NATIONAL PETROLEUM COUNCIL

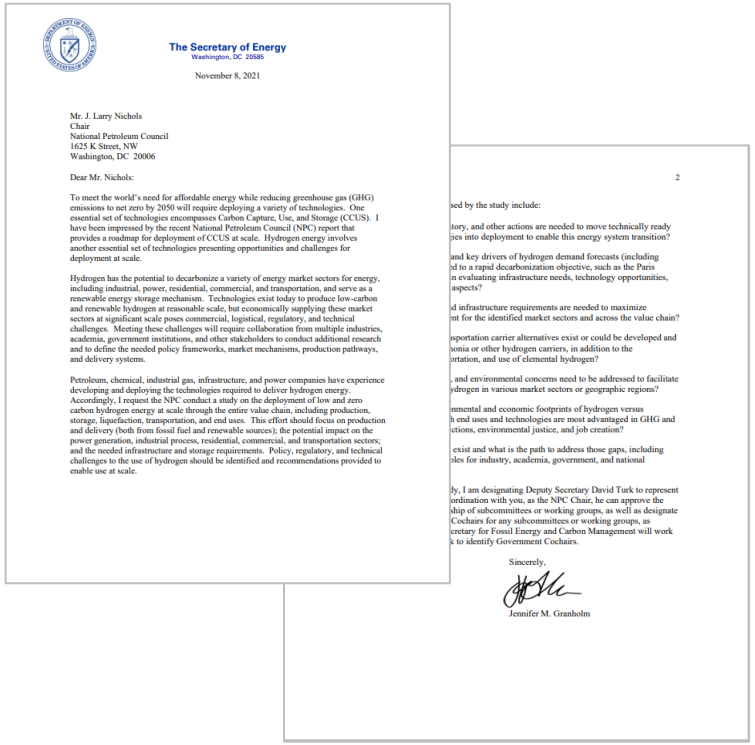
Deployment of Low Carbon Intensity (LCI) Hydrogen Energy at Scale

Progress Report

December 12, 2023

Diverse Perspectives Inform Response to Study Request From Secretary of the Department of Energy

Study will address **seven key questions**



The Secretary of Energy
Washington, DC 20585

November 8, 2021

Mr. J. Larry Nichols
Chair
National Petroleum Council
1625 K Street, NW
Washington, DC 20006

Dear Mr. Nichols:

To meet the world's need for affordable energy while reducing greenhouse gas (GHG) emissions to net zero by 2050 will require deploying a variety of technologies. One essential set of technologies encompasses Carbon Capture, Use, and Storage (CCUS). I have been impressed by the recent National Petroleum Council (NPC) report that provides a roadmap for deployment of CCUS at scale. Hydrogen energy involves another essential set of technologies presenting opportunities and challenges for deployment at scale.

Hydrogen has the potential to decarbonize a variety of energy market sectors for energy, including industrial, power, residential, commercial, and transportation, and serve as a renewable energy storage mechanism. Technologies exist today to produce low-carbon and renewable hydrogen at reasonable scale, but economically supplying these market sectors at significant scale poses commercial, logistical, regulatory, and technical challenges. Meeting these challenges will require collaboration from multiple industries, academia, government institutions, and other stakeholders to conduct additional research and to define the needed policy frameworks, market mechanisms, production pathways, and delivery systems.

Petroleum, chemical, industrial gas, infrastructure, and power companies have experience developing and deploying the technologies required to deliver hydrogen energy. Accordingly, I request the NPC conduct a study on the deployment of low and zero carbon hydrogen energy at scale through the entire value chain, including production, storage, liquefaction, transportation, and end uses. This effort should focus on production and delivery (both from fossil fuel and renewable sources); the potential impact on the power generation, industrial process, residential, commercial, and transportation sectors; and the needed infrastructure and storage requirements. Policy, regulatory, and technical challenges to the use of hydrogen should be identified and recommendations provided to enable use at scale.

