Industrial Processes Emissions Reduction (IPER) Technology Workshop – SwRI

Industrial Decarbonization

April 5, 2022

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EPRI Overview

Introduction to EPRI

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

BORN IN A BLACKOUT

Founded in 1972 as an independent, nonprofit center for public interest energy and environmental research

New York City, The Great Northeast Blackout, 1965

EPRI'S VALUE

To provide value to the public, our members, and the electricity sector

THOUGHT LEADERSHIP

INDUSTRY EXPERTISE

COLLABORATIVE MODEL

OUR MEMBERS...

- 450+ participants in more than 30 countries
- EPRI members generate approximately 90% of the electricity in the United States
- International funding – nearly 25% of EPRI's research, development, and demonstrations
- $415M Annual Funding

EPRI's Mission

Advance innovative solutions to make power systems more *flexible, resilient and connected,* to provide society with *safe, reliable, affordable, and environmentally responsible electricity*

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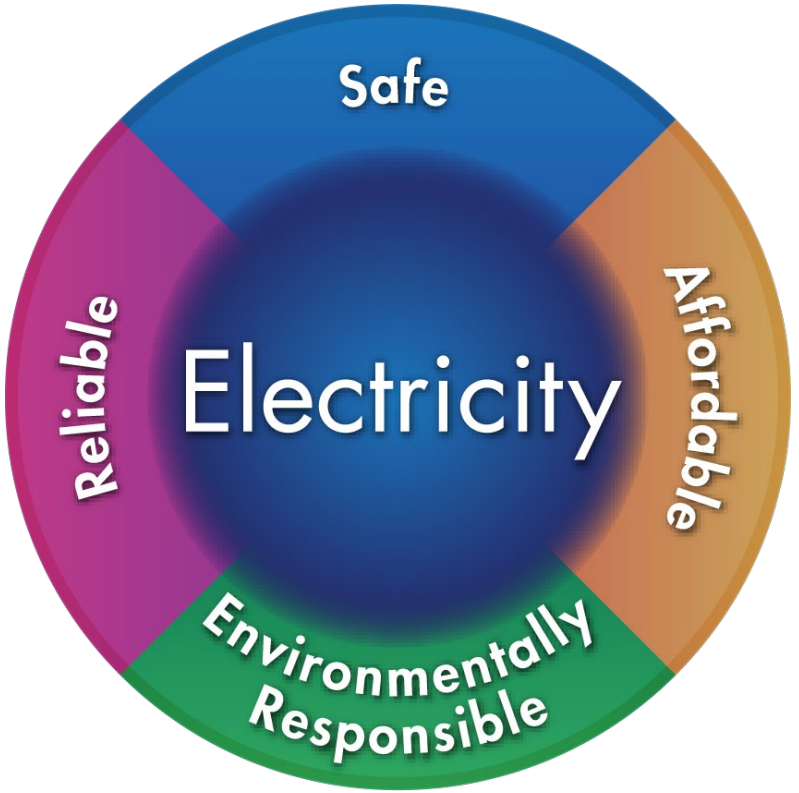
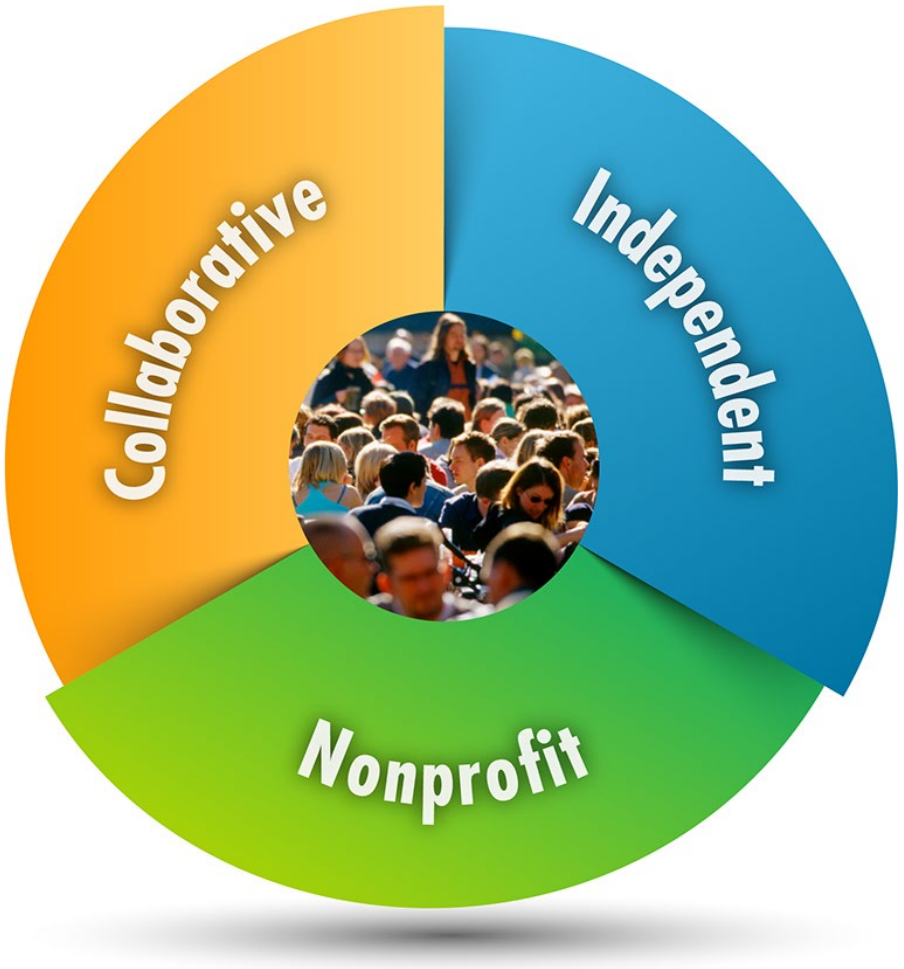


