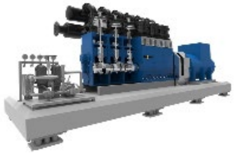
Data Source: McMillan 2019

Players in the Industrial Heat Pumps Space (1 of 3)

Source: Danish Technological Institute

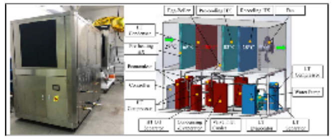
Players in the Industrial Heat Pumps Space (2 of 3)



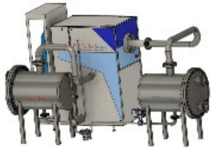





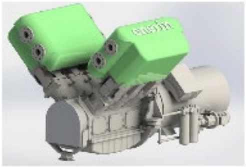
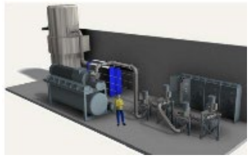
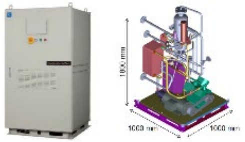




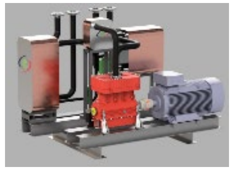


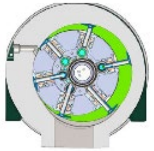






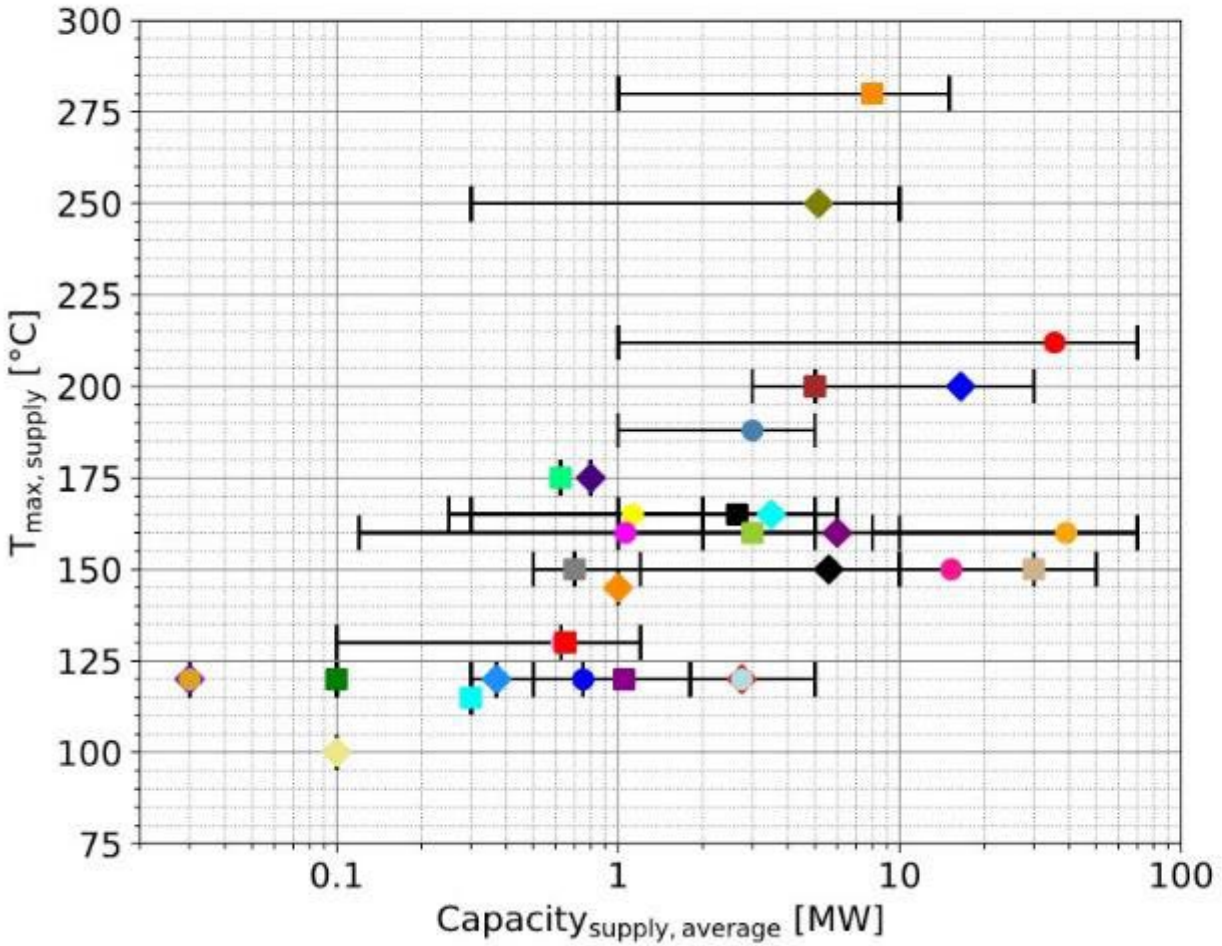




Source: Danish Technological Institute

EPRI

Players in the Industrial Heat Pumps Space (3 of 3)



Spilling	Ohmia Industry
Enerin	Epcon
Piller	MAN Energy Solutions
Olvondo	Mayekawa Europe (FC comp.)
Turboden	Mitsubishi
ToCircle	GEA Refrigeration Netherlands
Kobelco (SGH-165)	Fuji Electric
Kobelco (MSRC)	Emerson
SRM	Mayekawa (EcoSirocco)
SPH	Kobelco (SGH-120)
Heaten	Mayekawa Europe (HS comp.)
Rank	Fenagy
Weel & Sandvig	Hybrid Energy
Enertime	Johnson Controls
Siemens Energy	Skala Fabrikk
ecop	Mayekawa (EcoCircuit)

TRL level	4-9
Average specific cost	200 €/kW - 1500 €/kW
Capacity	0.03 MW - 70 MW
Max. supply temperature	100 °C - 280 °C
Availability	Geographical dependent, e.g. between Europe and Japan
Size of HTHP review	28 suppliers, 33 different technologies, and 83 performance use cases

Source: Danish Technological Institute

Electric Process Heating Technologies

Resistance | **Electro-Magnetic** | **Inert Gas**

Melting

Electric Arc Furnace

Resistance Melting

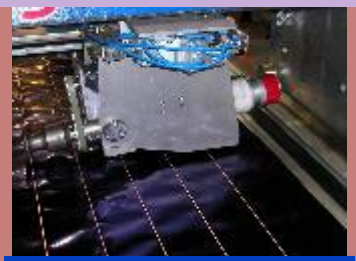
Induction Melting

Plasma Arc Melting

Heating

Convection Furnace

Radio Frq.



