2°Congreso Internacional de Hidrógeno

20 y 21 Abril 2023

Accelerating Technologies for Wide Economy Decarbonization

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www.epri.com

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EPRI 50th ANNIVERSARY

Outline

EPRI's overview

Low Carbon Resources Initiative (LCRI):
An Enabler to Worldwide Economy Decarbonization

Net Zero Industrial Clusters Initiative

Conclusions and open questions

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EPRI's overview

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Explore EPRI's research across the Nuclear, Generation, and Power Delivery and Utilization sectors ranging from decarbonization to grid modernization to low carbon resources.

COLLABORATION

EPRI's collaborative platform is unrivaled. Our R&D:

- Leverages your research dollars
- Connects you to a global network of peers
- Accelerates deployment of technology
- Mitigates the risk and uncertainty of going it alone
- Positions you as a leader in addressing industrywide challenges

CREDIBILITY

EPRI's independent research is guided by our mission to benefit the public. We offer:

- Objective solutions
- A proven track record
- Scientifically based research you can trust

EXPERTISE

For more than 50 years, EPRI has been applying R&D to help solve real challenges. With EPRI, you can:

- Reduce expenses and increase productivity
- Be more resilient today and better prepared for tomorrow
- Access an industry repository of collective experiences, technical expertise, and training resources
- Extend your staff and make your teams more robust and more confident
- Benchmark, learn and share best practices
- Increase your awareness of challenges that others are facing and alternate solutions to challenges you might be facing
- Save time and money troubleshooting problems EPRI and its stakeholders have seen before

Who We Are

Founded in 1972, the Electric Power Research Institute (EPRI) is the world's preeminent independent, non-profit energy research and development organization, with offices around the world.

Our Experts

EPRI's trusted experts collaborate with more than 450 companies in 45 countries, driving innovation to ensure the public has clean, safe, reliable, affordable, and equitable access to electricity across the globe.

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EPRI Accelerates Technology Advancement

LABORATORIES AND UNIVERSITIES

Basic research and development

SUPPLIERS AND VENDORS

Technology commercialization

EPRI

Collaborative technology development, integration, and application

Thought leadership illuminates emerging developments, opportunities, and trends.

Technology Innovation Scouting searches globally for emerging technologies and concepts to provide insights on industry challenges and solutions.

Sector R&D conducts research and demonstrations to address challenges, deploy results, and provide supporting services for existing and emerging technologies.

EPRI stimulates innovation and plays a key role in validating technology across multiple utilities, fostering widespread acceptance, and helping accelerate technology to commercial development and industry adoption

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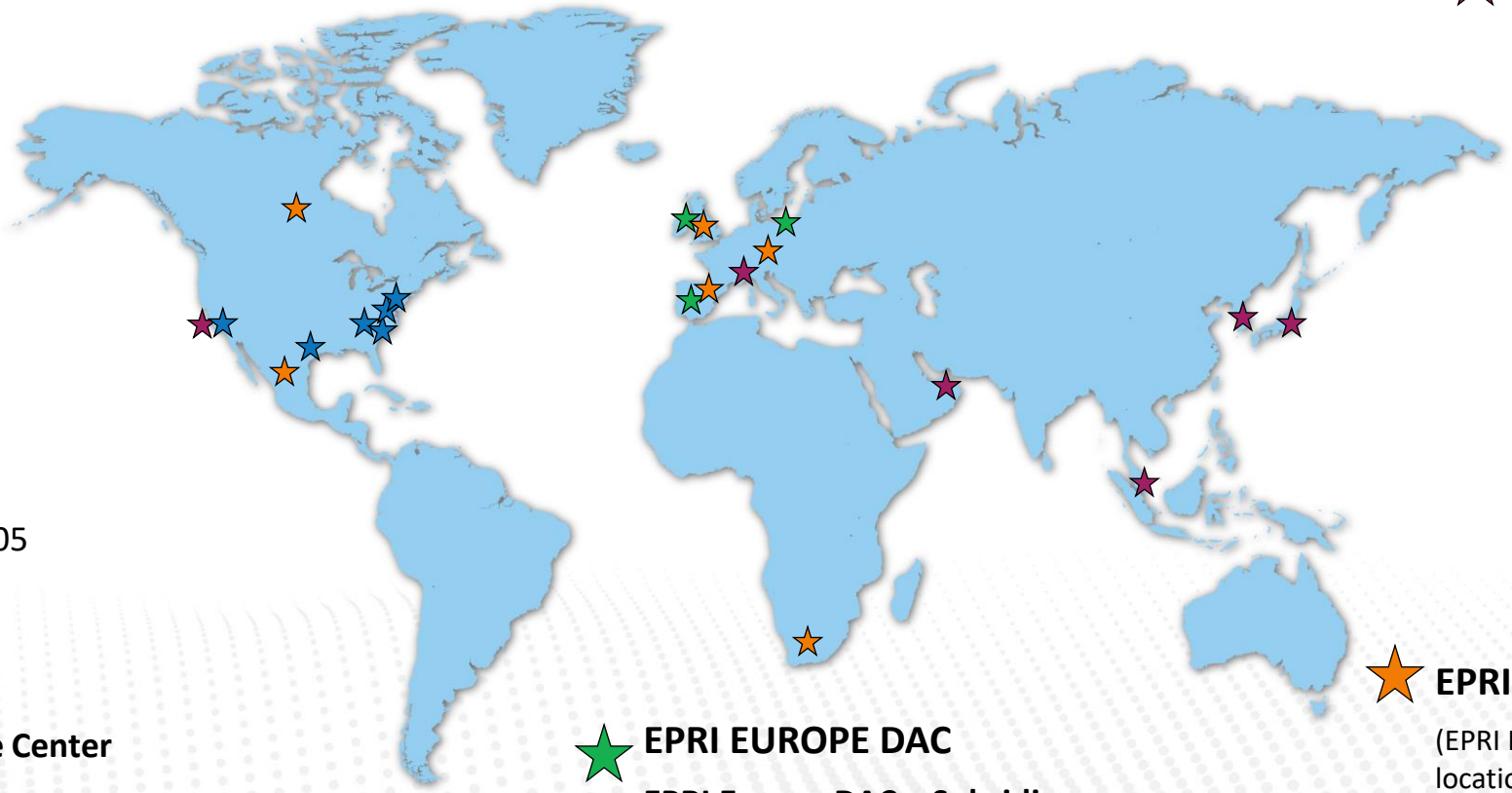

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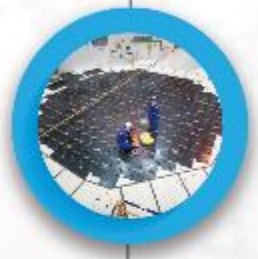
EPRI Research & Development

TECHNOLOGY INNOVATION

Driving thought leadership, advanced R&D, and technology scouting and incubation to sustain a full pipeline of solutions



Nuclear Power

Energy Supply and Low-Carbon Resources

Electrification and Sustainable Energy Strategy

Transmission and Distribution Infrastructure

Integrated Grid and Energy Services

STRATEGIC RESEARCH

Low-Carbon Resources

End-Use/ Economy-Wide Carbon Reduction

Electric System Reliability/Resilience

Electric System Flexibility

Market Transformation/ Policy/Regulatory Education

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Low Carbon Resources Initiative (LCRI): An Enabler to Worldwide Economy Decarbonization

