The North American Hydrogen Backbone (NHB)

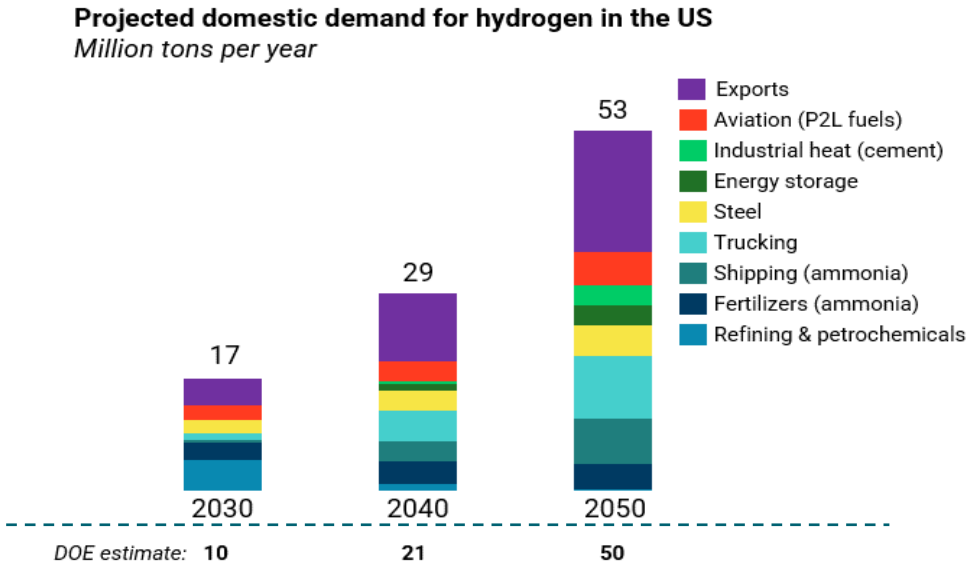
A Guidehouse and RMI Consortium

Guidehouse RMI

July 25, 2024

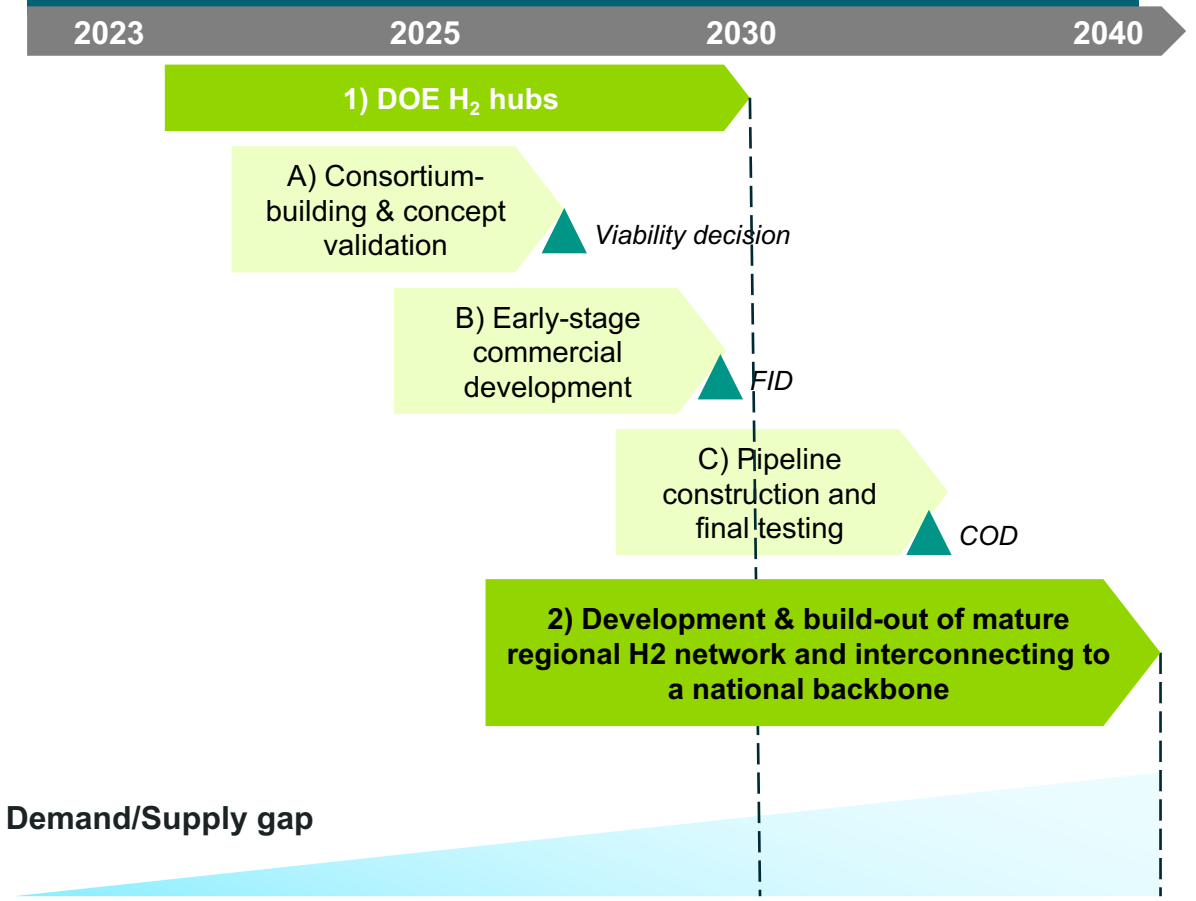
H_2 infrastructure planning is needed now to support at scale volumes of H_2 to meet decarbonization objectives – demand projected to double by 2030