Ultrasonics

UV Curing

Induction Htg

Infrared Heating

Steam

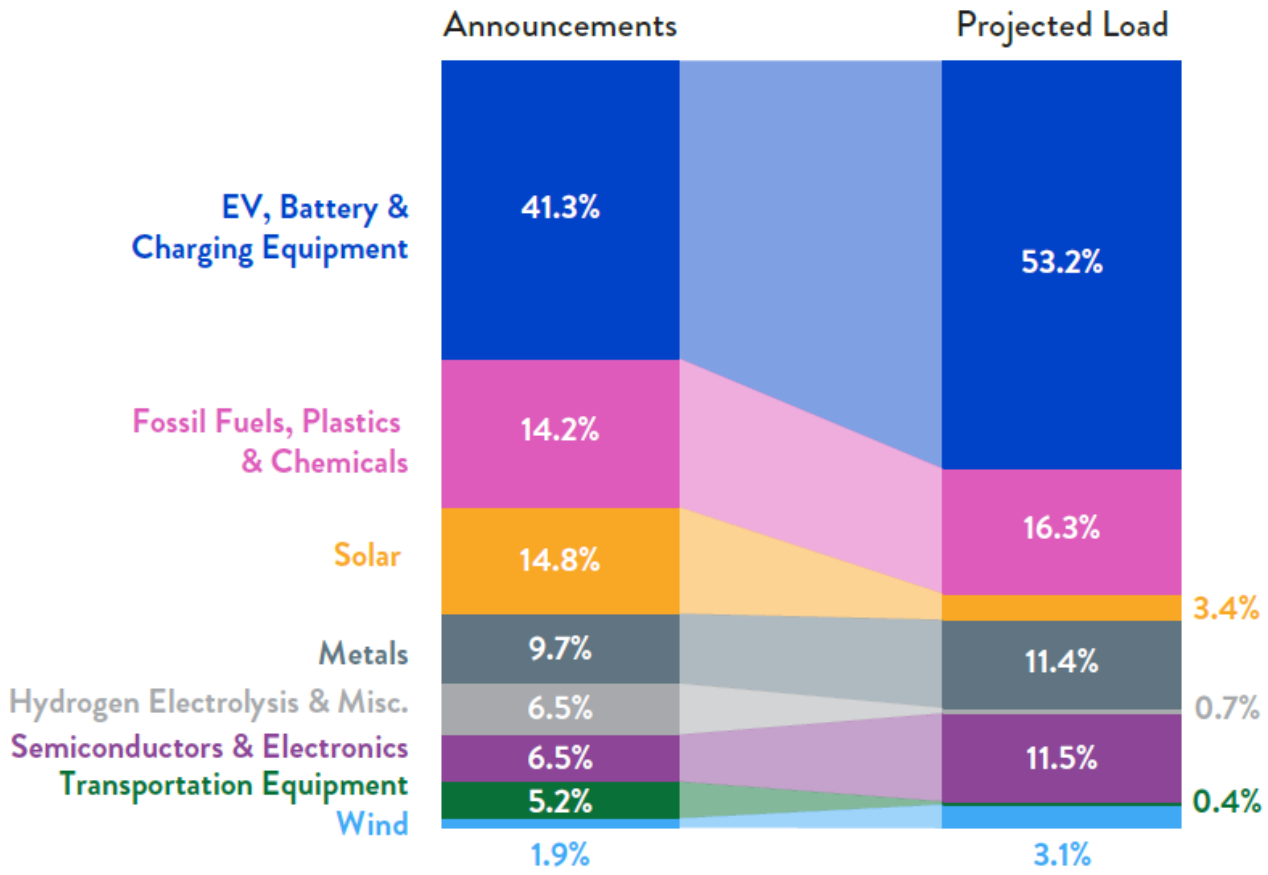
Electrode Boiler

MV Boiler

Heat Trace