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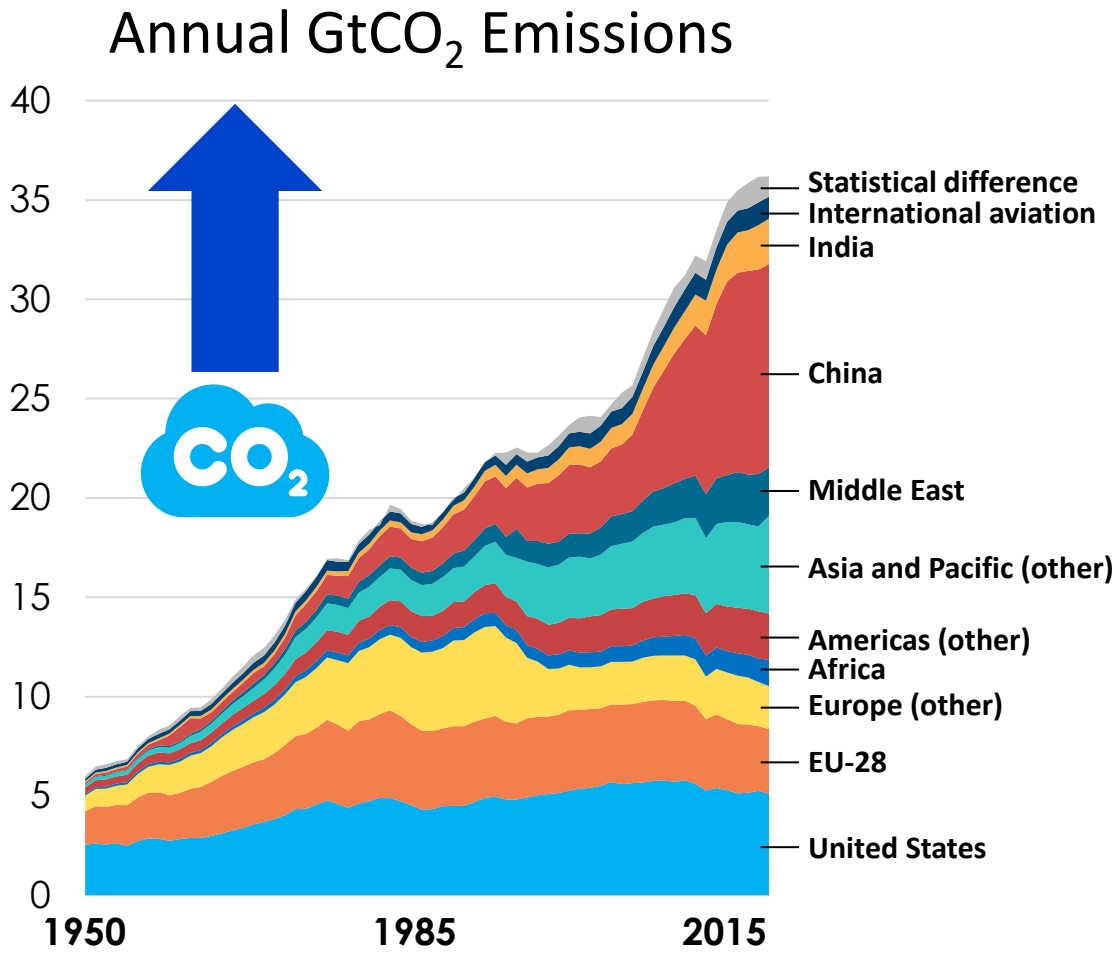
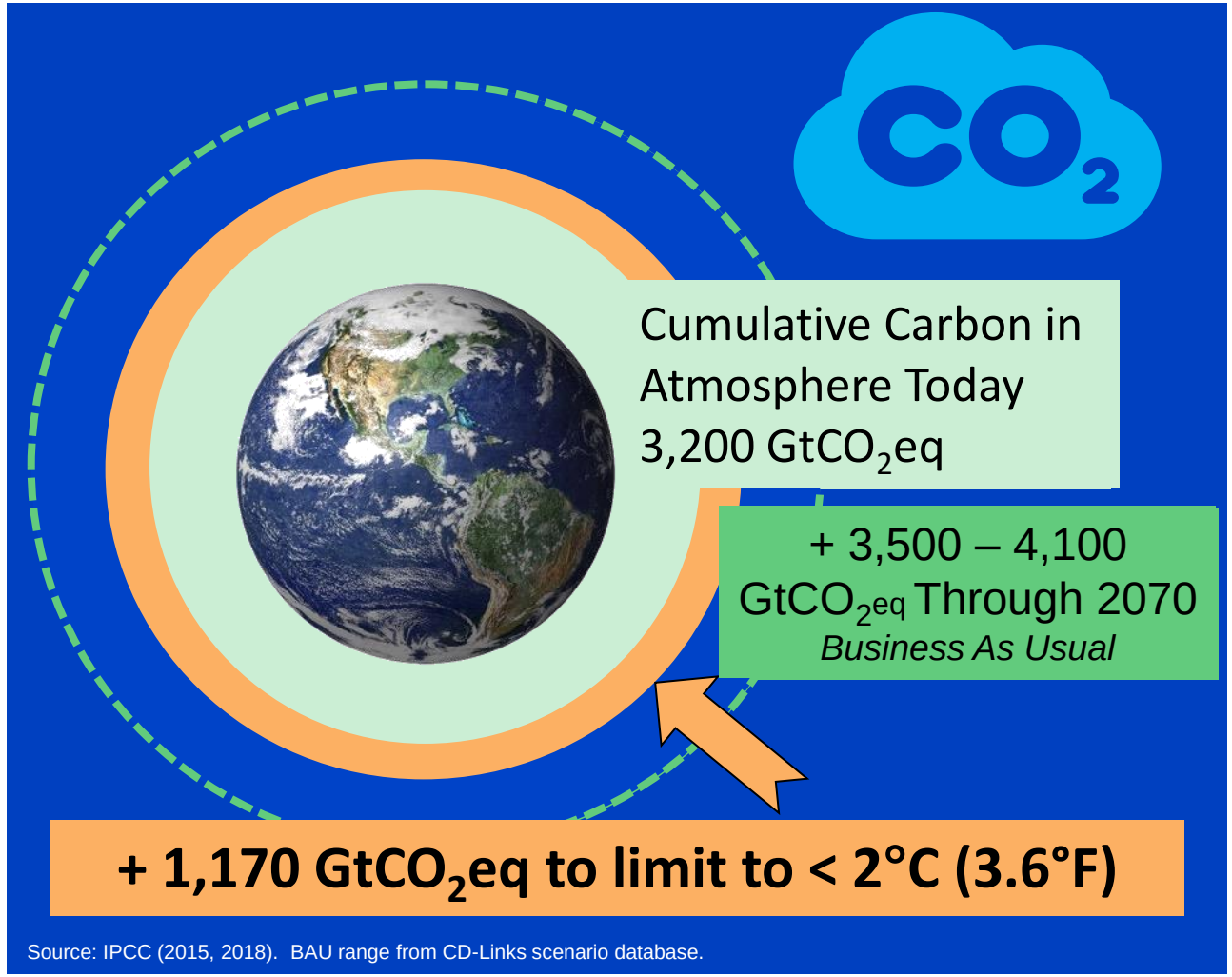
Global Carbon Dioxide Emissions Trends



Source: Carbon Dioxide Information Analysis Center



Source: IPCC (2015, 2018). BAU range from CD-Links scenario database.