Three Key Aspects of EPRI



Independent

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

Nonprofit

Chartered to serve the public benefit

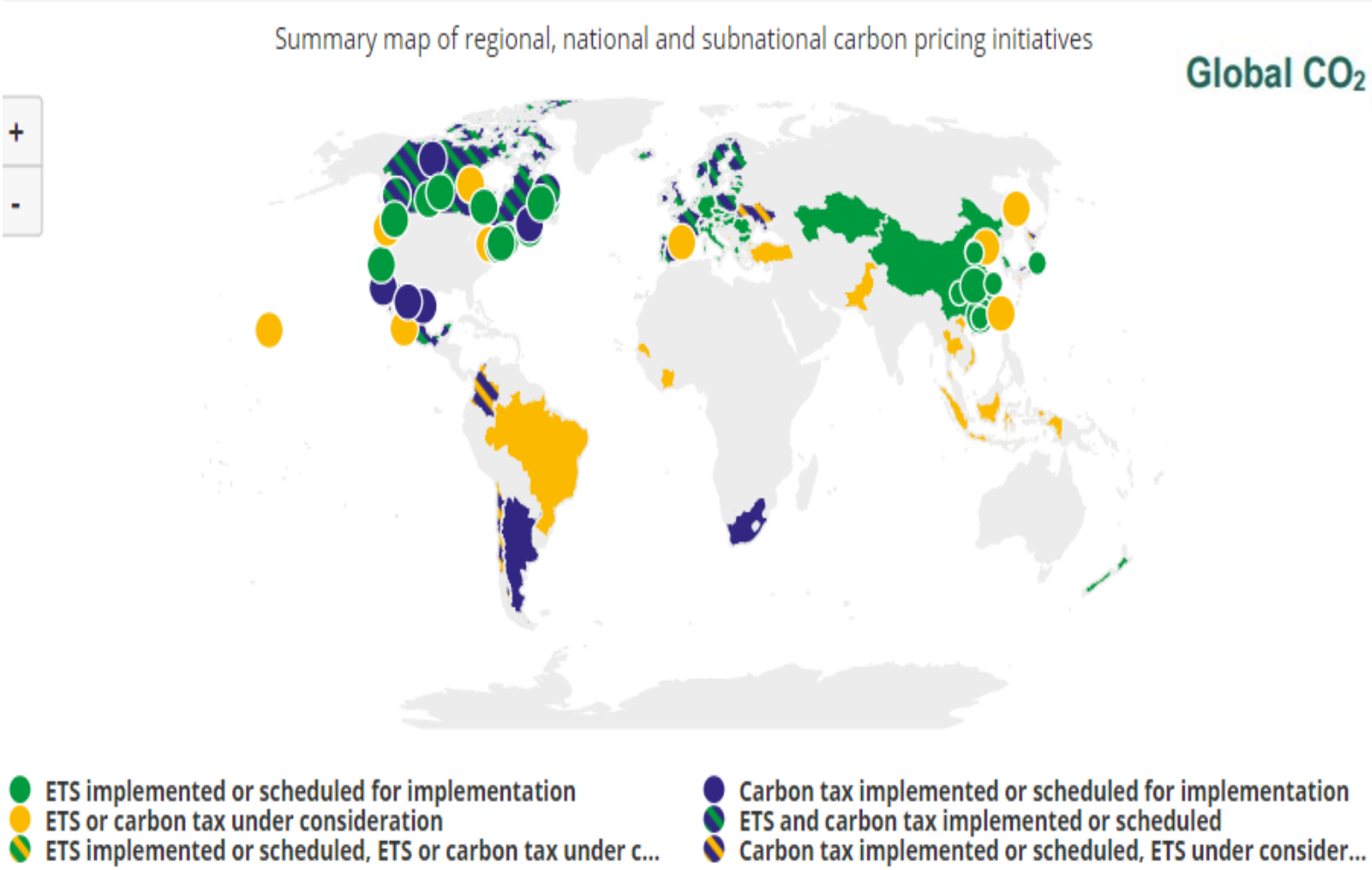
Collaborative

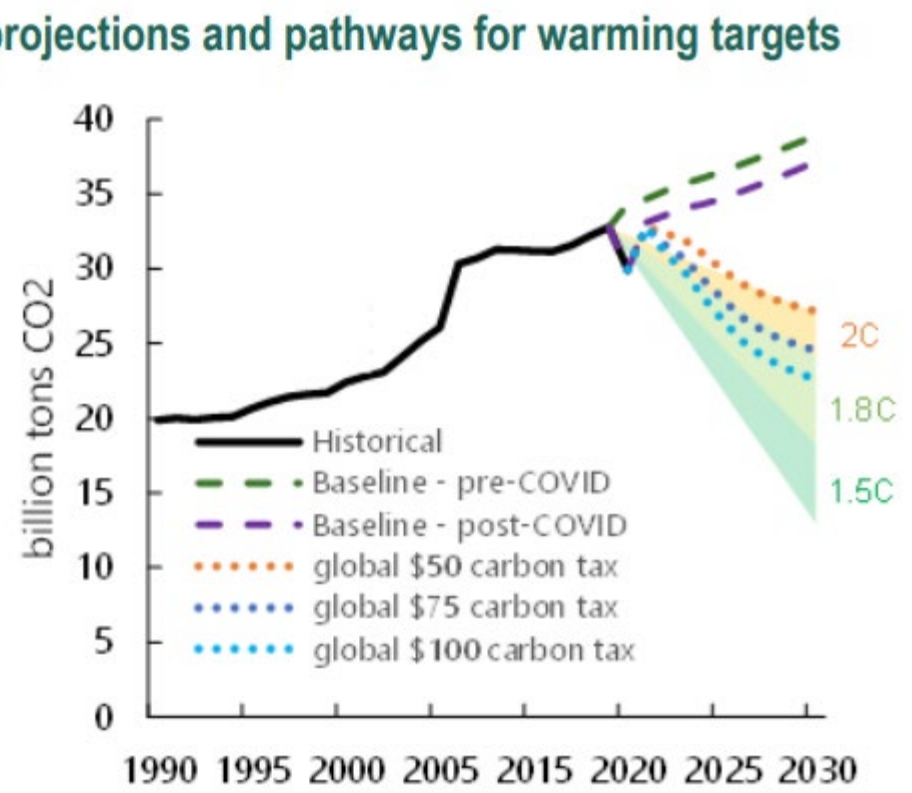
Bring together scientists, engineers, academic researchers, and industry experts