By 2030+ there will be an urgent need to build connective infrastructure to enable end-use H_2 uptake in growth sectors



- DOE Hubs have accelerated regional pockets of H_2 production, infrastructure, and offtake
- Connective infrastructure is not currently being addressed between hubs and supply/demand centers.

Infrastructure development times are long; 2030-2035 might be 'too late' for first-mover market participants.



15 Nov 2023, 11:44 Julian Wettengel

Germany backs investments to build 9,700-kilometre, €20 billion hydrogen grid

World's longest hydrogen pipeline, covering 700km, set for construction work this year at a cost of $845m

The Chinese record-breaker could facilitate renewable H2 exports from a port near Beijing, developers claim

China to build 6,000km hydrogen pipeline network to transport green H2 from renewables-rich regions

The H2 grid will connect northern and western windy and sunny areas with demand centres in the south and east

PRESS RELEASE | 15 February 2024 | Brussels

Commission approves up to €6.9 billion of State aid by seven Member States for the third Important Project of Common European Interest in the hydrogen value chain

UPDATE: SoCalGas proposes nation's largest green hydrogen infrastructure system

Department of Energy

Biden-Harris Administration Announces $3.5 Billion for Largest Ever Investment in America's Electric Grid, Deploying More Clean Energy, Lowering Costs, and Creating Union Jobs

OCTOBER 18, 2023

U.S. National Clean Hydrogen Strategy and Roadmap

Strategy 3: Focus on Regional Networks

2 Nov, 2023

Curtailment, congestion costs rise as transmission upgrades lag renewable growth

S&P Global Commodity Insights

54,500 GW-miles of within-region transmission needed for a clean grid, says DOE

OCTOBER 31, 2023

The European Hydrogen Backbone (EHB), led by Guidehouse has driven an analytically backed vision for H_2 infrastructure deployment

The European Hydrogen Backbone (EHB) established **a unified vision** of H_2 connective infrastructure co-optimized with electric/gas systems

and identified **priority corridors** connecting supply hubs with demand centers.