CO_2 emissions could outpace target for maintaining < 2°C

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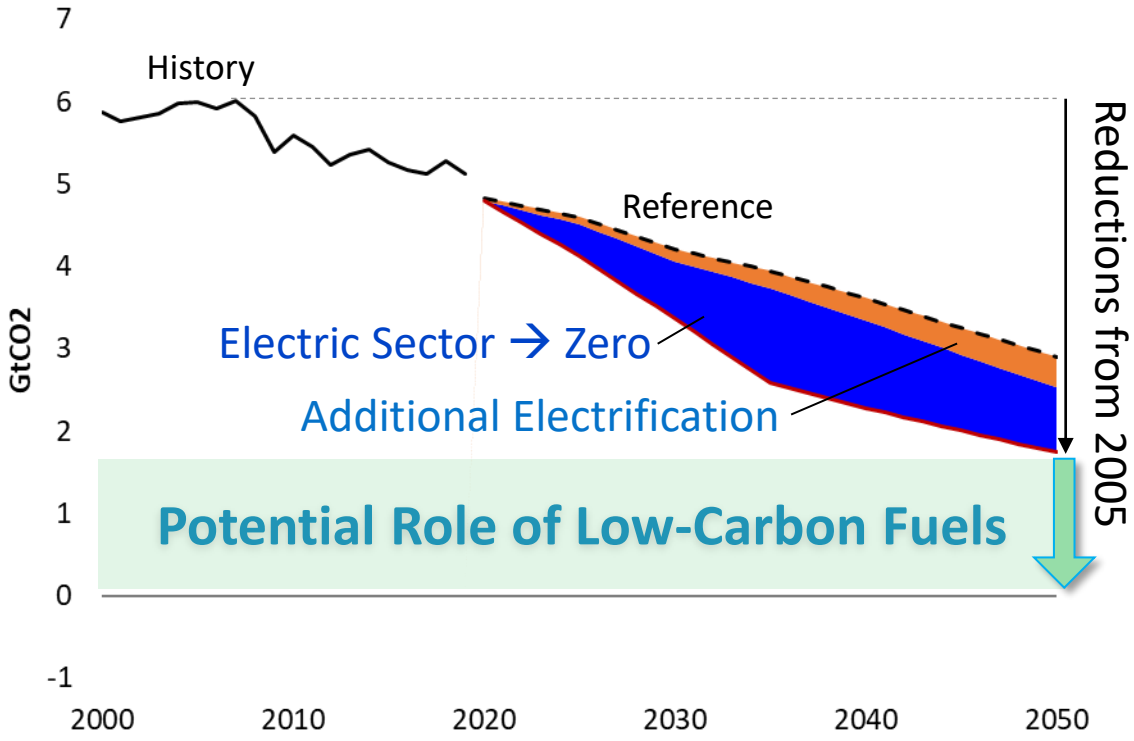
Integrated Energy System Approach to Decarbonization

Economy-Wide CO_2 Emissions



Low-carbon fuels may be required to achieve economy-wide decarbonization

Evaluating the Potential Role of Low-Carbon Fuels

- Various pathways exist to support carbon reductions across the energy-economy (e.g., efficiency improvements, electrification)
- Commercial options are currently limited for hard-to-abate areas and deep carbon reduction targets
- Significant need and opportunity to support the transition to low-carbon fuels using an integrated energy system approach

EPRI Report 3002020700

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Decarbonization Pathways Enabled by Innovation

~10-15 years

~15-30 years

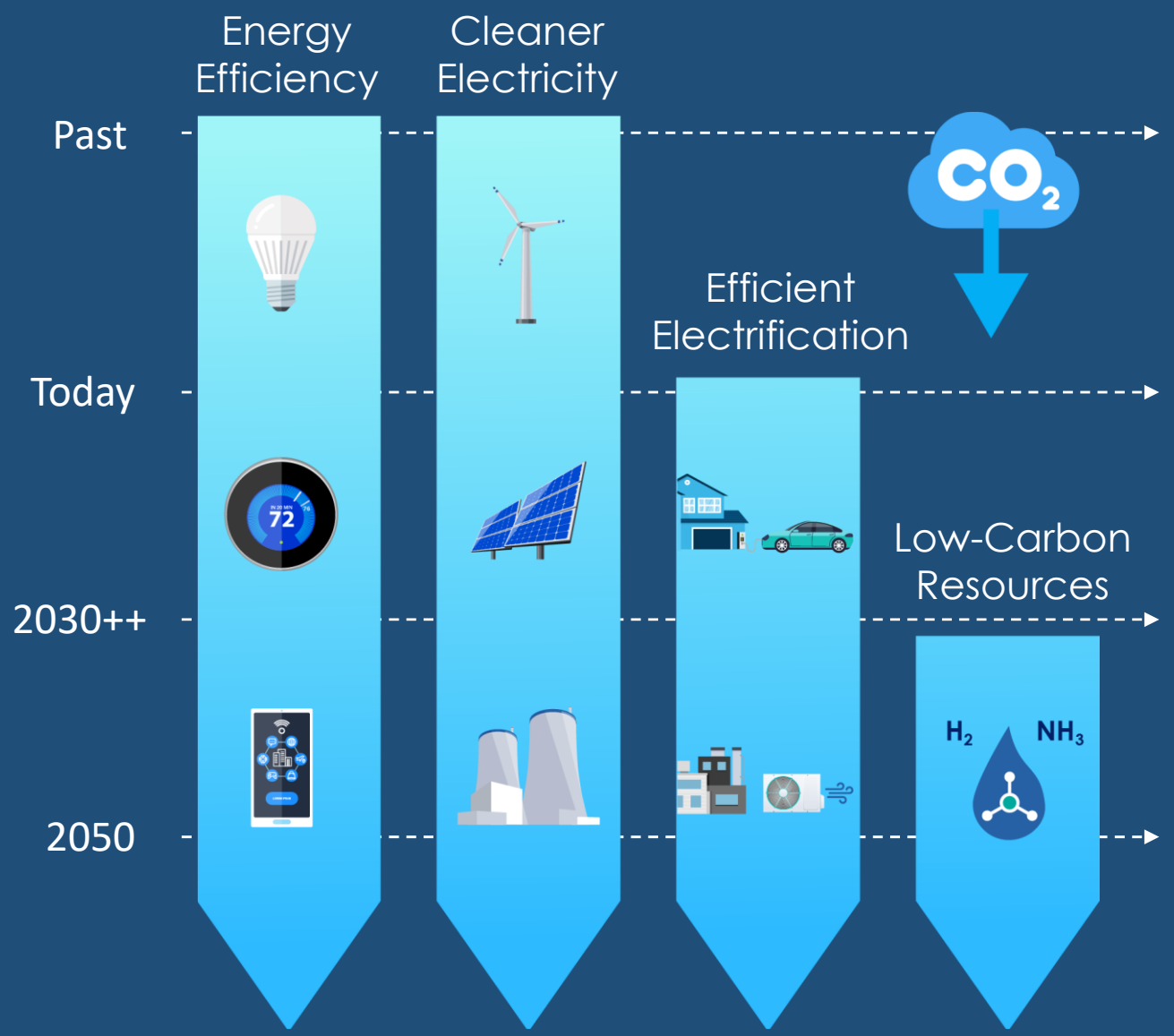
Decarbonization

Accelerate economy-wide, low-carbon solutions

- Electric sector decarbonization
- Transmission and grid flexibility: storage, demand, EVs
- Efficient electrification

Achieve a net-zero clean energy system

- Ubiquitous clean electricity: renewables, advanced nuclear, CCUS
- Negative-emission technologies
- Low-carbon resources: hydrogen and related, low-carbon fuels, biofuels, and biogas



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The **Low-Carbon Resources Initiative** (LCRI) is a five-year R&D commitment focused on the advancement of low-carbon technologies for large-scale deployment across the energy economy. This initiative is jointly led by **EPRI and GTI**. Visit the initiative webpage for more details: www.LowCarbonLCRI.com

LCRI LOW-CARBON RESOURCES INITIATIVE

ENGAGEMENT

Industry & Stakeholder Participation

54 Sponsors

Electric & Gas Utilities
Energy Producers
Equipment Manufacturers
EPC Firms

Funding & Leverage for R&D Activities

$136M Funding
$1B Leverage Goal (over 5 years)

Global Engagement & Collaboration

Research Organizations
Academia
NGO's
National Labs
Government Agencies

Apr 10, 2022

RESEARCH AREAS

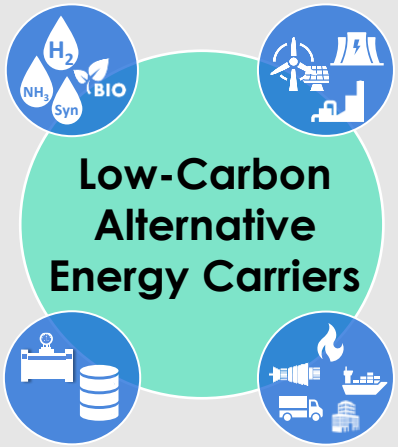
Hydrogen **Ammonia** **Synthetic/Derivative Fuels** **Biofuels**

Production

» Electrolysis from clean energy sources
» Biofuel and low-carbon processes
» Carbon capture & storage
» Innovative technologies