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sed by the study include:

tory, and other actions are needed to move technically ready ies into deployment to enable this energy system transition?

and key drivers of hydrogen demand forecasts (including ed to a rapid decarbonization objective, such as the Paris n evaluating infrastructure needs, technology opportunities, aspects?

d infrastructure requirements are needed to maximize nt for the identified market sectors and across the value chain?

sportation carrier alternatives exist or could be developed and monia or other hydrogen carriers, in addition to the ortation, and use of elemental hydrogen?

, and environmental concerns need to be addressed to facilitate ydrogen in various market sectors or geographic regions?

nmental and economic footprints of hydrogen versus h end uses and technologies are most advantaged in GHG and ctions, environmental justice, and job creation?

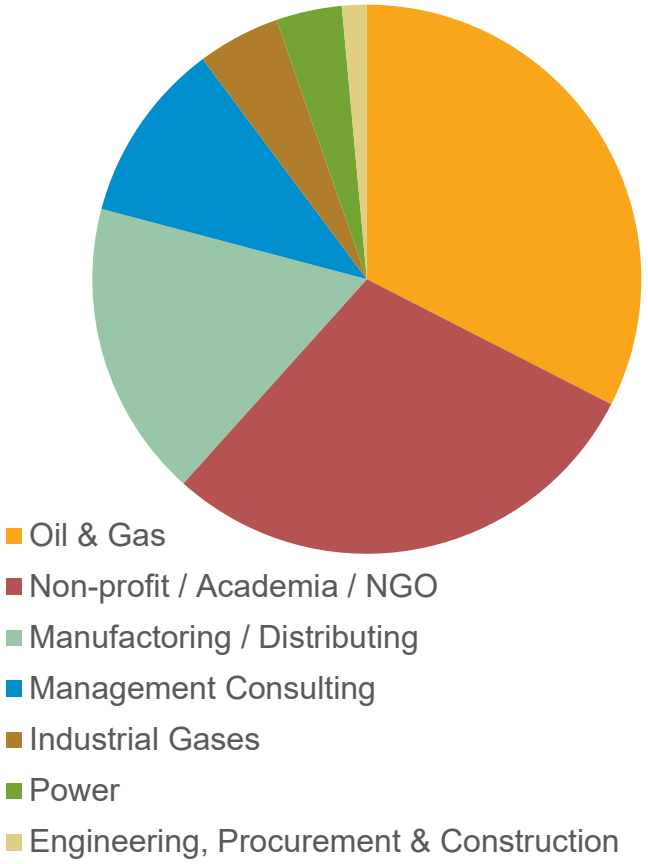
exist and what is the path to address those gaps, including oles for industry, academia, government, and national

ly, I am designating Deputy Secretary David Turk to represent ordination with you, as the NPC Chair, he can approve the ship of subcommittees or working groups, as well as designate Cochairs for any subcommittees or working groups, as cretary for Fossil Energy and Carbon Management will work k to identify Government Cochairs.

Sincerely,

Jennifer M. Granholm

>200 participants from **100 organizations** participating



Study structure

Chapter 1: Role of LCI Hydrogen in the U.S.

Chapter 2: Supply Pathways for Low-CI Hydrogen

Chapter 3: Midstream Infrastructure

Chapter 4: Supply Chain Carbon Intensity and Technoeconomics

Chapter 5: Demand Drivers

Chapter 6: Policy and Regulatory

Chapter 7: Safety, Societal Considerations and Impacts

Key Attributes of This Study

Expert Input – Technoeconomic modeling informed by diversity and experience of the study participants

Targeted Role of LCI hydrogen – Identify recommendations to enable LCI hydrogen adoption at a lower cost to society

Regionality – Comprehensive regional analysis across the LCI hydrogen value chain (supply, infrastructure, demand)

