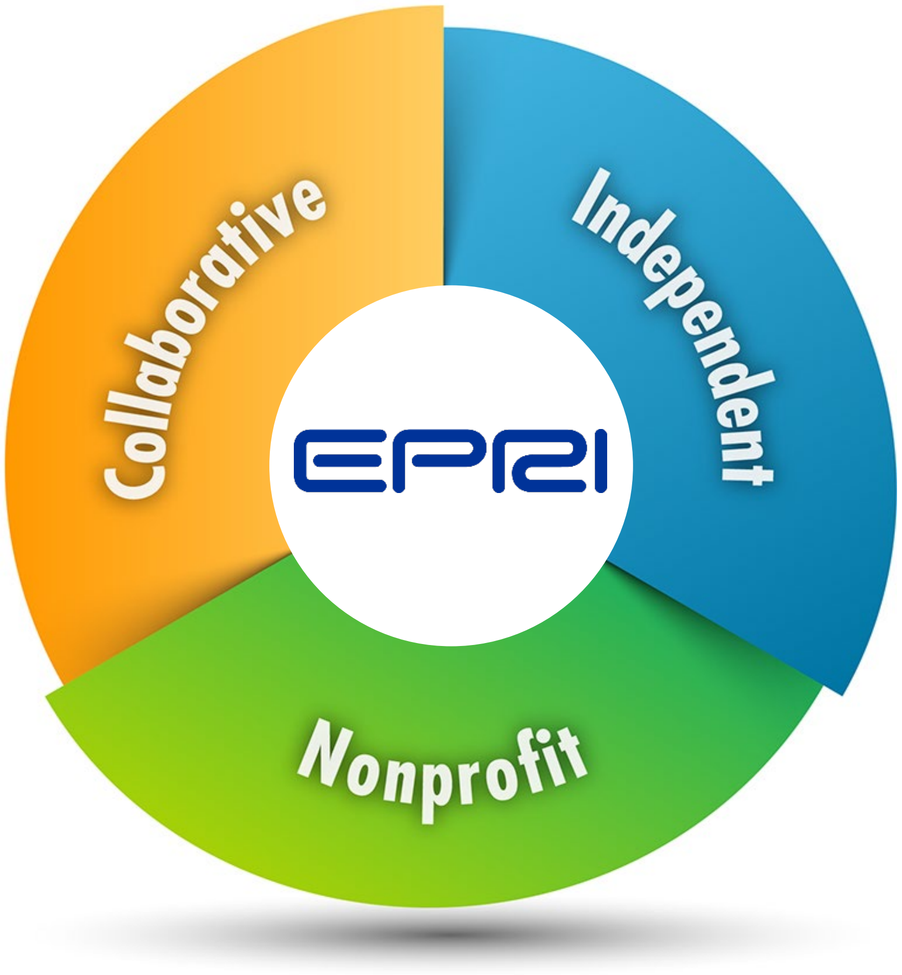
Power Sector Decarbonization: Hydrogen's Potential Role

Sacramento Municipal Utility District Board Meeting

Tom Martz
Senior Principal Team Lead
Low-Carbon Resources Initiative (LCRI)
EPRI
September 12, 2023