Net Zero Carbon World Initiatives

Carbon Policies Around the World

(ETS=Emissions Trading System; started in European Union in 2005)





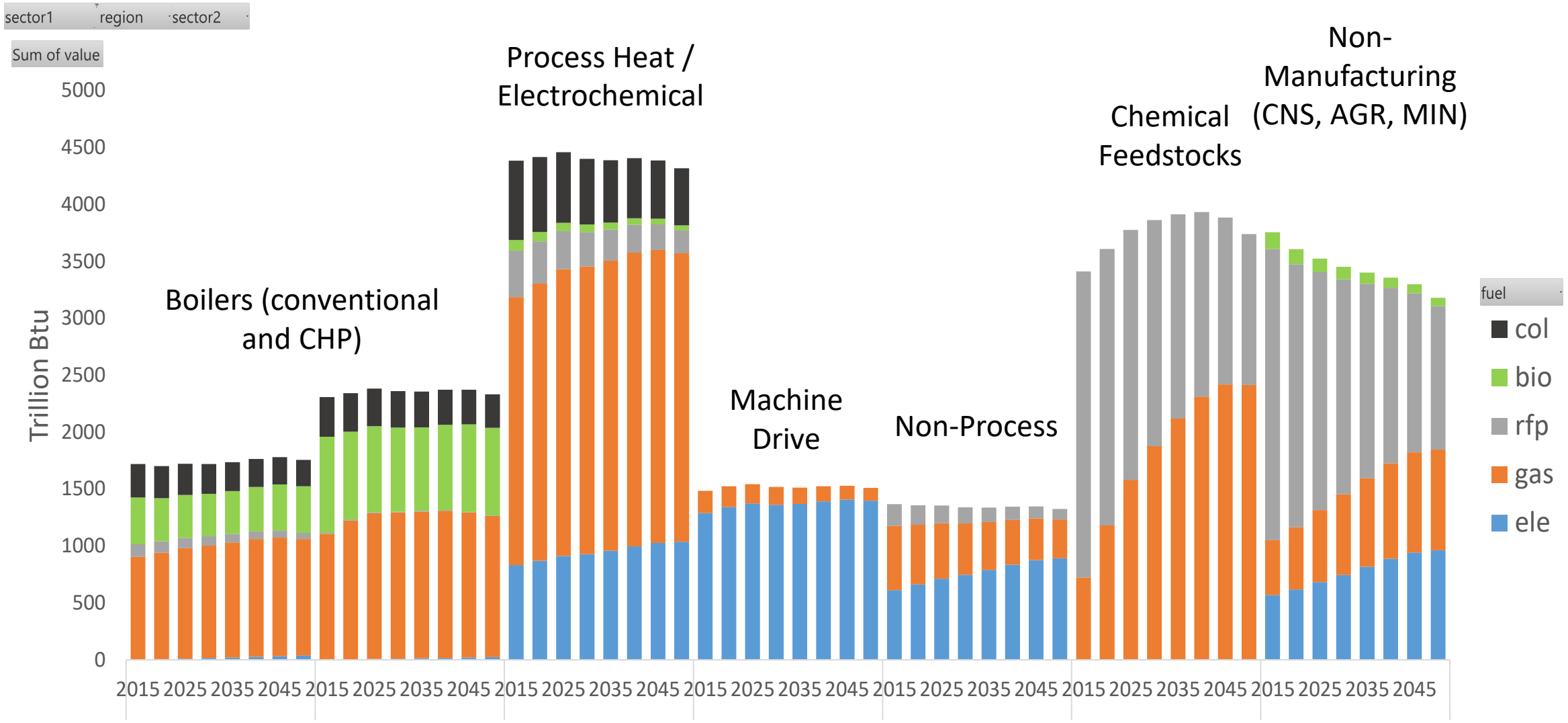
Many multinational companies are focusing on clean energy

- **90% of S&P 500 companies** have published sustainability reports, **up from 20% in 2011**
- 163 Fortune 500 companies have formal climate targets
- 23 countries have Fortune 500 headquartered companies
- Many multinational companies are needing green energy to meet their climate targets

Companies pressuring utilities to clean power supply to meet carbon reduction goals

