



MN Renewable Energy Roundtable

*THE HYDROGEN ECONOMY –
EVOLVING RURAL AND AGRICULTURAL OPPORTUNITIES*

December 6, 2023



Dan Skogen,
Emcee

Thank you to our sponsors!



slido



**Join at slido.com
#7605616**

ⓘ Start presenting to display the joining instructions on this slide.

slido



How would you best describe your outlook today?

ⓘ Start presenting to display the poll results on this slide.



Welcome

Luca Zullo, Ph.D.

*Sr. Director of Science and
Technology, AURI*

Hydrogen in the USA & Minnesota



Pete Wyckoff, Ph.D.
*Assistant Commissioner of
Federal & State Initiatives,
MN Department of Commerce*



Federal Incentives for Hydrogen



Pete Wyckoff | Assistant Commissioner
Minnesota Department of Commerce Division of Energy Resources

Minnesota has big climate plans (and big climate LAWS)



Minnesota has big climate plans

The Federal Government is here to help
(honest)

They Sent Me

(Until April, I had a different job)

Dr. Pete Wyckoff

Senior Policy Advisor for Energy & Climate

Office of Senator Tina Smith



Federal Investments



Infrastructure
Investment &
Jobs Act (IIJA)



Inflation
Reduction
Act (IRA)

Infrastructure Investment & Jobs Act (IIJA)



- Research Hubs/ Demonstration Projects (\$21.5 billion)
 - Hydrogen, carbon capture, advanced nuclear
 - \$8 Billion for Hydrogen Hubs
- Goal: “A national clean hydrogen network to facilitate a clean hydrogen economy”
- Note: this is on top of robust hydrogen funding through regular appropriations– mostly through DOE EERE and Office of Fossil Energy and Carbon Management

Minnesota has received hydrogen hub funding

BUSINESS

Xcel, Minnesota vie for billions in federal funds to create 'clean' hydrogen hub

The proposal would jump-start several hydrogen projects in North Dakota and Minnesota, including Xcel using renewable power to make hydrogen for a potential fertilizer plant in Morris.

By Mike Hughlett Star Tribune | MAY 20, 2023 — 8:00AM

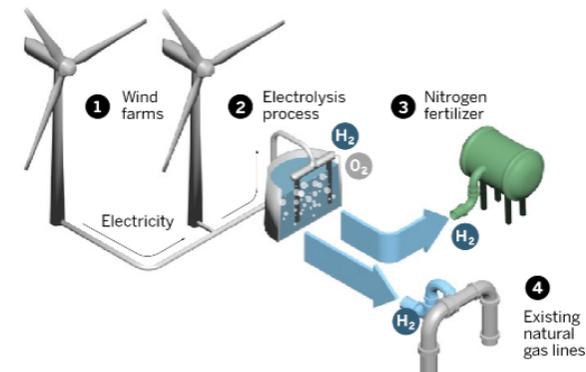


MIKE CIHAK, UNIVERSITY OF MINNESOTA

University of Minnesota research that pioneered turning wind into ammonia will be used in a new process that would use wind power to produce hydrogen.

CLEAN HYDROGEN FROM RENEWABLES

Xcel plans to use renewable energy — particularly wind — to convert electricity into hydrogen, which can be used for several clean energy processes.



The process

1. **Electrical power** is tapped from wind and farms.
2. **The electricity powers** a process called electrolysis, which splits water into oxygen and hydrogen gas.
3. **The clean-burning hydrogen gas** would be used to make nitrogen fertilizer.
4. **It would also be added** to existing natural gas lines to augment fuel sources for consumers and used as a supplement at Xcel's gas-fired power plants.

Source: Xcel Energy | By Mark Boswell, Star Tribune

Inflation Reduction Act of 2022 (IRA)



The Biggest Climate Action Law

Ever

Anywhere in the World

The IRA ...135 distinct programs and tax credits

Grants = \$110 billion (capped)

Clean energy loans ~ \$500 billion (capped)

Tax Credits ~ \$700 billion to \$1.2 trillion (uncapped, estimated)

IRA Loans (\$500 billion)

Joe Biden's \$400 Billion Man

Jigar Shah, who runs the Energy Department's loan program, is trying to hand out a lot of money for green-technology projects, while navigating an unforgiving political environment

Scott Patterson [Follow](#) and *Amrith Ramkumar* [Follow](#)

Updated July 3, 2023 12:05 am ET



LPO team visited Minnesota in July



Minnesota's Electric Cooperatives @MNRuralElectric · Jul 25

MREA was excited to help host @JigarShahDC from @ENERGY along with @LIUNAMinnesota! Co-op innovation along with federal support is fueling reliable, affordable clean energy for the 1.7 million Minnesotans served by co-ops. Teamwork makes us stronger! #Energy #CooperativePower



Hydrogen

DOE's First \$1B Loan Guarantee in Years Seeks to Bolster Turquoise Hydrogen Process

The Department of Energy's (DOE's) first conditional loan guarantee offered to a non-nuclear project since 2016 will finance the expansion of a pioneering commercial-scale "turquoise hydrogen" and carbon black production facility in Nebraska.

The agency's Loan Programs Office (LPO) on Dec. 23 offered a commitment to guarantee a loan of up to \$1.04 billion under the LPO's Title XVII Innovative Energy Loan Guarantee program to Monolith, a 2012-established firm that has developed a methane pyrolysis process to convert natural gas into hydrogen and high-purity carbon black using renewable energy. Carbon black, a solid carbon material, is a critical raw material in the automotive and industrial sectors.

Assuming Monolith fulfills certain conditions, the DOE intends to issue a final loan to help the company expand its Olive Creek facility (Figure 1) in Hallam, Nebraska, and boost its production capacity to 194,000 metric tons per year. Engineering, construction, and procurement (EPC) giant Kiewit is slated to spearhead construction of the project.

The screenshot shows the top navigation bar of the Energy.gov website with links for SCIENCE & INNOVATION, ENERGY ECONOMY, SECURITY & SAFETY, and SAVE ENERGY, SAVE MONEY. The main headline reads "DOE Announces First Loan Guarantee for a Clean Energy Project in Nearly a Decade" dated JUNE 8, 2022. The sub-headline is "\$504 Million Loan Guarantee to Advanced Clean Energy Storage for World's Largest Clean Hydrogen and Energy Storage Project in Utah". The main text begins with "WASHINGTON, D.C. — The U.S. Department of Energy (DOE) today announced it closed on a \$504.4 million loan guarantee to the Advanced Clean Energy Storage project in Utah — marking the first loan guarantee for a new clean energy technology project from DOE's Loan Programs Office (LPO) since 2014. The loan guarantee will help finance construction of the largest clean hydrogen storage facility in the world, capable of providing long-term low-cost, seasonal energy storage, furthering grid stability. The project is expected to create up to 400 construction and 25 operations jobs, advancing President Biden's climate and clean energy deployment goal of net zero emissions by 2050."



Monthly Application Activity Report

October 2023

181

ACTIVE APPLICATIONS¹

\$162.2

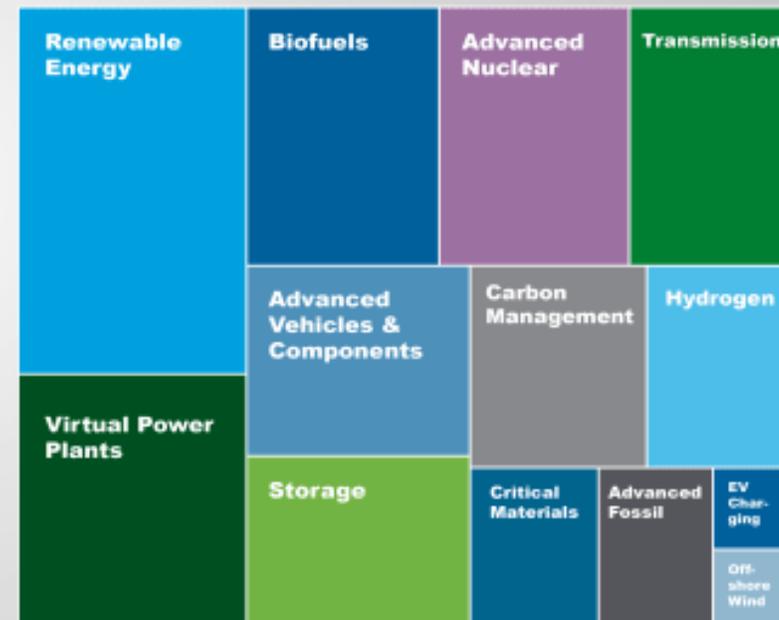
BILLION IN LOANS REQUESTED²

1.9

NEW APPLICATIONS PER WEEK³

\$162.2 BILLION

CURRENT AMOUNT OF LOANS REQUESTED BROKEN DOWN BY PROJECT TECHNOLOGY SECTORS



Notes

All data updated through October 31, 2023. For more details and a list of technology areas of interest within each LPO tech sector, see: [Energy.gov/LPOMAAAR](https://energy.gov/LPOMAAAR)

- 1) Active applications include applications that have been submitted by the project sponsor(s) through LPO's online application portal and are in different stages of active review and engagement by LPO and the applicant.
- 2) Individual requested loan amounts are estimated and potential, subject to change, and not necessarily representative of final financing terms. Requested loan amounts in current active applications do not affect available LPO loan authority. Figure rounded down to the nearest \$0.1 billion.
- 3) Current rolling average of new active applications per week over the previous 24 weeks. Figure rounded down to the nearest 0.1 application per week.