www.epri.com

Three key aspects of EPRI



Independent

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

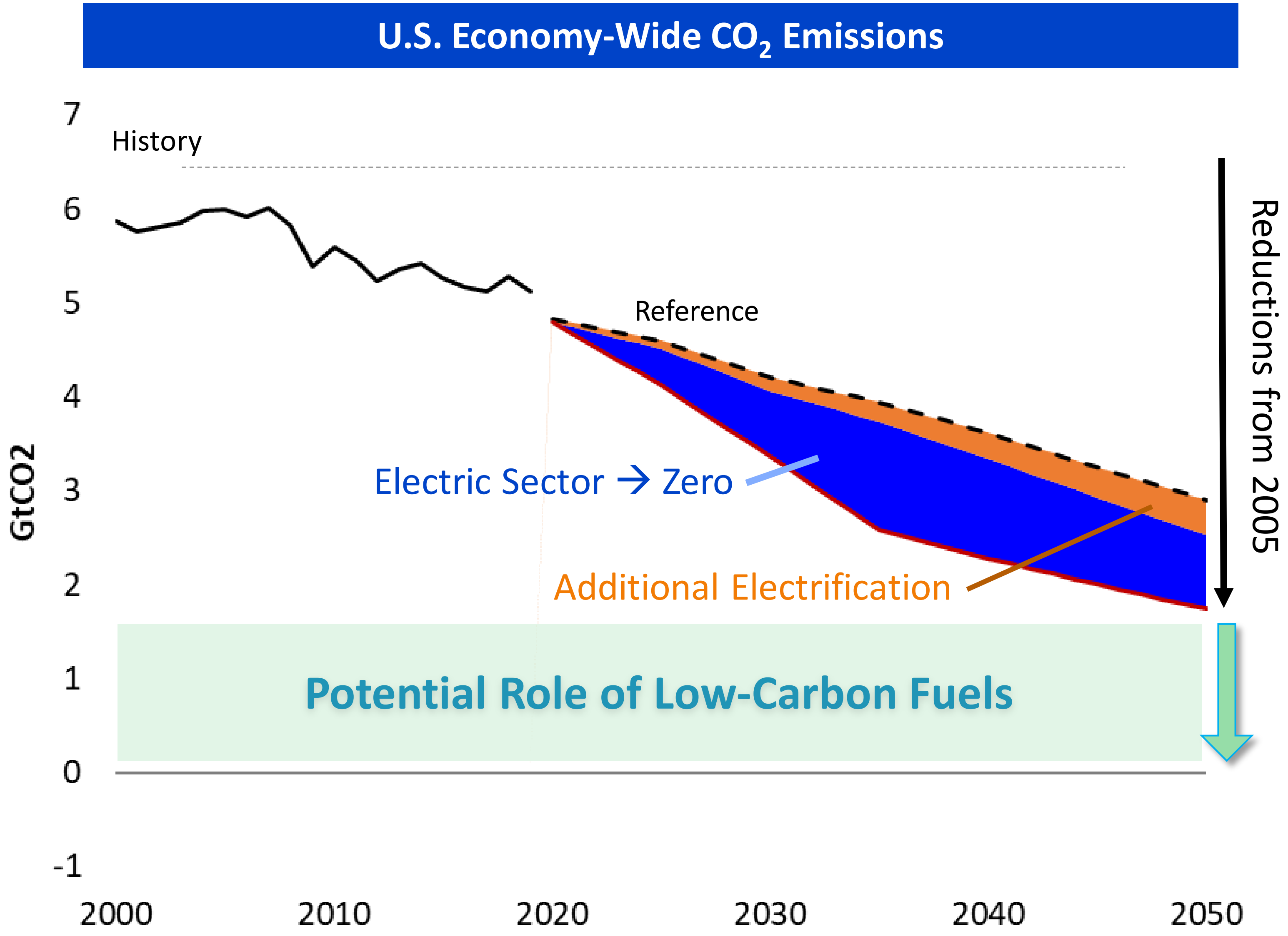
Nonprofit