Storage & Delivery

» Pipeline blending
» Safety and codes/ standards
» Underground & aboveground storage
» Chemical storage



Integration

» Energy system modeling & analysis
» Grid electricity, renewables & nuclear energy
» Gas networks/ infrastructure
» Consumer optionality

End Use Applications

» Transportation
» Industrial
» Power Generation
» Heating
» Commercial
» Residential

VALUE

Independent, Objective RD&D

Led by **non-profit research organizations** with missions to enhance the quality of life by making energy safe, affordable, reliable, and environmentally responsible

Low-Carbon Value Chain Approach

Comprehensive approach to address multiple pathways for low-carbon resource production, delivery, and economy-wide use

High-Impact Results

Technology demonstrations
Techno-economic analysis
Energy economy modeling
Safety and performance protocols
Environmental impact assessments

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EPRI GTI ENERGY

LCRI Technical Subcommittees

LCRI LOW-CARBON RESOURCES INITIATIVE

PRODUCTION

Electrolytic Processes

- Power-to-X technologies
- Technology integration with renewable and nuclear energy systems

Hydrocarbon-Based Processes

- Hydrogen production from steam-methane reformation, gasification
- Hydrogen production from methane cracking
- Fischer Tropsch and Haber-Bosch low-carbon alternatives
- Carbon capture and utilization, DAC

Renewable Fuels

- Biochemical processes
- Renewable natural gas
- Biofuel feedstocks and conversion
- Methane capture, Hydrogen

DELIVERY & END USE

Storage & Delivery

- Gas and liquid fuel infrastructure, storage and distribution (e.g., pipeline blending)
- Metal hydrides, liquid organic hydrogen carriers
- Safety and codes/standards
- Underground & aboveground storage

Power Generation

- Low-carbon fuels (pure or blended forms)
- Gas turbines, boilers, RICE, fuel cells
- Integrated plant impacts

Transportation, Industrial & Buildings

- Light duty, medium/heavy duty, off-road, aviation, maritime, rail
- Combustion and heating applications
- Feedstocks for chemicals and processing that may also serve as AECs

CROSS-CUTTING

Safety and Environmental Aspects

- Lifecycle environmental impact assessments
- Safety standards and protocols
- Decision support tools

Integrated Energy Systems Analysis

- Economic model to understand decarbonization pathways across the energy ecosystem
- Impact assessment of low-carbon energy on reliability
- Scenarios and sensitivities covering energy usage, economic considerations, environmental aspects, and consumer preferences

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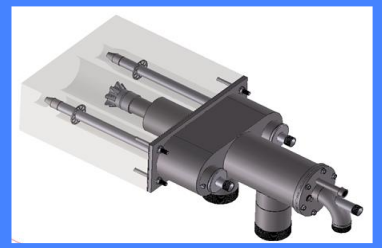
Current LCRI Technology Demonstration Portfolio

LCRI LOW-CARBON RESOURCES INITIATIVE

H_2 Production from Nuclear



Advanced Oxy-Combustion

Direct Air Capture of CO_2

Flexible Gasification for Generation

Moving-Bed Gasifier Performance

H2@Scale Electrolyzer

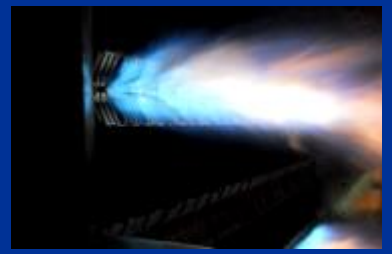
H_2 Storage for Flex Fossil Power Gen

Integrated H_2 Energy Storage

H_2 Grid Integration and Scaling

HyBlend Pipeline Demos

H_2 Negative Emissions Demonstration



H_2 Storage for Load Following

H2@Scale H_2 Fueling Station

H_2 Leak Monitoring

H2@Scale Fuel Cell Demo

H2@Scale SMR from Landfill Gas

H_2 Locomotive

H_2 in Combustion Turbines and RICE

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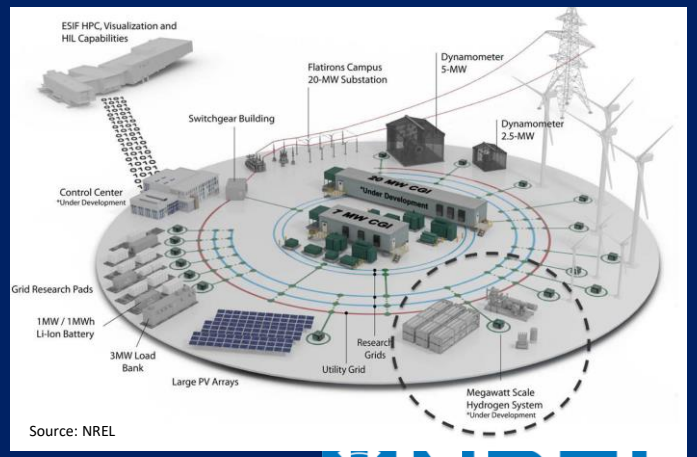
Examples on Hydrogen Demonstration Projects

LCRI LOW-CARBON RESOURCES INITIATIVE

PRODUCTION

Renewables + Electrolyzer Flexibility

- Operate 1.25 MW PEM electrolyzer
- Develop system characterization and monitoring guidelines



Source: NREL

NREL Transforming ENERGY

STORAGE & DELIVERY

H_2 Underground Storage

- Characterize and analyze the suitability of a bedded salt formation at commercial facility
- Obtain geochemical and well design information to inform on potential H_2 viability

Courtesy of Mitsubishi Power

END USE

H_2 & Power Generation Commercial Demos

44%v | GE LM6000
(45 MWe)
Executive Summary report

20.9%v | Mitsubishi 501G
(265 MWe)
White Paper report

25%v | Wärtsilä RICE
(18 MWe)
Press Release

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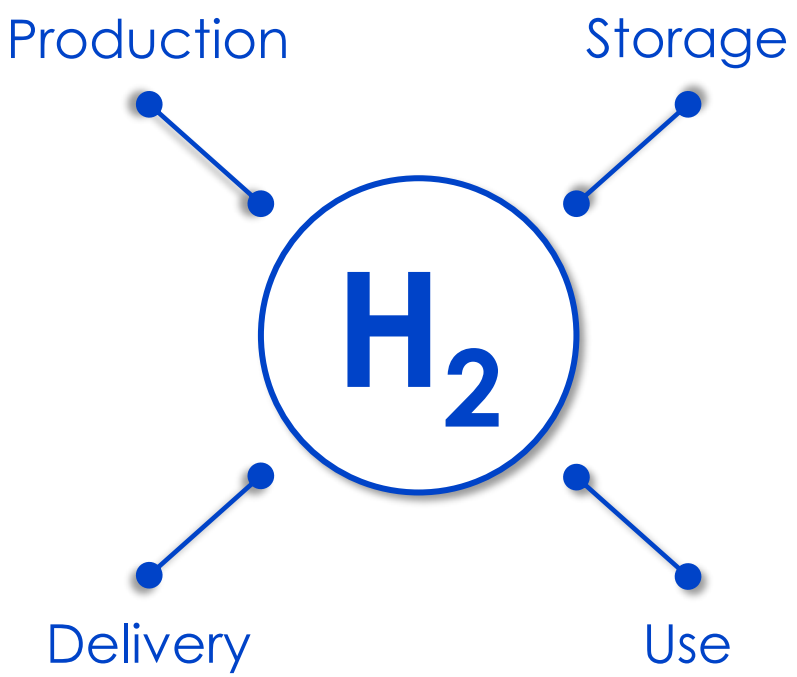
Example of H2 Production Tech. Acceleration

Initiative Scope

1. High Level Site Design Tool for Electrolysis + Renewable Electricity Generation and Storage
2. Engineering Design References for Renewable Hydrogen Production
3. Electrolyser System Performance and Degradation Impacts from Flexible Operation
4. Sustainability, Safety, and Environmental Assessments



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Example of H2 New Technology Acceleration