Tax Credits (\$700 Billion - \$1.2 Trillion, uncapped)

The Federal Government has a history of tax credits to encourage renewable energy deployment



Wind Production
Tax Credit (PTC)
since 1992



Solar Investment
Tax Credit (ITC)
since 2006

Expanded Tax Credits

Tax credit provisions incentivize low- & no-carbon electricity

PTC (45Y) and ITC (48E)

- Existing eligibility for PTC (wind) and ITC (solar) now broadened to allow both to use either tax credit
- Stand-alone energy storage projects can receive the ITC
- Expanded: geothermal, fuel cells, biomass, landfill gas, hydropower, combined heat and power
- Electric sector ITC/PTC for available until national emissions are <25% of 2022 emissions

Tax Credits for Industrial Decarb



Advanced Energy Project Credit (48C)--
manufacturing

Clean Hydrogen Tax Credit (45V)– most lucrative for
Green Hydrogen

Carbon Capture and Sequestration Tax Credit (45Q)

Coming soon... Clean Fuel Production Tax Credit–
SAF and other fuels that can be synthesized from
hydrogen

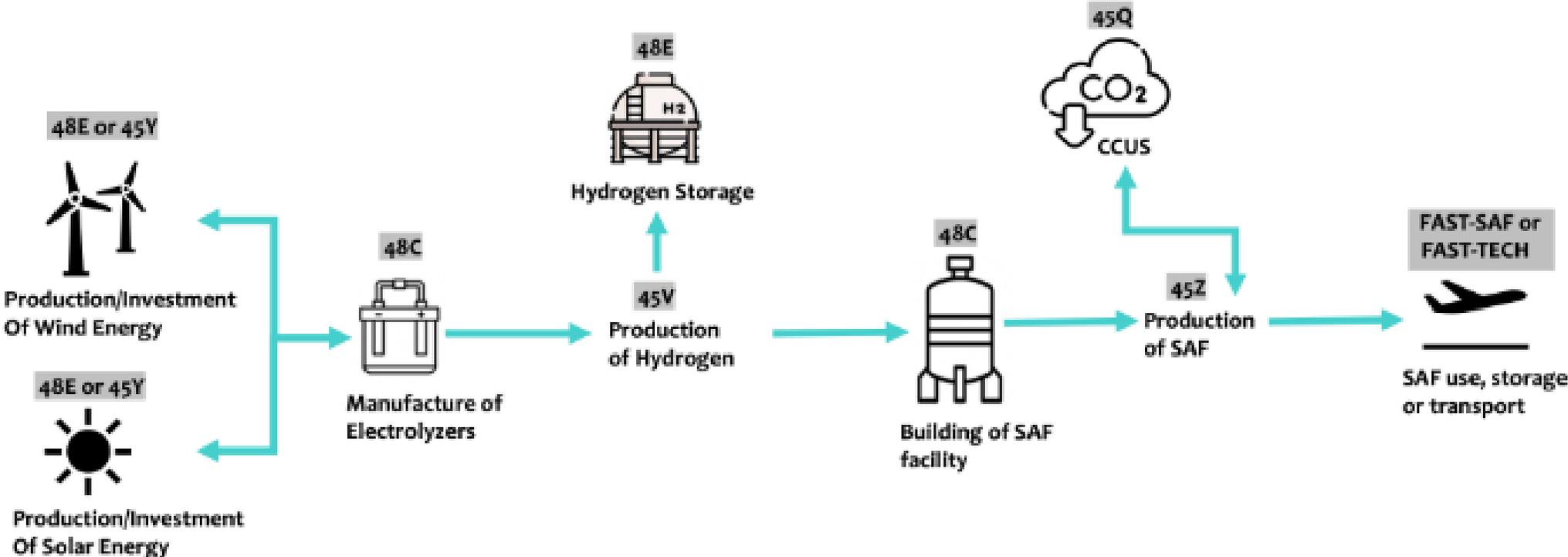
The hydrogen tax credit

Table 1. Values of the 45V Hydrogen Investment Tax Credit and Production Tax Credit

Life Cycle Emissions (kg CO ₂ e / kg H ₂)	ITC Percentage	PTC Value (2022\$/kg H ₂)
4-2.5	6 percent	0.60
2.5-1.5	7.5 percent	0.75
1.5-0.45	10 percent	1.00
0.45-0	30 percent	3.00

This subsidy is large: up to \$374 per ton of CO₂ abated
> the social cost of carbon?

Exhibit 1: IRA incentives along the sustainable aviation fuel (SAF) supply chain.



Growing a Hydrogen Economy in Minnesota

Supporting the Development of Hydrogen Markets in Minnesota

- Governor Walz' Executive Order 22-22
- Quad-state MOU on joint development of a proposal for the Heartland Hub's application to the U.S. Dept. of Energy's Hydrogen Hubs funding opportunity

STATE OF MINNESOTA
Executive Department



Governor Tim Walz

Executive Order 22-22

Directing State Agencies to Pursue Federal Funding for Clean Hydrogen Market Development in Minnesota

Hydrogen: what role do Minnesotans want it to play?

- Social license?
- Environmental justice
- Health impact: NOx
- Indirect greenhouse gas
- Impact of needs for water and renewables

Clean Hydrogen – what is it good for?

Electricity



Pure and blended hydrogen can be used in gas turbines to produce electric power. Energy conversion devices like stationary fuel cells can produce backup heat and power.

Industrial Heat



High-heat industrial processes make up the majority of industrial emissions. Hydrogen can provide high-density industrial heat without producing carbon emissions.

Raw Material



Hydrogen can be used as feedstock in various chemicals and products such as ammonia and synthetic fuel production. Hydrogen can also be used as a chemical agent to facilitate the production of steel.

Transportation



Light-duty and heavy-duty vehicles, rail, aviation, and marine vessels can be powered by hydrogen. Hydrogen is a light gas with high energy density, enabling fast refueling and long ranges.

Building Heat



Hydrogen can be blended with natural gas or substitute natural gas to decarbonize building spaces and water heating.

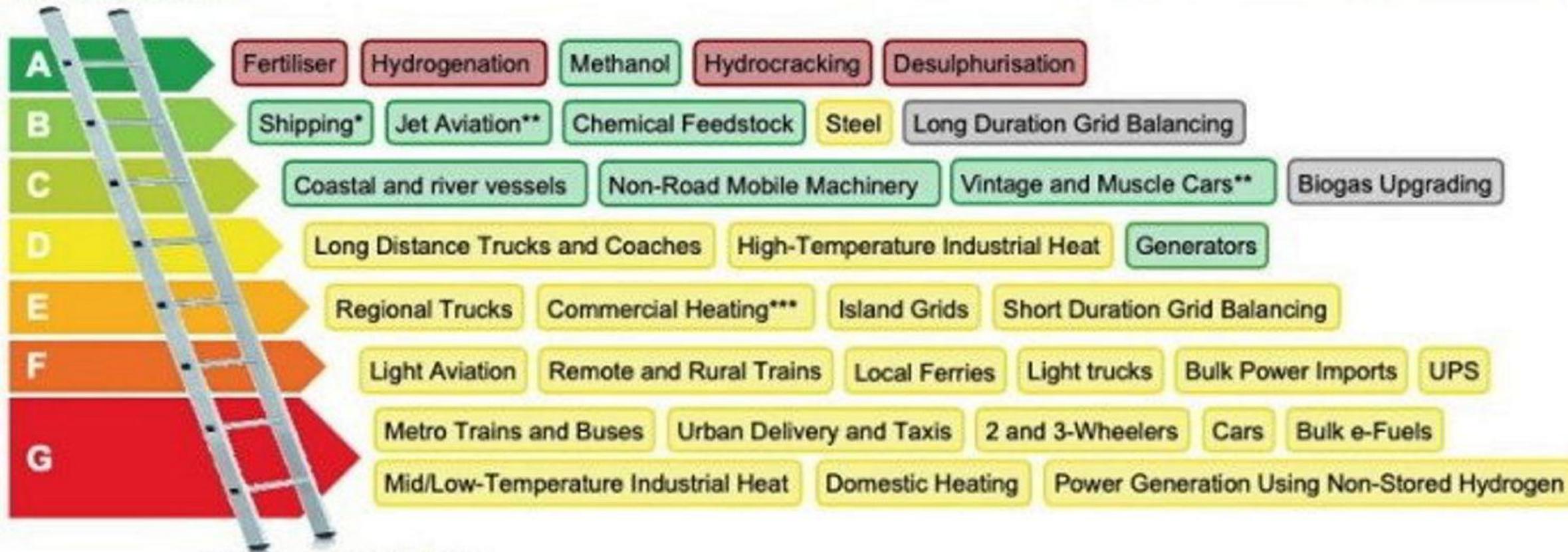
Factors to consider

- Hydrogen is an inefficient battery – direct use of electricity will often be superior
- Some uses better than others in terms of emission reductions and cost
- Hydrogen can be an important raw material (ammonia, urea, SAF, other complex hydrocarbons)

Hydrogen Ladder 5.0

Unavoidable

Key: No real alternative Electricity/batteries Biomass/biogas Other



Uncompetitive

*As ammonia or methanol **As e-fuel or PBTL ***As hybrid system

Source: Michael Liebreich/Liebreich Associates, Clean Hydrogen Ladder, Version 5.0, 2023. Concept credit: Adrian Hiel, Energy Cities. [CC-BY 4.0](https://creativecommons.org/licenses/by/4.0/)

Decarbonizing Minnesota Industry: Steel



CLEAN INDUSTRY



Maria Gallucci

Major steel users band together to place first big 'green steel' order

Microsoft, Trammell Crow, Nexttracker and other companies will request 2 million tons of "near-zero-emissions" steel in push to help U.S. steelmakers decarbonize.

12/8/2023

Finance

Sweden's H2 Green Steel raises \$1.6 billion for Boden plant

Reuters

September 7, 2023 6:10 AM CDT · Updated 13 days ago



OSLO, Sept 7 (Reuters) - H2 Green Steel has raised equity funding of about 1.5 billion euros (\$1.6 billion) to build the world's first large-scale green steel plant, the Swedish steel company said on Thursday, in line with plans [presented](#) in April.

The plant in the northern town of Boden will use hydrogen produced from renewable electricity - rather than coal - to deliver steel in a process emitting as much as 95% less CO2 than steel produced with traditional blast furnace technology, the company says.

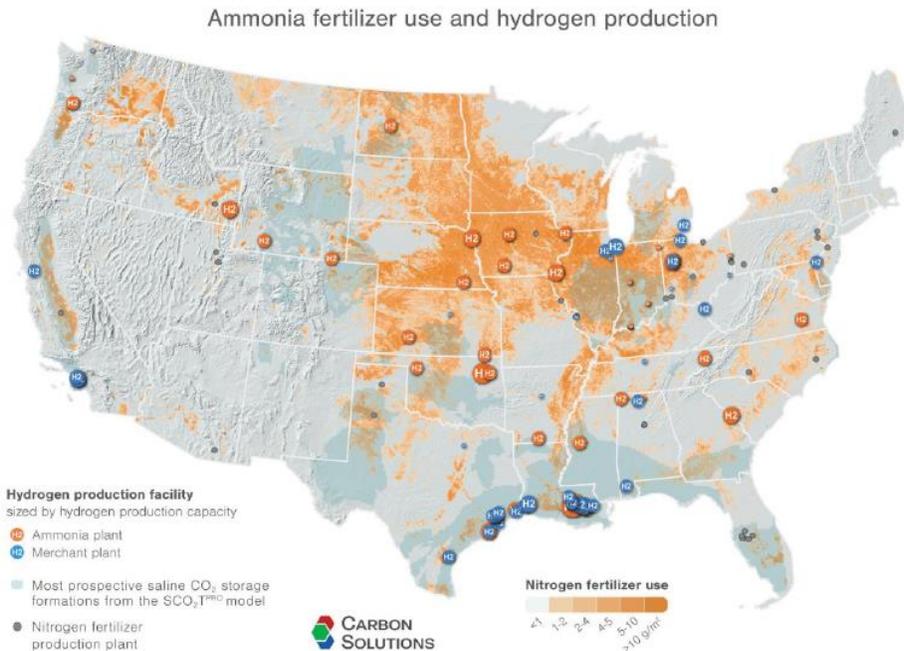


mn.gov/com

Decarbonizing Minnesota Agriculture: Fertilizer



US Hydrogen Production and Potential Opportunity Applications



Current Nitrogen fertilizer use approx. 10 g/m² in MN.
Nitrogen fertilizer accounts for approximately 78% of the fossil energy footprint from corn production.

Figure authored by Elizabeth Abramson, Carbon Solutions, March 20, 2023.
Source: Carbon Solutions LLC 2023; World Resources Institute 2023; Carbon Solutions LLC SCO₂T^{PRO} model 2023; Cao et al. 2017. Note, offshore saline geologic formations are not shown on this map.