Chartered to serve the public benefit

Collaborative

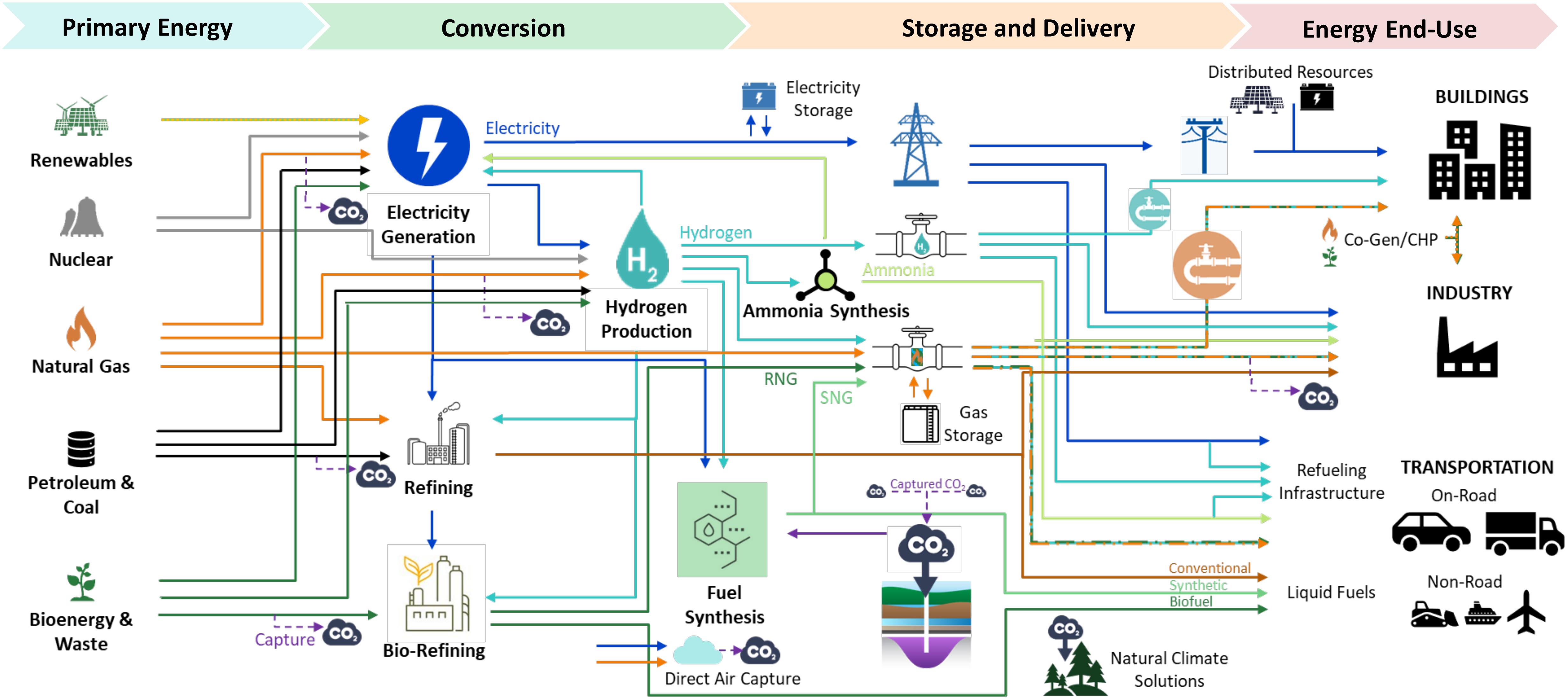
Bring together scientists, engineers, academic researchers, and industry experts

