Industrial heat pumps: electrifying process heat supply in the United States through technology demonstration and market transformation actions

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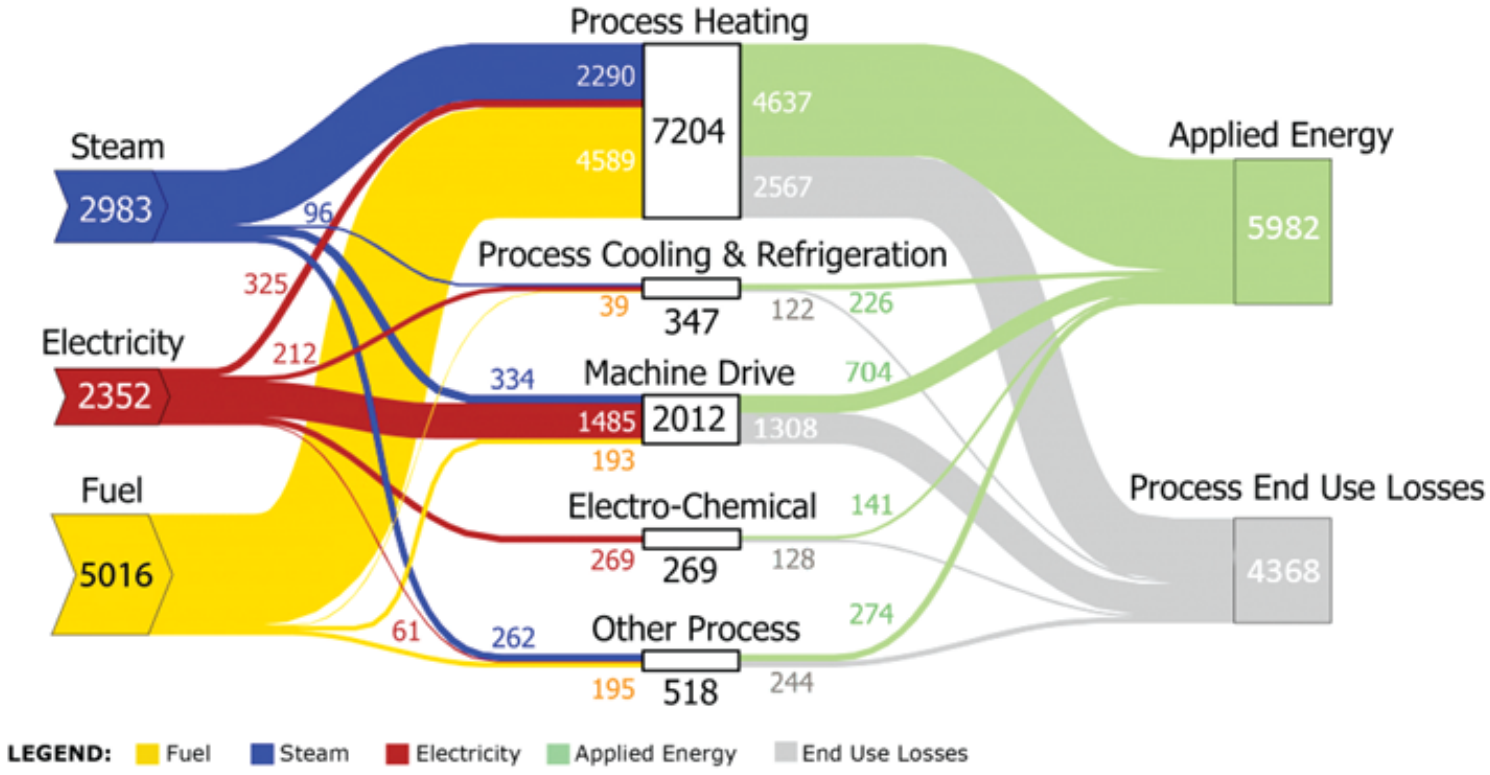
IHPs Have the Potential to Help Decarbonize Industry by Electrifying Industrial Process Heat