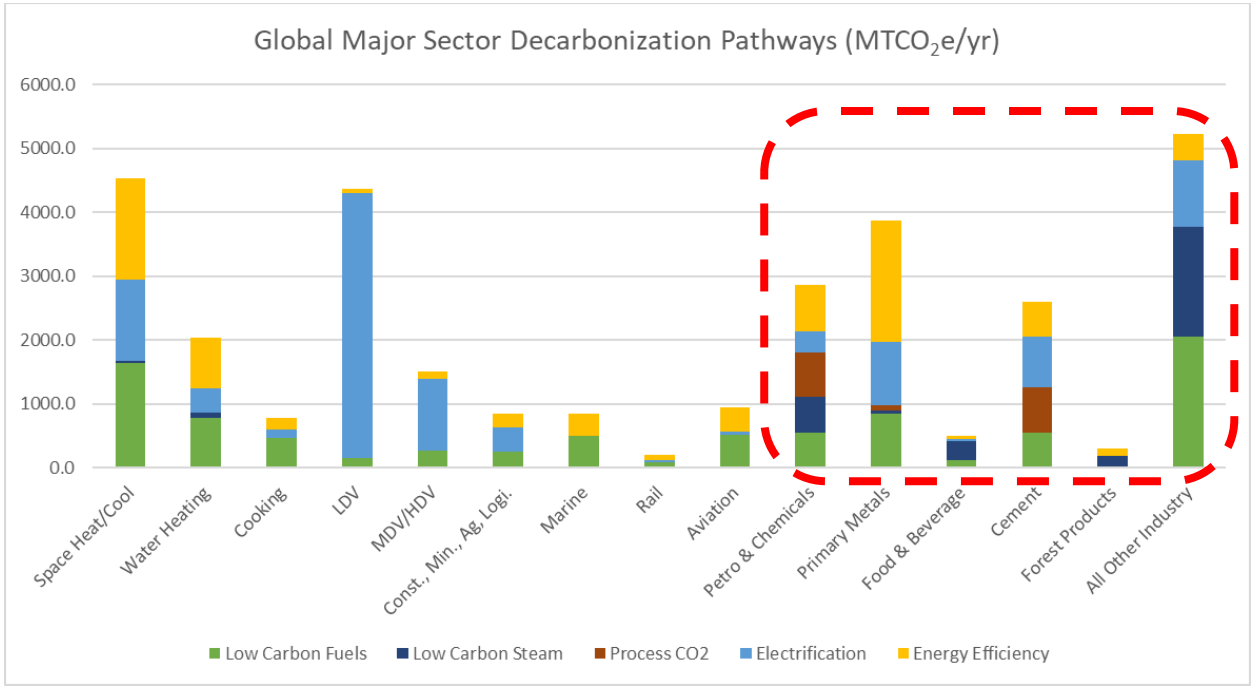
Industrial Decarbonization Strategy

EPRI National Electrification Assessment



Industrial Decarbonization Strategies

- **Step 1:** Energy Efficiency/Process Intensification
  - Better Plants Strategies
  - ISO 50001
  - Advanced Waste Heat Recovery
    - Industrial Heat Pumps
    - Thermodynamic Cycles
    - Metal Hydride Storage/Requalification
  - Advanced Membrane Separation
  - Thermal Catalysis
  - Oxy Firing
- **Step 2:** Direct Electrification
- **Step 3:** Process Redesign (Process Emissions)
- **Step 4:** Alternate Energy Carriers (Difficult to Electrify) or CCS/U



Industrial Electrification Measures

NAICS Description	Infrared Curing and Drying	Induction Surface Heat Treating	Induction Melting	Resistance Heating	Resistance Melting	RF/Ultraviolet Curing	Industrial Heat Pump/ Chiller
311: Food Manufacturing	✔	✔		✔		✔	✔
312: Beverage and Tobacco Product Manufacturing		✔		✔		✔	✔
313: Textile Mills	✔					✔	✔
314: Textile Product Mills	✔	✔					✔
315: Apparel Manufacturing	✔						
316: Leather and Allied Product Manufacturing	✔					✔	
321: Wood Product Manufacturing	✔					✔	✔
322: Paper Manufacturing	✔					✔	✔
323: Printing and Related Support Activities	✔					✔	
324: Petroleum and Coal Products Manufacturing				✔			✔
325: Chemical Manufacturing				✔		✔	✔
326: Plastics and Rubber Products Manufacturing		✔		✔			✔
327: Nonmetallic Mineral Product Manufacturing	✔				✔		✔
331: Primary Metal Manufacturing	✔		✔				✔
332: Fabricated Metal Product Manufacturing	✔	✔		✔			✔
333: Machinery Manufacturing	✔	✔		✔			
334: Computer and Electronic Product Manufacturing	✔	✔		✔			
335: Electrical Equipment, Appliance, and Component Manufacturing	✔	✔		✔		✔	
336: Transportation Equipment Manufacturing	✔	✔		✔		✔	
337: Furniture and Related Product Manufacturing	✔	✔		✔		✔	
339: Miscellaneous Manufacturing	✔			✔		✔	

Low Carbon Resources Initiative

LCRI Sponsorship | Expanding the Collaboration

Current Status

52 Sponsors

Electric & Gas Utilities

Energy Producers

Equipment Manufacturers

EPC Firms

$131M Funding

80:1 Avg Sponsor Leverage	20+ Active R&D Projects
40+ Technology Reports & Assessments	20+ Preliminary Techno-Economic Cases

Sponsorship Goals

50 Sponsors

Value Chain Diversity

Global Perspectives

Relationship Expansion

LCRI Sponsorship

LCRI LOW-CARBON RESOURCES INITIATIVE

Electric Only

American Electric Power
aps
aeci
Bonneville Power Administration
East Kentucky Power Cooperative
FirstEnergy
Hawaiian Electric
LES
LA DWP Los Angeles Department of Water & Power
minnesota power
Missouri River Energy Services
Nebraska Public Power District
NY Power Authority
NOMAC
NC Electric Cooperatives
OglethorpePower
OPPD Omaha Public Power District
Portland General Electric
PowerSouth Energy Cooperative
SRP
Southern California Edison
TVA Tennessee Valley Authority
TEPCO
Tri-State

Gas Only

Atmos Energy
Intermountain Gas Company
National Fuel
NW Natural
SoCalGas A Sempra Energy utility

Dual Fuel

Alliant Energy
Ameren
CenterPoint Energy
conEdison
Consumers Energy Count on Us
CPS Energy
Dominion Energy
DTE
Duke Energy
Exelon
Fortis Inc.
nationalgrid
NiSource
ppl
Southern Company
TECO Tampa Electric An Emera Company
WEC Energy Group
Xcel Energy

OEMs

GE
Mitsubishi Power

O&G

ConocoPhillips

EPC

Babcock & Wilcox
Black & Veatch

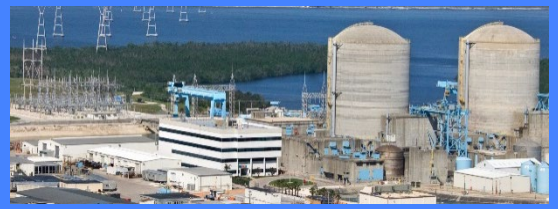
Beyond 2030 – Integration of Low-Carbon Energy Carriers

LCRI Focus: Hydrogen · Ammonia · Synthetic/ Derivative Fuels · Biofuels

Production Sources

Next Gen Technologies

Integrated Clean Electricity



Integrated Nuclear (Current & Advanced)