Minnesota 100% by 2040, MN Natural Gas Act, EPA Power Plant Rule: what role for hydrogen (and related chemicals)?

E&E NEWS ENERGYWIRE Publications Subscription About Contact Us Start Free Trial Login

<< BACK TO ENERGYWIRE

Hydrogen and the EPA power plant rule: 3 issues to watch

By David Iaconangelo | 05/03/2023 07:15 AM EDT



The background of the slide is a repeating pattern of colorful speech bubbles, each containing a question mark. The colors include red, yellow, pink, and white, set against a teal background. The speech bubbles are scattered across the top half of the slide.

Questions?

Fedquestions.commerce@state.mn.us

Or pete.wyckoff@state.mn.us

Audience Q & A



Jennifer King, Ph.D.
*Research Engineer,
National Renewable Energy
Laboratory*



Industrial Decarbonization Potential in MN

Dr. Jen King

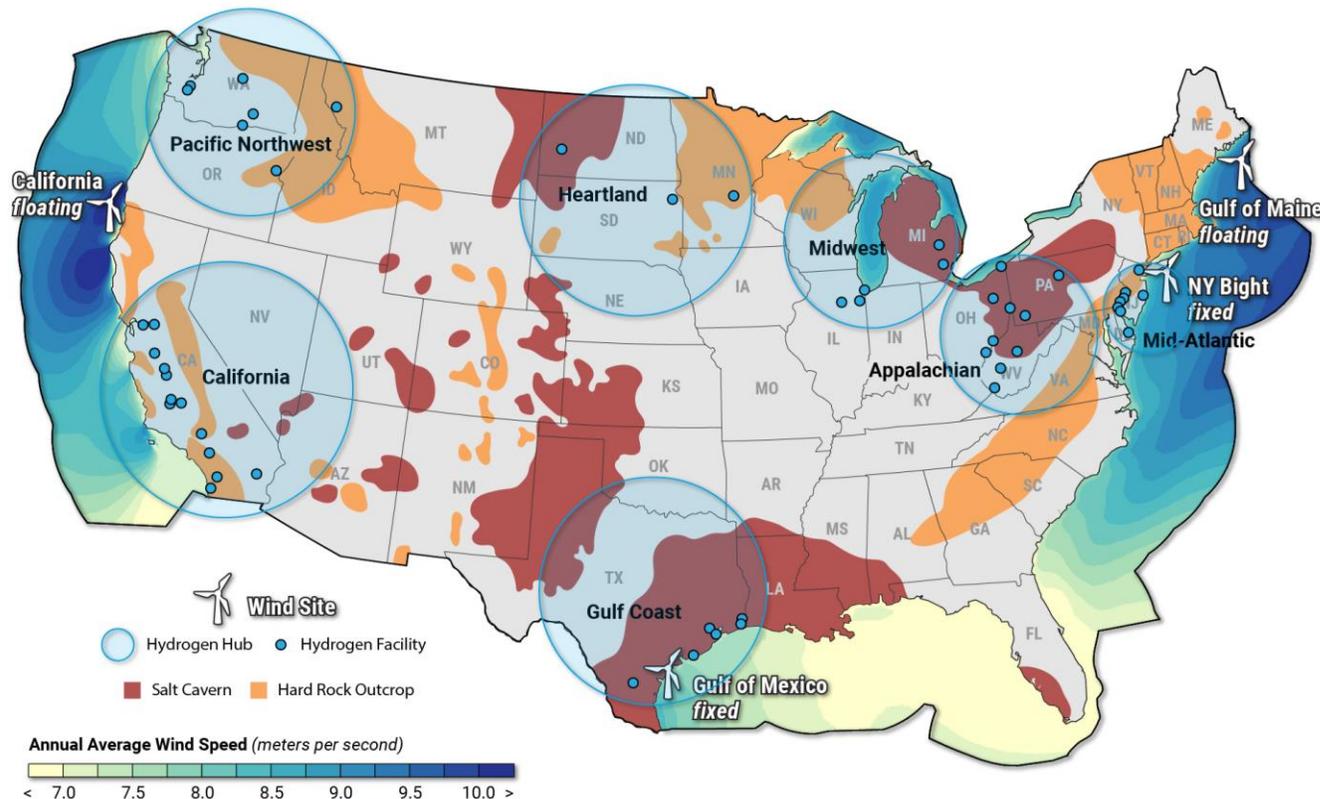
December 6, 2023

Jennifer.king@nrel.gov



Project Goal – Tightly Coupled Systems

- **Vision:** Develop reference designs for GW-scale off-grid, tightly-coupled, hybrid energy systems purpose-built for green H₂ production, in close proximity to or co-located with industry end uses, that can accelerate the path to decarbonization for hard to abate industries.



Team effort (lead noted):

LBNL – Hanna Breunig

ANL – Pingping Sun

SNL – Myra Blaylock

ORNL – Joao Pereira Pinto

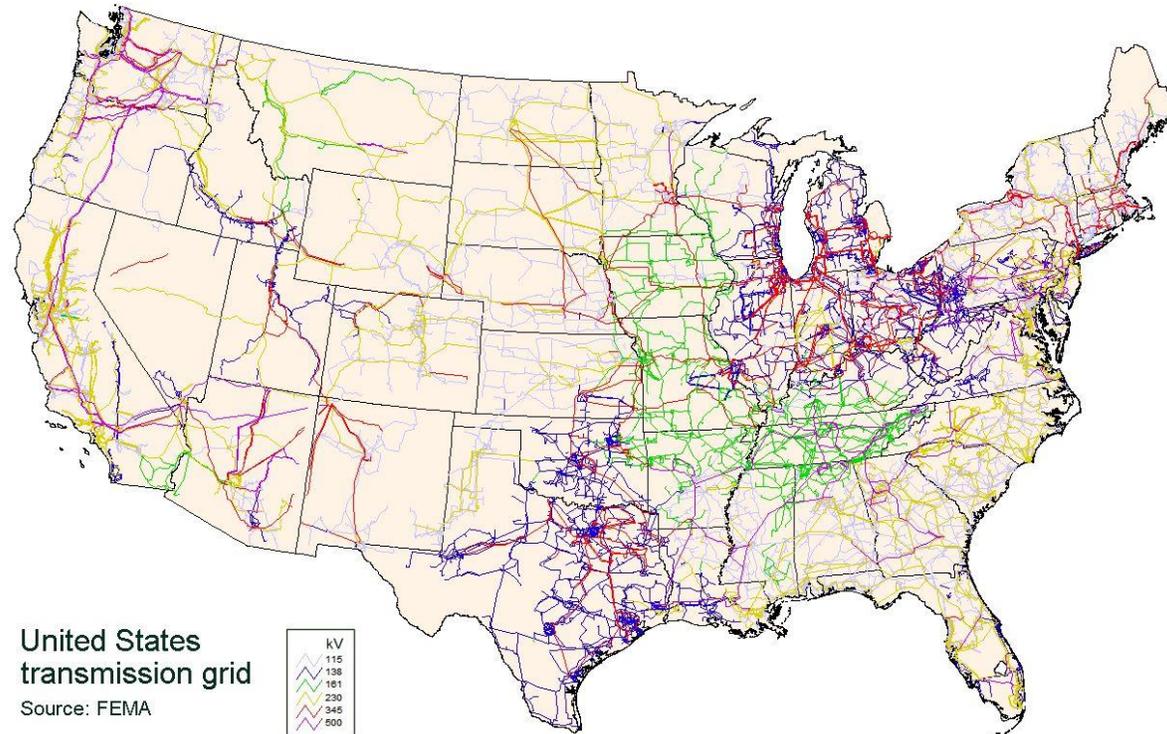
NREL contributors –Evan Reznicek, Masha Koleva, Dan Rowland, Matt Kotarbinski, Elenya Grant, Kaitlin Brunik, many others

Why is this important?

Potential Impact: Time to deployment can be reduced

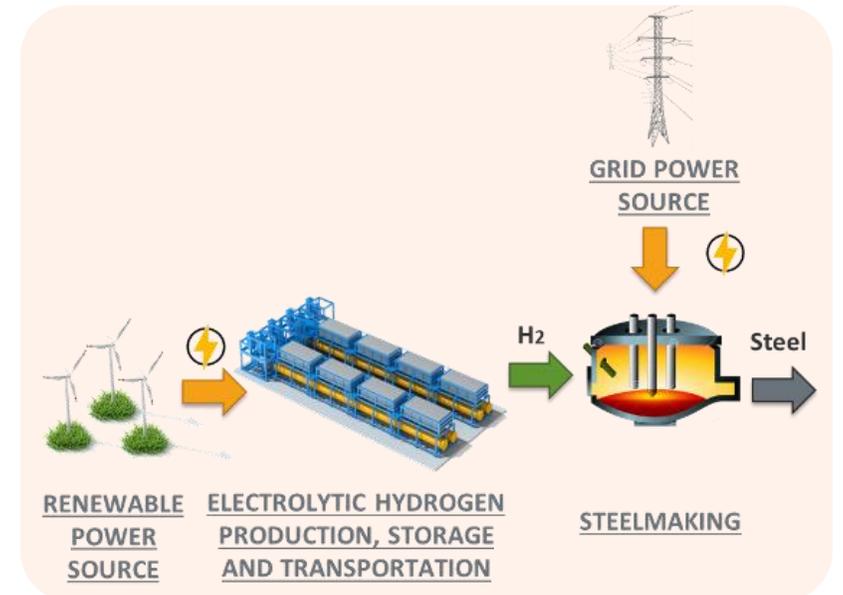
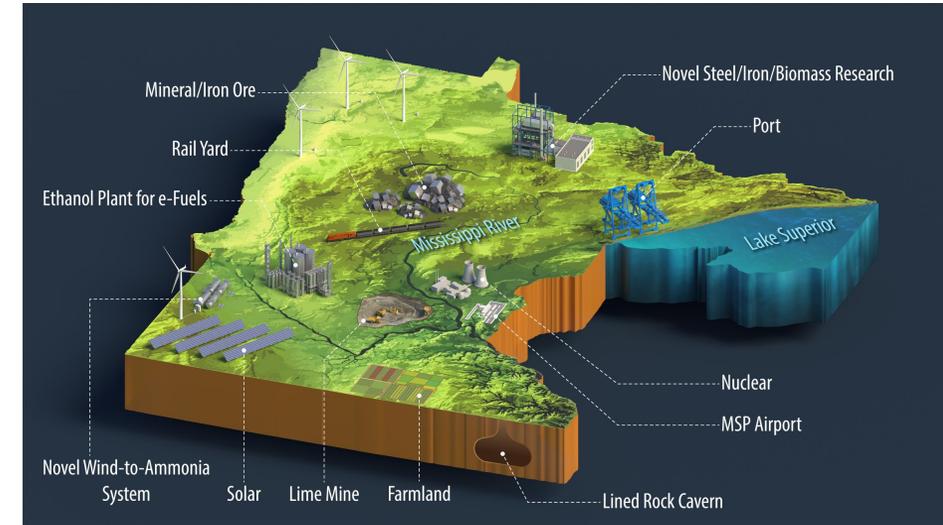
Integrated H2 (directly coupled wind-H2) provides an accelerated deployment pathway and opens up new locations that lack grid infrastructure. Maximize existing infrastructure.