Modeling Collaboration Between NPC and MIT Energy Initiative

Key Inputs

International Energy Agency

NREL

U.S. DEPARTMENT OF ENERGY

National Petroleum Council

Analysis

Key Outputs

Economy-wide **energy mix, emissions trajectories** and **costs**

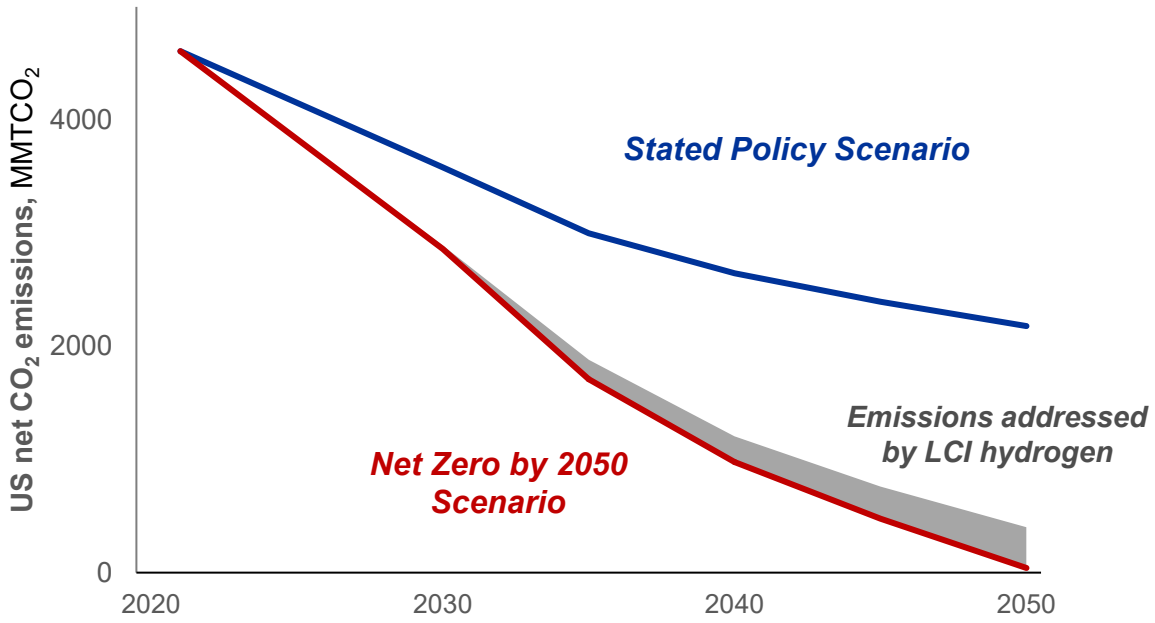
Two scenarios: **Stated Policies** and **U.S. Net Zero by 2050**

National and regional **supply** and **demand techno-economics**

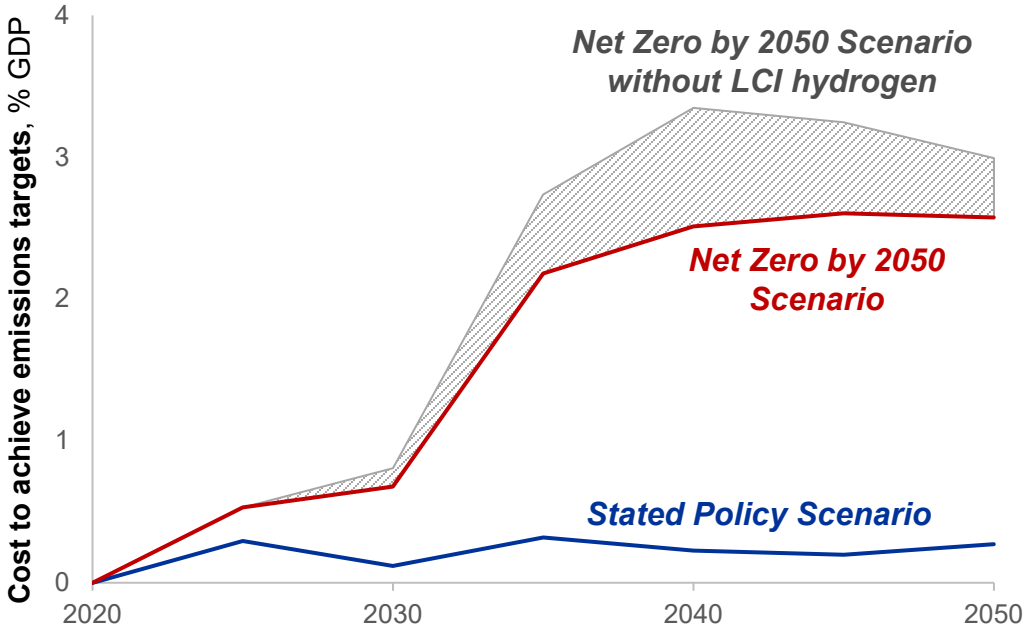
Select **regional infrastructure optimization**