Natural Gas with CCS

Delivery & Storage

Existing Natural Gas Pipeline through Blending and/or New Infrastructure

Shipping, Trucking, and Conversion/Intermediates

Aboveground and Underground Storage

End Use Applications

Combustion

Heavy Duty Transportation

Electricity Generation

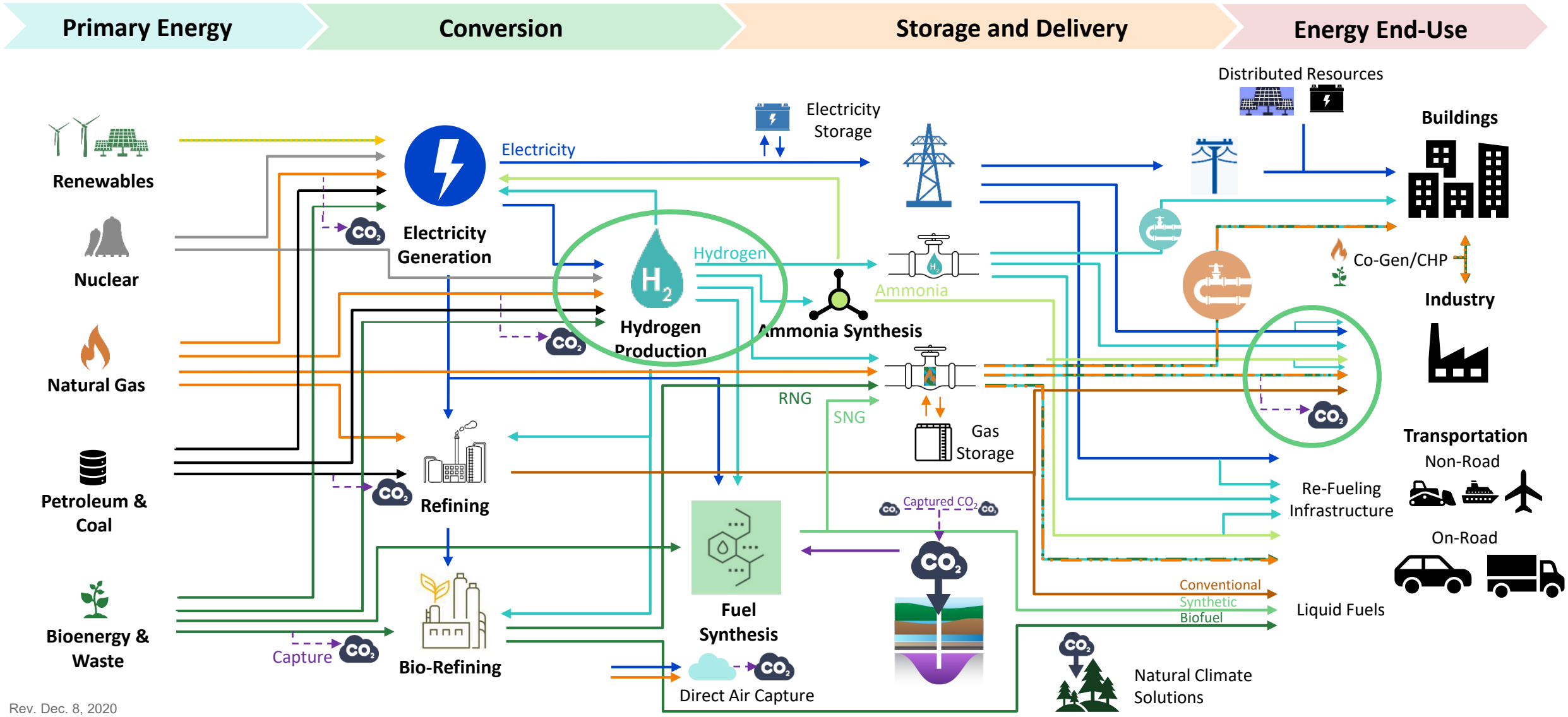
Advanced Fuel Cell

Large Industry