Co-location of assets can provide cost savings and cross-sector **coupling opportunities**.

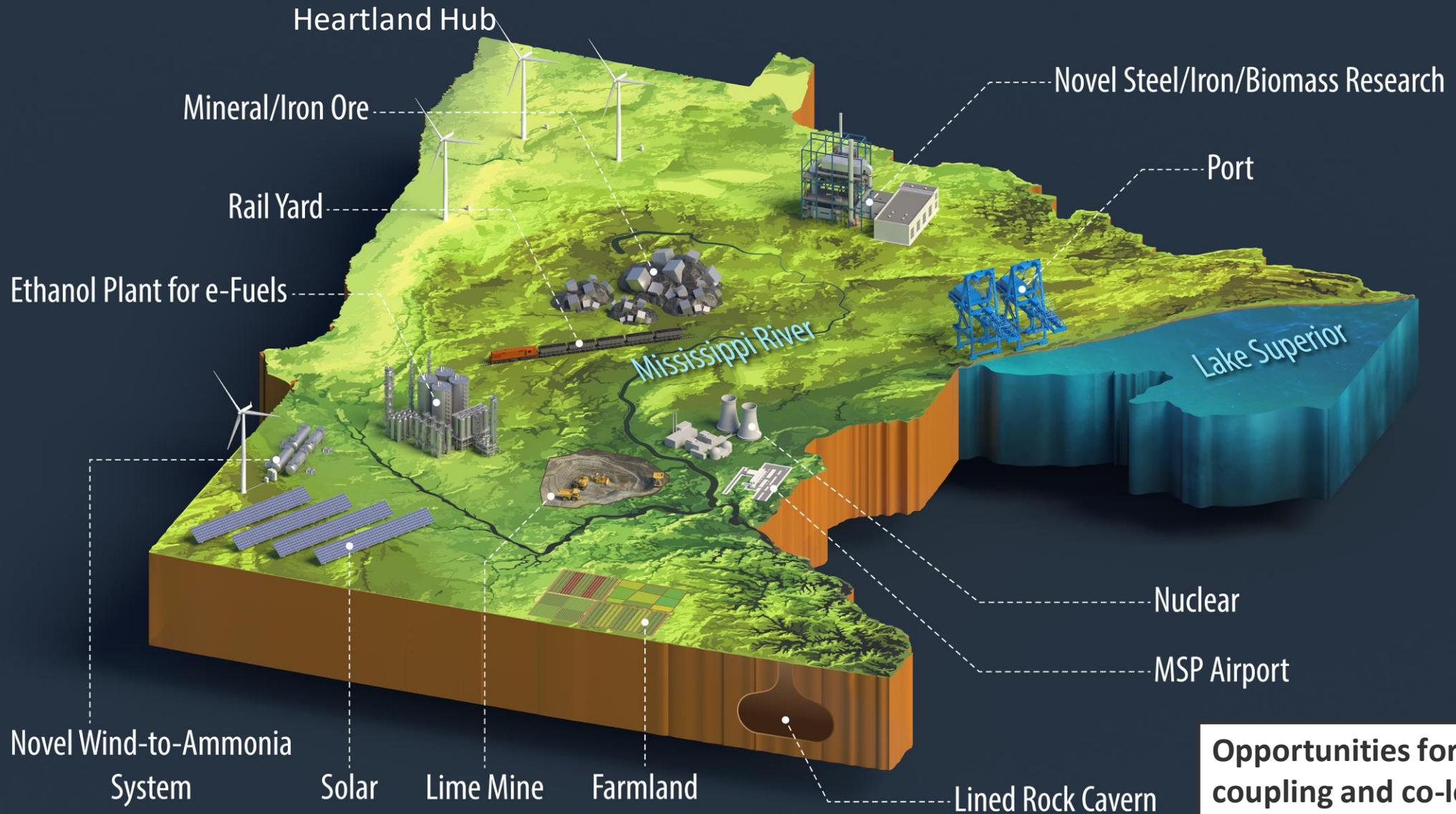


Industrial decarbonization In more detail

- Focused on 4 pillars driven by clean fuels (H₂+e-fuels): **green ammonia, green steel, green concrete/cement, and clean e-fuels**
- Industrial decarbonization requires combination of:
 - Green electrons (renewables)
 - Geologic storage (lined rock caverns) to store H₂
 - Access to raw materials, **water, iron ore, etc.**
 - Existing (or emerging delivery) infrastructure or location for end-use
- **Northern MN (Duluth, Iron Range) has been identified as a location for low-cost steel.**
 - IRA tax incentives are a game changer
 - Results of a community-driven program (C-LEAP)



MN Has ALL the Key Attributes for Decarbonized Industry



Opportunities for cross-sector coupling and co-location

Minnesota: The Integrated Research Engine for Industrial Decarbonization

Community Engagement and Ownership

Understand energy challenges and goals, communicate clean energy benefits, and prioritize equitable economic opportunities and workforce development.

Analysis, Modeling, Demonstration

Refine analysis with partners, identify cross-cutting technology opportunities, pinpoint implementation barriers, and mitigate risk.

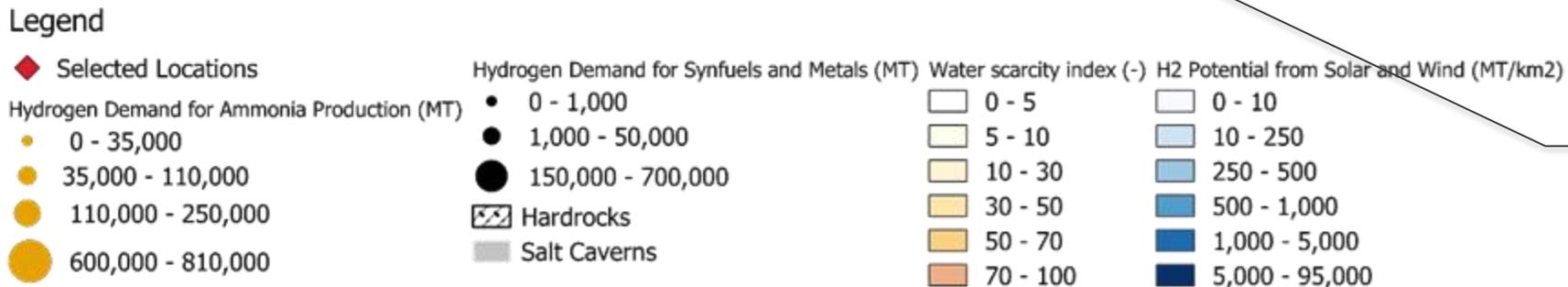
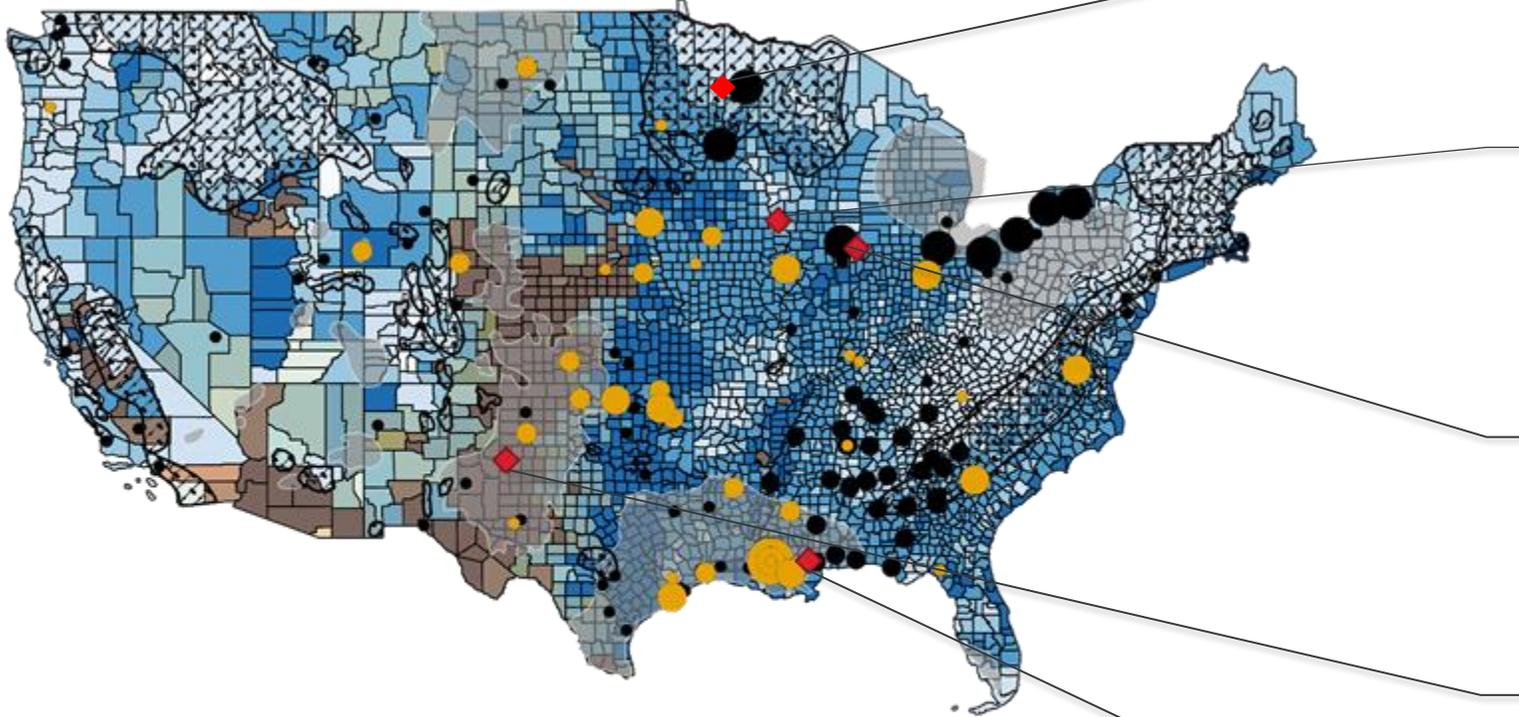
Partnership Coordination

Develop partnerships, facilitate collaboration, build and maintain trust, and establish and support roles.