Reducing economy-wide CO_2 emissions

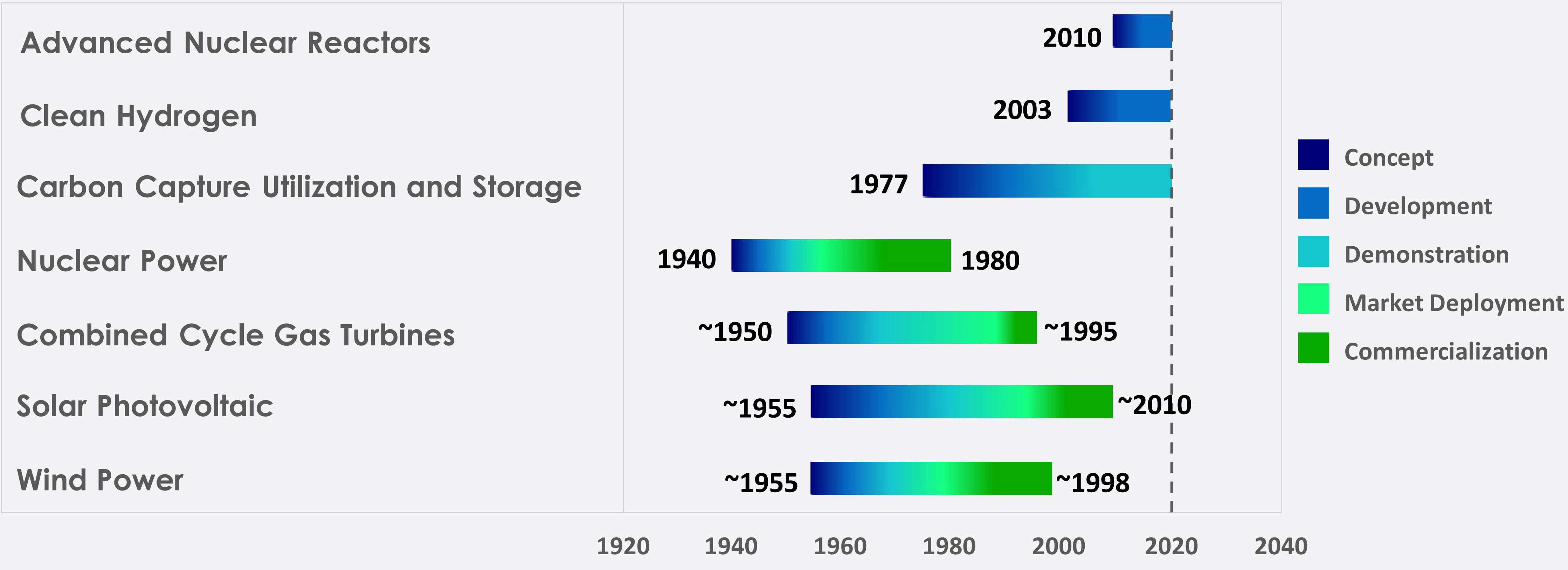


EPRI Report 3002020700

Energy system is becoming more complex



Concept to commercialization takes decades



Notional timelines

Low-Carbon Resources Initiative

FOCUS

Multiple options and solutions to establish viable low-carbon pathways

Technologies for hard-to-decarbonize areas of the energy economy

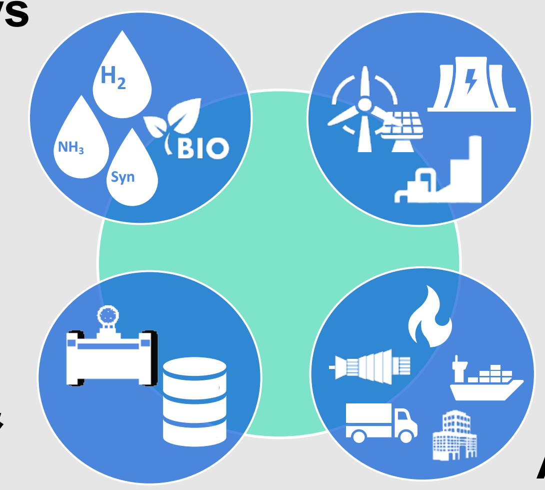
Affordable, reliable, and resilient integrated energy systems for the future