Chemical Processes

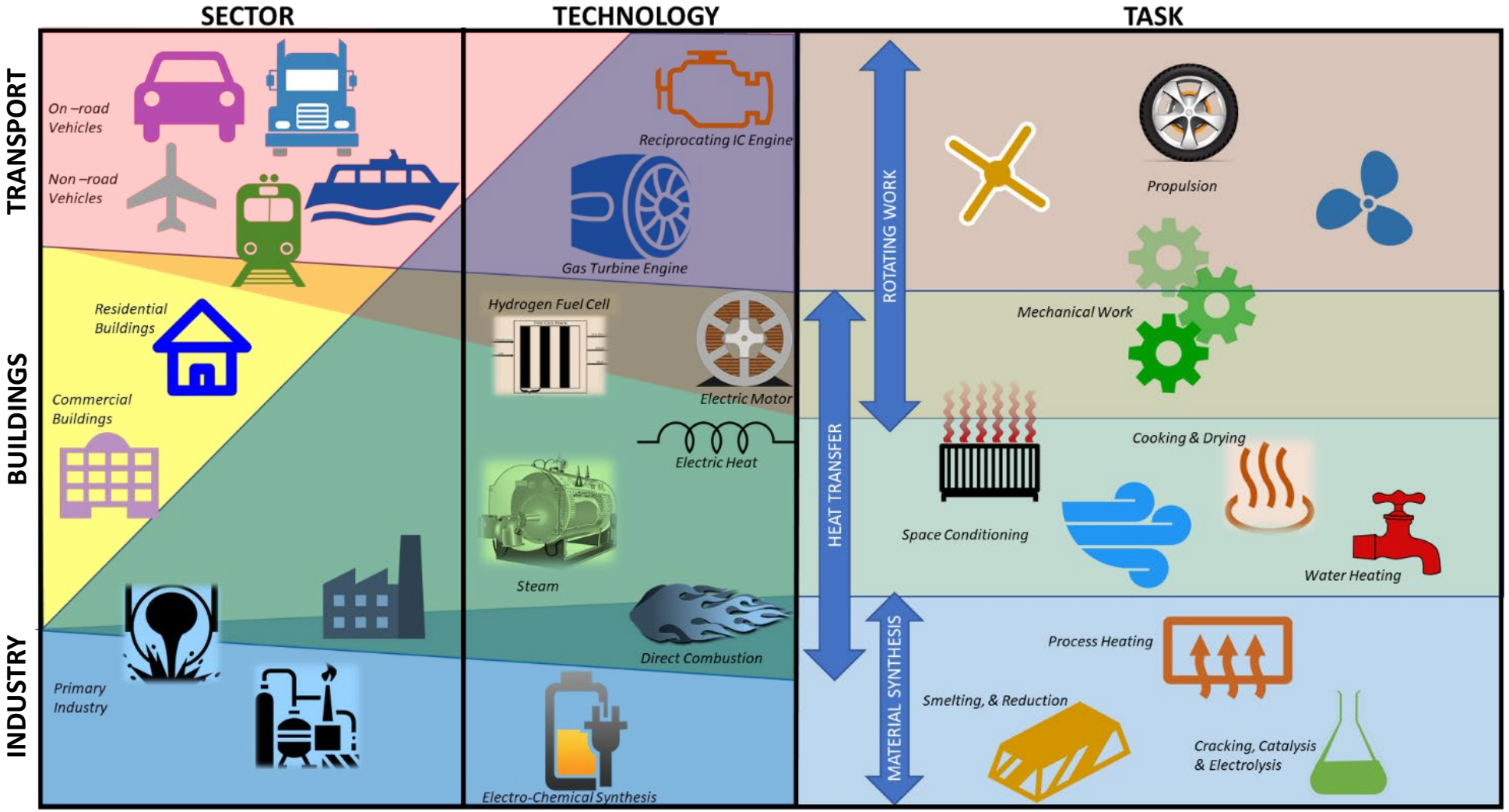
EPRI

Low-Carbon Energy Ecosystem



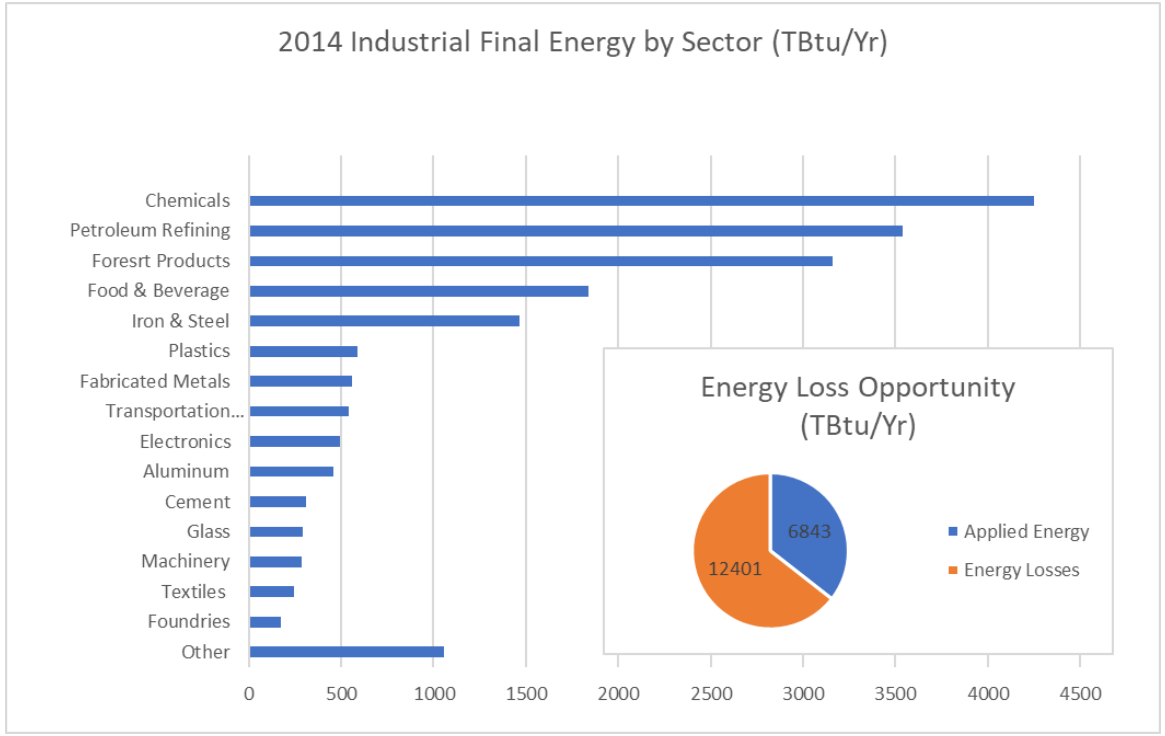
Rev. Dec. 8, 2020

End Use TSC Focus: Decarbonization of Final Energy



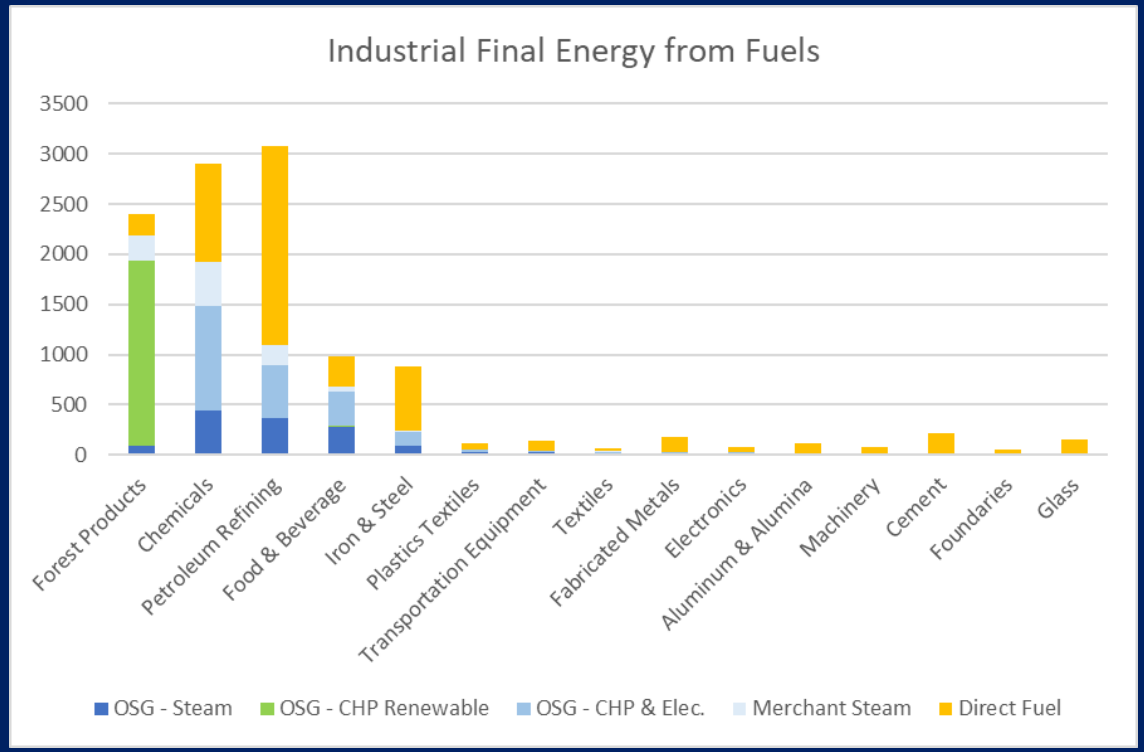
Focus on Evaluation of Task Efficiency, Technology Cost and Market Potential for Low-Carbon Fuels

