ET Summit 2023

Presented by

EMERGING TECHNOLOGIES COORDINATING COUNCIL

Decarbonization Technologies in Buildings, Transportation, and Industrial Sectors

An Overview

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EPRI

Outline

- About EPRI
- Decarbonization in Buildings
- Decarbonization in Transportation
- Decarbonization in Industry
- Summary

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EPRI…

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

Nonprofit
Chartered to serve the public benefit

Collaborative
Brings together scientists, engineers, academic researchers, industry experts

- Completed 50 years on April 5, 2022!
- 450+ participants in more than 30 countries
- EPRI members generate approximately 90% of the electricity in the United States
- International funding of nearly 25% of EPRI's research, development, and demonstrations

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At EPRI – Advanced Buildings & Communities Research is About…

Enhance knowledgebase

Quantifying Benefits of Building Decarbonization

De-risking the Scalability of Electrification

Inform Codes & Standards

Implications of Policy, Codes, and Building Performance Standards

Best Practices for Building-to-Grid Integration

Enable Technology Transfer

Insights on Enhanced Utility Customer Programs

Practical Pathways to Affordable Decarbonization

…..piloting building decarbonization methods at scale

EPRI Activities – Stages for Developing Advanced Buildings & Communities

1. Design and Application Services – "Plan It"

- Community planning
- Feasibility assessments
- Roadmapping support
- Advisory Group/Steering Committee support

2. Demonstration Activities with Utility Members – "Do It"

- Connected community demonstrations
- Building electrification demonstrations

3. Analyze Existing Utility Demonstration Activities – "Value and Scale It"

- Data analysis of existing demonstration projects
- Stakeholder workshops

4. Government Projects and RFP Responses – "Leverage It"

- Collaborate w/ members and stakeholders to leverage government funding
- Respond to member RFPs on the topic

Customer Demonstrations that Reimagine the Relationship Between Customers and Their Energy Providers in a Decarbonized Economy

- Customized scope w/ energy companies with combination(s) of work streams
- Collaborates with EPRI programs and initiatives
- Results sharing within the collaborative and through the program

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EVs2Scale™ 2030

EVs2Scale™ - A Major Initiative

Three-Pillar Strategy

1 COALITIONS & ROADMAPS

Bilateral Convening Series
- Utility-OEM Forum
- Utility-Fleet Forum

National EV Driver Research Board

50-state Roadmap to 2030 outlining EV loads, grid impacts, lead times, workforce, costs

2 STRUCTURAL SYSTEM REFORMS

Charging Infrastructure

- Reliability: Benchmarking, Standards
- Charging innovation & affordability

Grid Readiness

- Streamlined Grid Interconnect
- Managed Charging at Scale
- Interconnect Standards for V2H/V2B/V2G

3 UNIFYING TOOLS & PILOTS

- Approved Product List (APL)
- NEVI/NEHC Coordination with EEI
- GridFAST Online Data Exchange
- OEM/Utility V2H/V2B Pilot
- EV Resilience/Evacuation Pilot

Enabling Regulatory and Oversight Framework

Equity Blueprint & Workforce Development

EVs2Scale™ 2030 | Fleet Supplemental | ETIPS

2022 2023 2024 2025 2026 2027 2028 2029 **2030**

50% EV Sales

Utility Industry & EV Ecosystem

EVs2Scale 2030 - Multi-Industry Initiative

- Prepare the industry to achieve large-scale electrification by 2030

2030 Roadmap & Coalitions | *Structural System Reforms* | *Unifying Tools & Pilots*

INJECT MARKET ACCELERATING MECHANISMS

Utility Industry

Base Program

EPRI's Electric Transportation Program (P18)

- Strategic market and technology insights
- Research, development & demonstrations
- Member-specific application of RD&D

Base Program

EPRI Distribution Operations and Planning Program (P200)

EPRI Transmission Planning Program (P40)

ETIPS - Customized utility support

- Design "customer facing" EV infrastructure deployment programs

Joint Supplemental

Fleet Supplemental (MD/HD)

- Vehicle technology maturity, vehicle power and energy needs
- Available grid capacity on a distribution level