Key Findings

LCI Hydrogen Plays a Key Role in Achieving Emissions Reduction at a Lower Cost to Society



LCI hydrogen accounts for **~8% of emissions reductions** in **hard-to-abate sectors**

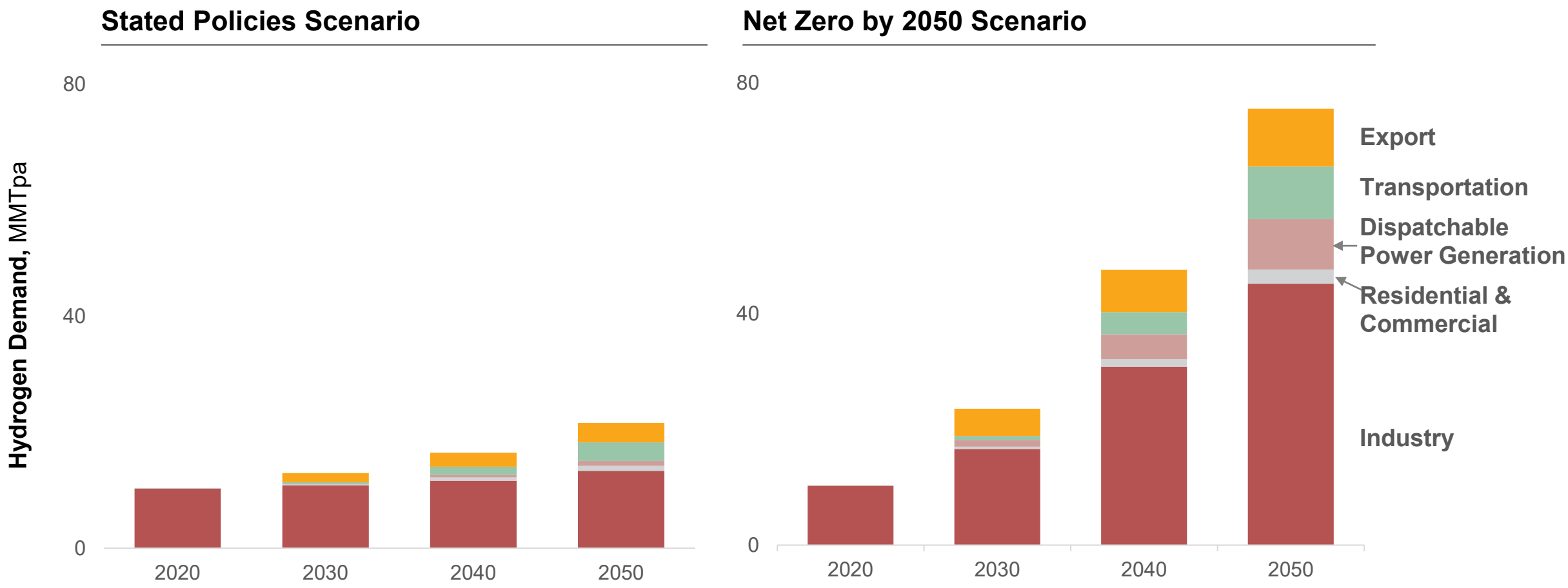


Costs to achieve Net Zero increases to **~3% of GDP** by 2050

Without LCI hydrogen, costs to achieve Net Zero could **increase by an additional 0.5-1% GDP**