LCRI LOW-CARBON RESOURCES INITIATIVE

LCHA Low-Carbon Hydrogen Accelerator

LEARN MORE: bit.ly/LowCarbonH2

Addressing technology gaps to reach 2050 net-zero targets by **exploring novel startup company opportunities**

EPRI · HOUSTON CLIMATE ACTION PLAN · Greentown Labs · URBAN FUTURE LAB NYU TANDON

GOAL: **Accelerate technology commercialization**

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Net Zero Industrial Clusters Initiative

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WORLD ECONOMIC FORUM

Transitioning Industrial Clusters towards Net Zero

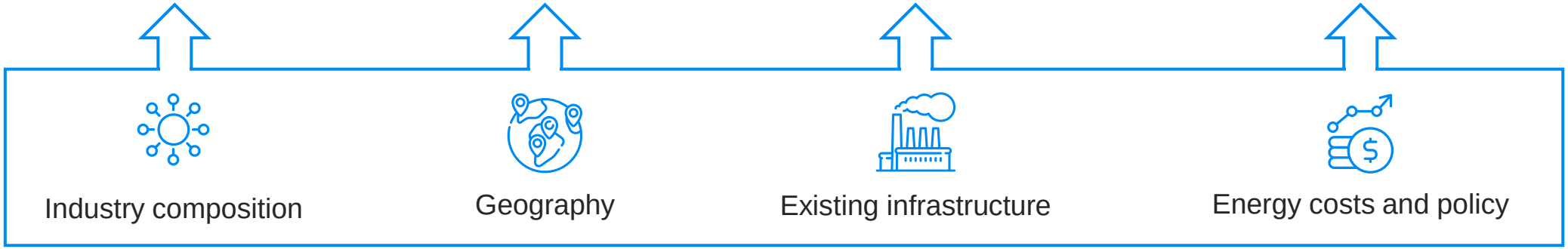
[3-8-22]

In collaboration with Accenture & EPRI

Industrial Clusters: The Net-Zero Challenge

With industry responsible for 30% of total global CO2 emissions, industrial clusters will be a critical player in accelerating the path towards net zero

Industrial clusters are geographic areas where **co-located companies, representing either a single or multiple industries, provide opportunities for scale, sharing of risk/resources, aggregation and optimization of demand.**



A holistic and collective approach is required to optimize emissions solutions and **create an integrated energy system** that maximizes **system value outcomes** across economic, social and environmental aspects.

Source: Accenture's [2021 Net Zero Industrial Clusters Report]

Transitioning Industrial Clusters towards Net Zero

The World Economic Forum in collaboration with Accenture and EPRI has launched a global initiative to support industrial clusters in their paths toward net zero.

Initiative Objective

To catalyse the decarbonization of the industrial cluster through convening and supporting existing, co-located facilities in defining their significant emissions reduction goal and the path to achieve it.

The initiative is founded on 4 key principles:

- Technology neutrality
- Global reach with local focus
- Cross-industry collaboration
- Focus on environmental, social and economic impact

Pathway to our Goal

The *Transitioning Industrial Clusters* initiative convenes industrial players at all stages of ambition development in an impartial forum to collaboratively shape strategies and share lessons learned.

We support our **seventeen** signatory clusters in implementation of their emission reduction strategies and continuously engage with 20+ prospective clusters to identify opportunities.

Initiative Impact

1.6 B
MT of CO_2

$2.5 Tr
USD

18 M
Jobs

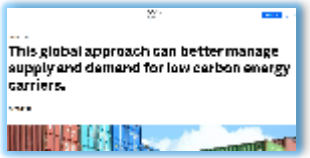
Building on existing commitments, the initiative is targeting to build a community of 100 global Signatory Clusters. Representing emissions double that of Germany, our clusters will contribute the metrics at right.

Featured Resources

Report
Transitioning Industrial Clusters Annual Report 2023

Article
Opportunities for Financial Industrial Clusters

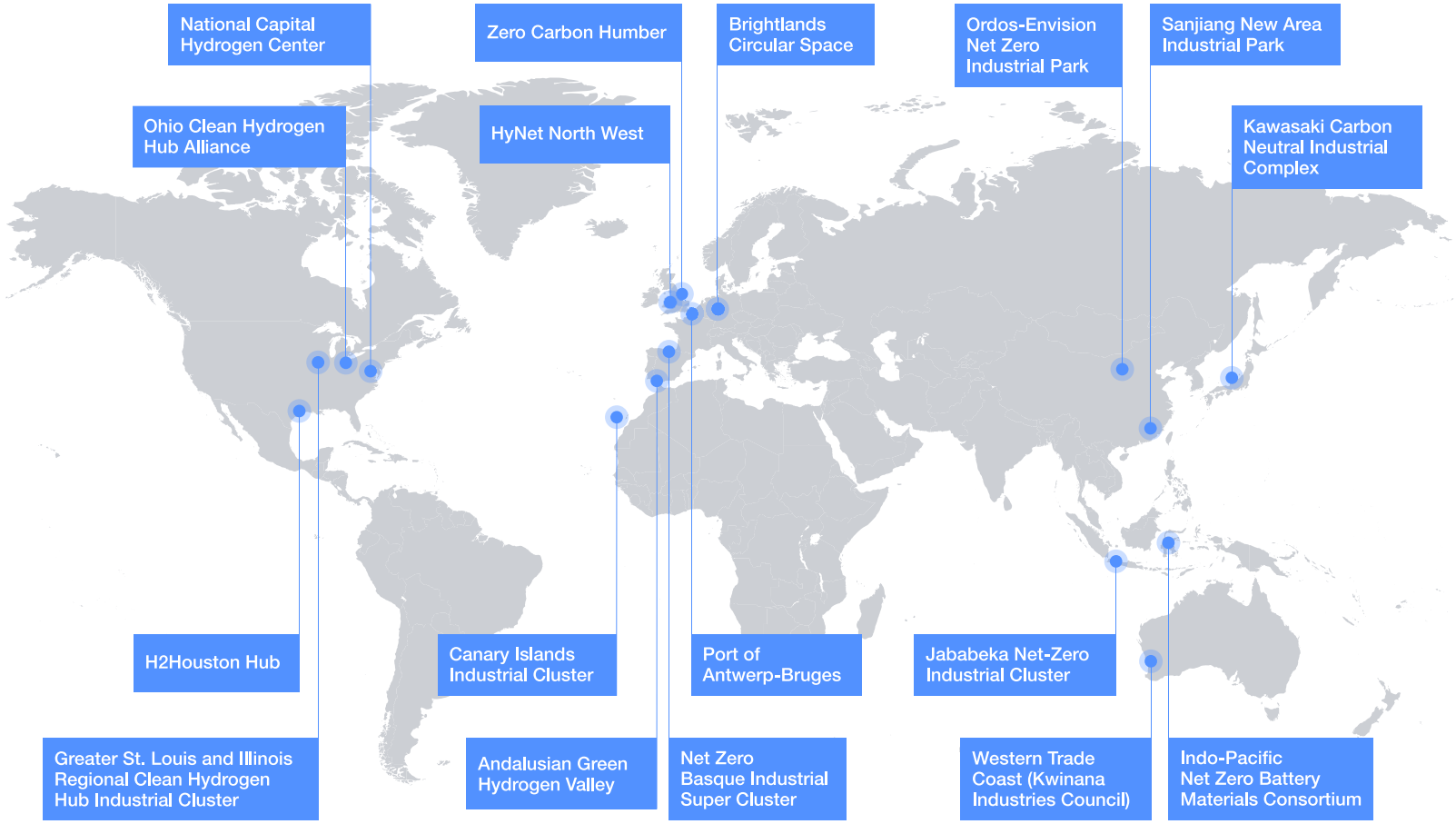
White Paper
Transitioning Industrial Clusters Towards Net Zero: National Policy Enablement



Blog Article
Global Approach to Manage Supply and Demand for Low Carbon Energy Carriers

Initiative's Signatory Clusters

Today the initiative's seventeen clusters represent annual emissions greater than Turkey, spanning a diversity of industries across North America, Europe and Asia-Pacific.