ACEEE research has found that IHPs in key sectors can create:

- Net energy savings 26-32% (427-518 TBtus/year)
- CO_2 savings 30-43 million metric tons/year

- IHP Sales opportunity: **~$17 billion** capital investment, over $5.6 billion/year energy cost savings



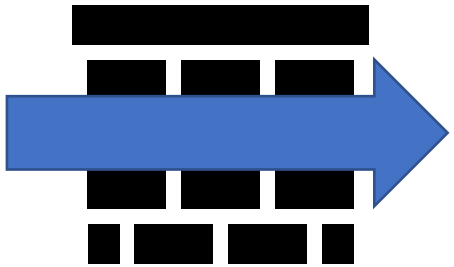
Catalyzing the United States IHP Market

Stakeholder Type	Entity	Collaboratives & Programs
End users	Individual Companies	Renewable Thermal Collaborative
Industrial Heat Pump Suppliers	Individual OEM suppliers	Nat. Electrical Manufacturer Assoc., Amer. Heating & Refrig. Inst.
Utilities	Individual Utilities, Energy Efficiency Program Administrators, State utility commissions	EPRI, NARUC
Government and Research Organizations	U.S. Department of Energy, State energy agencies, National Labs, Universities	DOE Technical Assistance Partnerships & Industrial Assessment Centers
NGOs and Trade/Technical Assoc.	ACEEE, Amer. Chemistry Council, Amer. Forest & Paper Assoc., regional Food Assoc.	-
Energy Engineering	Engineering firms and IHP System Installers	Assoc. of Energy Engineers

Transforming the Industrial Process Heat Market

Current US IHP Situation

- End-users have process heat needs that can be met with available IHP tech
- There is limited commercial availability of IHPs in the U.S.
- The U.S. has fallen behind the EU, Japan, AU, others in IHPs, industrial electrification at large

