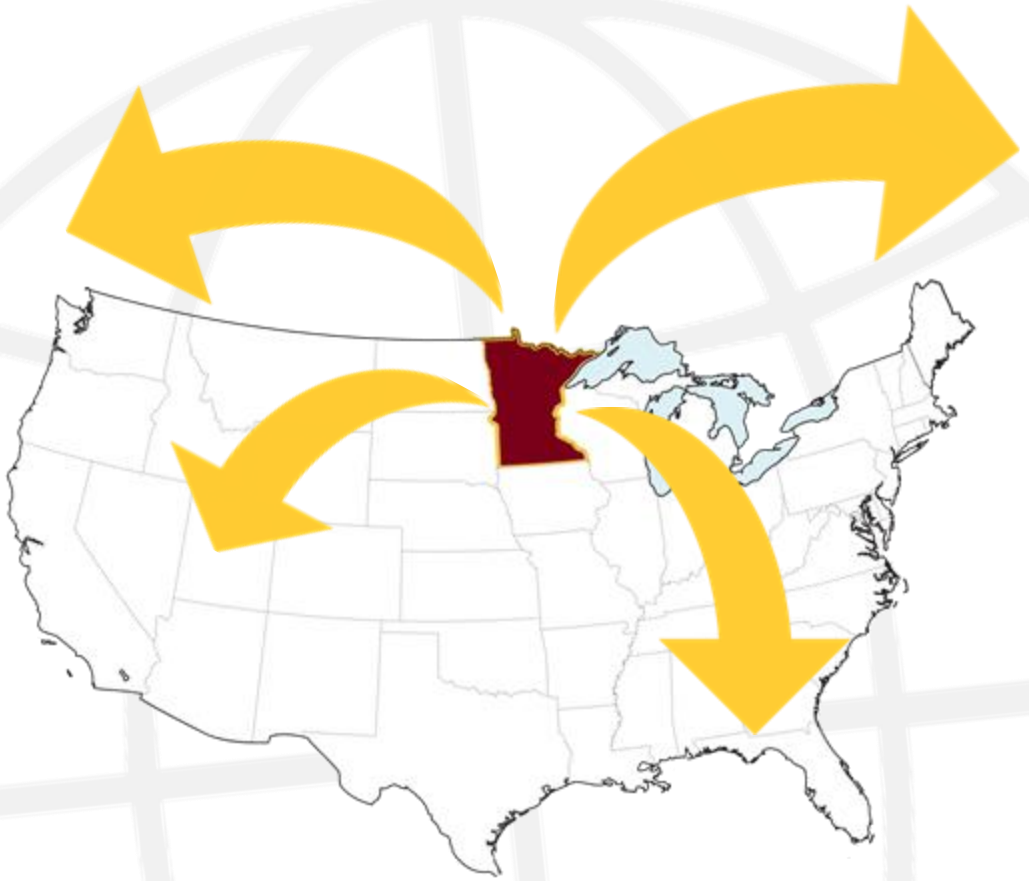
MIDWEST INDUSTRIAL TRANSFORMATION INITIATIVE



Hydrogen Economy Collaborative
Briefing
March 13, 2025

MIDWEST INDUSTRIAL TRANSFORMATION INITIATIVE

A first-of-a-kind collaboration between research institutions, industry partners, communities, funders, and state, local and Tribal governments to **accelerate the transition of bedrock American industries** to a new era of innovation, global leadership & reduced carbon emissions.

The Challenge

- The industrial sector is the nation's **largest energy consumer** and second largest source of greenhouse gas emissions
- The domestic steel industry is expected to **grow 40% by 2040** to support industry, infrastructure and national security demands.
- Cross-sector industrial transformation requires **leadership, innovative solutions and significant investment.**