451 Mt CO_2

Abated emissions represented

2.7 million

Direct/indirect job represented

$218 billion

GDP contribution represented

The need for an integrated approach to establish a net-zero cluster

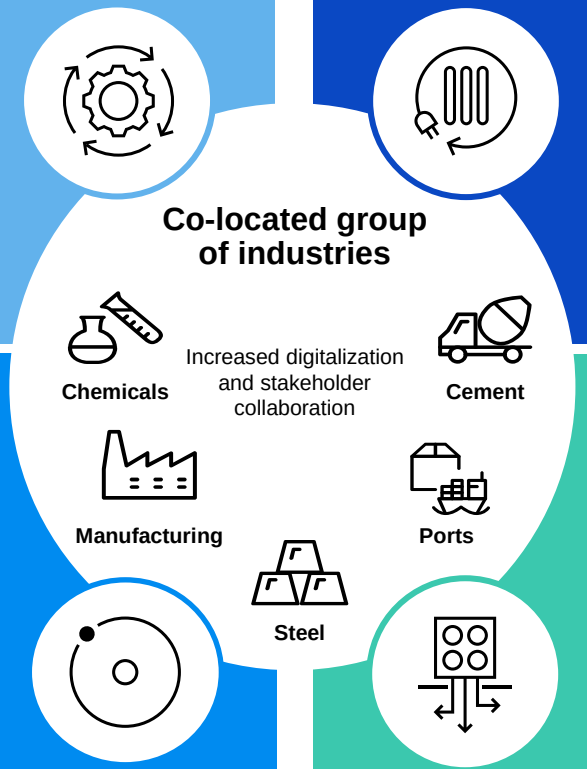
A holistic and collective approach is required to optimize emissions solutions and create an integrated energy system that maximizes system value outcomes across the cluster.

Systemic Efficiency & Circularity

- Increase circularity within a cluster through cross-entity waste utilization
- Integrate processes within a cluster to share energy and material streams
- Provide cost-effective system benefits outside the cluster

Direct Electrification & Renewable Heat

- Electrify low-to-medium temperature and pressure processes
- Generate low-cost, renewable electricity and heat onsite (e.g. rooftop solar, biomass, CSP)
- Pursue shared infrastructure (e.g. microgrid, storage, flexibility)



Hydrogen

- Leverage electricity and heat from nearby zero carbon sources (wind, solar, nuclear, biomass)
- Produce low-to-zero carbon hydrogen from the most economical source (e.g. blue, green)
- Use produced H_2 as an alternative fuel for hard-to-electrify industrial processes, building heating, and transport

Carbon Capture, Utilization & Storage (CCUS)

- Capture carbon from energy and hydrogen production
- Use captured carbon for industrial and manufacturing processes
- Store carbon underground where feasible

Engaging with Transitioning Industrial Clusters

01

In order to sign up to the Statement of Ambition for participation in the Transitioning Industrial Clusters initiative, the cluster must meet the following minimum requirements:

Cluster Characteristics*

- ✓ An industrial cluster of at least **three geographically co-located companies** with an **emission reduction or avoidance potential** of at least **2MT of CO2 per annum**
- ✓ A **joint decarbonization ambition as a cluster** (individual companies' pledges are not sufficient)

Representation

- ✓ **At least 3 parties** (three companies or two companies and a government body) which will represent the cluster and sign the Statement of Ambition.
- ✓ **Nomination of cluster representatives** who will participate in initiative's work (one point of contact/central PMO and representatives of at least two corporates)

Permission

- A **public announcement** of the cluster's decarbonisation goals (through cluster's press release or website etc.).
- ✓ **Permission to use cluster name publicly**.

** See details in Statement of Ambition*

Align Leadership on Cluster Strategy → Champion Initiative among Ecosystem Partners → Define Goals & Scope of Effort → Onboard to Initiative with Public Announcement

GRUPO spri TALDEA

EUSKO JAURLARITZA
GOBIERNO VASCO
EKONOMIAREN GARAPEN, JASANGARRITASUN ETA INGURUMEN SAILA
DEPARTAMENTO DE DESARROLLO ECONÓMICO, SOSTENIBILIDAD Y MEDIO AMBIENTE

Net-Zero Basque Industrial SuperCluster

Basque Government, Iberdrola, Petronor and Industrial Clusters are working together to achieve net zero emissions by 2050, while fostering green and innovation economy in the Basque Country

CONTEXT IN EUSKADI:

2,2 M
Population in the Basque Country

209.000
Jobs in industrial sector in the Basque region

24,2%
Industry Contribution to GVA in 2021

46,15%
of GHG emissions are emitted by industrial sector

NZBIS INICIATIVE:

5 sectors
Pulp & Paper, Cement, Oil Refining, Steel Foundry

65%
of GHG emissions are emitted by these industries

EXPECTED IMPACT:

GDP
2B€ to 3B€ (>2030) (3%-5% of GDP 2021)

Jobs
20k to 30k (>2030) (2-3% of Jobs 2021)

Emissions reduction
100% emissions reduction generated by industrial sector energy consumption by 2050

The SuperCluster will act as enabling mechanism by prioritizing those technologies with potential to transform the Basque industries, not only by looking at the decarbonizations profile, but especially focusing on their capacity to activate the entire value chain within the region.

Launch → Design & Develop →

0 Project launch

Initiative presented in the Basque Country and in the COP- 26.

1 Characterization of the industry

Focusing on energy consumption from process perspective and describing the evolution of the sector in the Basque Country.

2 Technologies identification

Roadmap for each sector that identify the best technologies and measures to reduce CO2 emissions associated with energy consumption.

3 Value Chain

Evaluation of the current or potential value chain in the Basque Country for the development and supply of the identified measures and technologies.

4 Pilot projects

Identification/ prioritization of pilot projects and demonstrators for the application of technological solutions.

5 Communication and international positioning

6 Governance of the SuperCluster

EPRI *will contribute with*:

- **Deep knowledge** of technologies.
- **Experience** in technological development.
- Provide **international projection.**

Sector characterization on energy consumption and in the processes concentrating most of emissions derived from it.

	Phase 1			
	Production plants	Energy consumption	GHG Emissions *[kt CO2 eq./year]*	Emission factor *[Kt CO2/Kt product]*
Pulp and paper	10	32% / 68%	462	0,34*
Oil refining	1	7% / 93%	2.148	0,22
Cement	3	11% / 89%	1.002	0,44
Steel	8	49% / 51%	862	0,28
Foundry	49	35% / 65%	212	0,50