Approach: Four Land-based Locations for Phase I

- Steel and ammonia production are primarily in central U.S.
- Selected initial four central locations for analysis, with various attributes



MINNESOTA

- Suitable renewables
- Lined rock caverns; raw materials

IOWA

- Existing ammonia pipeline
- Close to ammonia and steel demand centers
- No geologic storage

INDIANA

- Largest steel mill in the U.S. with 8.2 MMT steel/year capacity
- No geologic storage

TEXAS

- Salt caverns and water stress region
- Excellent wind resources

MISSISSIPPI

- Close to existing demand
- Salt caverns

Key Insights

#1: MN has been identified as a great location for clean industrial applications

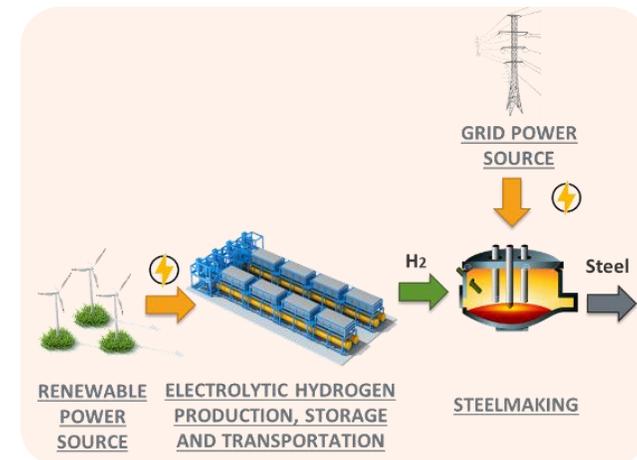
- Access to low-cost renewables, H2 geologic storage, existing infrastructure/raw materials

#2: IRA policy is a game changer. Stacking credits: wind PTC, solar ITC, H2 PTC, storage ITC

#3: Co-locating hydrogen production with end-use (e.g. steel) is critical.

- Co-locating renewables is desirable for lowest electricity cost

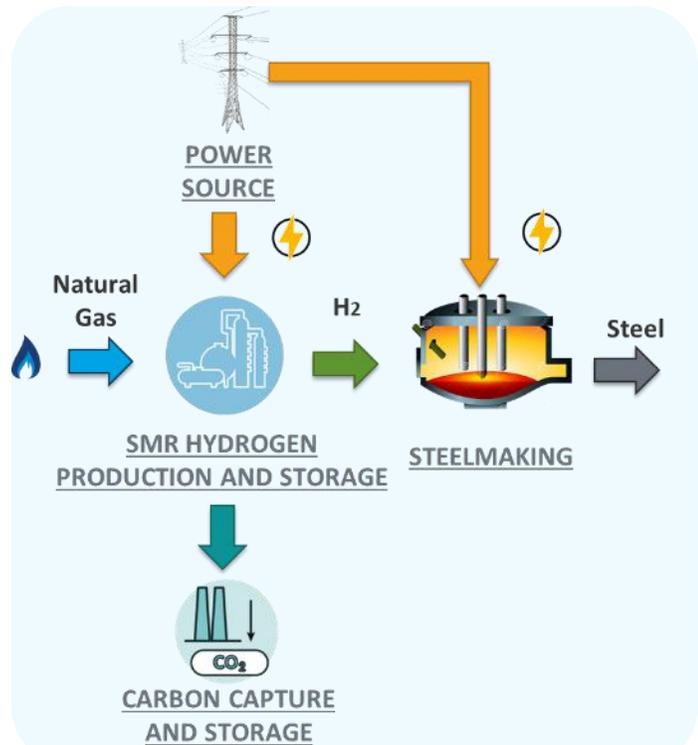
#4: Hybrid systems (wind+solar+storage) can substantially drive down costs.



Clean Electricity to Industrial Production – Use Cases

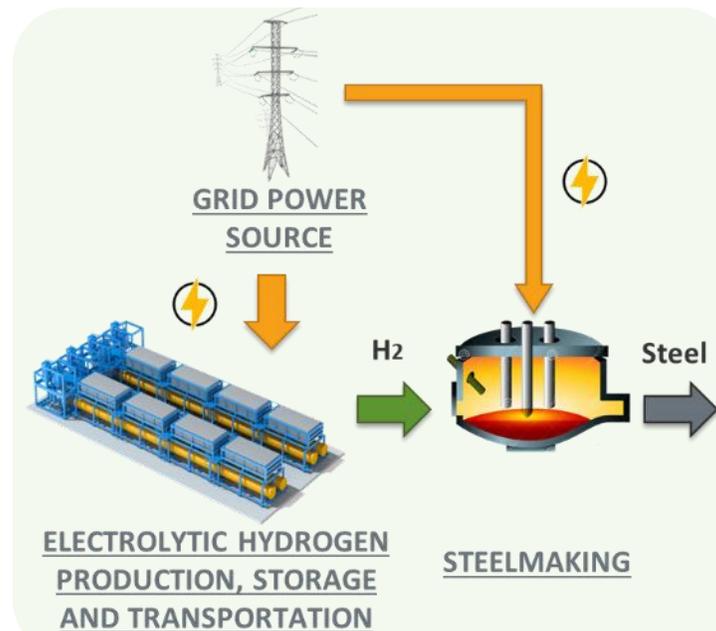
1

Fossil-H₂-Steel/Ammonia Production (with CCS option)



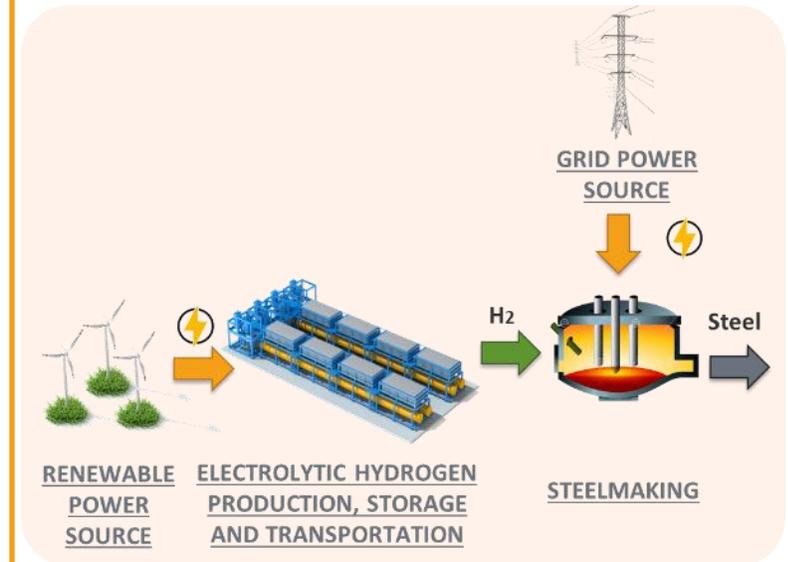
2

Grid Connected H₂ Production co-located Steel/Ammonia



3

Integrated, Off-grid H₂ Production with co-located Steel/Ammonia



Determine the cost savings and potential advantages to off-grid, tightly coupled wind-H₂-industrial end uses

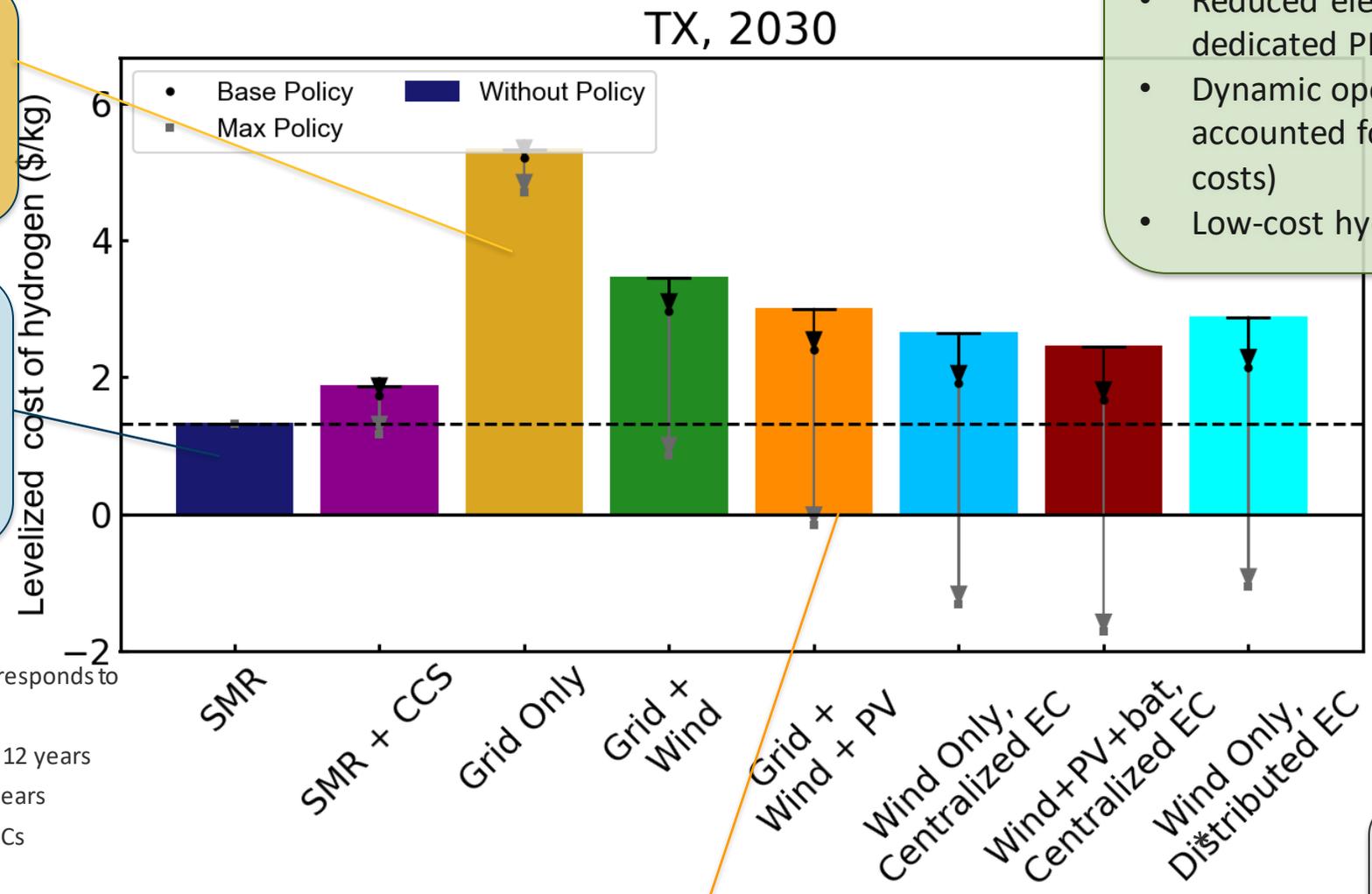
Delivered LCOH in Best Location Analyzed Texas, TY 2030

Dependent on electricity price. This plot includes retail rates at 8.6 cents/kWh

PTC credit considered but CCS credit is the more lucrative credit in the best-case scenario

Off-grid costs less than on-grid:

- Reduced electricity costs (retail vs. dedicated PPA results in decrease)
- Dynamic operation of H2 allowed (and accounted for in increased replacement costs)
- Low-cost hydrogen storage (salt caverns)