US Industrial Energy Consumption



US Industry Final Energy and Losses (TBtu/Yr)

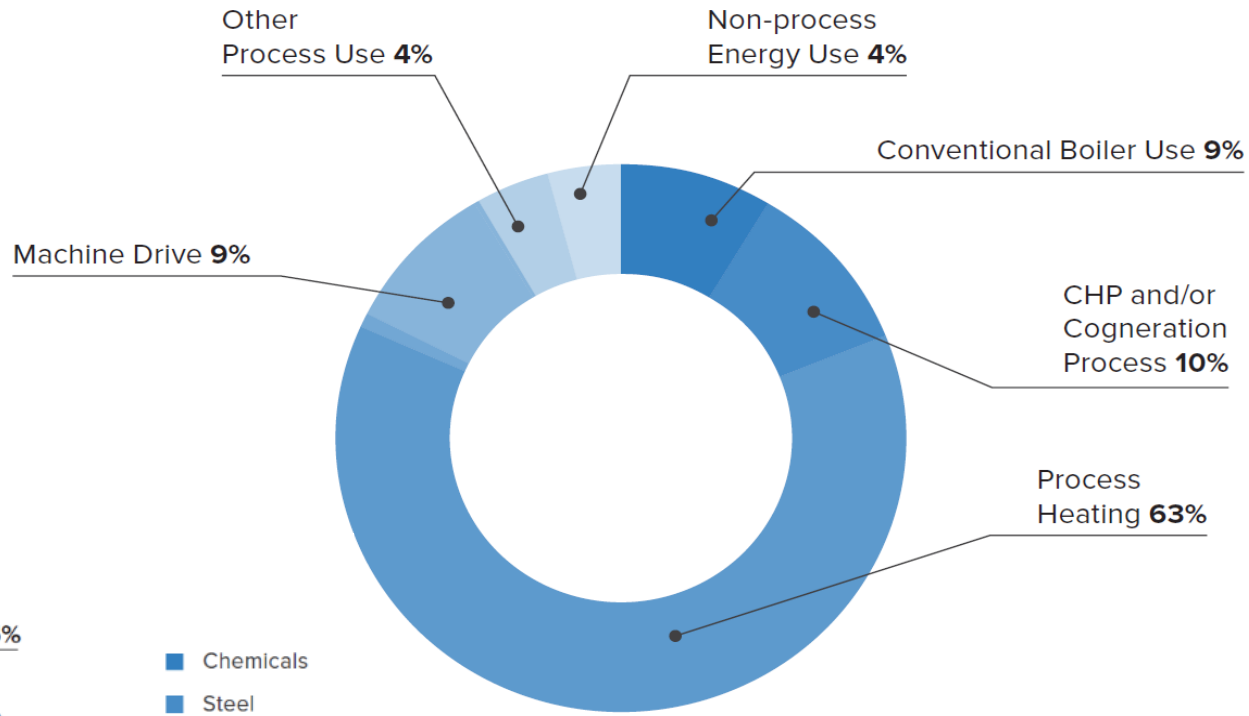
Industrial Final Energy from Fuel Combustion (Tbtu/Yr)



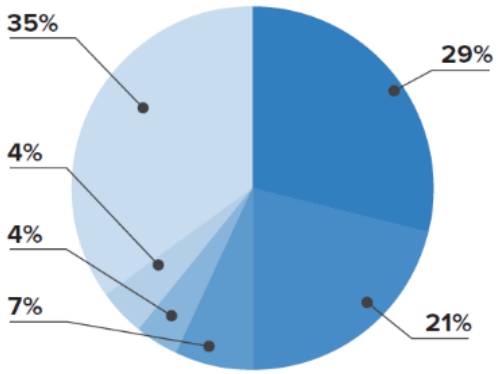
Industrial End Uses and Emissions

(Source: Global Efficiency Intelligence)

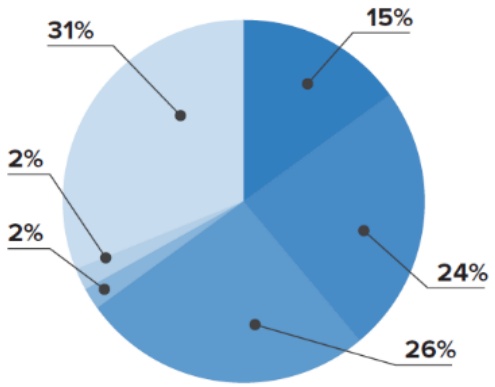
Final energy end uses in the U.S. steel industry