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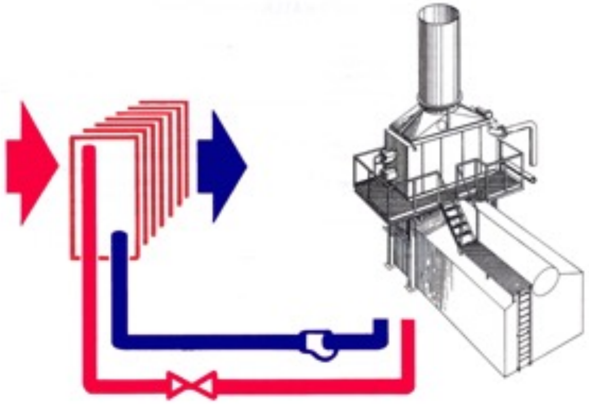
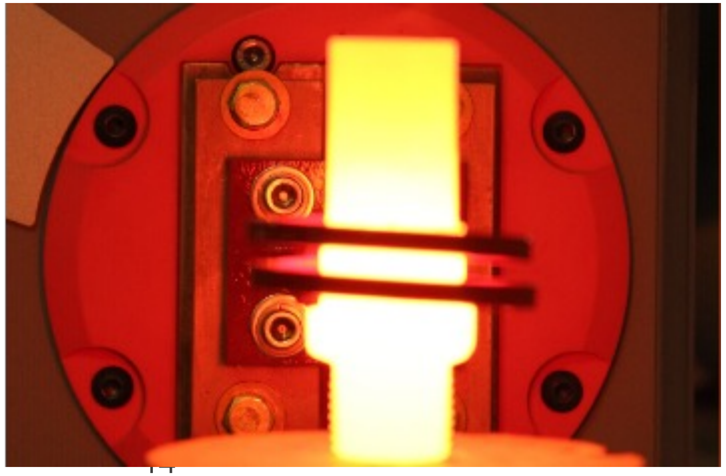
Opportunities for Decarbonization in Industry

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



EPRI's History in Industrial Heat Pumps

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Topics:
End use
Electrotechnology
Heat pumps
Technology utilization
Electrification
Industry

EPRI EM-6057
Project 2783-11
Final Report
October 1988

Industrial Heat Pump Manual

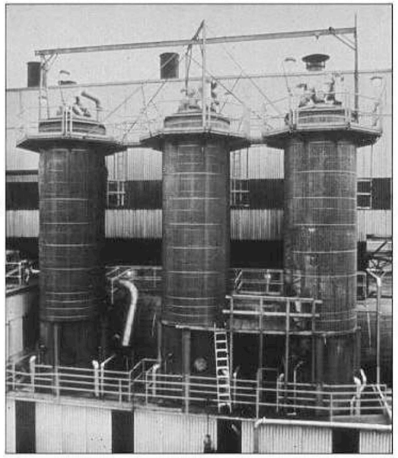
Technical and Applications Resource Guide for Electric Utilities

Prepared by
Linnhoff March, Inc.
Leesburg, Virginia

TECHCOMMENTARY

INDUSTRIAL HEAT PUMPS

Published by the EPRI Process Industry Coordination Office — Vol. 1, No. 4, 1988



An MVR heat pump conserves heat in this six-stage falling-film evaporator at a paper mill.

CAPTURING WASTED HEAT

There are often better ways to supply heat to industrial processes than burning fuel in steam boilers or process heaters. For many evaporation, distillation, and drying processes, industrial heat pumps represent a lower total energy cost alternative to fuel-consuming options.

For many industrial processes, energy costs represent over 25% of total manufacturing costs. Where applicable, industrial heat pumps can capture relatively low temperature waste heat and use a modest amount of mechanical energy to elevate the waste heat to a temperature that supplies process energy needs.

The unique heat recovery feature of heat pumps reduces energy costs for businesses such as

- Food processing
- Lumber drying
- Papermaking
- Chemical processing
- Petroleum refining.

Besides reducing costs, industrial heat pumps avoid gas discharge issues associated with direct fuel consumption.

ADVANTAGES

When properly applied and designed, heat pumps yield many benefits:

Lower energy costs — Heat pumps can substantially reduce energy costs, sometimes by 50% or more. Corresponding cooling requirements are also reduced, an important consideration when cooling water supply and treatment costs are high.

Reduced emissions— Unlike boilers and furnaces, electric-driven heat pumps do not produce pollutants. Installing heat pumps can help plants maintain or increase production capacity without violating ever-tightening restrictions on air and water emissions.

Increased capacity— Using a heat pump can overcome limitations in a plant's heating and cooling system. For example, using a heat pump may avoid the purchase of a steam boiler and cooling tower, which might have been required to evaporate and condense water in a product concentrator.