RESEARCH AREAS

Hydrogen | Ammonia | Synthetic/ Derivative Fuels | Biofuels

Production Pathways

Integrated Energy Systems



Storage & Delivery

End Use Applications

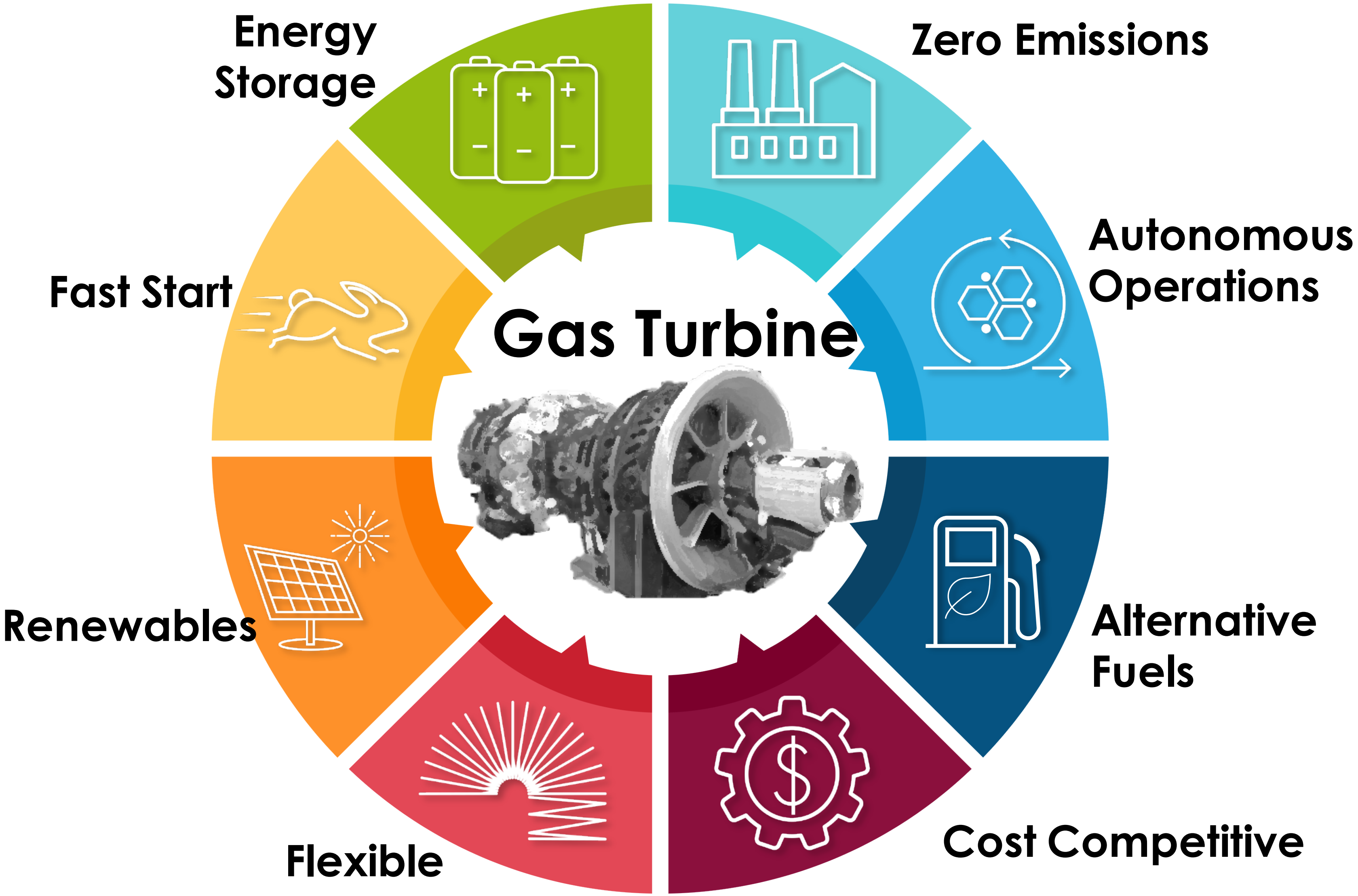
VALUE

Independent, objective research leveraged