Thermal energy

Electrical energy

*Agreggated value for pulp and paper production

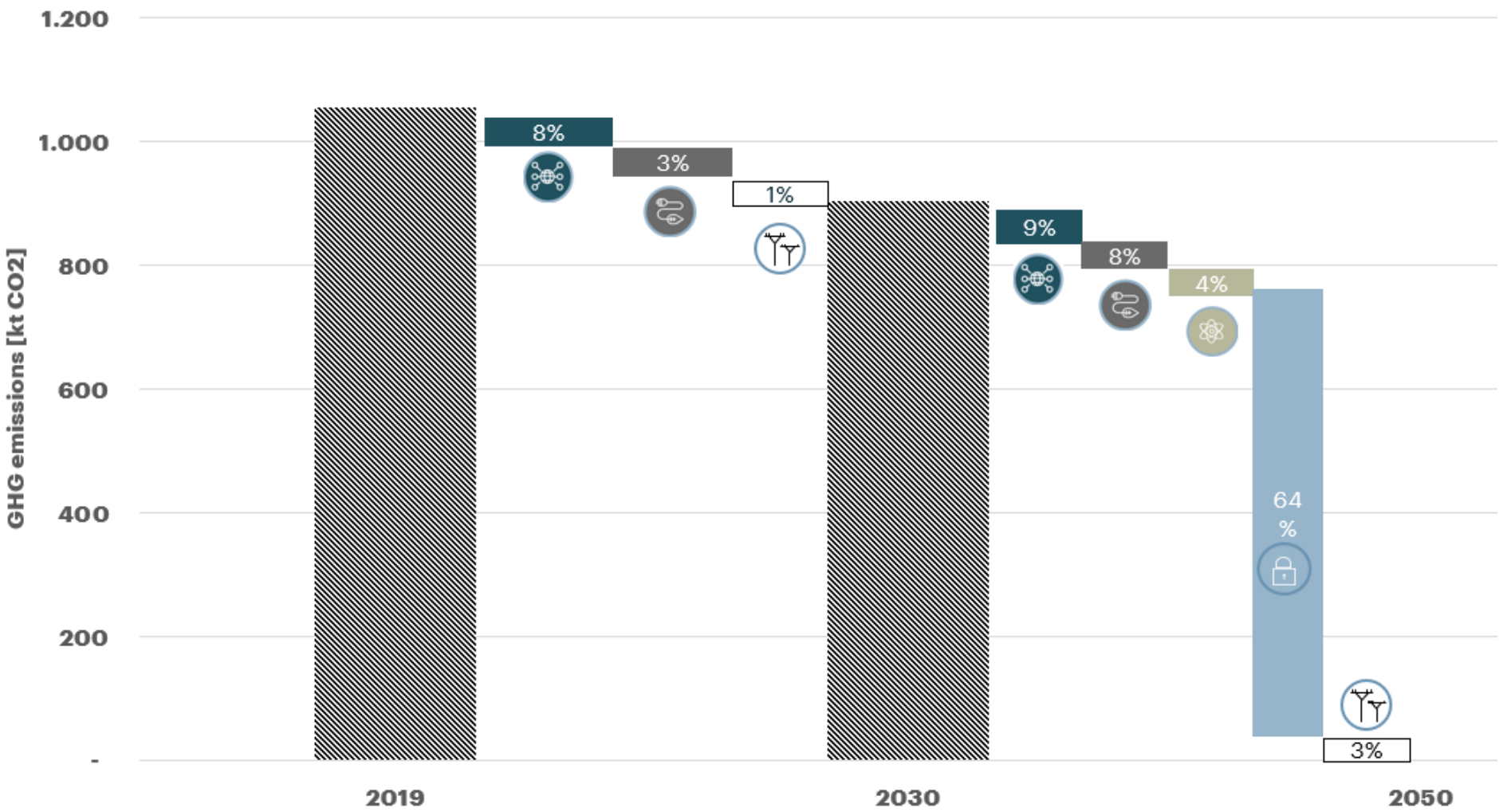
The technology measures identified are distributed as follows between themes and sectors.

58 technological measures

	Pulp and paper	Cement	Steel	Oil refining	Foundry
Energy efficiency and circularity	✓	✓	✓	✓	✓
Electrification and alternative sources	(✓)	✓	✓	✓	✓
Renewable hydrogen		✓	(✓)	(✓)	(✓)
Carbon capture, use and storage		(✓)		✓	

(✓) Main technological developments in the sector

Significant part of emissions will be abated through CCS, given the high percentage of process emissions



Systemic efficiency and circularity

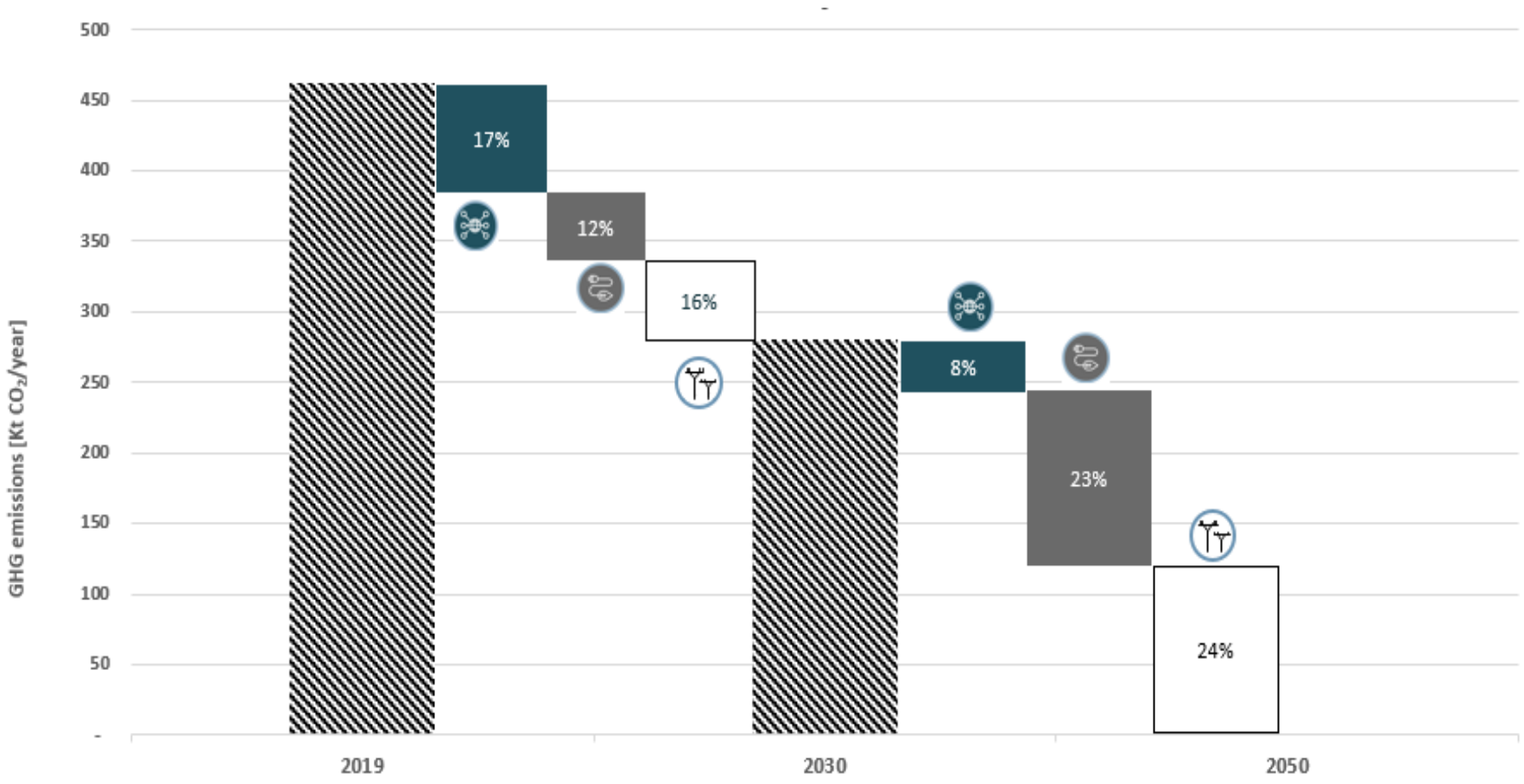
Direct electrification and renewable heat

Green Hydrogen

CCU

Decarbonization of the electric grid

In the short term, greater part of emissions abatement is expected to come from efficiency measures. After 2030, considering the development of high temperature heat pumps, electrification will play the main role in decarbonization