Future Growth – Onshoring of Industrial Facilities

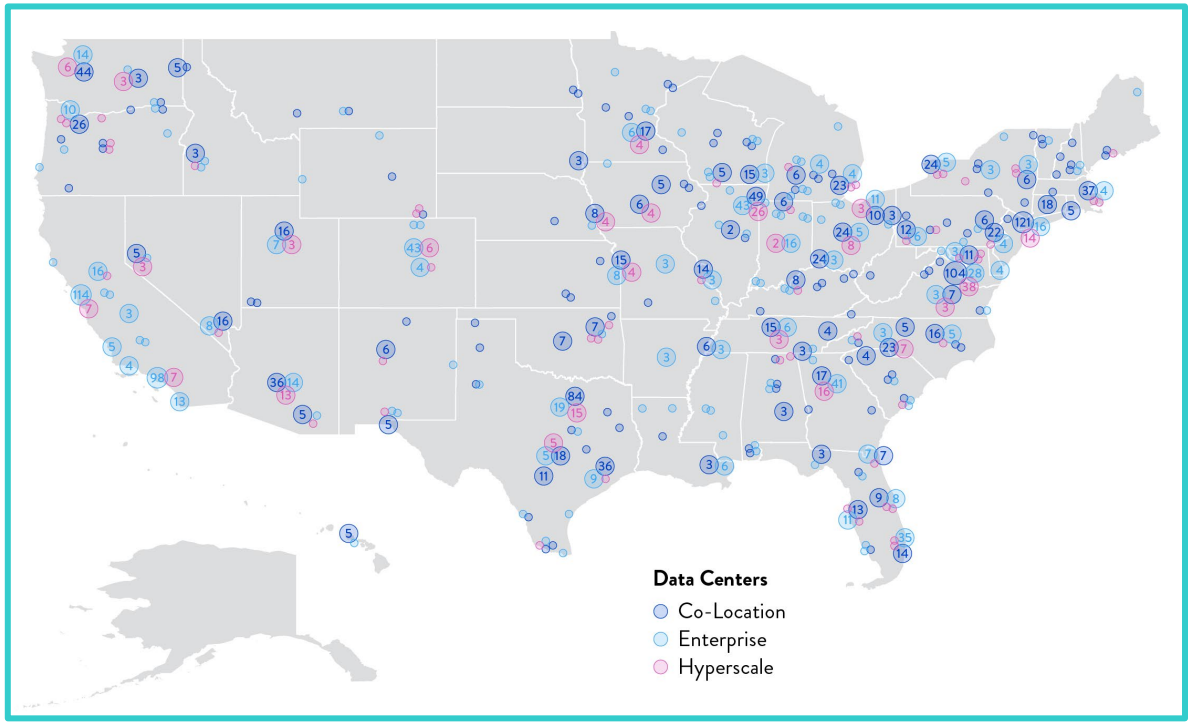
ONSHORING ANNOUNCEMENTS & PROJECTED LOAD BY SECTOR