by global engagement and collaboration

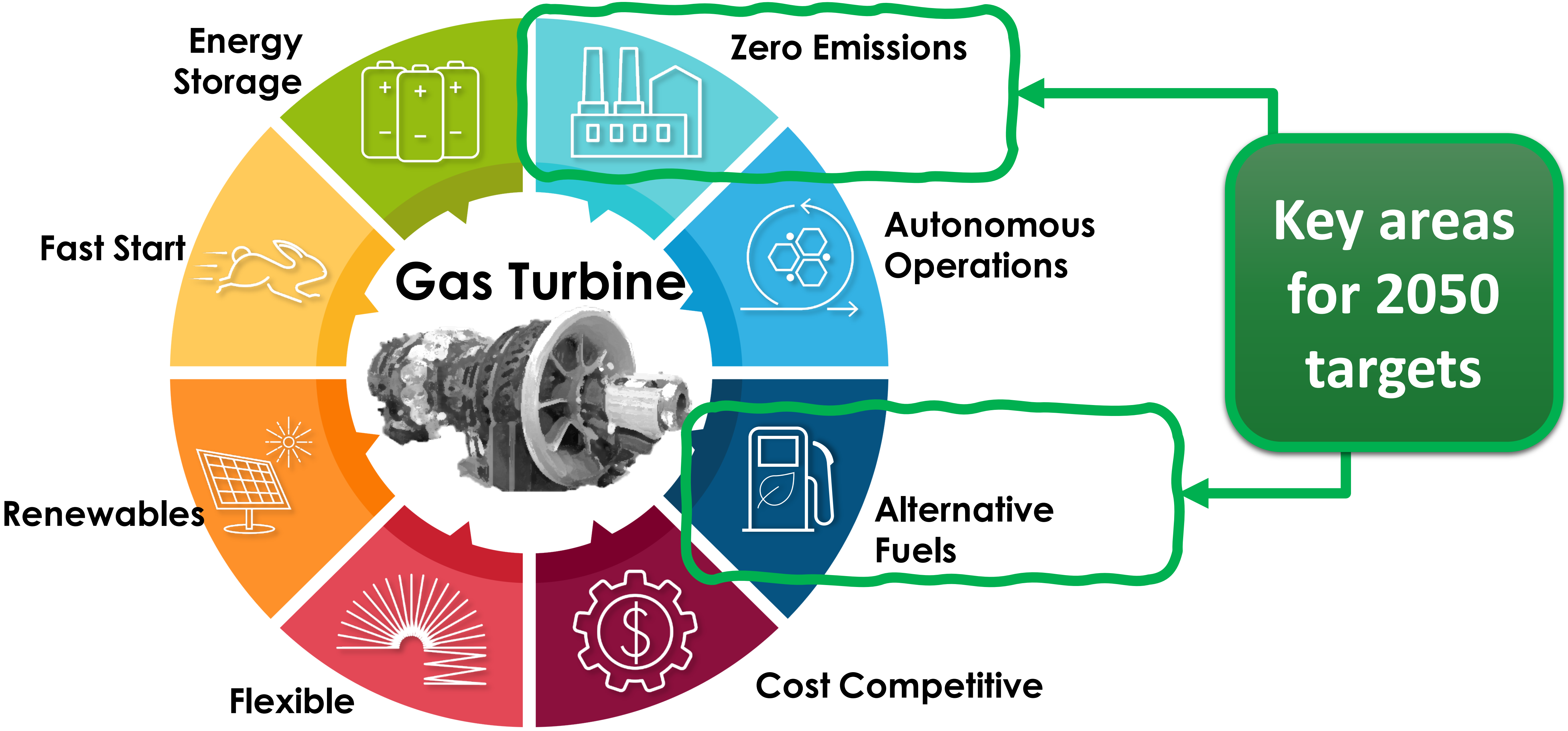
Comprehensive approach to low-carbon value chain and technology analyses

High-impact results from technology evaluations, and safety, environmental, and economic assessments