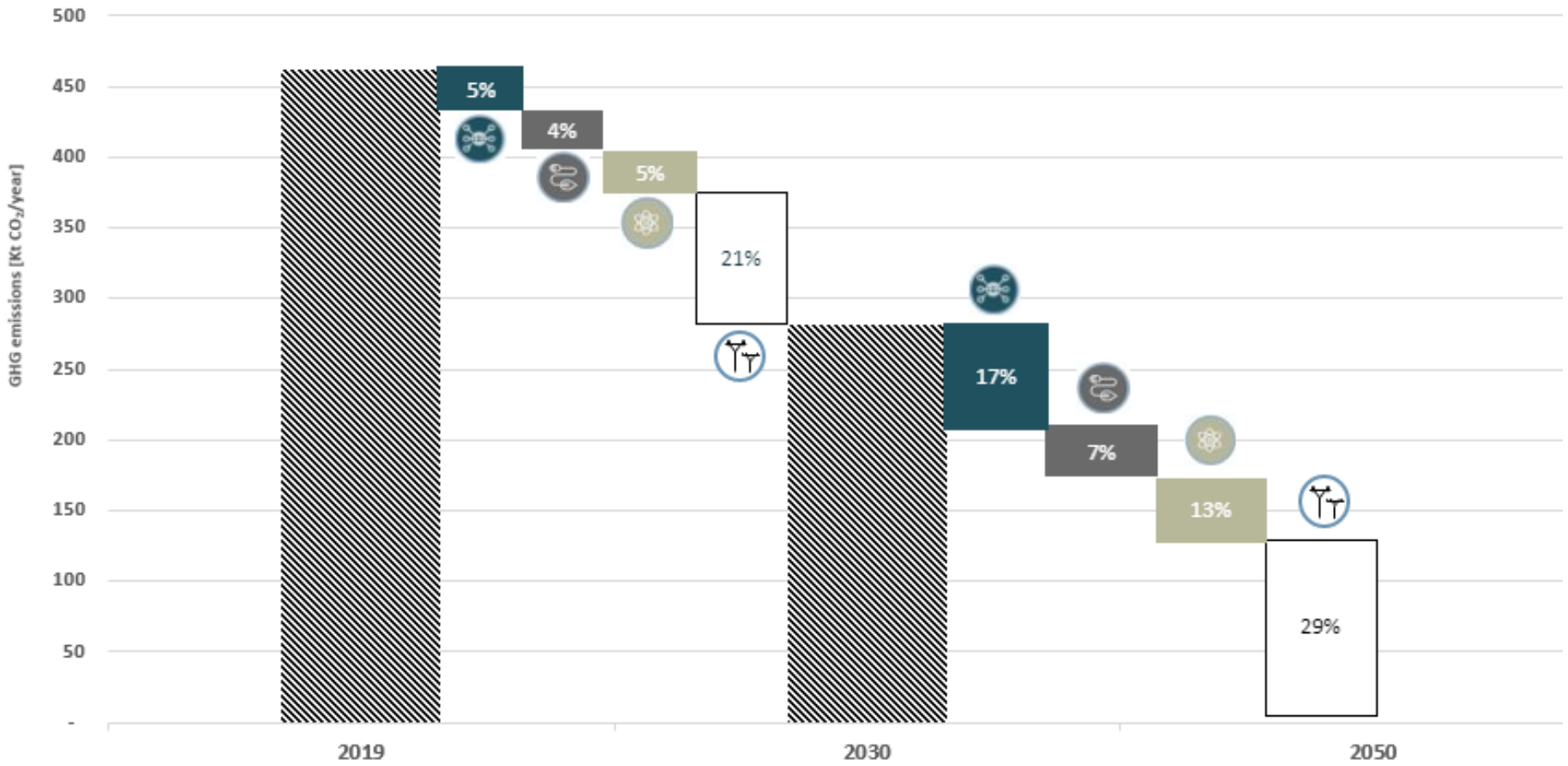


Systemic efficiency and circularity

Direct electrification and renewable heat

Decarbonization of the electric grid

Given the presence of electricity in the mix, significant part of abatement will come from the grid decarbonization. After 2030 energy efficiency will be boosted with oxy-combustion and heat recovery from gases coming out from EAF, complemented by a significant role of H2 in the energy mix



- Systemic efficiency and circularity
- Direct electrification and renewable heat
- Green Hydrogen
- Decarbonization of the electric grid

Multi-sector solutions and synergies across sectors

	Pulp and paper	Cement	Oil refining	Steel	Foundry	Others*
1 Electrolysis retrofit, carbon capture and synthetic fuels production	●	★	★	●	●	
2 Electrolysis of calcium carbonate as a source of H2, O2 and CO2 for other industrial processes	●	★	●			
3 Promotion of an advanced waste management system.	●	●	●	●	●	●
4 Enzymatic hydrolysis for biofuels generation	★		●			
5 Lignin extraction - precipitation and acidification	★		●			●
6 Waste and sludge gasification at the water treatment plant	★	●	★	●	●	●

★ Driver Sector (D) ● Benefited Sector (B)

** Other industries: construction, chemical industry and plastics.*

Conclusions and open questions

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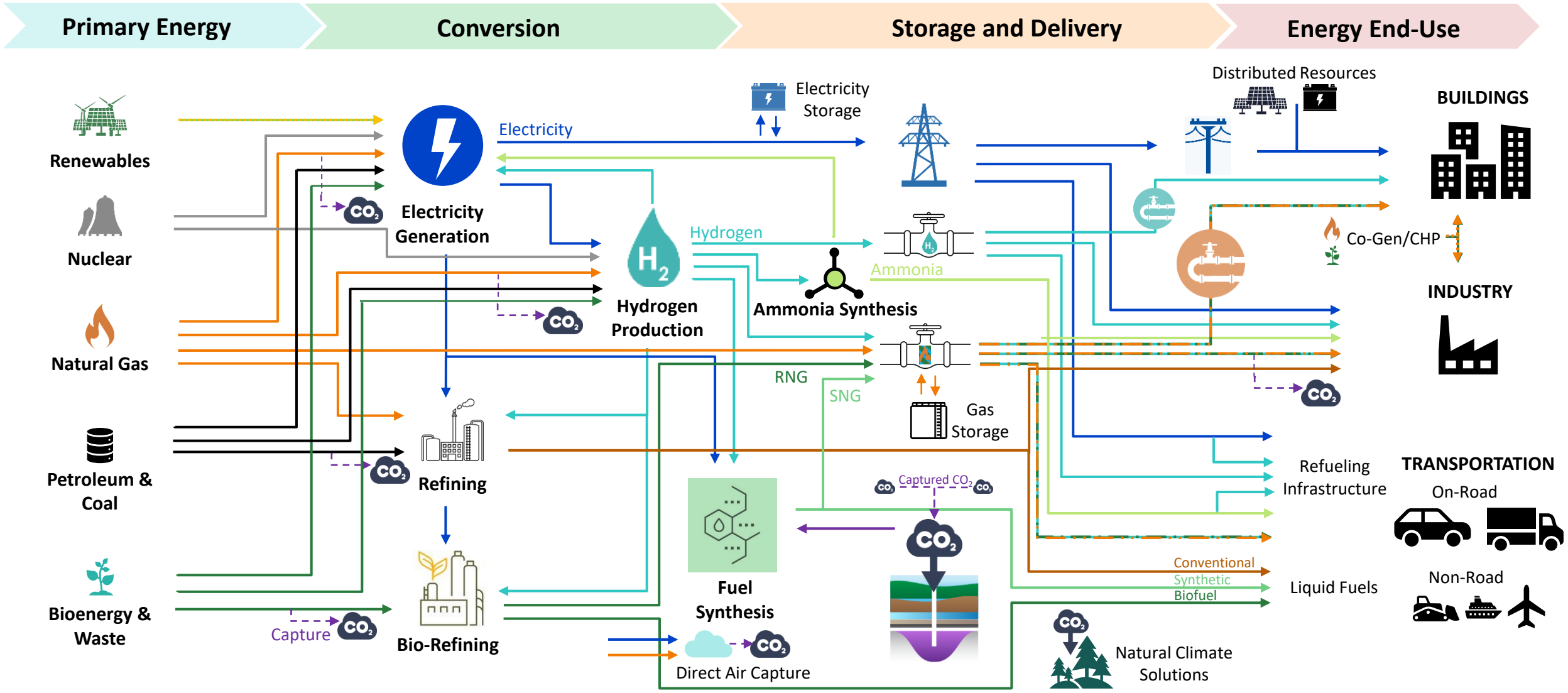
Energy System is Becoming More Complex



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Final remarks and conclusions

✓ **KEY FACTORS TO BE CONSIDERED:**

- Technology optionality with an integrated approach.
- Global Collaboration and pace.
- Energy security.

✓ **THE COLOMBIAN CASE:**

- 4 factors (Clean Matrix, EE, Electrification and LCR) – Transport.
- Electricity prices very competitive for H2 production and export.
- Innovation ecosystem drives to new business models.
- To achieve 3GW of electrolysis capacity, Colombia will require an important renewable investment.
- What is going to be Colombia's role in the global H2 supply-demand chain?

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