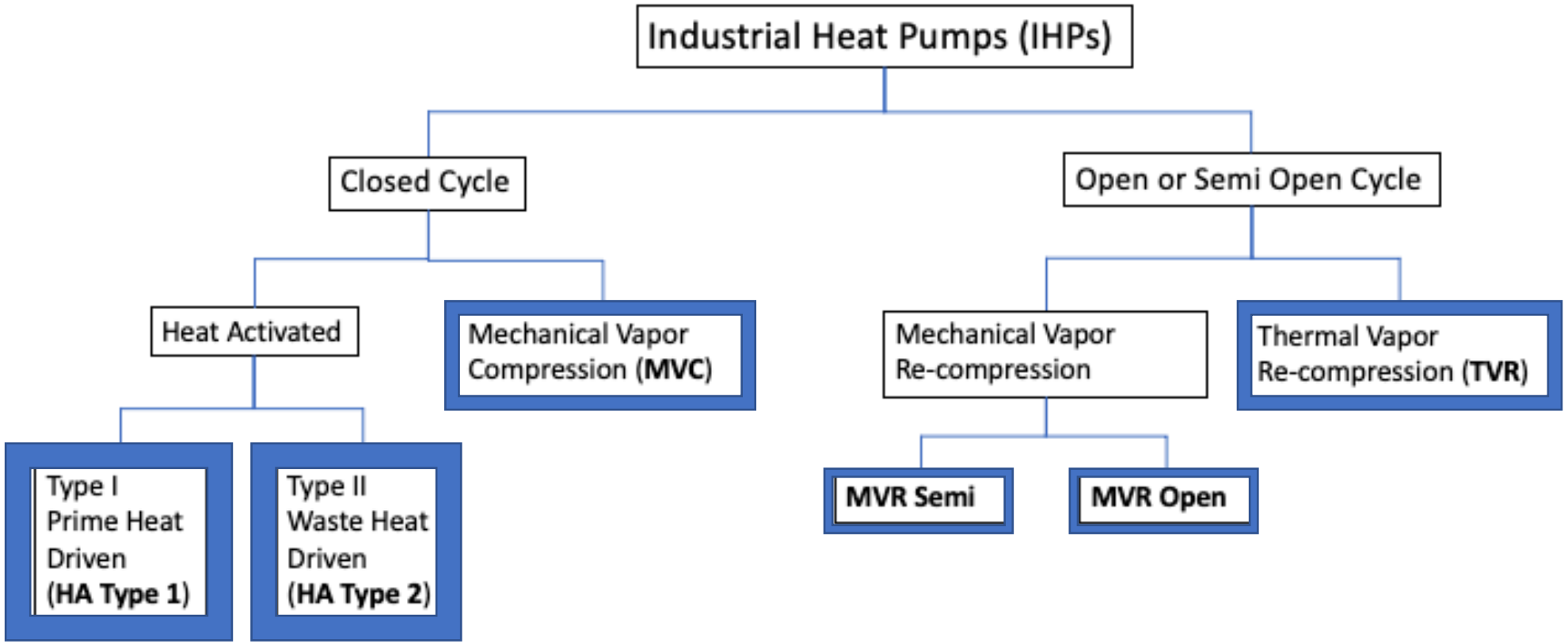


Current Barriers

Where We Want to Go

- *IHPs widely recognized as clean, economic pathway to decarbonize U.S. industry*
- Robust domestic IHP supply chain supported by capable workforce