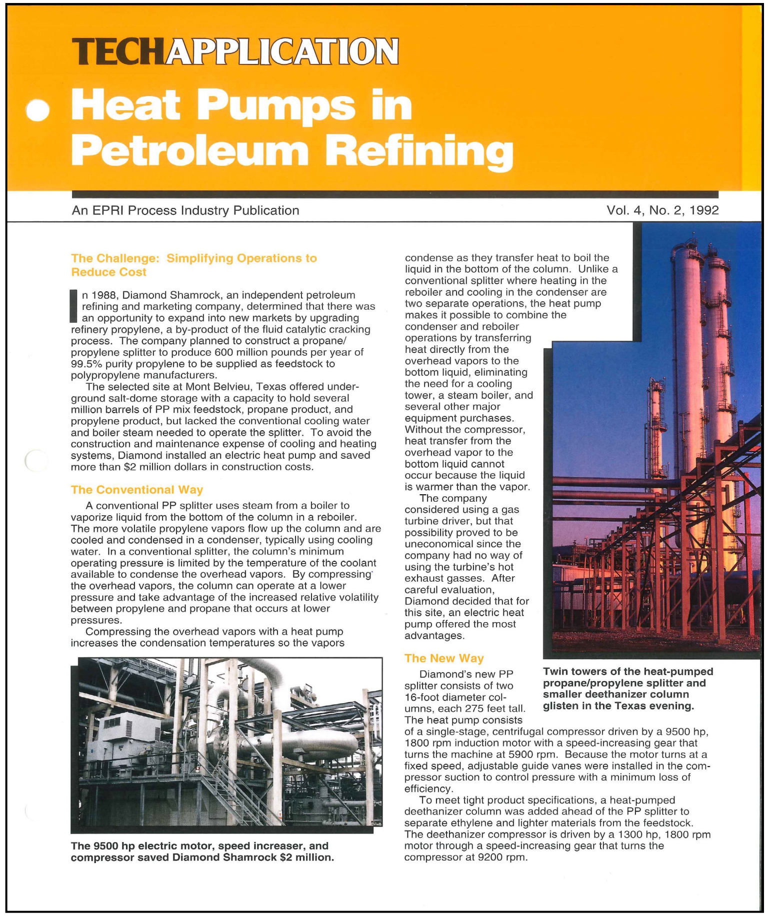
Improved product quality— Heat pumps generally provide heat at lower temperatures than other alternatives. As a result, heat-sensitive products avoid contact with localized hot spots, which degrade product properties and performance.

Less floor space— Heat pumps often require less space than competing energy supply systems. Heat pumps may be the solution to a tight layout design

TechCommentary / Vol. 1 / No. 41

Started in the 1980s!

EPRI’s History in Industrial Heat Pumps, Continued



TECHAPPLICATION

Heat Pumps in Petroleum Refining

An EPRI Process Industry Publication Vol. 4, No. 2, 1992

The Challenge: Simplifying Operations to Reduce Cost

In 1988, Diamond Shamrock, an independent petroleum refining and marketing company, determined that there was an opportunity to expand into new markets by upgrading refinery propylene, a by-product of the fluid catalytic cracking process. The company planned to construct a propane/propylene splitter to produce 600 million pounds per year of 99.5% purity propylene to be supplied as feedstock to polypropylene manufacturers.

The selected site at Mont Belvieu, Texas offered underground salt-dome storage with a capacity to hold several million barrels of PP mix feedstock, propane product, and propylene product, but lacked the conventional cooling water and boiler steam needed to operate the splitter. To avoid the construction and maintenance expense of cooling and heating systems, Diamond installed an electric heat pump and saved more than $2 million dollars in construction costs.

The Conventional Way

A conventional PP splitter uses steam from a boiler to vaporize liquid from the bottom of the column in a reboiler. The more volatile propylene vapors flow up the column and are cooled and condensed in a condenser, typically using cooling water. In a conventional splitter, the column's minimum operating pressure is limited by the temperature of the coolant available to condense the overhead vapors. By compressing the overhead vapors, the column can operate at a lower pressure and take advantage of the increased relative volatility between propylene and propane that occurs at lower pressures.

Compressing the overhead vapors with a heat pump increases the condensation temperatures so the vapors condense as they transfer heat to boil the liquid in the bottom of the column. Unlike a conventional splitter where heating in the reboiler and cooling in the condenser are two separate operations, the heat pump makes it possible to combine the condenser and reboiler operations by transferring heat directly from the overhead vapors to the bottom liquid, eliminating the need for a cooling tower, a steam boiler, and several other major equipment purchases. Without the compressor, heat transfer from the overhead vapor to the bottom liquid cannot occur because the liquid is warmer than the vapor.

The company considered using a gas turbine driver, but that possibility proved to be uneconomical since the company had no way of using the turbine's hot exhaust gasses. After careful evaluation, Diamond decided that for this site, an electric heat pump offered the most advantages.

Twin towers of the heat-pumped propane/propylene splitter and smaller deethanizer column glisten in the Texas evening.

The New Way

Diamond's new PP splitter consists of two 16-foot diameter columns, each 275 feet tall. The heat pump consists of a single-stage, centrifugal compressor driven by a 9500 hp, 1800 rpm induction motor with a speed-increasing gear that turns the machine at 5900 rpm. Because the motor turns at a fixed speed, adjustable guide vanes were installed in the compressor suction to control pressure with a minimum loss of efficiency.

To meet tight product specifications, a heat-pumped deethanizer column was added ahead of the PP splitter to separate ethylene and lighter materials from the feedstock. The deethanizer compressor is driven by a 1300 hp, 1800 rpm motor through a speed-increasing gear that turns the compressor at 9200 rpm.

The 9500 hp electric motor, speed increaser, and compressor saved Diamond Shamrock $2 million.