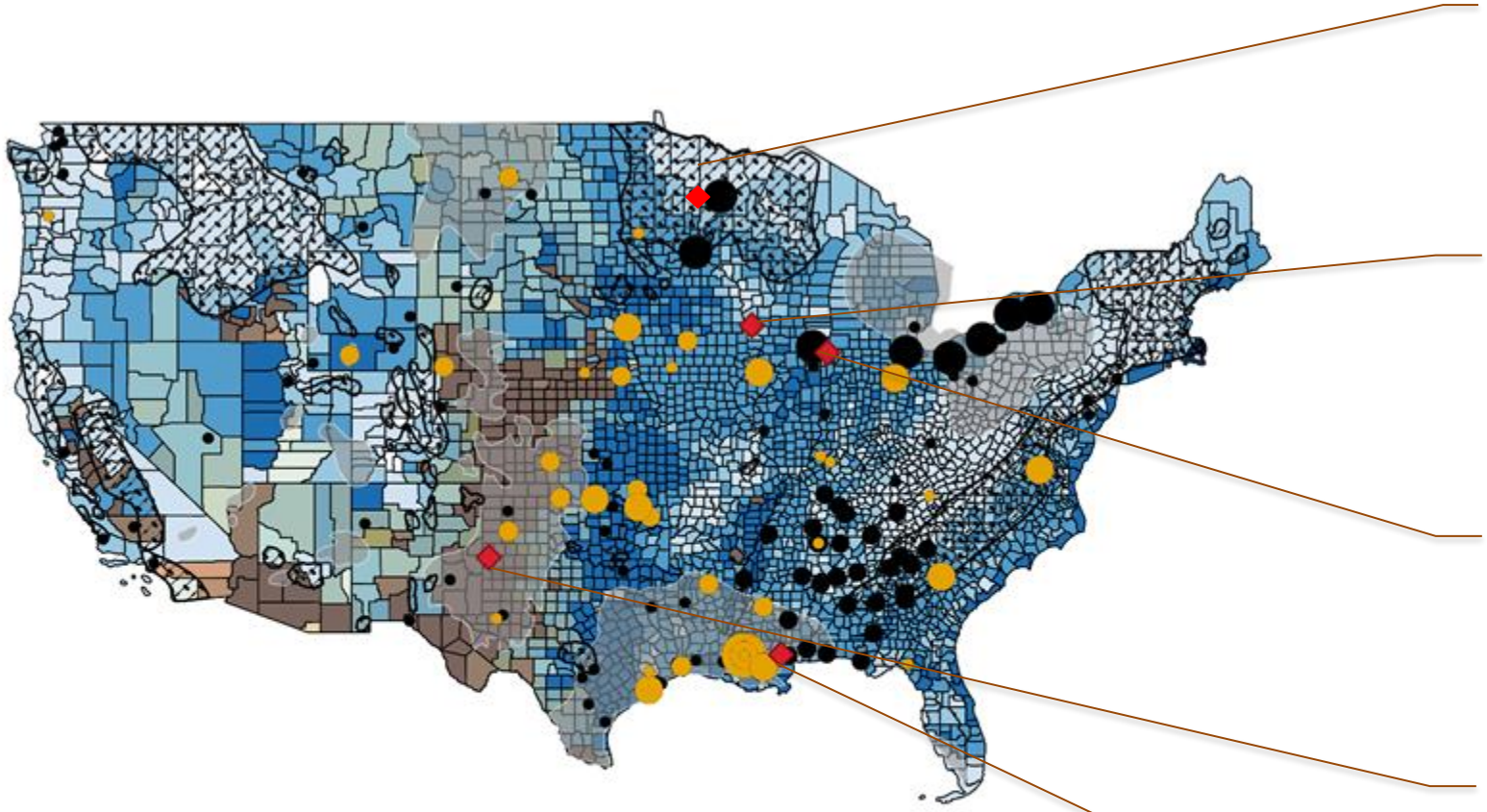
The Opportunity

- Minnesota has **key attributes** (water, energy, hydrogen) that are required for cost-competitive green steel production — that could also be relevant for other heavy-emitting sectors

- Northeastern Minnesota produces **85% of all iron produced for domestic steelmaking.**

- Minnesota's **mining industry and workforce** are engaged and ready to lead the transformation.

US DOE Study: Locations for Green Steel



Legend

- Selected Locations

Hydrogen Demand for Ammonia Production (MT)
- 0 - 35,000
- 35,000 - 110,000
- 110,000 - 250,000
- 600,000 - 810,000

Hydrogen Demand for Synfuels and Metals (MT)
- 0 - 1,000
- 1,000 - 50,000
- 150,000 - 700,000
- Hardrocks
- Salt Caverns

Water scarcity index (-)
- 0 - 5
- 5 - 10
- 10 - 30
- 30 - 50
- 50 - 70
- 70 - 100

H2 Potential from Solar and Wind (MT/km2)
- 0 - 10
- 10 - 250
- 250 - 500
- 500 - 1,000
- 1,000 - 5,000
- 5,000 - 95,000

MINNESOTA
- Suitable renewables
- Lined rock caverns; raw materials
- Infrastructure

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

INDUSTRY

Iron and steel

The American iron and steel industry is vital to modern society and essential for building climate solutions like rail and fuel-efficient vehicles. It is also an essential part of the U.S. economy, accounting for more than $520 billion in economic output and nearly two million jobs. The iron and steel industry accounts for approximately 7% of greenhouse gas (GHG) emissions globally.

Cement and concrete

Cement and concrete are essential for modern infrastructure given its use for construction, paving and other projects. Decarbonizing the industry is a challenge because of the high heat needed to make cement. The industry is responsible for 4-8% of carbon emissions globally.