- Decarbonization of process heat integrated with other solutions (i.e., thermal storage, renewables)

Six Different IHP types Considered in Study



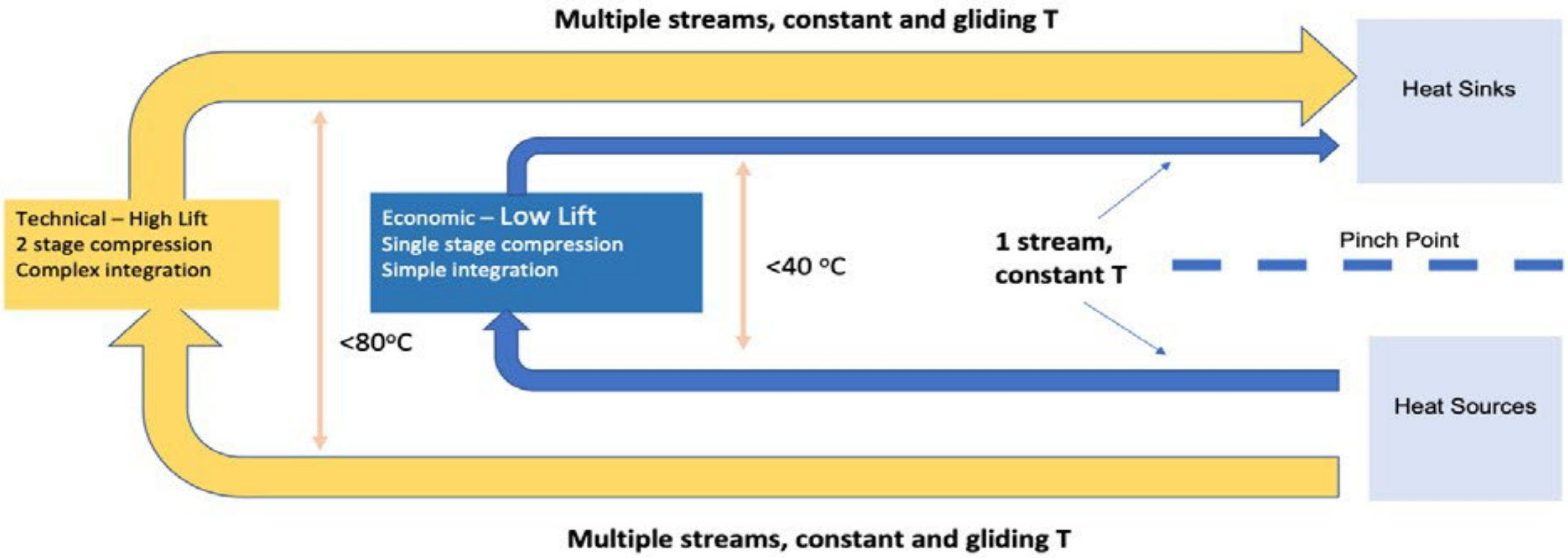
Pinch Analysis Found Optimal IHP Placement