TECHAPPLICATION

Heat Pumps in Food Processing

An EPRI Process Industry Publication Vol. 3, No. 4, 1991

The Challenge: Evaporating Energy Costs and Milk

Galloway-West Co., Inc. of Fond du Lac, Wisconsin required an energy efficient and flexible method to condense whole milk, skim milk, and whey products for use in sweetened condensed milk, dry milk powders, and milk solids sold to other segments of the food industry. The company's two steam-powered evaporators were expensive to operate due to high fuel costs for the gas-fired boilers supplying the steam. The limited range of evaporating temperatures of the older units also strained Galloway-West's ability to produce dairy products requiring low or high processing temperatures.

Galloway-West overcame its production limitations by installing an energy-efficient mechanical vapor recompression (MVR) heat pump that increased production capacity and enabled the company to produce a wider range of products.

Galloway-West's MVR system with a turbofan reduced energy costs by 70%.

The Old Way

Galloway-West used a thermal vapor recompressor (TVR) system and a straight steam-driven evaporator with a combined throughput of 40,000 lbs/hr. The company considered upgrading its existing evaporators, but the older technology would not be as successful in the production of specialty milk products and a gas-based system would still be expensive to operate and vulnerable to fluctuating fuel prices. However, the operating cost of an electric-based system promised to be more predictable and less expensive.

The New Way

In mid-December 1990, Galloway-West started up its new MVR falling-film evaporator and began saving energy right away.

The new evaporator is a two-effect, multi-pass, semi-open heat pump driven by a 600 hp motor with a variable speed drive coupled to a turbofan. Since most of the energy used by the unit is electrical, the company reduces production costs by running the unit "off-peak" much of the time.

The MVR heat pump compresses the low-pressure water vapor removed from the evaporating milk products to a higher pressure, increasing the vapor's temperature. The hot compressed steam is then used to further evaporate the milk. The product makes multiple passes through the unit, becoming more and more concentrated. A new TVR finisher is used to boost concentrate levels on some products. As part of the MVR's heat-exchange design, cold incoming milk is pre-warmed as it cools the condensed product and condenses the steam.

The MVR heat pump in conjunction with a heat treatment system ahead of the MVR provides a greater range of heat treatments, so Galloway-West can more easily produce the products its customers want.

The new system lets operators adjust the turbofan's speed and use a variety of heat treatments.

The Results: Much More For Much Less

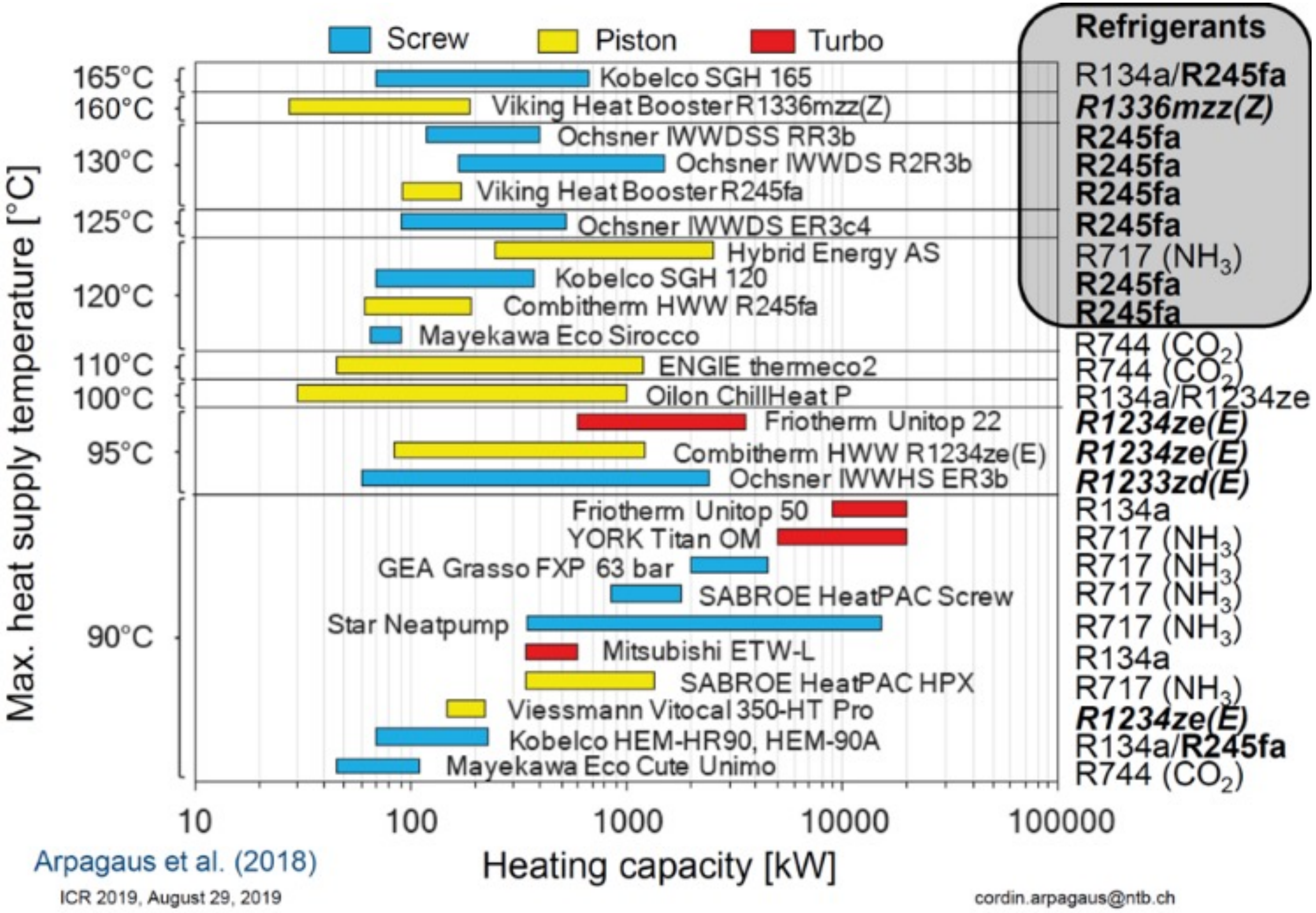
By switching to the MVR evaporator, Galloway-West saves energy and labor while increasing revenues.