Gas turbines in a decarbonized future



Gas turbines in a decarbonized future



Current gas turbine fleet: OEM literature

OEM	*Type*	*Notes*	*TIT C[F] or Class*	*H_2 % (Vol)*
MHPS	Diffusion	N2 Dilution, Water/Steam Injection	1200~1400 [2192~2552]	up to 100
	Pre-Mix (DLN)	Dry	1600 [2912]	up to 30
	Multi-Cluster	Dry	1650 [3002]	up to 30
GE	SN	Single Nozzle (Standard)	B,E Class	up to 100
	MNQC	Multi-Nozzle Quiet Combustor w/ N2 or Steam	E,F Class	up to 100
	DLN 1	Dry	B,E Class	up to 33
	DLN 2.6+	Dry	F,H Class	up to 20
	DLN 2.6e	Dry	H Class	up to 50
Siemens Energy	DLE	Dry	E Class	up to 30
	DLE	Dry	F Class	up to 30
	DLE	Dry	H Class	up to 30
	ACE	Dry	HL Class	up to 50
Ansaldo	Sequential	GT26	F Class	up to 30
	Sequential	GT36	H Class	up to 50
PSM	LEC-III™	DLE	B, E Class	up to 50
	Current Flamesheet™	DLE	Frame 5, 6B, 7E, 9E, 7F, 9F, 501F, 701F	up to 60
Baker Hughes	DLN	Frame 6/7/9	Frame 6/7/9	up to 32
	Diffusion	Frame 6/7/9	Frame 6/7/9	up to 100

Supported demonstrations of H_2 for power generation

H_2 Demonstration Objectives

- Operate unit without major modifications
- Measure impacts on CO_2, NOx, CO, and unit performance
- Develop best practices for H_2 blending

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

44%v | GE LM6000
(45 MWe - Aeroderivative)

Executive Summary Report

Georgia Power

20.9%v | Mitsubishi 501G
(265 MWe – Heavy Frame)

White Paper Report

WEC Energy Group

25%v | Wärtsilä RICE
(18 MWe - RICE)

Executive Summary Report

Egyptian Electricity Holding Company

5%v | GE LM6000
(45 MWe - Aeroderivative)

Press Release

Hydrogen as a gas turbine fuel

Main technical or scientific challenges

100% hydrogen-capable gas turbines are not commercially ready

- EPA 30% vol. H_2 blend target by 2032 is feasible for most of the GT fleet
- EPA 96% vol. H_2 target by 2038 gives some flexibility for designs, but major changes probable (code compliance & new hardware)

NOx emissions

- Hydrogen blending demonstration data sets above 44% vol. do not exist; lab research underway in LCRI to develop fundamental curves
- Demonstrations to date show no issues with maintaining NOx at lower blends across a variety of machines
- All OEMs are targeting constant NOx emissions from the GT prior to the SCR as part of future DLN design

Availability of sufficient clean hydrogen and infrastructure is unclear

Costs today

- **Blending costs** are heavily attached to costs of H_2 production, transport, and storage
- **Current demonstrations** utilize existing hardware/ infrastructure with only H_2 metering added

Main non-technical challenges

Perception is a major issue involving safety, feasibility, & emissions

- **Safety**: Hydrogen can be used in a safe manner and can be managed just as natural gas or other hydrocarbons
- **Feasibility**: H_2 currently does not have sufficient production/availability or infrastructure for power generation
- **Emissions**: With lack of 100% DLN H_2 engine data, NOx emissions assumed to be higher than natural gas; however, demonstration data proving otherwise

Largest Demonstration / Commercial Projects

- **Several examples** of GTs using **off-gas from refineries**
  - Typically, older technologies/non-DLN
  - Can be done safely, consistently, and fuel flexibly
- **Southern Company McDonough** – 1st Advanced Class DLN Demo @ 20%
- **NYPA Brentwood** – @ 44% vol. blend and existing SAC hardware with consistent NOx emissions as natural gas
- **Coming soon** – @ 38% vol. blend on Advanced Class DLN
- **Long-term demo** (6 mo.) on small-scale GT *in planning*
- **ACES** project scheduled to start @ 30% vol. in 2025