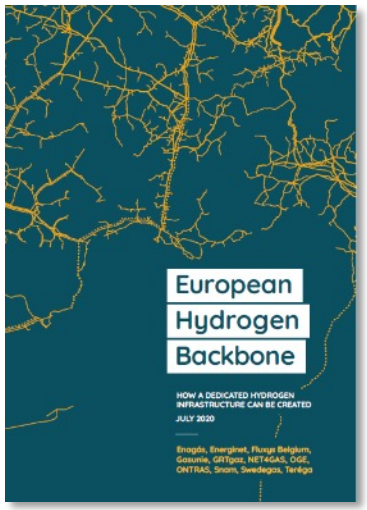
The vision provided **confidence to developers, and investors** accelerating the implementation of key corridors through commercial consortia

Gradual increase in the importance of hydrogen and associated infrastructure in the political discourse

Further discussion of the NHB outputs are provided in slide 24

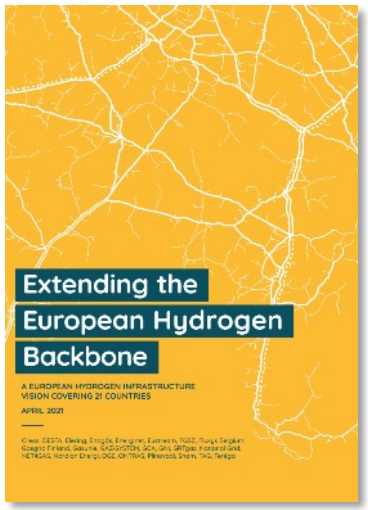
Our team has been actively involved in the EHB for years and can leverage some learnings for North America, when appropriate

All of the EHB reports are public and published to the EHB website here: The European Hydrogen Backbone (EHB) initiative | EHB European Hydrogen Backbone.