Energy Savings: Using the MVR, Galloway-West saves 70% of its previous energy expense. The unit operates at a rate of $0.46 for every 1000 lbs of water removed, compared to the old system's rate of $1.56. An annual energy savings of $263,000 is projected from having replaced gas with electric power and utilizing its economical off-peak rates.

The evaporation process itself accounts for 92% of the savings, while 4% is due to the system's design for preheating and cooling product and for condensing steam. The rest of the savings results from the MVR's 50% turndown that allows the product to run directly to the dryers, avoiding cooling costs during storage and subsequent reheating.

Documented in early 1990s

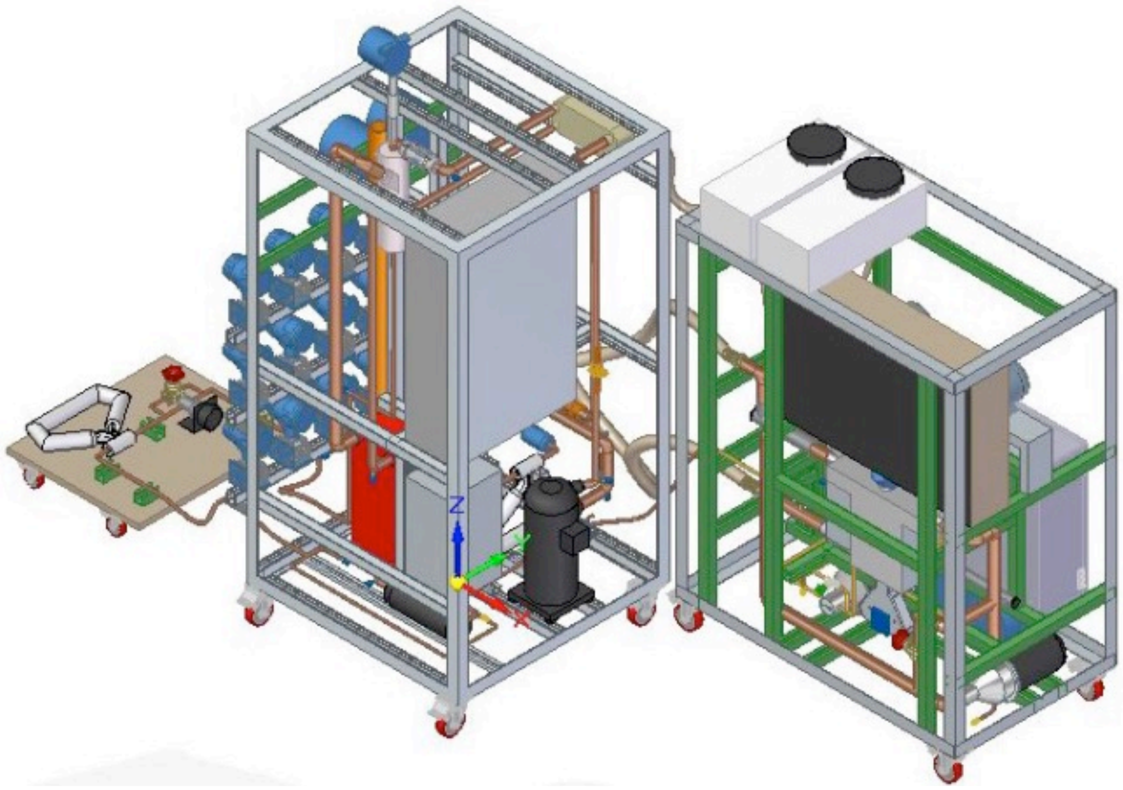
Industrial HPs in Development Around the World



Photos: Courtesy of Danish Technological Institute

Current CEC-funded Project: High-Temperature Heat Pump That Can Produce Steam at Low Pressure

- Key characteristics of the heat pumps:
  - 30 kW prototype system
  - Low-ODP, GWP refrigerant
  - Develop prototype system produce steam at 120^{o}C from waste heat (80^{o}C) @ COP of 3.4
  - Test in a lab in California; make it ready for field deployment
  - Offer solutions for industrial decarbonization in California and Nation