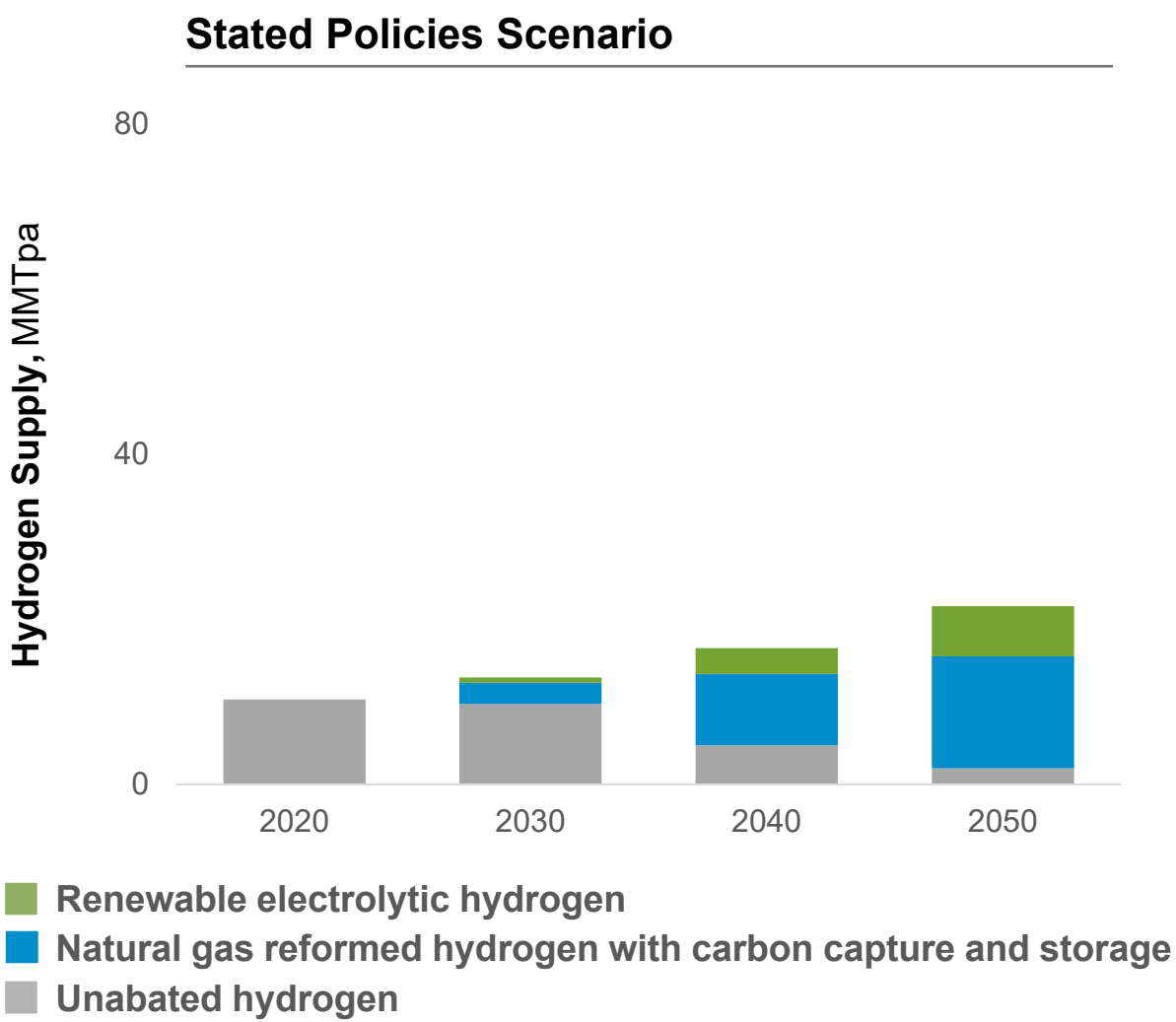
Source: MIT modeling for NPC Hydrogen study; $MMTCO_2$ – million metric tons CO_2 equivalents; GDP – Gross Domestic Product