Industrial Energy Consumption



Industrial Emissions

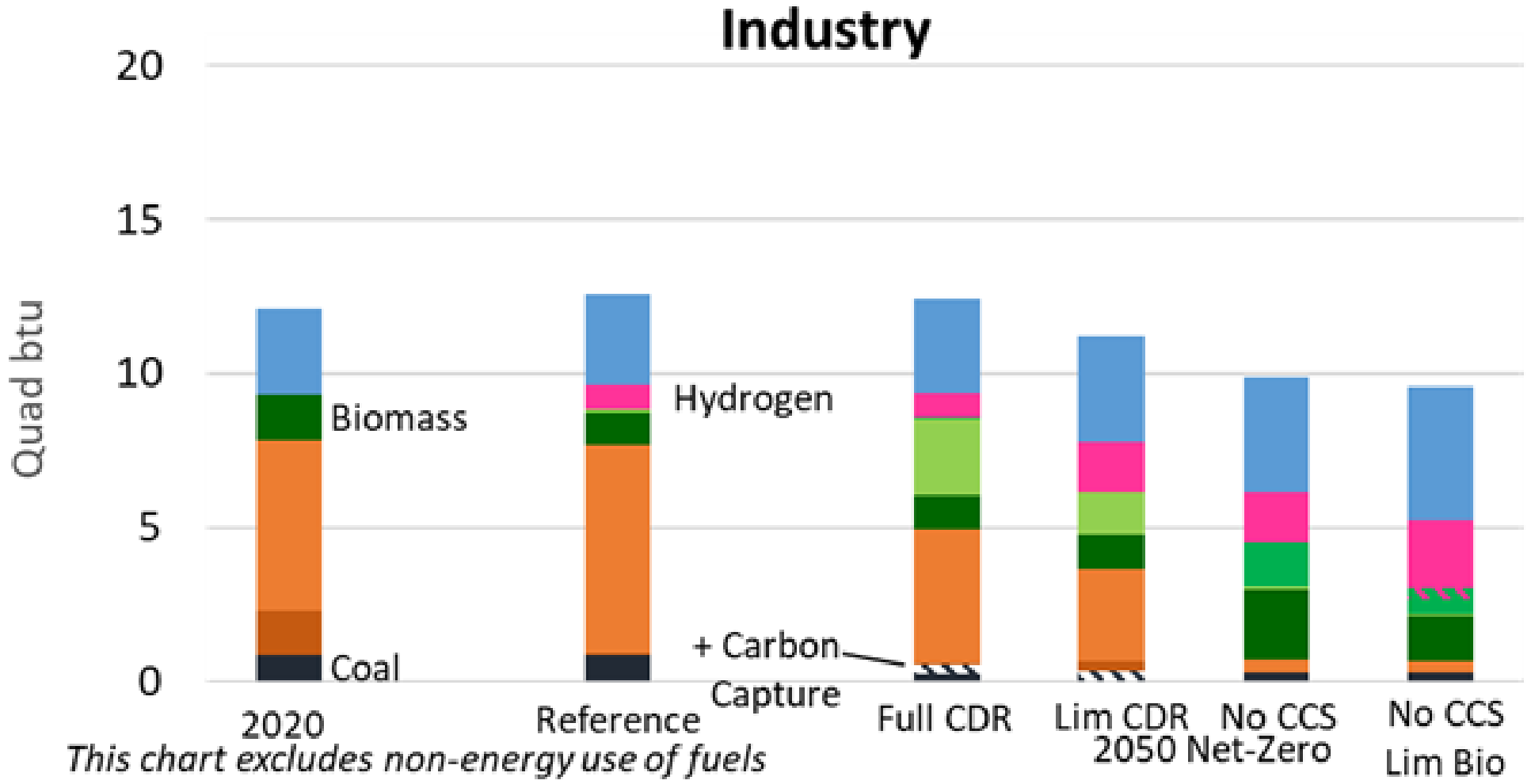


Energy consumption and emissions percentages

Updated Scenarios for 2050 Net-Zero Target

	Bioenergy	Geologic CO_2 Storage	Hydrogen	Direct Air Capture	Natural Climate Solutions
Full CDR	Carbon Neutral Residues and Energy Crops	Available at low cost	Reference cost declines for blue and green H_2	Available but with costs and energy requirements at high end of estimates in literature	Maximum 300 $MtCO_2$ available (additional quantity may be available but needed to offset other GHGs)
Limited CDR	Carbon Neutral Residues Only (Energy Crops limited)	Available at higher cost	Reference cost declines for blue and green H_2		
No CCS	Carbon Neutral Residues and Energy Crops	Unavailable	Accelerated cost declines for green H_2	Not available	
No CCS, Limited Bio	Carbon Neutral Residues Only (Energy Crops limited)	Unavailable	Accelerated cost declines for green H_2		
Notes:	Regional bioenergy supply curves derived from land-use modeling: Residue supply = 7 quads (4 @ $5/mmbtu) Energy crop supply = 29 quads (16 @ $5/mmbtu) Limited energy crops scenario → maximum of 4 quads	CO2 transport and storage costs vary by region/geology and application/scale: Low cost scenario: $3-$15/tCO_2 injection $1-$10/tCO_2 pipeline High cost scenario: $6-$30/tCO_2 injection $5-$20/tCO_2 pipeline	Blue hydrogen (99% capture) levelized cost assuming $3/mmbtu gas: $1.25/kg by 2050 Green hydrogen (PEM) capital costs (levelized cost depends on scenario/region): $310/kW-e by 2050 (reference) $130/kW-e by 2050 (accel.)	Primary option is a high-temp solvent technology with NG input (with flue gas capture) Key metrics by 2050: $140 per net tCO_2 removed levelized non-energy cost 7.7 mmbtu NG, 586 MWh per net tCO2 removed ~$200/$tCO_2$ total levelized cost	Total potential scale of forestry, agriculture, and wetlands measures is on the order of 1 $GtCO_2$ with marginal costs ranging from $10-$400/t Some of this potential will be required to achieve net-zero in No CCS cases

Industrial Decarbonization Scenarios



Preliminary Results from US REGEN Model

Industrial Sector – 1st Wave Project

Core Activity

EUI1: Competitive TEA analysis of AEC feedstock, AEC process heat, and CCS applications for industrial sector decarbonization.

- Develop analytical framework to conduct TEA assessing the competitiveness of AEC- and CCS-based solutions with competing decarbonization pathways
- Acquire and validate data on the cost and performance trajectories for prioritized technology pathways

Key Research Questions

What is the technoeconomic potential of AEC and CCS-based solutions for various industrial sectors, and how do these solutions compete with alternative decarbonization pathways?

What equipment and/or process modifications are required to enable use of AECs for industrial process heating or as chemical feedstocks, and what are their cost and performance impacts?