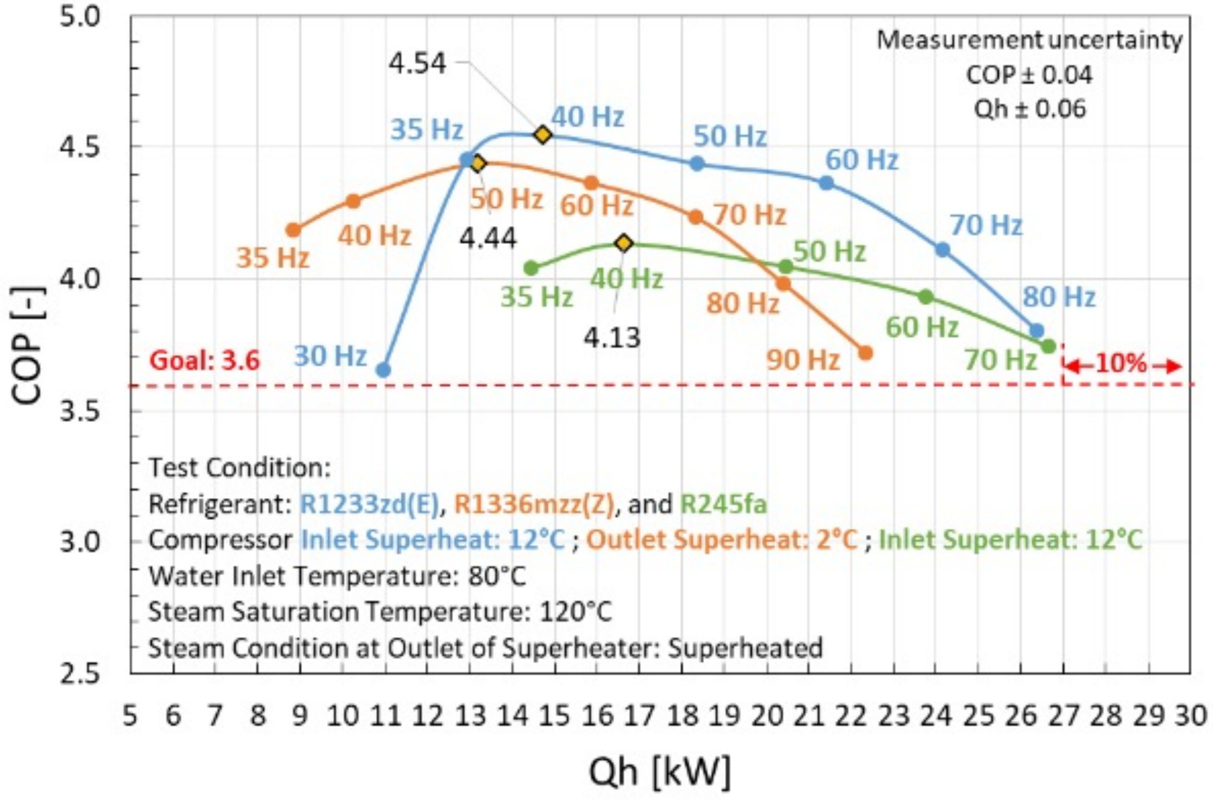
Project funded by the CEC EPIC Program – Ongoing