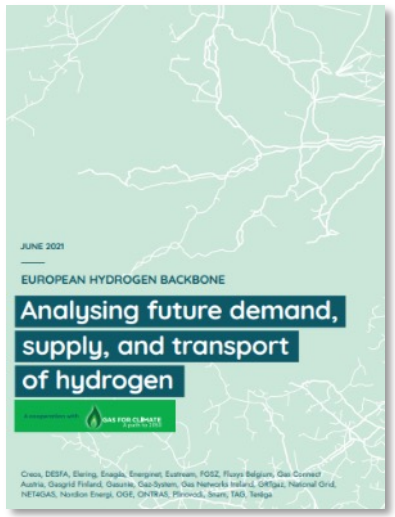
July **2020**

Visionary pan-EU maps



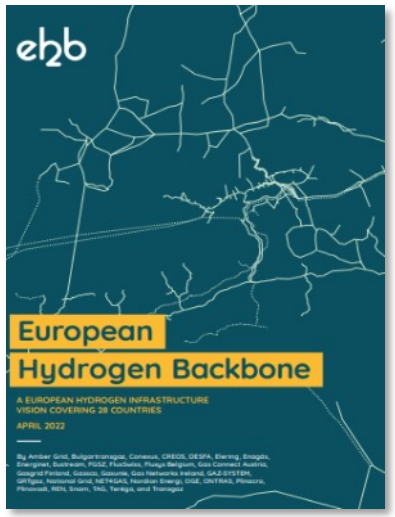
April **2021**

Updated and extended vision



June **2021**

Detailed **analysis of future hydrogen demand by sector**

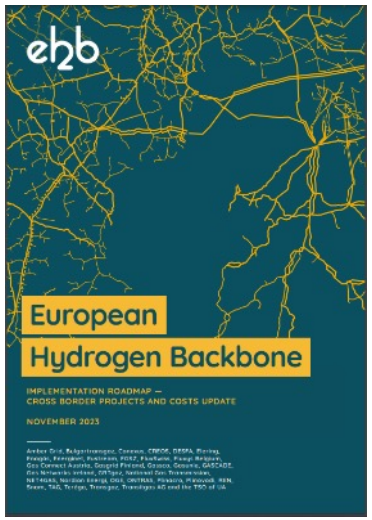


April **2022**

Substantial **acceleration** of hydrogen infrastructure build-out until 2030

May **2022**

Analysis of supply and demand of **five supply corridors connecting Europe**

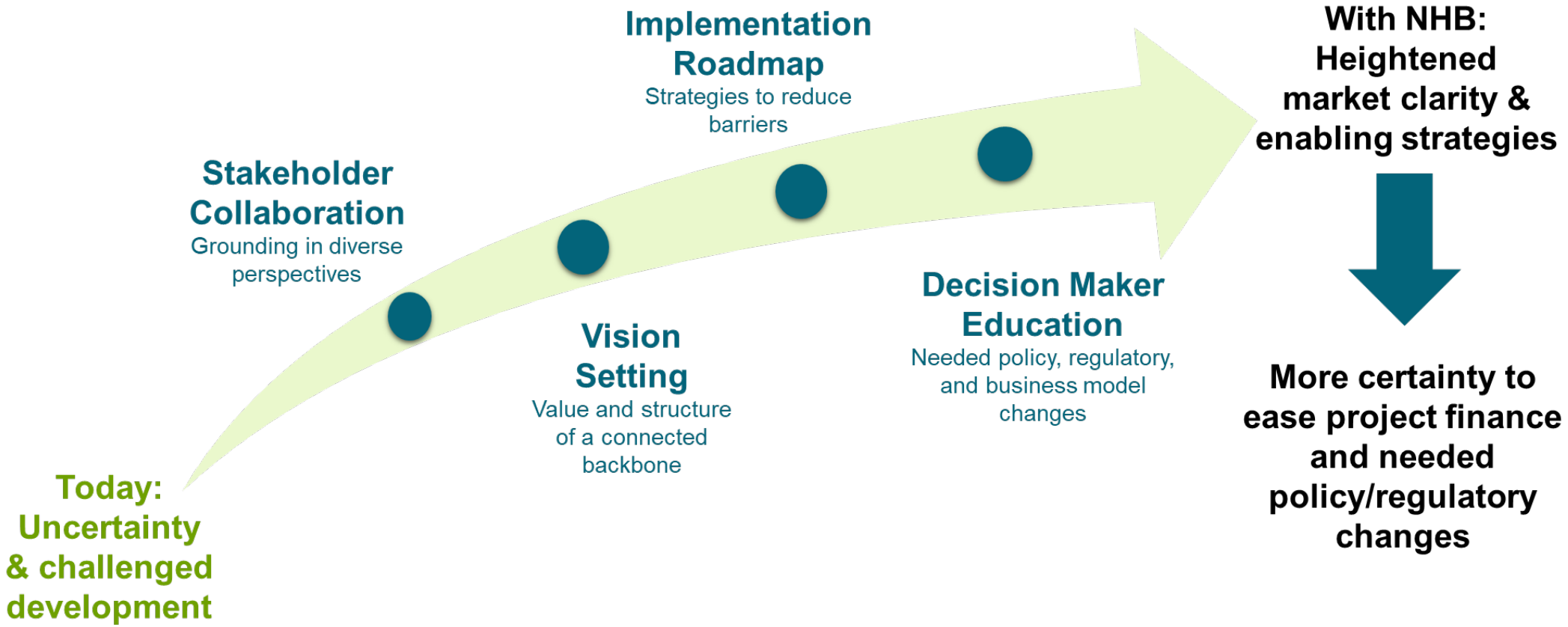


November **2023**

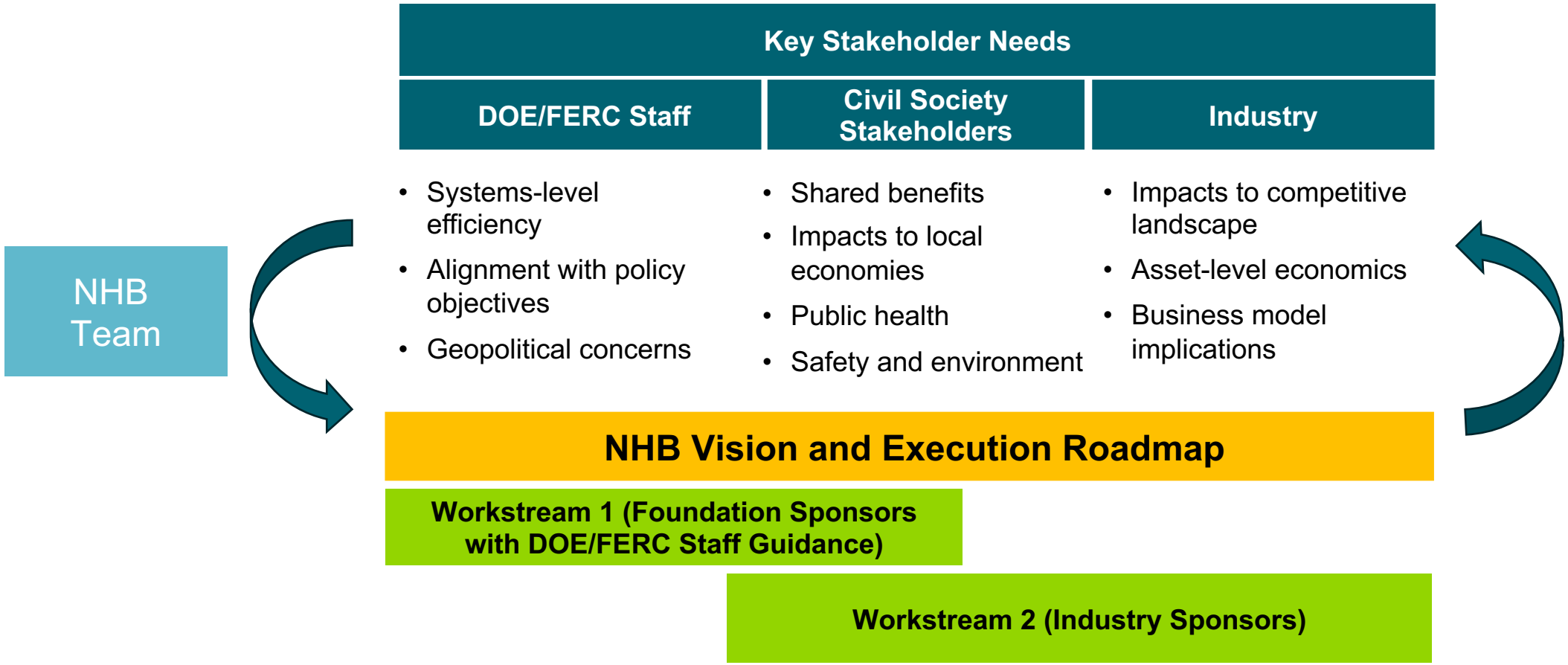
Analysis of the most recent **hydrogen infrastructure developments and cost estimates**

Guidehouse RMI

The North American Hydrogen Backbone (NHB) will strive to provide an analytically-backed vision for the deployment of connective H_2 infrastructure



An “optimal” and “implementable” solution will need buy-in from a diverse set of industry stakeholders



A workshop in January 2024, identified key themes and needs of stakeholders

Key Themes

- **Uncertainty of hydrogen demand is a major barrier**
  - Lack of near-term projects with established hydrogen adoption plans
  - Need for supportive policies and incentives to stimulate demand
- **Regulatory ambiguity hinders development**
  - Lack of clear federal oversight for hydrogen transportation
  - Need for standardized regulations across states
- **Public perception challenges must be addressed**
  - Safety concerns and environmental impact worries
  - Early community engagement and education are crucial
- **Financing difficulties due to perceived high risk**
  - Large upfront costs and lack of secure market deter investors
  - Innovative financing models and risk-sharing strategies needed
- **Technology development required**
  - Concerns over pipeline durability and leak detection
  - More R&D needed for hydrogen-specific infrastructure components (compressors)
- **Regional connectivity benefits recognized**
  - Potential to enhance access to low-cost supply and increase market liquidity
  - Questions raised about the extent of necessary pipeline buildout