- Data from 140 Processes from prior research (Chalmers ETA)
- For 9 selected processes found optimal location/size of Industrial Heat Pump for each process
- Used actual industrial heat and cooling stream process data
  - mass flow rate,
  - specific heat
  - Enthalpy change, temperature increase or decrease
- Each of 6 IHP types placed and sized at optimum process location

Industrial Groups & Unit Operations Analyzed

Industrial Group	Unit Operation
Paper	Pulp mill – digestor Pulp mill – multi-effect evaporator Non-integrated paper mill – pulper
Food Processing	Wet corn milling – steepwater – high fructose corn syrup starch conversion Potato processing – hot air dryer
Chemicals	Ethylene (above ambient) – process water stripper reboiler – debutanizer Ethanol fuel, dry mill

Economic and Technical IHP Potential



Heat Pump Analytical Methodology

Sector Process Analysis

Overall U.S. sector production (tons product/yr)

Sector total process heat demand (GJ/yr)

Process heat unit operation hot utility targetable by IHP (GJ/ton)

Pinch and Heat Pump Analysis

Pinch analysis of heating and cooling streams to identify streams (source/sink) for heat pumping

Calculate heat pump energy savings for 6 different IHP types

Calculate heat pump energy savings on unit operation (site and source)

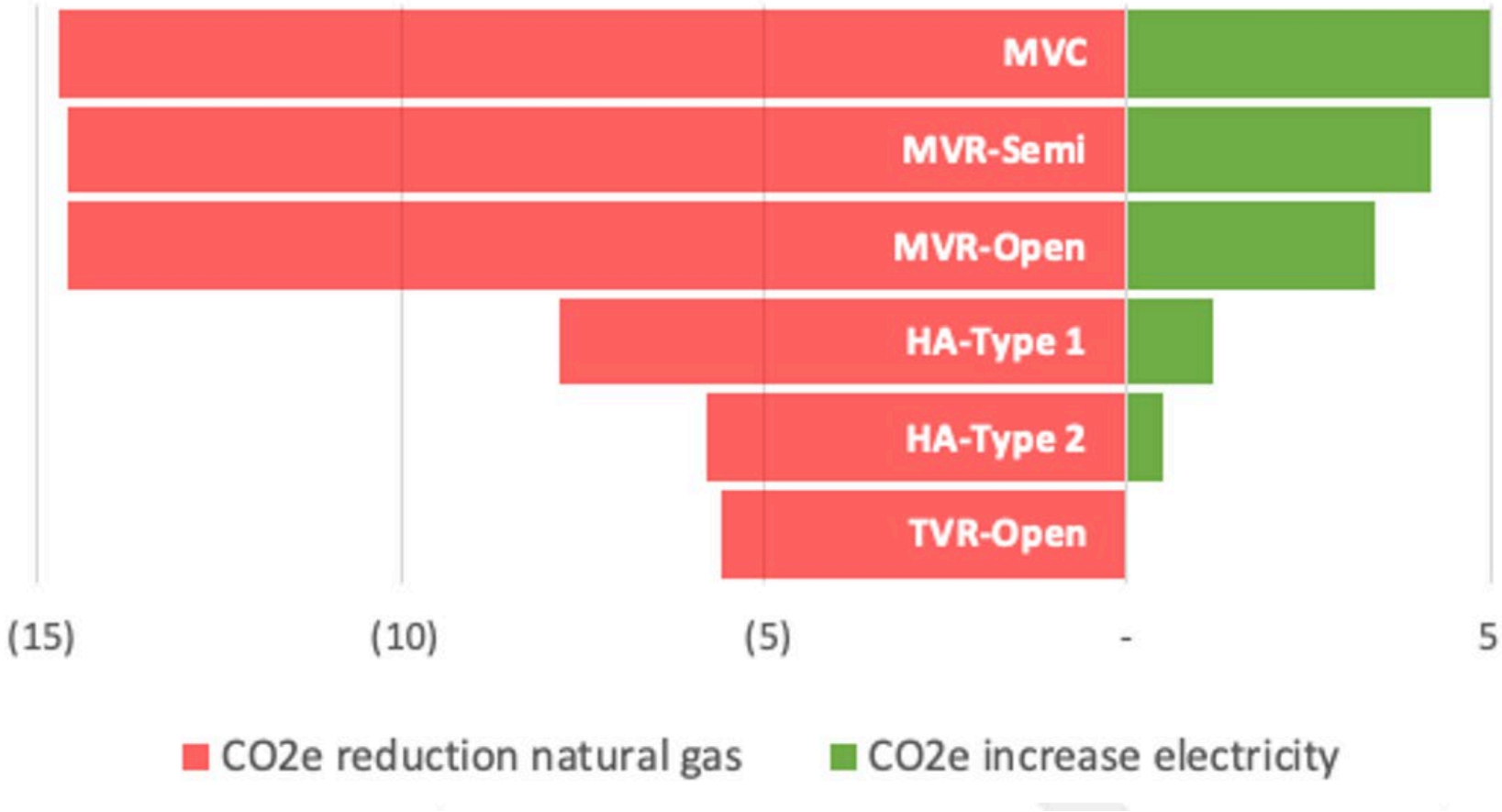
Sector Process Analysis

Apply heat pump savings for 6 IHP types across all sector facilities

Calculate overall sector site and source energy savings

Calculate overall sector carbon emission reductions

Changes in CO_2e across all nine unit operations, Economic case, MMT CO_2e/year.