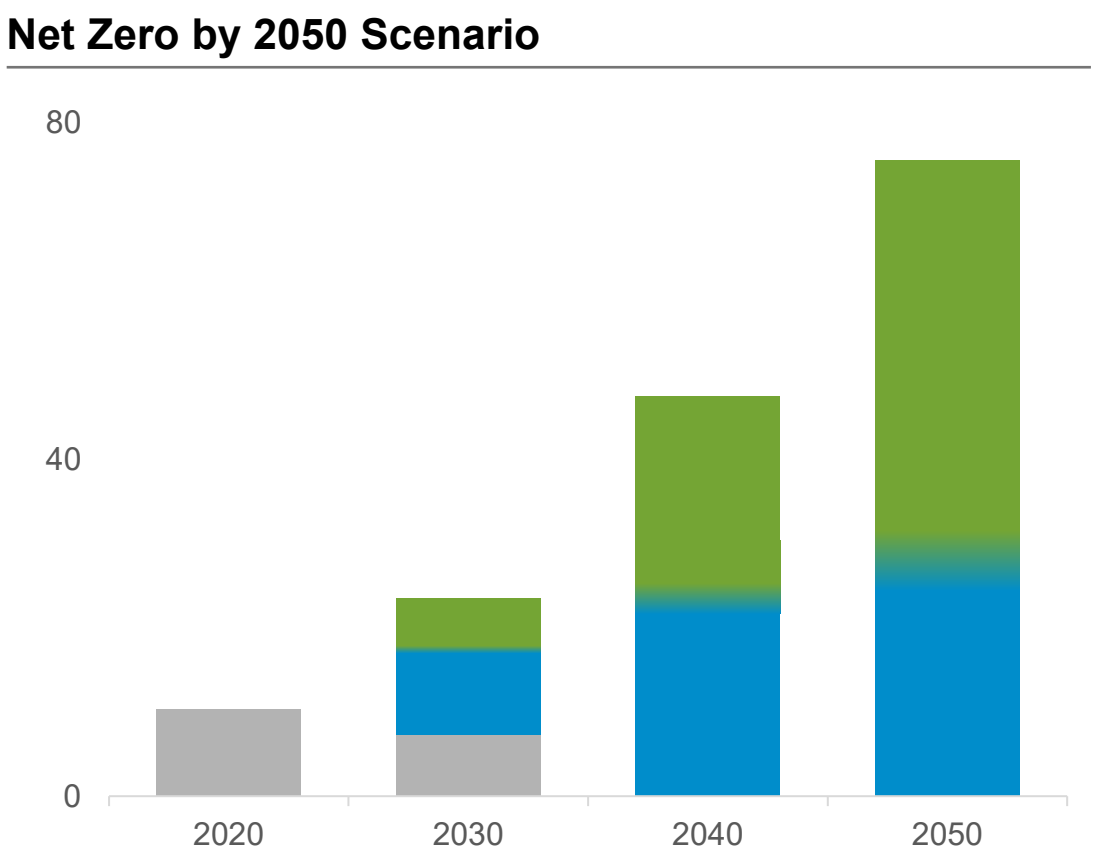
Unlocking Demand Sectors Will Require Significant and Immediate Action



Source: MIT modeling for NPC Hydrogen study
MMTpa – Million metric tons per annum