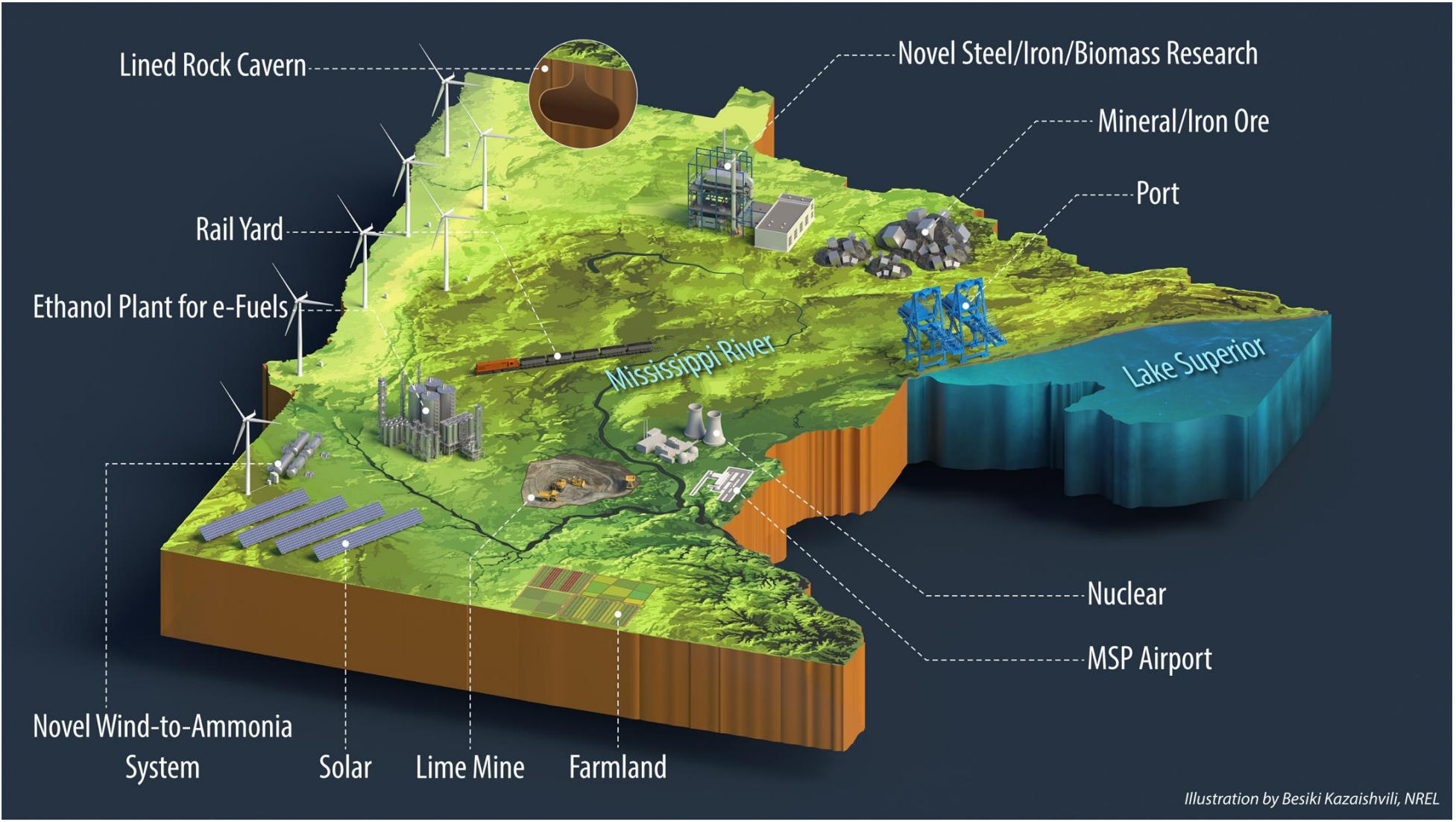
Renewable fuels & carbon products

Renewable fuels (E-fuels) are fuels in gas or liquid form that are produced from renewable energy and hydrogen and non-fossil carbon. Heavy mobility accounts for about a quarter of global carbon emissions. By drastically reducing the emissions associated with combustion engines, e-fuels are a potential replacement for fossil fuels like diesel, jet fuel, and gasoline.

Ammonia and fertilizers

Ammonia is the primary ingredient in most fertilizers and a significant source of emissions, contributing roughly 1-2% of global greenhouse gas emissions. Using “green” ammonia, meaning ammonia made using renewable energy, could drive down farming’s carbon footprint by as much as 90 percent for corn and small grain crops.