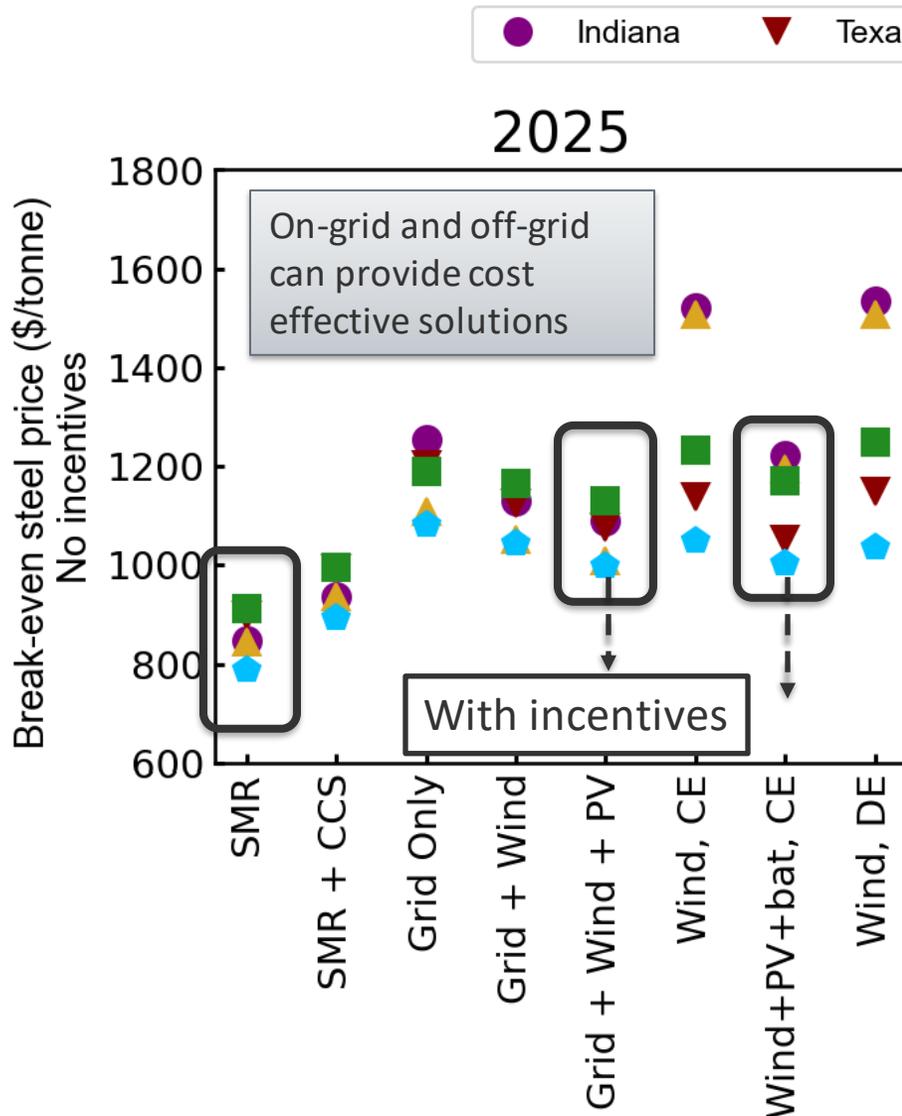


- Notes:**
- Technology year (TY) 2030 corresponds to operational year 2035
 - CCS credit considered for over 12 years
 - H2/wind PTC applied over 10 years
 - Model does not account for RECs
 - **LCOE for TX 2030**
 - Off-grid: 1.3 cents/kWh with PTC
 - On-grid: 8.6 cents/kWh (retail rates), 4.1 cents/kWh (wholesale rates)

Co-located renewables + electrolyzer backfilled with grid electricity

Key Insight:
IRA can be a significant driver for integrated LCOH

Levelized Cost of Steel (LCOS)

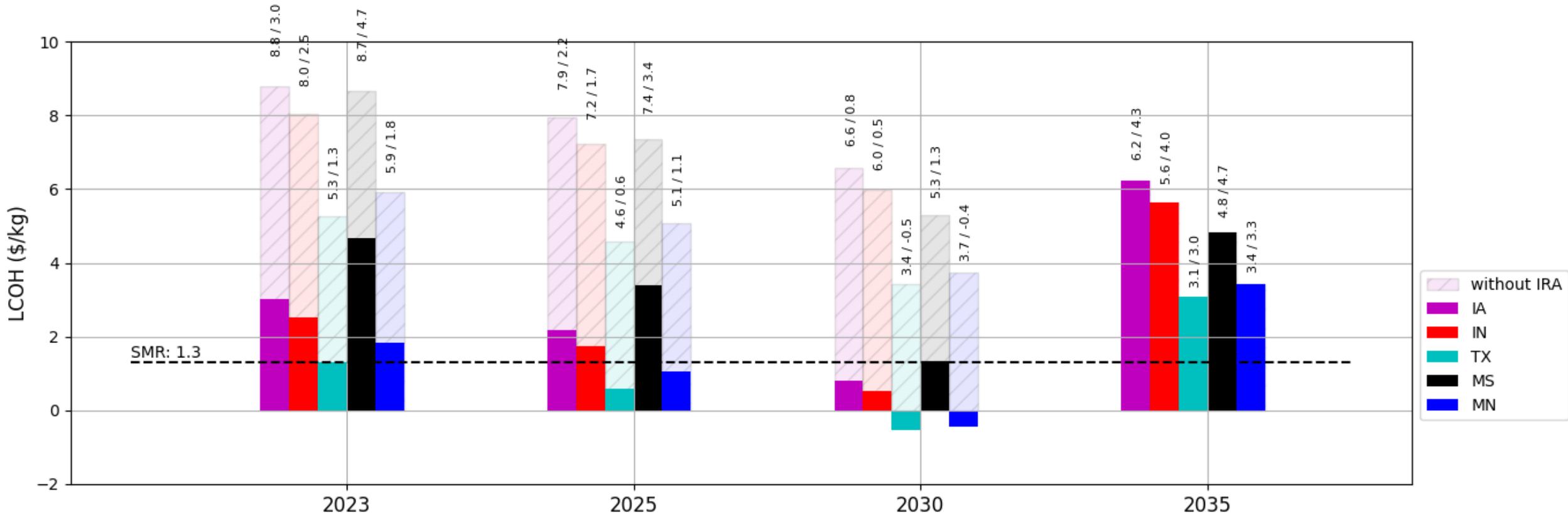


Assumptions:

- Using publicly available data for costs
- Annual Technology Baselines from DOE where applicable
 - Electrolyzer costs based on HFTO projections
- Electricity prices are difficult to forecast and are based on a decarbonized grid (retail prices)
- Current supply chain limitations are not represented
- Steel technology of DRI + EAF is modeled
- Costs are region specific

With incentives, costs are driven to be low-cost option.

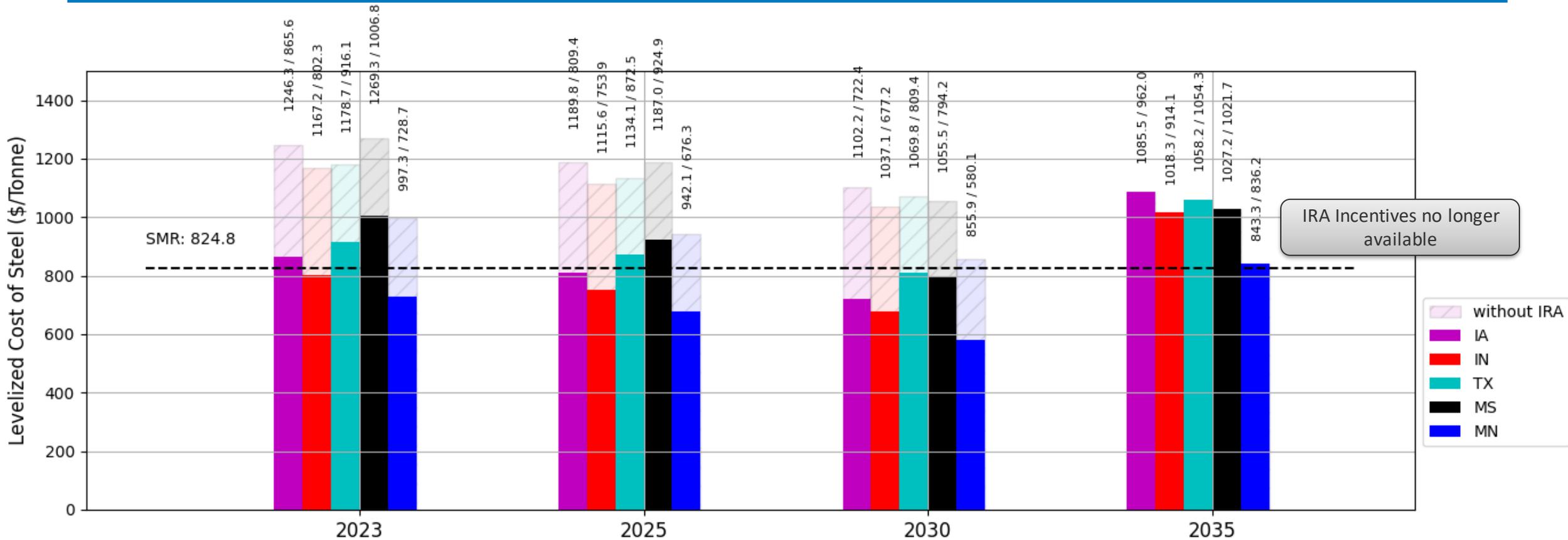
Levelized Cost of Hydrogen – Off-grid



Key Takeaways:

- **MN can produce low cost hydrogen relative to other locations**
- LCOH is cost competitive with SMR by 2025.
- Off-grid indicates that significant transmission build out is not required.
- **IRA makes this possible in the near-term.**

MN Produces Low Levelized Cost of Steel (LCOS)



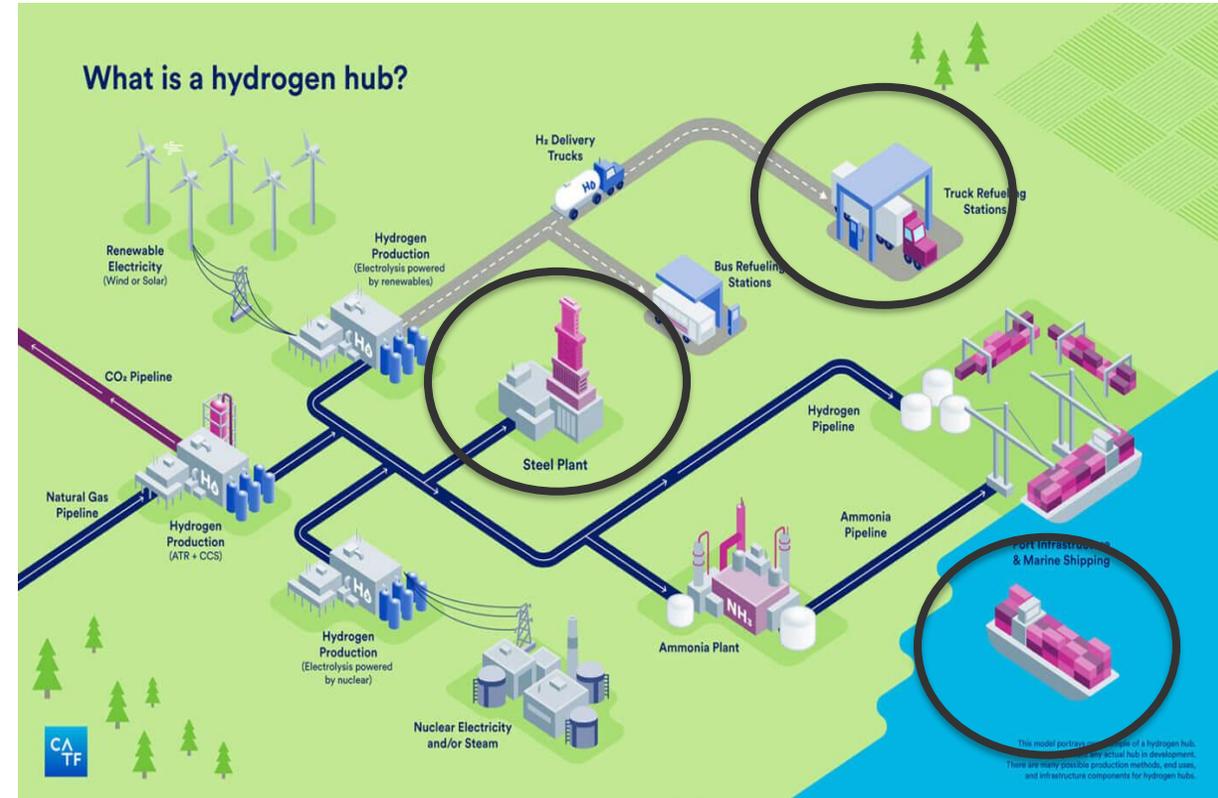
Key Takeaways:

- **MN has been identified as a place for low-cost green steel.**
- Lowest cost hydrogen does not necessarily translate to lowest cost of end use.
- Cost competitive with SMR (steam methane reform) now.
- **IRA makes this possible in the near-term.**

Note: Cost projections provided by DOE annual technology baseline (ATB) for relevant technologies and by HFTO for hydrogen technologies

Additional opportunities for Cross-Sector Coupling

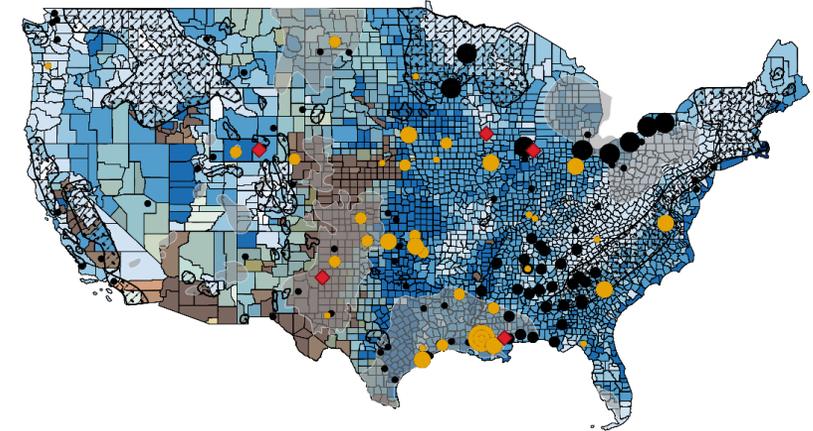
- **Wind-to-ammonia systems** – recognized global leader in this space
- **E-fuels** from ethanol plants have immediate potential pairing green hydrogen with carbon capture, opportunity co-locating with cement/concrete and port (demand)
- **Cement/concrete** – opportunities to co-locate with other industrial end-uses such as steel and/or ammonia as well as access to raw materials including lime in the state
- Several **key partners** co-located in the state



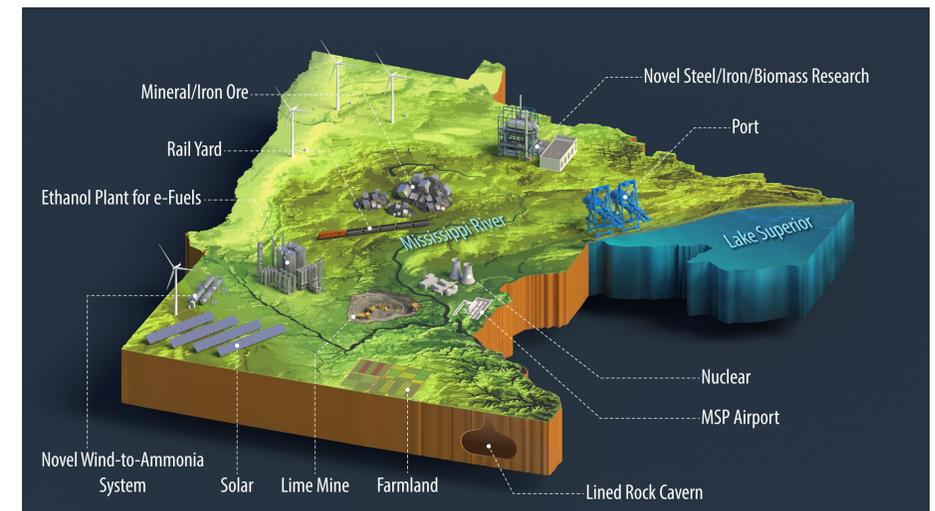
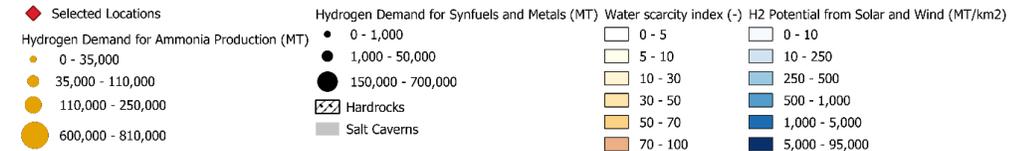
Cement

This is the First Step

- MN can be **leader** in industrial decarbonization
- **Urgency** and window of opportunity
 - Energy transition is happening now
 - IRA is finite (Approx. 10 years)
- MN **ALL key components** - resources, infrastructure, clean electricity, research, and industry
- Vast **economic potential** across multiple industries and potential for coupling.



Legend



Audience Q & A



Mike Jensen, PE-MN
*Director, Clean Fuels PMO,
Xcel Energy*



XCEL ENERGY & THE HEARTLAND HYDROGEN HUB

Mike Jensen | Director, Clean Fuels PMO

December 6, 2023

slido

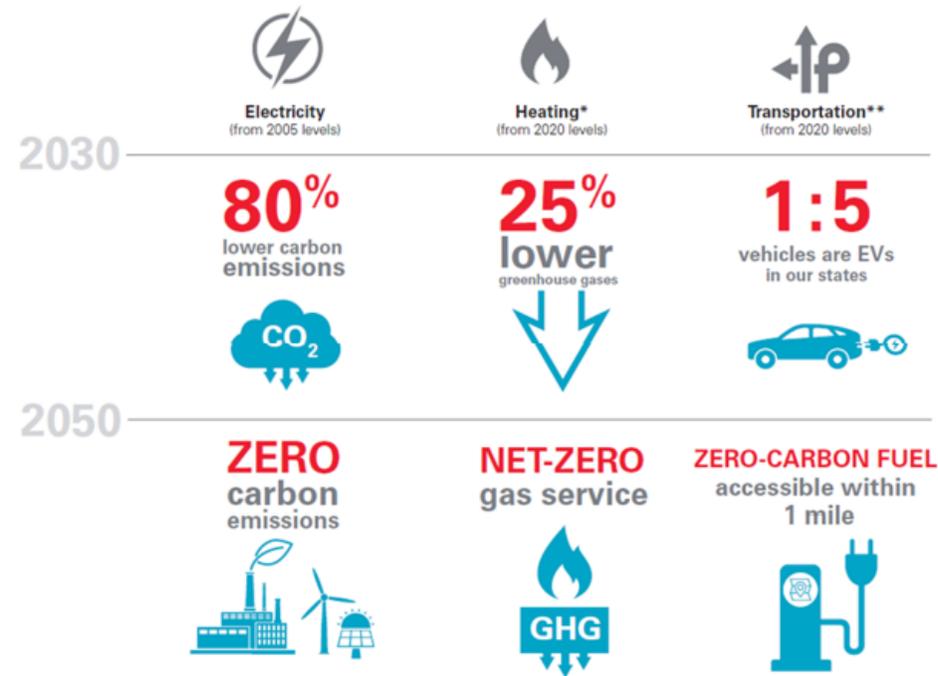


What use of Hydrogen are you most excited for?

ⓘ Start presenting to display the poll results on this slide.

Clean Fuels Policy Drivers

Critical to support 2050 Goals



*Spans natural gas supply, distribution and customer use

**Includes the Xcel Energy fleet; zero-carbon fuel is electricity or other clean energy

Selected Regional Clean Hydrogen Hubs



slido



How many Hydrogen Hub concept papers were originally submitted to the DOE?

① Start presenting to display the poll results on this slide.

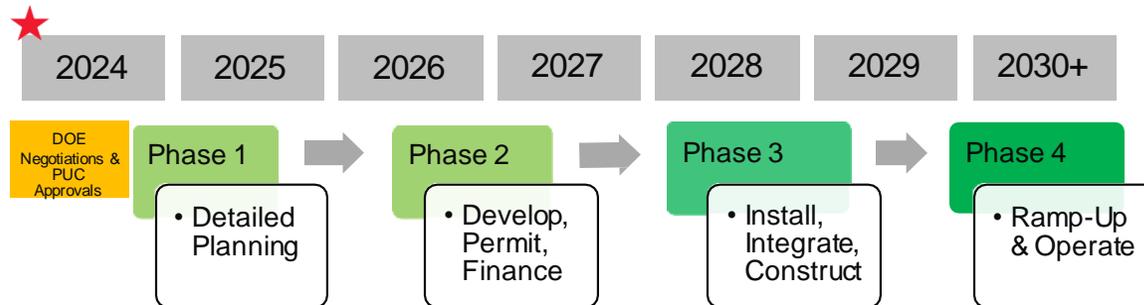
Regional Clean Hydrogen Hubs

Heartland Hydrogen Hub (NSPM) selected for \$925M DOE Award

- Hydrogen Hubs represent scale of business investment
- \$8B from 2021 Infrastructure Investment & Jobs Act (IIJA)
- Xcel Energy partner in two hub applications, one selected out of 7 awards and 26 full applications
 - **Heartland Hub, NSPM**
- Award negotiations to begin Nov. 2023