Photos of the 30kW Prototype System

Prototype Testing Results

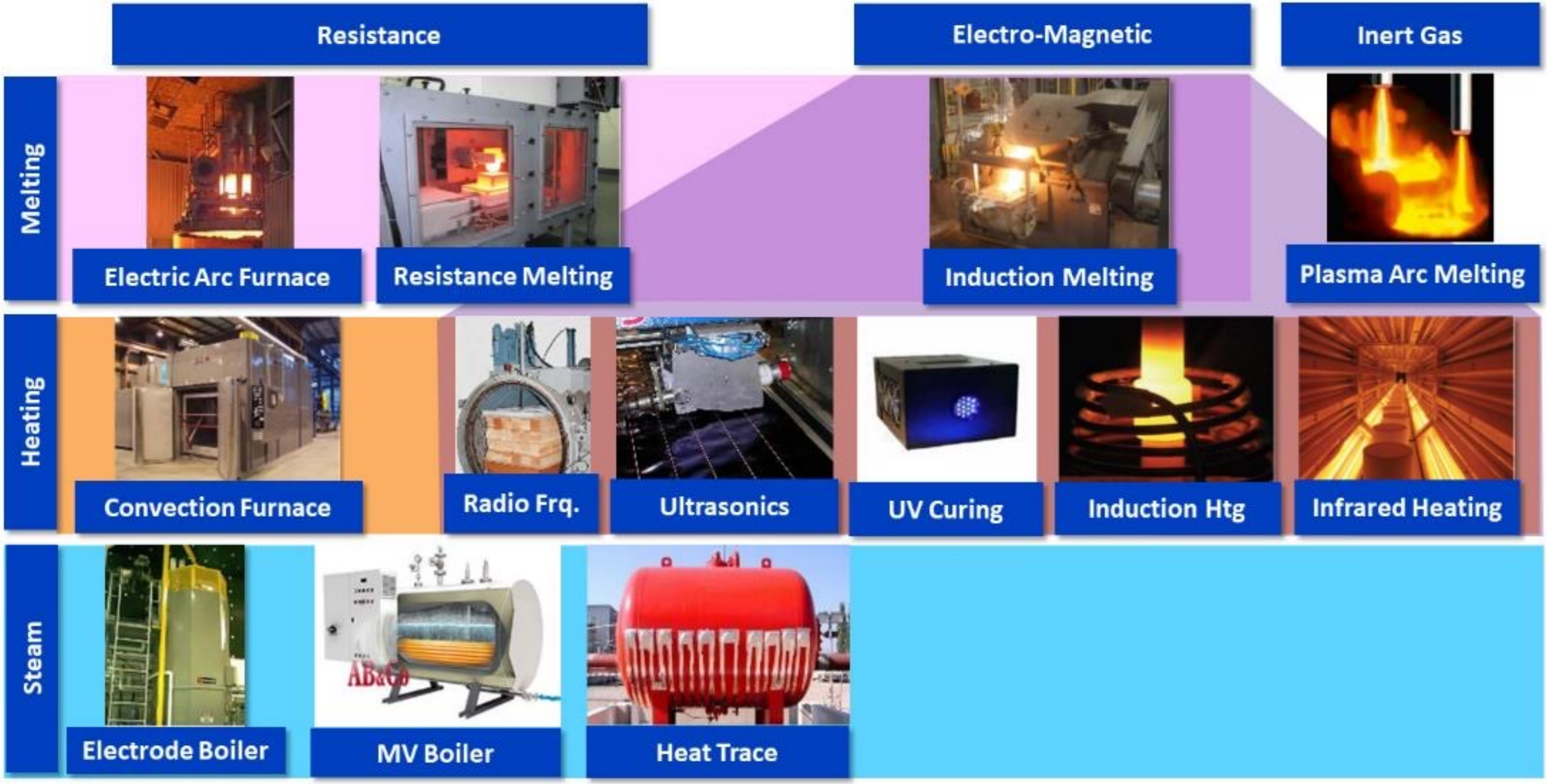
Key findings from the tests:

- Coefficient of Performance (COP) has an inverse relation with system speed, a direct indicator of system load
- Higher load (capacity) or compressor speed results in lower COP values
- Two refrigerants performed the best
  - R1233zd[E]: Higher COP, but has ODP
  - R1336mzz[Z]: Lower COP, no ODP
  - System should be optimized to obtain the target COP>3.4 or greater



Next Steps – EPRI Lab Tests + Field Tests

Electric Process Heating Technologies



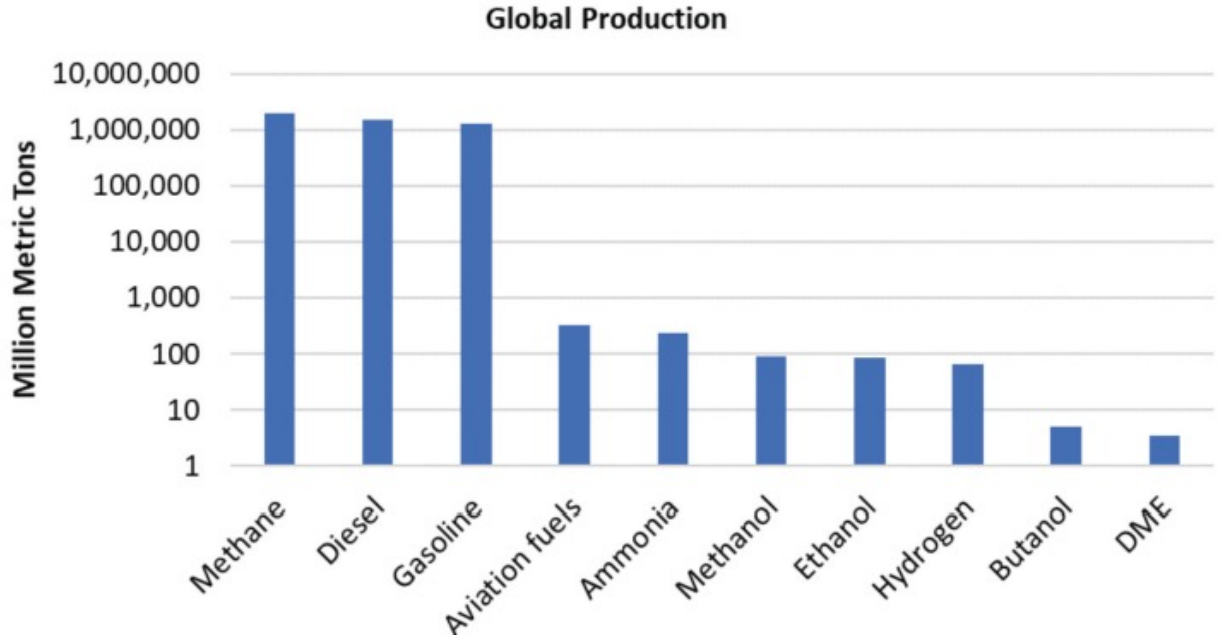
Low Carbon Resources – Alternative Energy Carriers