Minnesota: All the Key Attributes



- ✓ **Natural Resources**
  - Water
  - Minerals
  - Forest products
  - Agriculture
- ✓ **Power**
  - Generation portfolio
  - Grid distribution
  - MN 2040 commitment
- ✓ **Infrastructure**
  - Multimodal transport
  - Industry
- ✓ **Manufacturing**
  - Iron
  - Fuels
  - Forest products
  - Materials & equipment
  - Water management
- ✓ **Regional Engagement**

The Partnership

NREL Transforming ENERGY + Natural Resources Research Institute, University of Minnesota Duluth, Driven to Discover℠ + Great Plains Institute

- Renewable generation, transmission, storage
- H_2/NH_3 production
- Grid modeling
- Industry coordination
- e-fuels technologies

- Industry relationships
  - Technology de-risking
- Community relationships
- Location
  - Resources
  - Infrastructure
- Experimental capabilities
- Demonstration capacity
- UMN System
- Commercialization

Cross-Sector Partners

- Tribes
  - Renewable energy assets
  - Energy sovereignty
- Business & Industry
  - Social license
  - Permitting
- Philanthropy
  - Project scoping & learnings
  - Financial and in-kind support
- Communities
  - Workforce development
  - Historical context/concerns

Integrated Regional Engagement

MIDWEST INDUSTRIAL TRANSFORMATION INITIATIVE

ENGAGE

Communities, Tribes, Government

Engage with Tribes, governments, communities and labor to ensure project aligns with community priorities

ENABLE

Permitting, policy, regulatory, social license

Work with elected officials and government agencies to create the conditions that enable industrial innovation

BUILD

Feasibility, design, construction

Start with research aimed at de-risking the anticipated project followed by pilot testing, demonstration, and commercial scale adoption

INSPIRE

Demonstrate the possible

Position Minnesota as a model for industrial transformation domestically, to compete globally

State Strategy: Renewable Energy/Hydrogen generation & demand; Feedstock supply chain

Launched by community. Driven with community.

- Ensure activities are informed by **historical context and learnings**
- **Actively involve stakeholders** in planning, development and implementation
- Ensure alignment with **community priorities**
- Provide **coordinated messaging** and timely dissemination of information
- Surface, document and address **community questions, perceptions** and **concerns**
- Uncover opportunities for **collaboration** and shared benefit

Community Engagement Networks

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Work with state legislators and other agencies to help create the enabling conditions for industrial transformation

GREAT PLAINS INSTITUTE

Create the enabling environment

Realizing Minnesota's potential as a hub for industrial innovation requires strong policy and permitting pathways, engaged communities, and a supportive state-wide policy framework.

Inputs	Strong relationships with state legislators	Engaged community members, Tribes and other stakeholders	Identified permitting needs and state-level strategies
Activities	Legislator awareness and education	Host community engagement activities; convene Community and Tribal Advisory Panels	Input into state-level strategies on green iron and geologic hydrogen Two bills – geoH2 and feedstocks
Outputs	**State legislation** that supports a modernized iron and steel industry in Minnesota	Strong **social license** for operation	Clear **permitting pathways** for approving new projects

MIDWEST INDUSTRIAL TRANSFORMATION INITIATIVE

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Communities, Tribes, Government

Engage with Tribes, governments, communities and labor to hear perspectives and ensure an inclusive project

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Work with state legislators and other agencies to help create the enabling conditions for industrial transformation