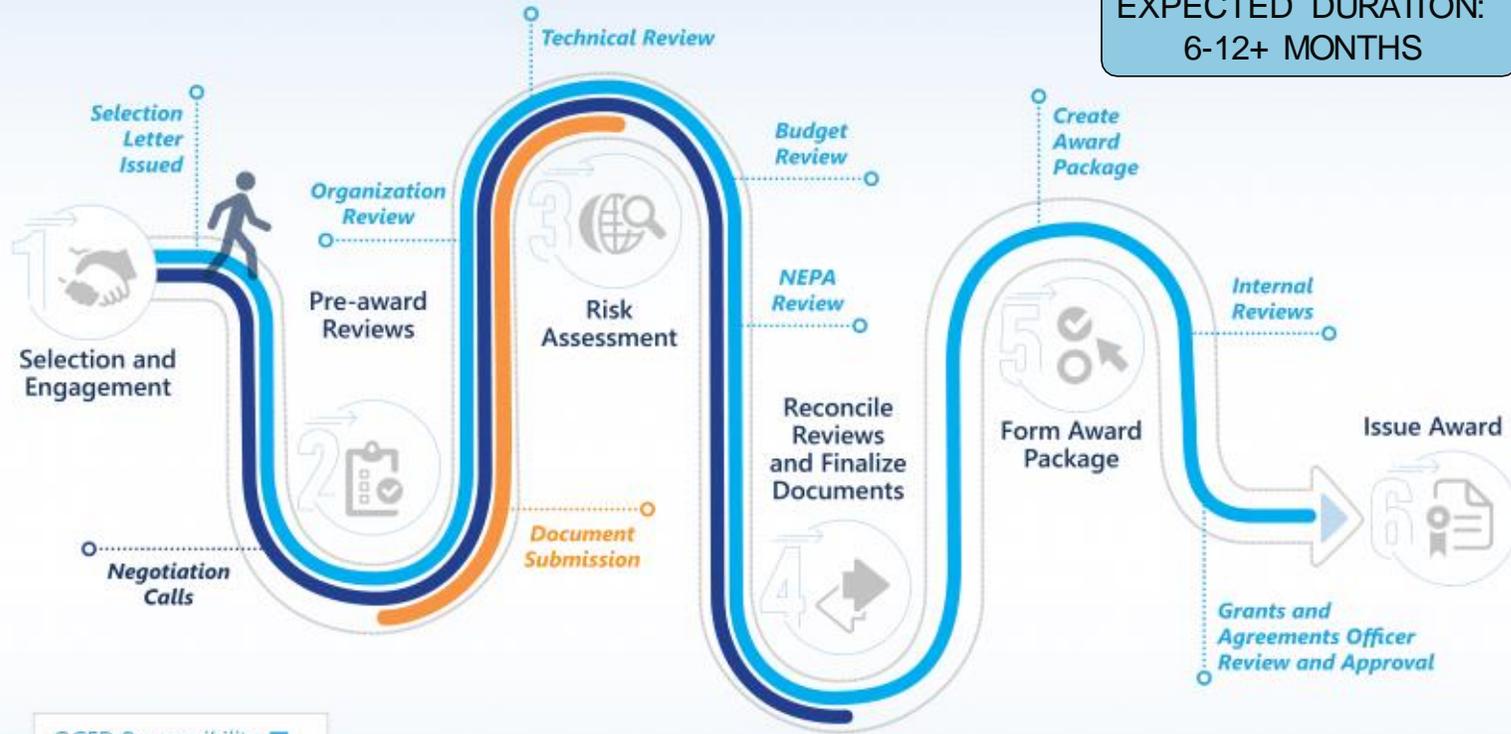
Heartland Hydrogen Hub Snapshot

- Utilizes carbon-free Wind, Solar & Nuclear generation in the Upper Midwest to produce hydrogen
- Uses include blending into power generation, existing natural gas distribution systems, and other agricultural and industrial applications.
- HH2H Cost of \$5B with \$925M DOE
- Xcel Energy investment of \$1.5 to \$2.5B with DOE cost share of up to \$565M
- Provides opportunity for incremental renewables buildout, along with significant jobs and other community benefits
- Partners include Marathon Petroleum, TC Energy and the University of North Dakota Energy and Environmental Resource Center (EERC)



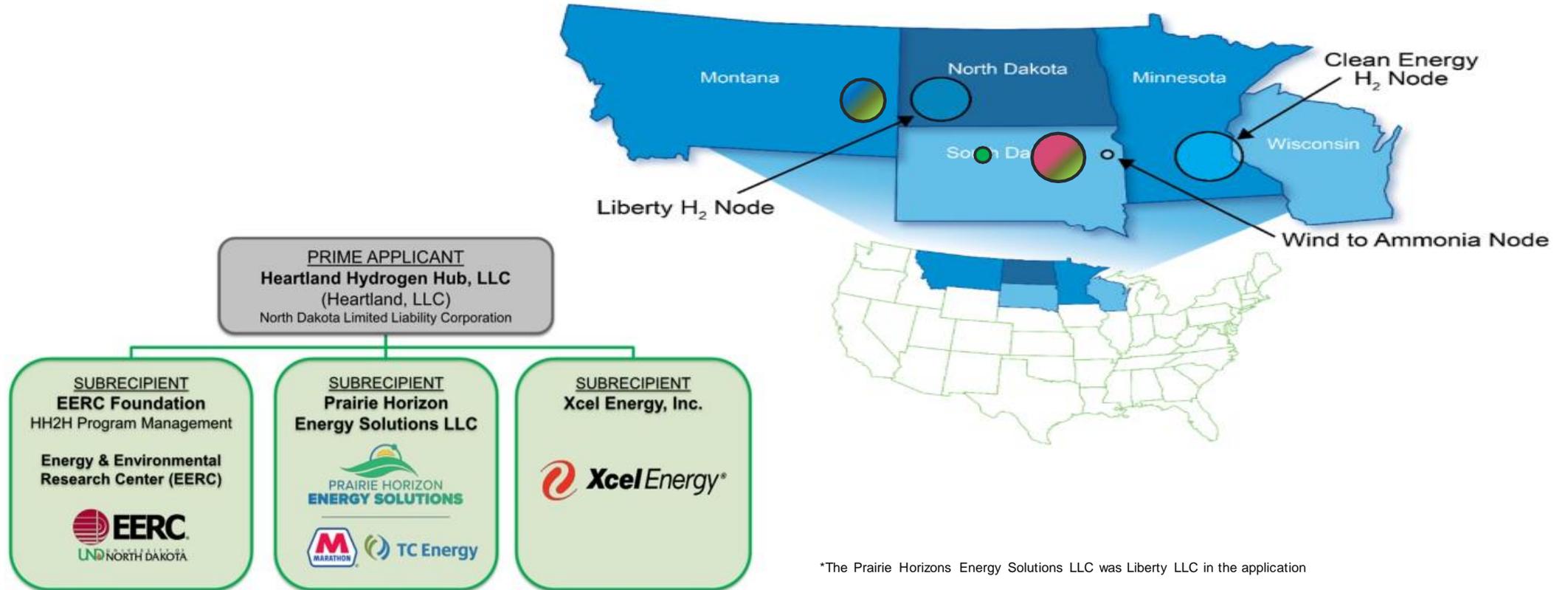
Award Negotiation Map

EXPECTED DURATION:
6-12+ MONTHS



OCED Responsibility ■
 Selectee Responsibility ■
 Joint Responsibility ■

HEARTLAND, LLC, AWARD STRUCTURE



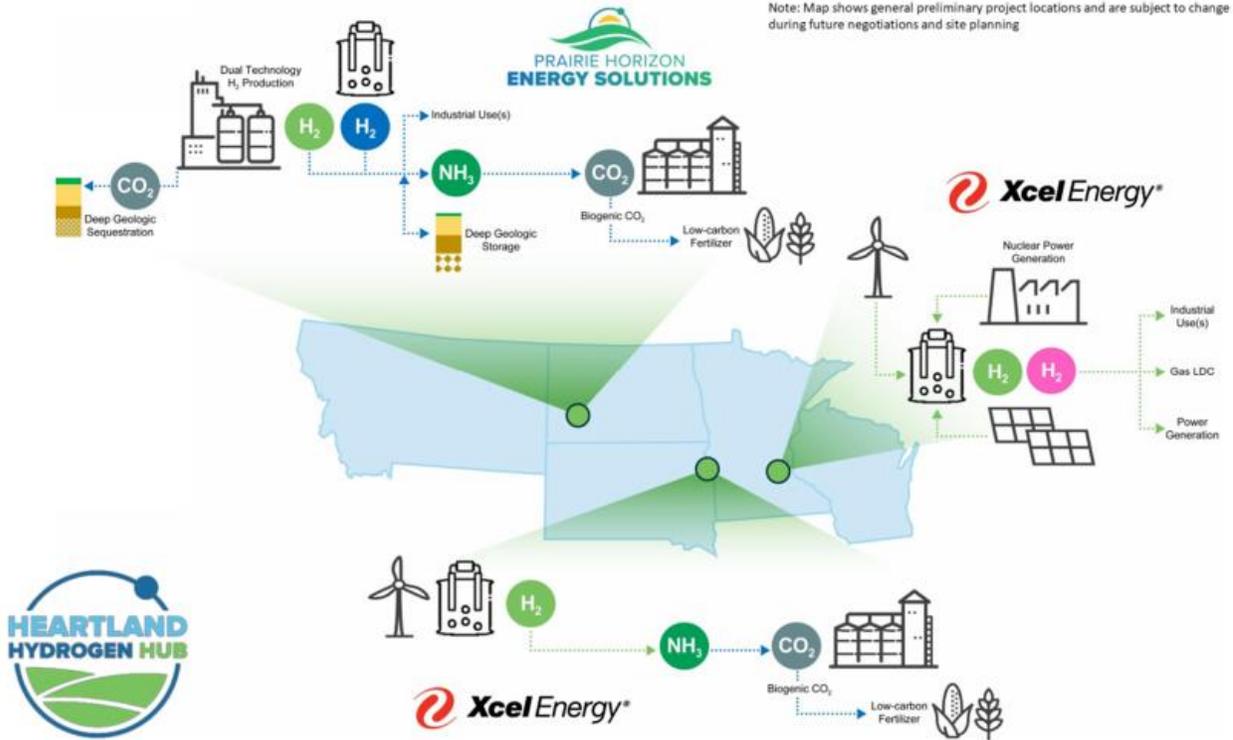
*The Prairie Horizons Energy Solutions LLC was Liberty LLC in the application

DOE HYDROGEN HUB PROGRAM AWARD: HEARTLAND HYDROGEN HUB

DOE funds advancing through negotiation: \$925 million

Application Strengths and Community Benefits Plan

- Diversity of H₂ supply: Green, Blue and Pink; use in agricultural sector (hard to decarbonize)
- IBEW, MN Building Trades, NREL (for leak detection and monitoring) and Tribal engagement commitments



COMMUNITY BENEFITS PLAN



Strategic Partners (examples)

Community and Labor Engagement

Host communities (CAPs), **Tribal communities** (MHA, SWO), **Marginalized Communities, Labor Organizations** (IBEW, ND+MN Buildings and Trades)

American Workforce

Education Consortium (UW, MTU, UTTC) **Labor** (IBEW, TrainND), **Workforce Development** (Energy Careers Academy), **Just Transition** (CAEL, CEWD)

DEIA

Supplier Diversity (NMSDC), **Minority-Serving Institutions** (UMM), **Tribal Colleges** (UTTC), **Economic Development Councils** (Stark County Development)

J40

Disadvantaged Communities (MHA, SWO, rural, urban)

Nearly 60 letters of support signed by strategic partners

slido



What state is ready to lead the Hydrogen economy?

ⓘ Start presenting to display the poll results on this slide.



Audience Q & A

Networking Break

Thank you to our sponsors!