Hydrogen production, storage and transport

Main Technical or Scientific Challenges

- **Production of hydrogen via electrolysis is a mature process**; however, **large-scale integration into the electric sector** and **understanding flexible operations** is still under development.
- Due to **variability of materials** used in existing natural gas transmission pipelines, **blending limits should be analyzed on a case-by-case basis**. Active studies ongoing and material analysis ongoing.
- **Underground storage of hydrogen in salt caverns is mature but geographically limited**. Storage in **depleted natural gas reservoirs offers the greatest potential** but still needs to be evaluated and demonstrated.

Main non-technical challenges

- **Electrolyzer supply chains not yet at scale** to support deployment. Worldwide manufacturing capacity in 2021 (per IEA) ~8 GW/year.
- **Carbon accounting methods** remain uncertain.
- **Lower energy per volume with hydrogen** could reduce total energy flow if existing natural gas infrastructure is repurposed.
- Deployment of infrastructure could potentially **face regulatory and construction challenges** due to stakeholder opposition.
- **Natural gas derived hydrogen production with carbon capture** has been demonstrated but would face fossil fuel and CO_2 management obstacles and would need >90% capture rates to meet 'clean hydrogen'.

Costs Today and Potential Incentives

Levelized costs of hydrogen production

- Electrolysis: $2 to $20/kg
  - @50% CF and 0.05/kwh $5.50 – $12.50
  - @90% CF and 0.05/kwh $4.50 - $9
- Natural gas derived with CCS: $1.5 to $5/kg
- Biomass gasification with CCS: $6 to $12/kg
- Plastic waste gasification with CCS: $6 to $10/kg
- LCOHs driven by electricity/feedstock prices & capacity factors

Infrastructure CAPEX estimates

- Hydrogen pipeline: $20/MMBtu-day-mile
- Hydrogen underground storage: $60/MMBtu
- Hydrogen delivery: $2,600/MMBtu-day

IRA Tax Credits

- 45V H_2 production $0.6 to $3/kg
- 45V credit dependent on life-cycle CO_2 intensity & workforce requirements
- Fossil- and biomass-derived H_2 production with CCS has option to elect 45Q ($85/tonne CO_2) in lieu of 45V

Largest Demonstration / Commercial Projects

Electrolyzers

- Alkaline: Baofeng Energy 150 MW (27,000 tons H_2/year, China); 260 MW plant under construction (mid-2023 COD)
- PEM: Air Liquide 20 MW (3,000 tons H_2/year, Canada)

Fossil derived H_2 with CCS

- 8 projects (4 natural gas, 3 coal/coke, 1 crude)
- Largest project: Shell Quest (328,500 Mt H_2/year; up to 1.2 MMT tons/year CO_2 capture, Canada)

Pipelines & storage

- 1,600 miles of H_2 pipeline (US Gulf Coast)
- 10 commercial subsurface H_2 storage facilities (3 US, 7 Global)

Together…Shaping the Future of Energy®

EPRI.com

EPRI.com is our online resource to support your business needs

Set bookmark and shortcut to our website: www.EPRI.com

Resources Include:

- Program Overviews and Research Project Progress
- Results to fit your needs:
  - Reports
  - Guidelines
  - Databases
  - Software
  - Training Modules
  - Tools
  - Videos
- Events, Webcasts, and Collaboration Spaces
- Email Subscriptions, Announcements, and News
- Supplemental Project Opportunities
- A Personal Dashboard where you can subscribe to email notifications, favorite EPRI content, and register for events.

Log-In today to get started!

For questions or website assistance, please contact EPRI Customer Assistance Center (CAC) at askepri@epri.com or 800-313-3774, option 4.