BUILD

Feasibility, design, construction

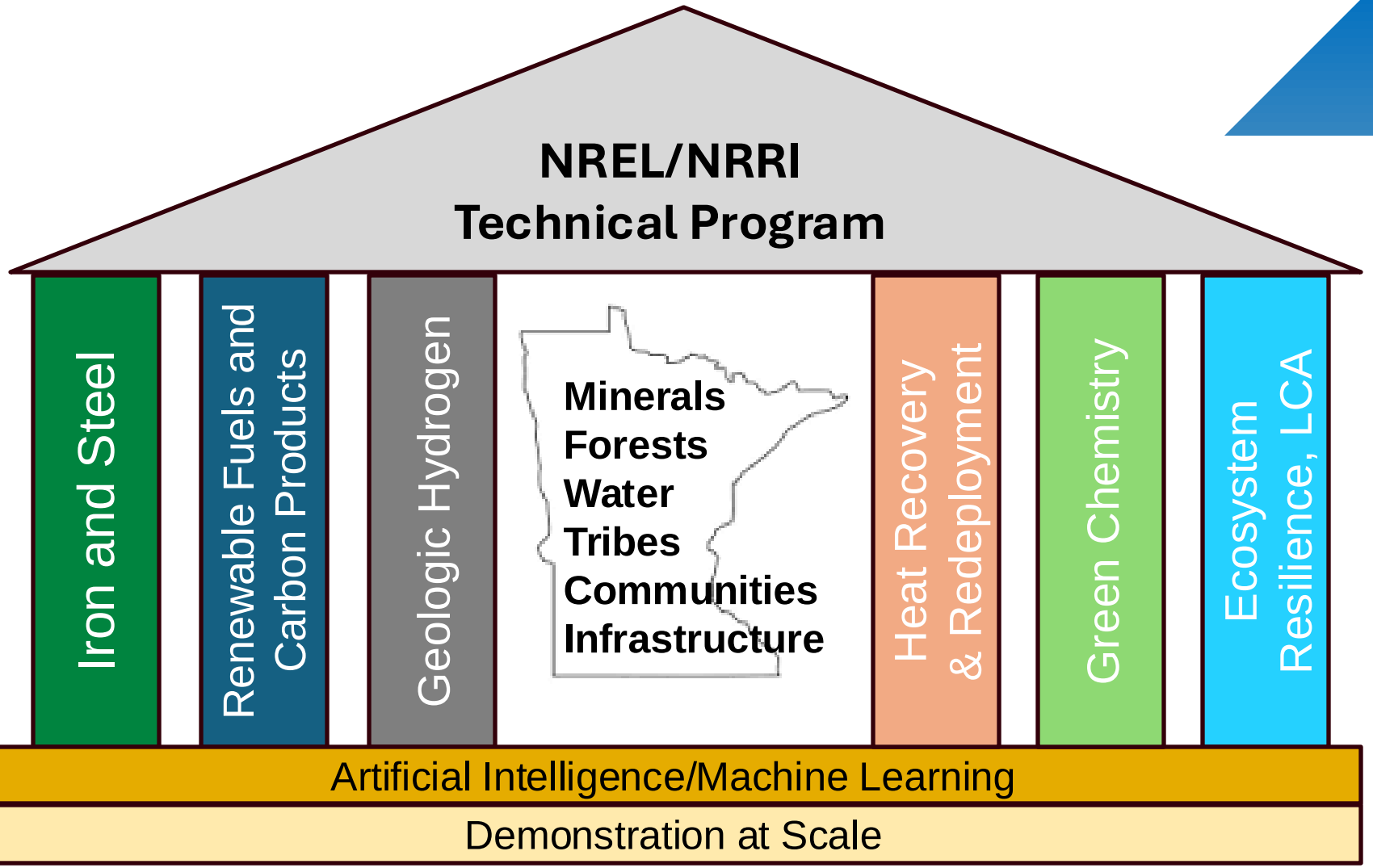
Begin with de-risking research, the project will then move to pilot, demonstration and commercial scale

Energy and Natural Resource Innovations to Transform National Industries

Defined Partnership

Research & Demonstration Program Portfolio

Cross-cutting Support



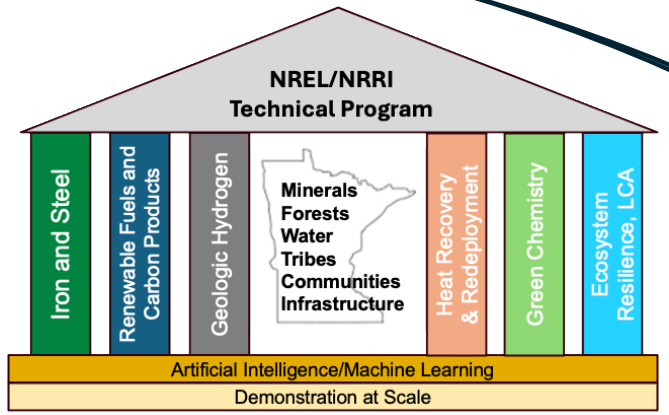
Impacts

- Innovation diffusion; National scaleability
- Economic & workforce development
- Globally competitive industries
- National security

De-risking Platform Concept

Energy/hydrogen generation
e-fuels
AI/ML

NREL
NATIONAL RENEWABLE ENERGY LABORATORY



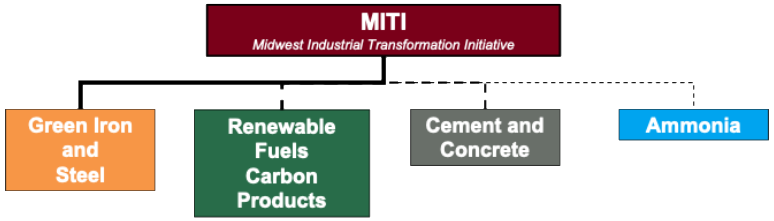
Industry Partnerships

- ❑ PI-to-PI relationships
- ❑ Working technical teams
- ❑ Digital twinning

U.S. DEPARTMENT OF ENERGY

NL infrastructure
Industry relationships
LCA/TEA
AI/ML, Modeling

Ecosystem data
Biomass conversion
Community engagement
Mineral processing, metallurgy