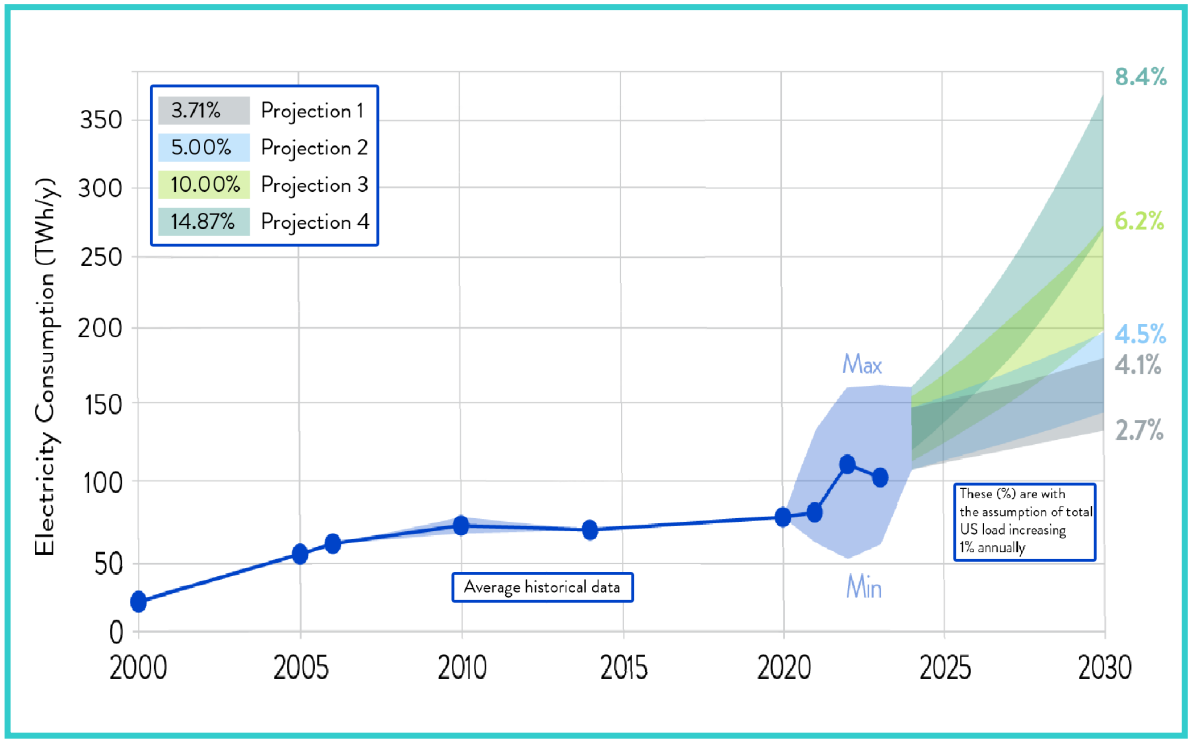
TOTAL	OPERATIONAL BY 2025
> 155 Facilities	> 100 Facilities
> 13,000 GWh/yr Annual Load	> 6,500 GWh/yr Annual Load
> 38 Facilities with Average Demand > 10 MW	> 25 Facilities with Average Demand > 10 MW

Future Growth – AI and Data Centers

Geospatial Trends in Data Center Distribution in the United States (2022)



Growth Projections



Summary

- Focus now is on “End-Use Decarbonization”
- Energy Efficiency and Efficient Electrification need to go Hand in Hand
- Good Progress in Residential and Commercial
- Industrial Decarbonization – Hard Nut to Crack
  - Onshoring (or Reshoring) is Happening
  - Load Growth is Forecasted

Thank You!

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