Optimal Supply Mix Driven by Speed to Scale, Cost and Carbon Intensity



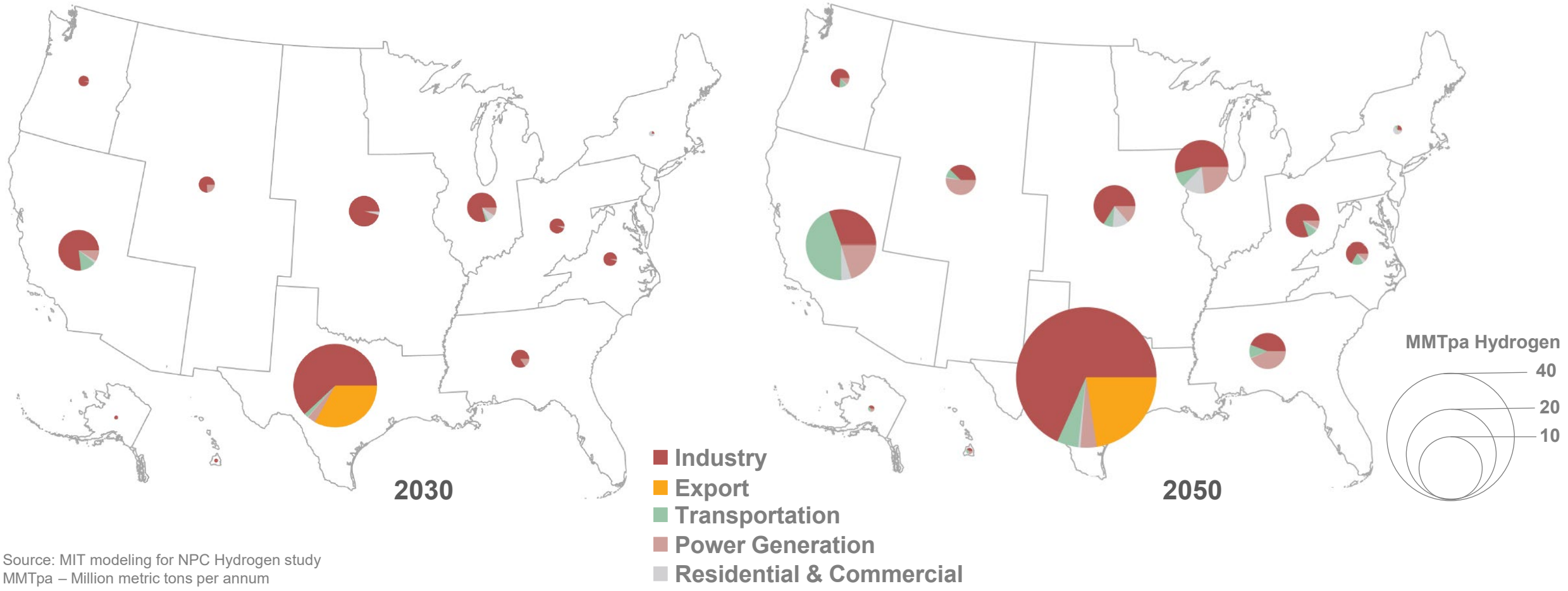


Source: MIT modeling for NPC Hydrogen study
MMTpa – Million metric tons per annum

Existing and Future Anchor Demand Will Impact Regional Sectoral Adoption

Regional development also driven by renewable and natural gas resources, infrastructure and supportive State policies