MIDWEST INDUSTRIAL TRANSFORMATION INITIATIVE

Green Iron and Steel

MN Green Iron Project
(HDRI)

Phase 1: Feasibility
Phase 2: Design
Phase 3: Construction
Phase 4: Operation

Renewable Fuels Carbon Products

Cement and Concrete

Ammonia

We are here now

Funding "*secured*" for Phase 1 Feasibility/Pre-Feed Study:

- Cost-effective energy, infrastructure and process vision with options
- Deliver energy innovation, globally-competitive industry, national security

Green Iron Feasibility Study Components

Master Project Plan

Technology

- Size of plant
- Renewable energy generation size/siting
- Hydrogen generation
- Energy/hydrogen phased demand
- Hydrogen storage/delivery
- Product definition & offtake
- HDRI plant design
- Plant lifecycle analysis
- Permitting data

Community

- Jobs and workforce training
- Energy generation opportunities
- Environmental impact management
- Ecosystem resilience planning
- Economic development
- Tribal & Community partnerships
- Government support
- Permitting & policy

Go/No Go Decision

Technoeconomic/Social License

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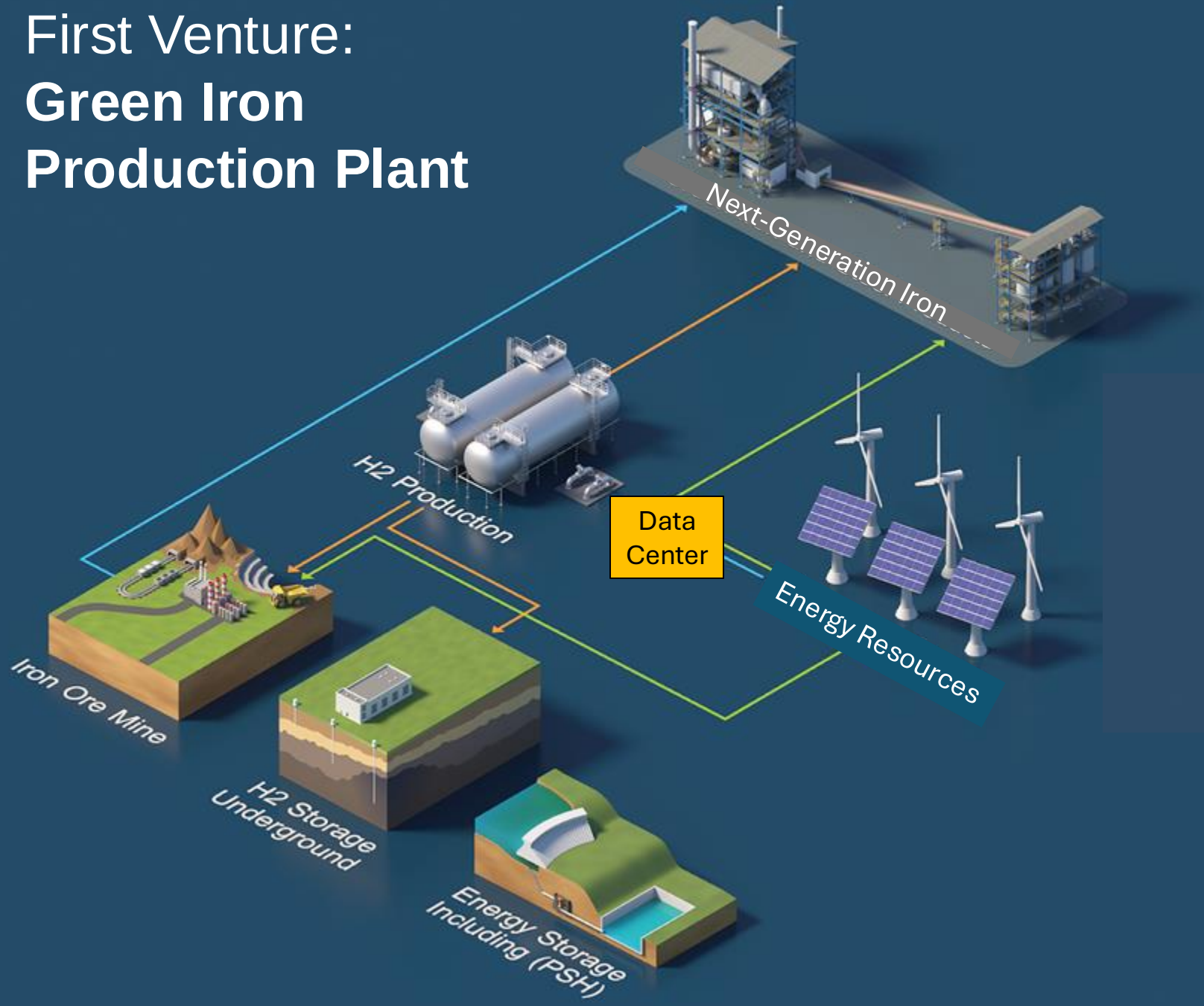
First Venture: **Green Iron Production Plant**