AECs: Molecules created from conversion of other energy sources to more easily transport and/or store energy

Hydrogen → Ammonia → Biofuels → Synthetic fuels → More

Can be created using low-carbon resources

- Low-carbon electricity
- Fossil fuel feedstock with CCS
- Biological resources



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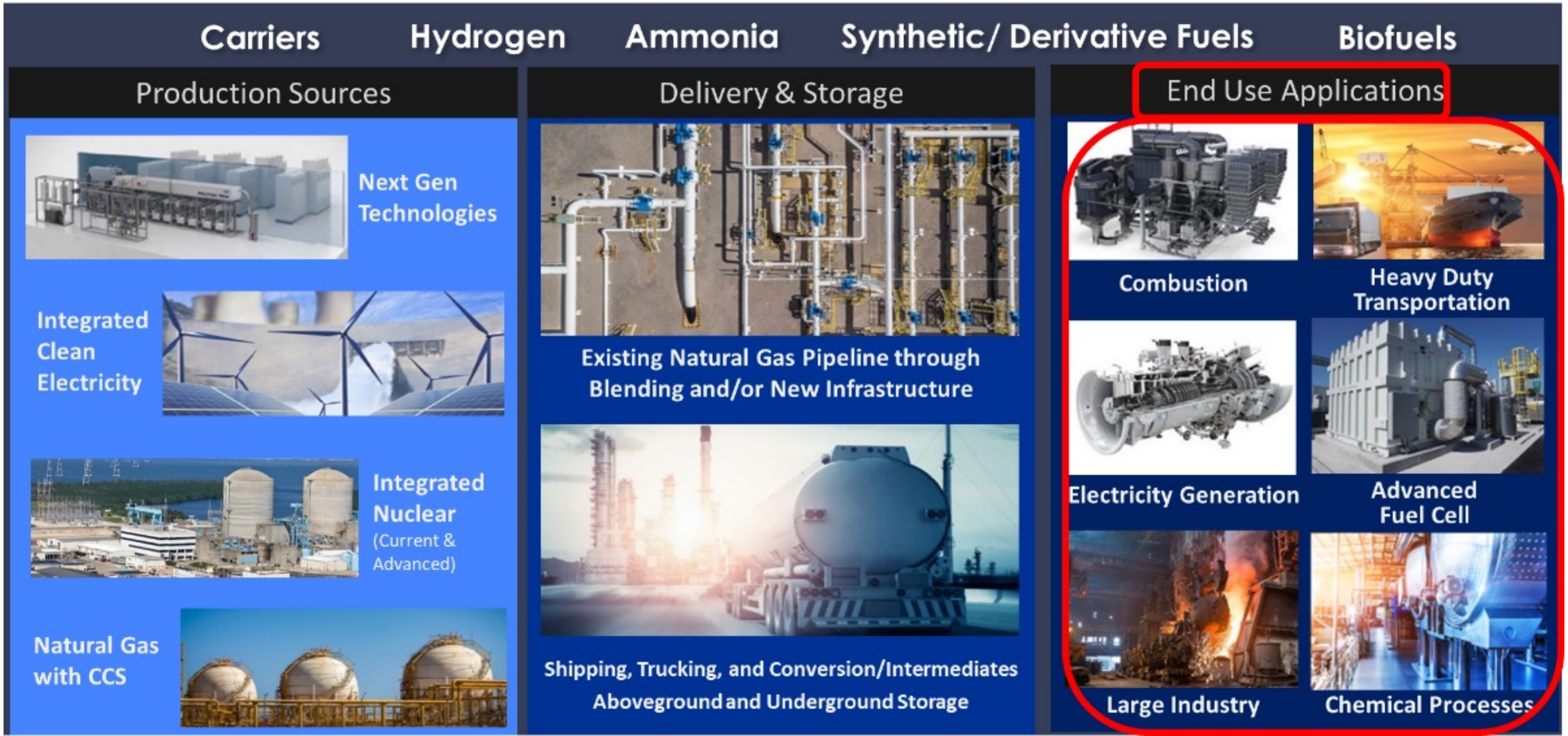
Solutions to address hard-to-decarbonize sectors & achieve deep decarbonization

EPRI's LCRI – Low Carbon Fuels for End-use Applications



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- Robust R&D collaboration in decarbonization of all sectors.
- Buildings – Easier to decarbonize. Technologies available.
- Transportation – Many activities in California and around the country.
- Industry – Hardest to decarbonize. Several RD&D activities underway.

Thank you!

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