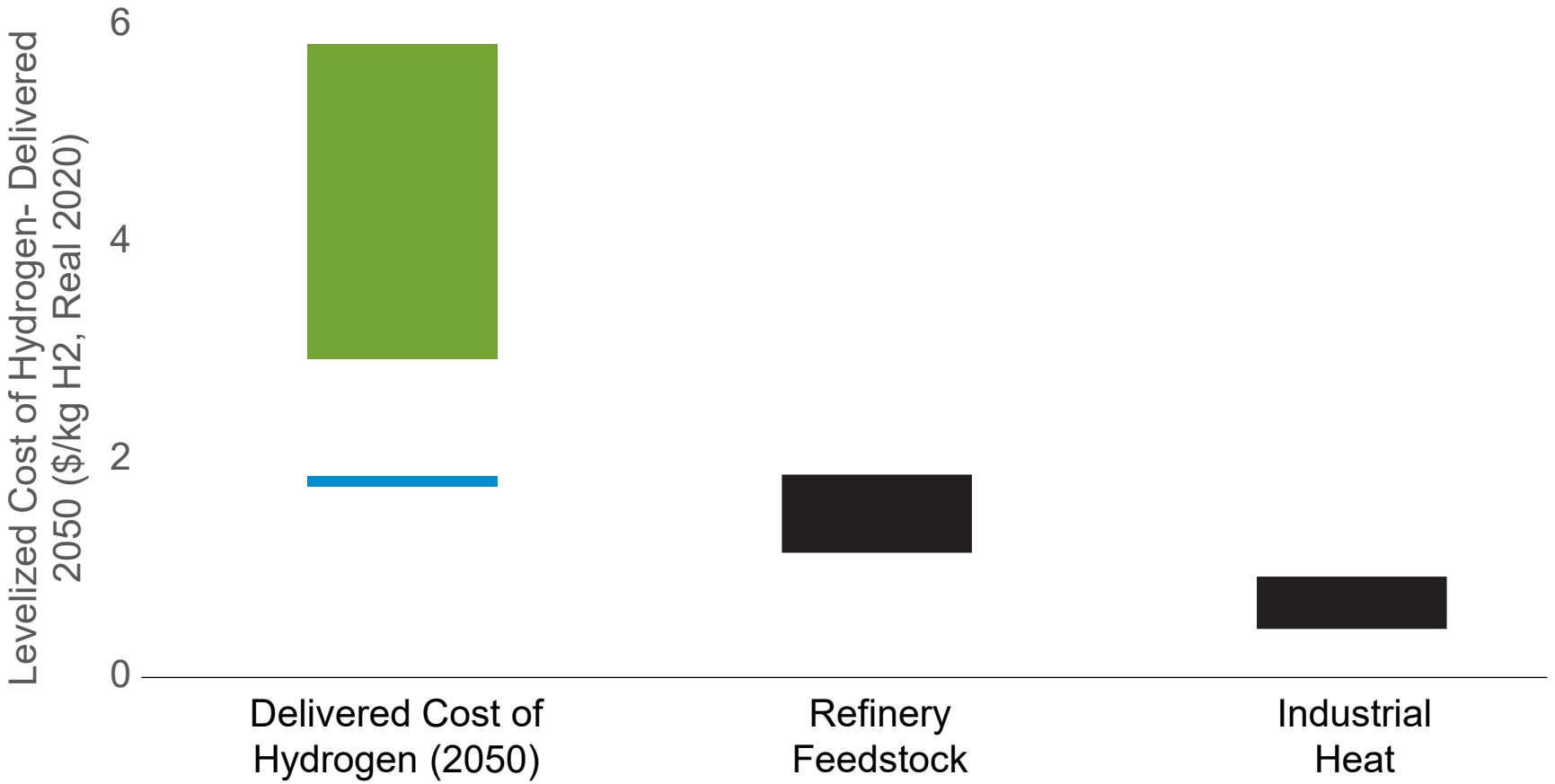
Regional Demand by Sector – U.S. Net Zero by 2050 Scenario



Source: MIT modeling for NPC Hydrogen study
MMTpa – Million metric tons per annum

Cost Parity Gap to Incumbents (Threshold Price Example)

Gulf Coast Region – Industrial Demand Sector - 2050



By 2050 **cost parity gaps** to incumbent fuels and feedstocks **still exist**

Different demand sectors need hydrogen at **different cost to reach parity to incumbents**

- **Delivered Cost-Renewable Electrolytic Hydrogen (2050)**
- **Delivered Cost Natural Gas Reformed Hydrogen with Carbon Capture and Storage (2050)**
- **Hydrogen Cost Needed to Reach Parity with Incumbent Fuel**

Source: MIT modeling for NPC Hydrogen study
$/kg – Levelized cost of hydrogen, Real 2020 $

Coordinated DOE, Policymaker and Industry Action is Needed to Unlock At-Scale LCI Hydrogen Deployment

- **Policy to close cost gaps**
- **Regulatory and permitting reform to facilitate supply and infrastructure build-out**
- **Targeted technology and RD&D investments with national labs and public/private programs**
- **Safety, societal considerations and impacts to improve local stakeholder engagement and provide societal benefits (education, workforce readiness, environment, health)**

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