Over 50 attendees, from across the value chain

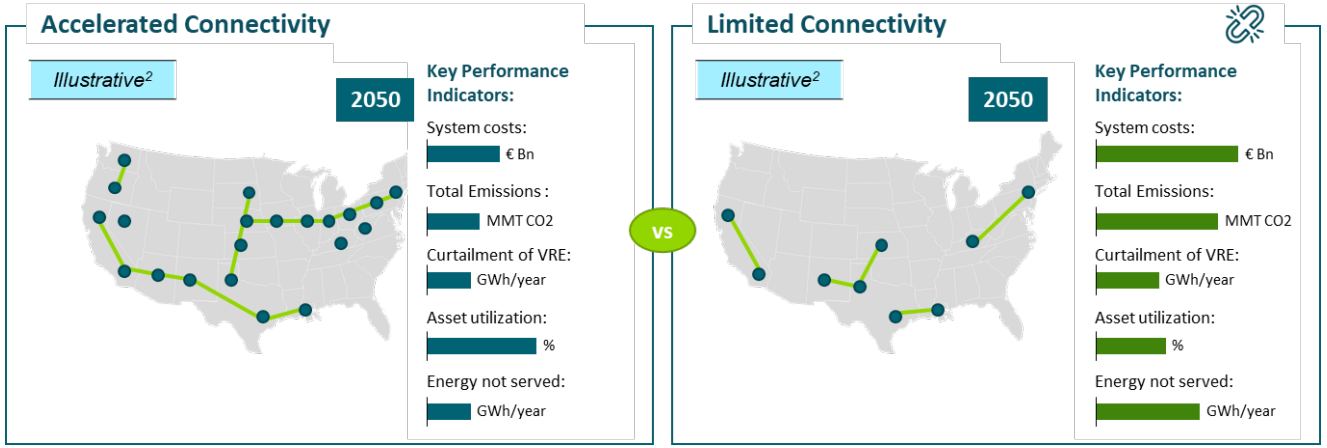
National Analysis: scenario modelling establishes insights into the optimal structure for development of connective H_2 infrastructure

Key Objectives

- Develop **insights into the appropriate shape and size of connective infrastructure in North America** – understand what a hydrogen backbone could look like in North America
  - Quantify national system needed CAPEX and OPEX by 2050
  - Identify sizing and regional retrofit opportunities
  - Highlight key regional pipeline corridor's
  - Analyze potential benefits of connective infrastructure
- Derive insights from the comparison of **two development scenarios**: *Allowed Connectivity* vs *Limited Connectivity*
- Assess the potential benefits and challenges of the scenarios to derive insights on the appropriate **policy and regulatory frameworks** to support industry development
- Inform a detailed **H_2 infrastructure routing and implementation roadmap**

Scenario Framework

Compare KPIs associated with different scenarios…



Logic: An enabling environment developments for the development of hydrogen transmission infrastructure across North America

Logic: Infrastructure development is limited to regional or local development, e.g. between states.

Note: The objective is to highlight potential benefits and buildout of a H_2 backbone. It is <u>not</u> to assess how end-use sectors can be decarbonized most cost-efficiently (direct electrification vs. CO_2-free molecules).

Where we are with NHB today

What We've Accomplished

- ☑ **October 2023:** Kicked off the Vision workstream leveraging funding from Breakthrough Energy
- ☑ **January 2024:** Brought together 50+ attendees for the first *Visioning Workshop*
- ☑ **May 2024:** Commenced Southern California regional modeling
- ☑ **May 2024:** Brought the North American Hydrogen Backbone concept to the World Hydrogen North America conference in Houston
- ☑ **June 2024:** Brought the North American Hydrogen Backbone concept to the Edison Electric Institute annual conference in Las Vegas

Where We're Going

- ☐ **Q3-Q4 2024:** Continue to build the Vision through our foundational modeling
- ☐ **Q3 2024:** Kickoff a Southwest regional working group, focused on detailing the infrastructure needs in southern California and beyond
- ☐ **Q4 2024:** Kickoff a Gulf Coast regional working group, focused on detailing the infrastructure needs in the Gulf (and interconnection with the Southwest)
- ☐ **Q4 2024:** Host a second *Visioning Workshop* to bring together key stakeholders to further detail the vision