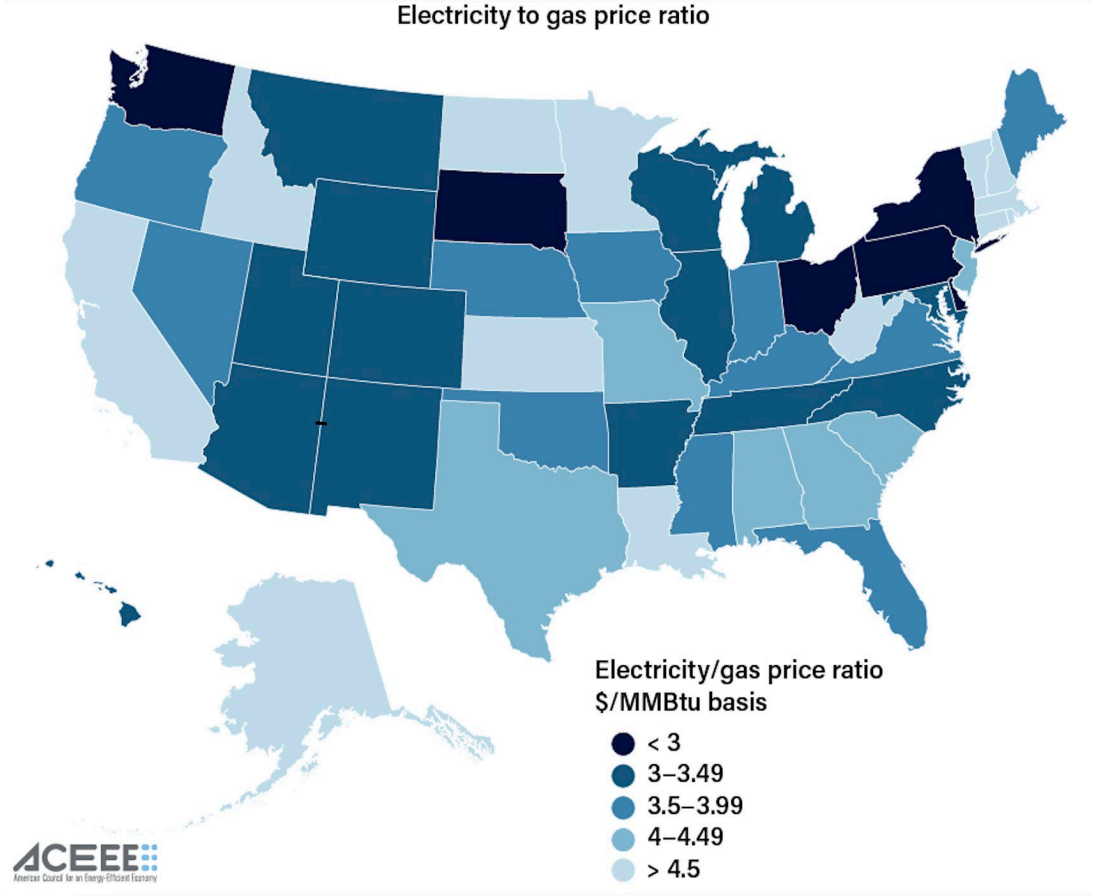
Results - U.S. Food, Paper and Chemical Sectors

- IHPs typically able to save 10 to 30%
- Vapor compression type IHPs natural gas savings were typically 2.7 to 3.7X the increases in electricity use
- Simple paybacks for the compression type IHPs were near or under 3 years for favorable economic conditions
- **IHPs in Food, Paper & Chemicals sectors could reduce natural gas use by 12 - 15% and reduce CO2 by 4 - 5%**

Unit Operations	Food	Paper	Chemicals	Total
Natural Gas Savings (PJ/year)	6-21.1	36.3-134.1	267	309.3-422
Electricity demand increase, MW	32.9-144.2	171.2-770.6	1,209.5	1,413.6-2,124
Heat pump output, MW	152.6-535.3	921.9-3,402.8	6,773.1	7,847.6-10,711
CO_{2e} savings (long term) MT/year	0.3-0.9	1.6-5.7	11.6	13.4-18.2

Sector-wide Projections	Food	Paper	Chemicals	Total
Natural Gas Savings (PJ/year)	21.1-76	50.6-188.8	721.6	793.4-986.4
Electricity demand increase, MW	115.3-519.2	238.6-1,084.9	3,269.3	3,625.7-4,964.9
Heat pump output, MW	535.3-1,927.1	1,284.7-4,791	18,307.7	20,127.7-25,037
CO2e savings, long term MT/year	1.1-3.2	2.2-8.0	31.4	34.4-42.5