TIMELINE

- **Phase one**: Pre-feed Study (2025)
- **Phase two**: >600MW Green Iron Plant (2027 / 2028)

Cross Sector Coupling
Hydrogen Demand Hub
Green Electrons

Full Vision: **Industrial Transformation Hub**

Green iron plant **with cross-sector-coupled industries**

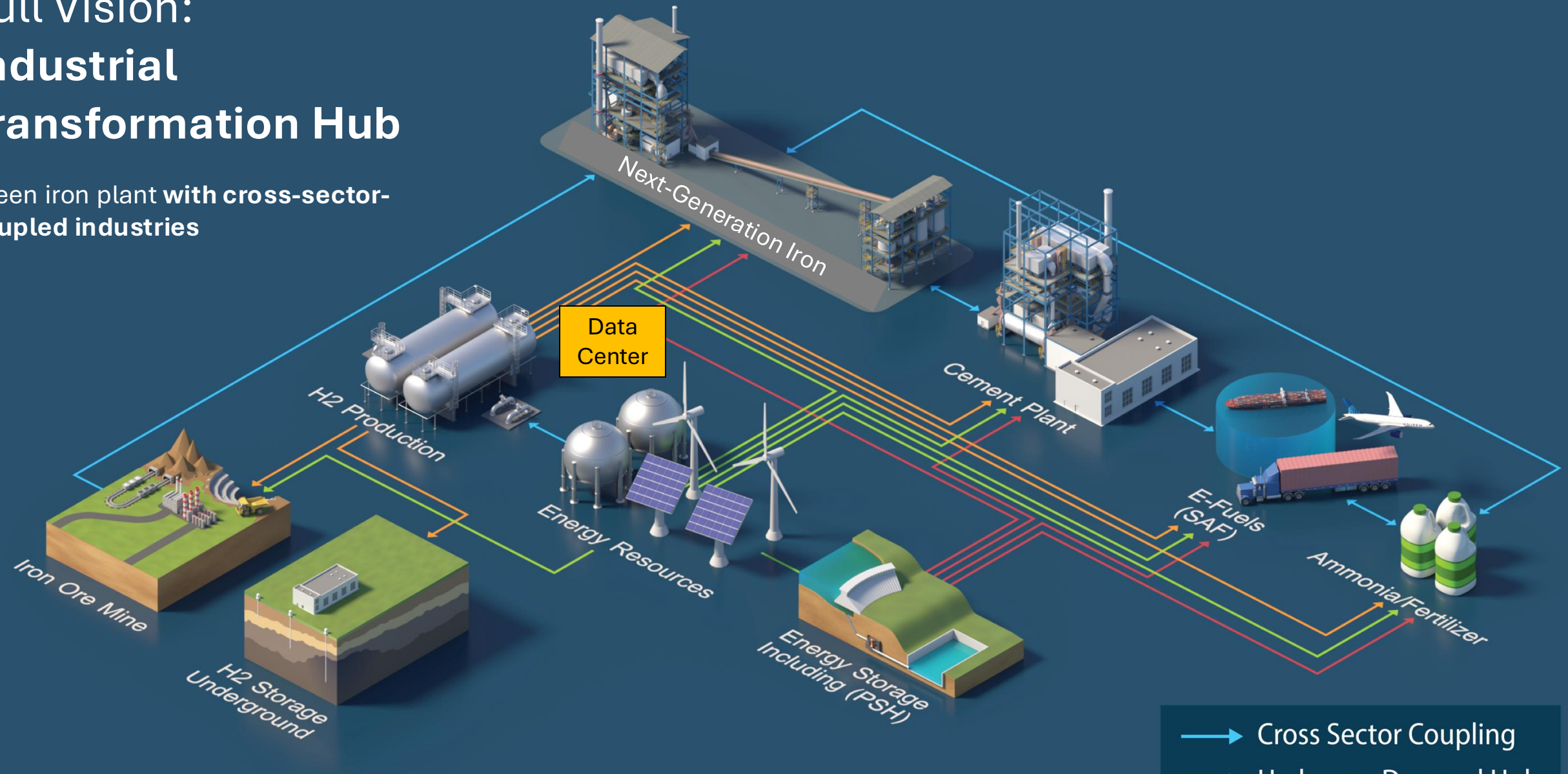


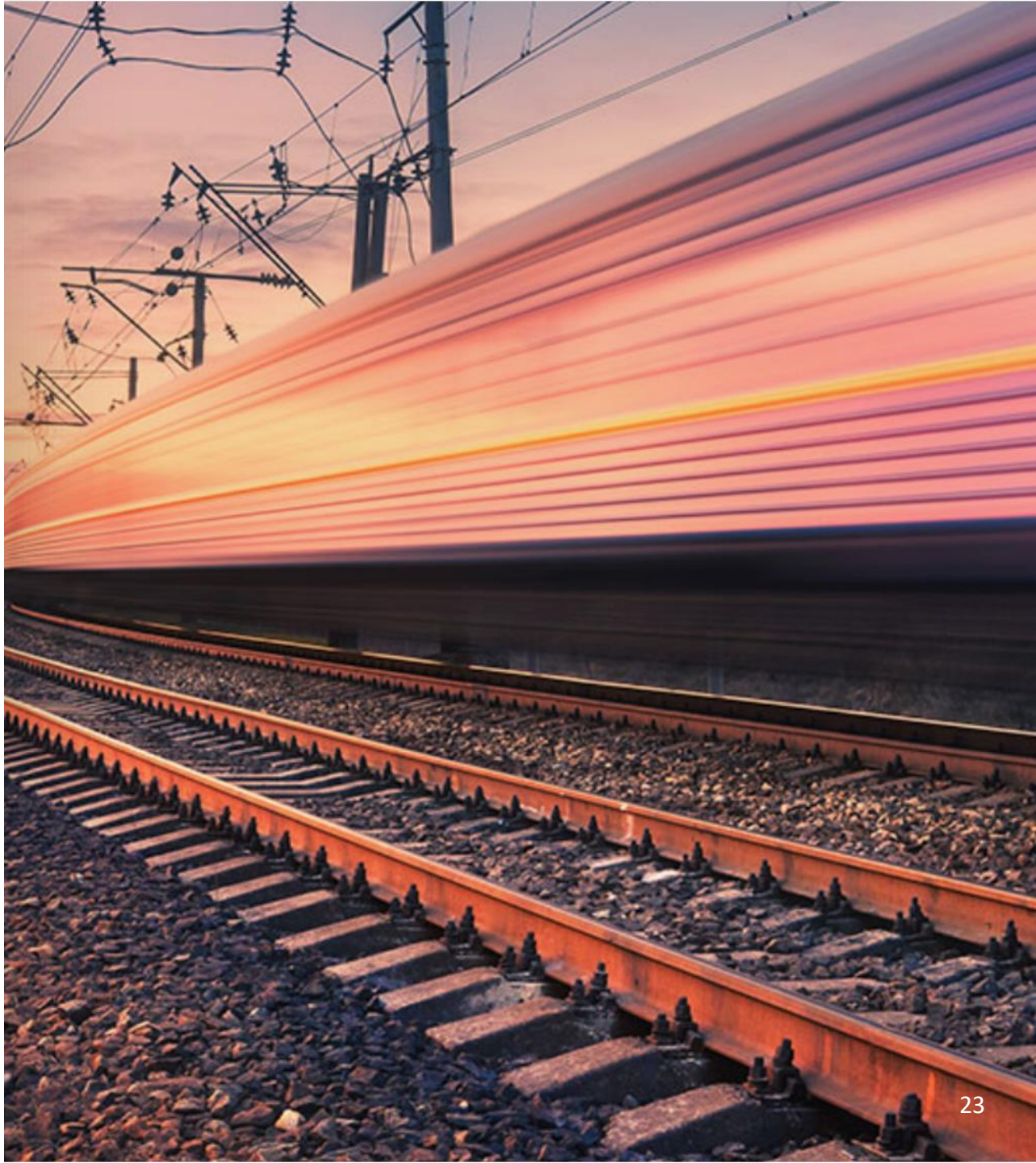
Illustration by Besiki Kazaishvili, NREL

Alignment with federal priorities

- Unleash US **energy innovation and abundance**
- Advance **energy addition**, not subtraction
- Promote **cost-effective** and **market-driven** energy choices
- Improve **grid reliability and security**
- Increase domestic steel production for **national security**
- Create **globally-competitive industries**

Anticipated Impacts

- Minnesota demonstrates the blueprint for **national and global industrial decarbonization**
- **Near zero carbon iron and steelmaking** in the United States
- **Cross-coupled industries** for maximized efficiency
- **Community** engagement, investment & participation across political divides
- High-skill **jobs and training**
- **Global market competitiveness**
- Secured value chain for **nationally-strategic industries**



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Thank You