Why Engage? Shape the vision for a North American H_2 infrastructure implementation roadmap to drive success

Our Vision of NHB Success

1. ***Alignment across varied stakeholders of a vision for the location of H_2 pipeline infrastructure***, that will be necessary to achieve a cost competitive H_2 economy (including repurposed NG pipeline and new dedicated pipelines between hubs)

2. ***A collaborative group of commercial players*** who align on clean H_2 as a critical component for achieving a carbon neutral economy, and who can ***leverage a unified brand and quantitatively backed insights to result in needed policy and regulatory change***

3. ***Identification of potential business models needed to invest*** in the development of this pipeline infrastructure

4. ***Solidification of valuable development partnerships*** that potentially result in joint H_2 backbone infrastructure projects

5. ***Initiation of pipeline infrastructure development*** to support the NA hydrogen economy between hubs

Contacts

Oleksiy Tatarenko
Senior Principal, RMI
720.347.5376
otatarenko@rmi.org

Danielle Vitoff
Director, Guidehouse
303.728.2460
danielle.vitoff@guidehouse.com

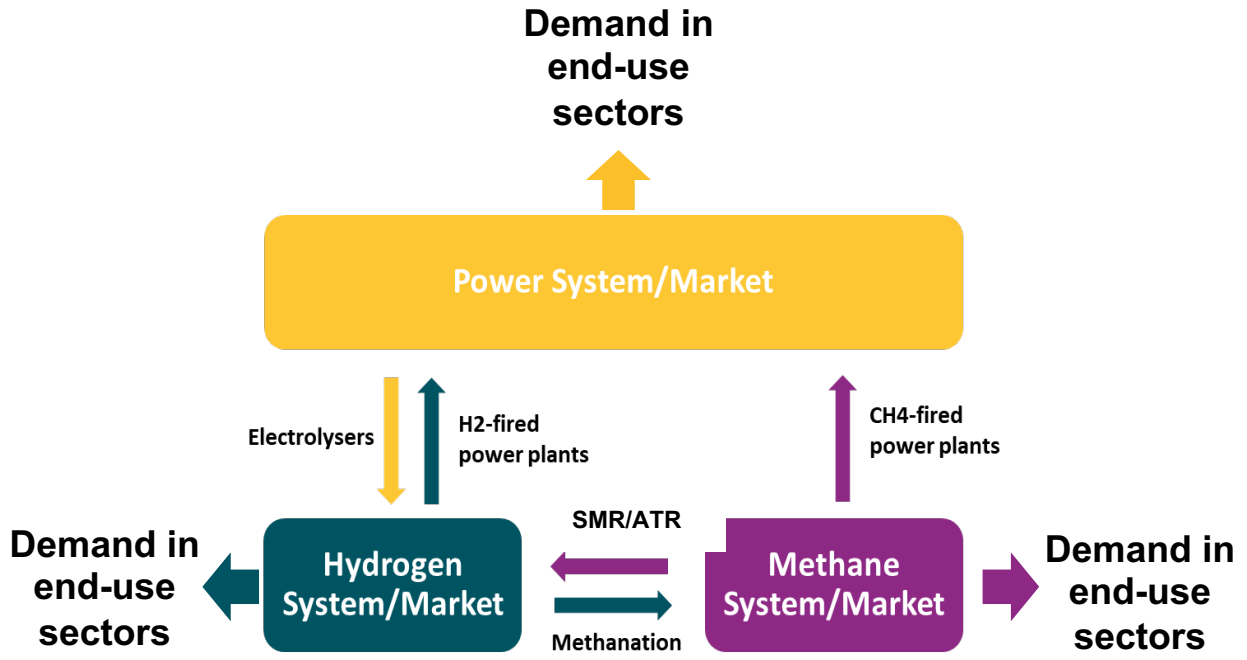
July 29, 2024

Appendices

July 29, 2024

The modeling approach for NHB takes a long-term planning perspective that co-optimizes the electricity, gas, and hydrogen system to achieve net zero