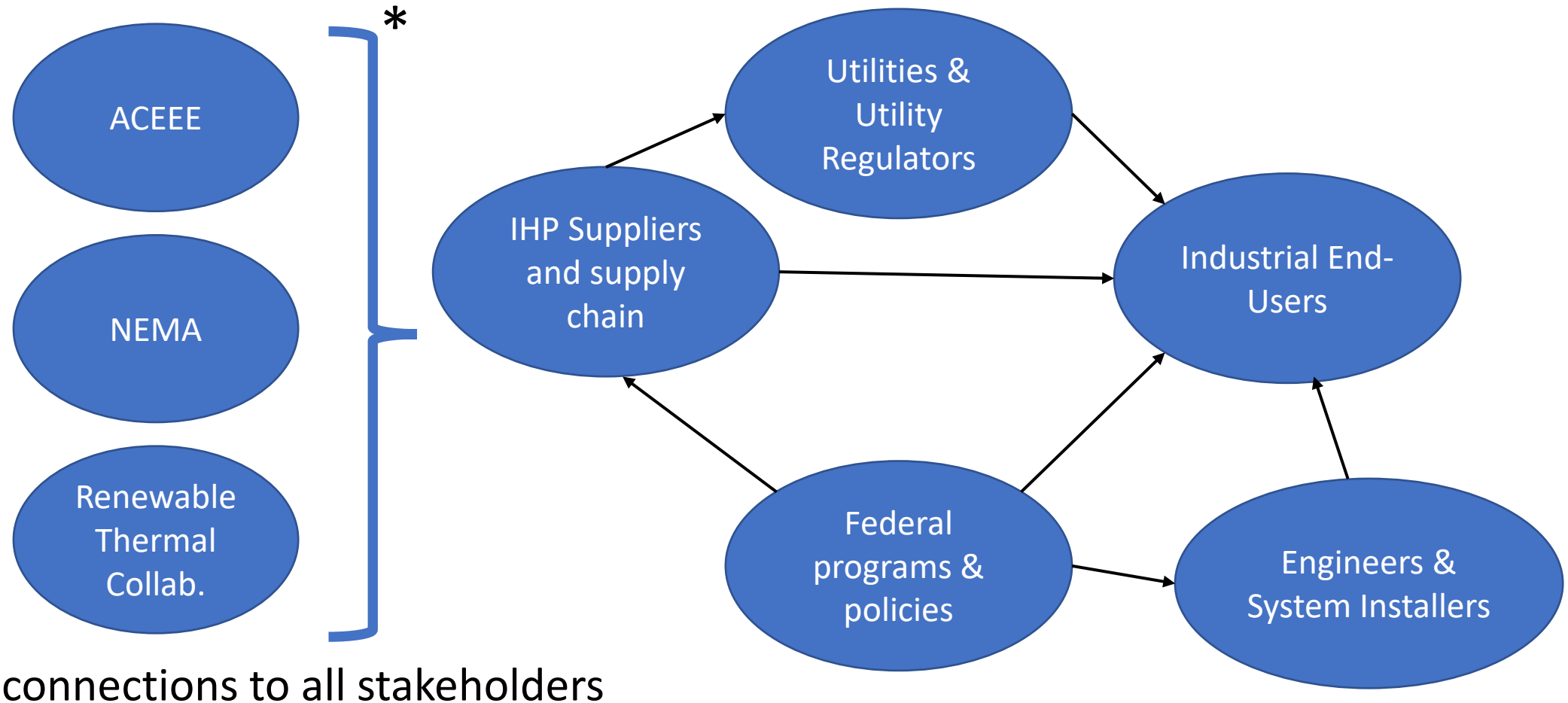
IHP Economics Varies by state



U.S. Barriers to IHP Adoption

- *Limited product availability in North America*
- *Limited knowledge by industrial decision-makers and engineers*
- *Economic challenges: Unfavorable spark spread and high CAPEX*
- *Access to trained service and maintenance staff and parts*
- *Electrical service capacity increase limitations*
- *Equipment certification*

Important Stakeholder Interconnections in the IHP Value Chain



* connections to all stakeholders

Conclusions – Strategy Moving Forward

- IHP impact potential is large (517 Petajoules/yr, 42 MM CO2e impact by 2040)

- IHPs a key route for companies to realize GHG impact AND route to electrification (low-medium temperature heat)

- To achieve impact market transformation is needed:
  - Scale-up domestic IHP manufacturing to increase availability of equipment
  - Collaborate (utilities, regulators, agencies…) to foster IHP adoption
  - Demonstrate IHPs across range of applications leveraging Federal and state incentives
  - Information, tools, education & workforce development
  - Enable adoption (incentives, address spark spread)