- **Interaction** between power, hydrogen and methane systems **must increase significantly** in the future to decarbonize end-use sectors and to integrate large shares of variable renewable energies efficiently
- Grid level system reliability analysis to understand **how hydrogen infrastructure can support electric reliability standards** as renewable penetration increases
- Potential **integrations between hydrogen and electricity systems** and role of hydrogen as an **energy storage** medium
- Understand **natural gas pipeline retrofit potential** to hydrogen as gas demand declines



WS1 Approach: Vision alignment for optimized North American H_2 backbone

Task	1. Identify Geographic Focus Areas	2. Define Stakeholder Needs & Concerns	3. Develop 2050 H_2 Infrastructure Vision
Core Questions	**Where are the major H_2 hubs and regions that will need connective infrastructure?**	**What stakeholders should be involved, and which scenarios should be modeled to determine the most cost-effective H_2 backbone build out?**	**What H_2 infrastructure needs to be in place in NA to ensure cost-effective & resilient H_2 supply/demand?**
Activities	• Determine major supply/demand centers and NA H_2 hub locations • Consideration of system shaping, including supply and demand non-direct alignment • Define different H_2 demand/supply scenarios for modeling • Develop initial view of prioritized H_2 connective corridors needs in NA	• Identify initial stakeholder list based on select calls with H_2 producers & off-takers • Conduct two convenings with stakeholders to understand needs & concerns. • Gather stakeholder insights in support of comprehensive strategy formation • Test scenario assumptions and gather input on modeling approach and supply/demand scenarios	• Conduct integrated energy modeling on 23 nodes (e.g., 8-hubs and 15 supply/demand regions) to identify a high-level H_2 backbone with co-optimized electric and gas systems. • Determine H_2 supply/demand dynamics within the integrated US energy system • Share preliminary modeling results and gather feedback • Based on final modeling, provide detailed maps of the connected H_2 infrastructure needed for US (until 2050)
Key Output	• NA regional H_2 supply/demand scenarios • PowerPoint report defining geographic locations of interest for midstream H_2 development	• Summarize key stakeholder needs in a PowerPoint report for H_2 infrastructure build-out (2024 – 2050)	• Key stakeholder alignment for 2050 H_2 infrastructure needs • PowerPoint report summarizing H_2 vision

WS2 Approach: H_2 Infrastructure Implementation Roadmap

Task	1. Refine Infrastructure Vision	2. Develop Policy Recommendations	3. Engage Key Stakeholders
Core Questions	**What is the detailed vision for regional pipeline development, including consideration of new and repurposed infrastructure?**	**What policy levers need to be encouraged or enabled to deliver on the regional vision for infrastructure development?**	**Who are the key stakeholders that can support or challenge the development of regional H_2 pipeline infrastructure?**
Activities	• Adopt the vision of pipeline infrastructure hypothesized and modeled in WS1 and overlay critical regional considerations, including interaction with the DOE awarded H_2 hubs • Identify priority infrastructure corridors and the general timeline for development across the region • Assess the investment required to develop the envisioned pipeline infrastructure	• Develop an understanding of the current policy and incentive landscape to support regional infrastructure buildout • Determine the business models most appropriate to supporting the envisioned regional infrastructure development, • Develop up to two (2) business cases to articulate the investment required to support infrastructure development to inform policy recommendations and discussions	• Identify a regional stakeholder engagement plan for communicating about the regional vision • Develop materials to be utilized for stakeholder communication, targeted to key audiences identified in the stakeholder engagement plan • Socialize the vision with the key regional stakeholders, test communication strategies, and refine material development
Key Output	• Report highlighting regional H_2 infrastructure vision, identifying key supply and demand locations and pipeline corridors • Report highlighting investment required to deliver on the regional vision	• Report highlighting current regional policy landscape and future structure necessary to support infrastructure development • Detailed business cases (up to 2) articulating the investment plan required to support infrastructure development	• Regional stakeholder engagement plan • Communication materials for external stakeholder engagement