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UNIVERSITY OF MINNESOTA

Geologic Hydrogen in MN

Presence, Opportunities

Mineland Vision Partnership

25 February 2026

Geologic Hydrogen, Defined

Natural

- Radiolysis of water in old rocks with high radioactivities (e.g. granite)

  H_2O + ionizing radiation → $e^-(aq)$, $HO^{\cdot}$, $H^{\cdot}$, $HO_2^{\cdot}$, H_3O^+, OH^-, H_2O_2, **H_2**

- Microbial activity

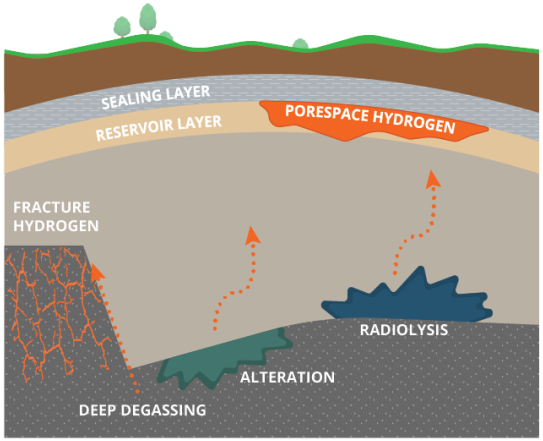
  Generate and consume hydrogen

- Serpentization of iron minerals in ultramafic rocks

Olivine + H_2O → Serpentine + Brucite + Magnetite + **H_2**

$3Fe^{2+} + 4H_2O \rightarrow Fe_3O_4$ (magnetite) + **H_2** + $6H^+$

- ➢ Requires “traditional” cap rock; not prevalent in MN
- ➢ Abundance and distribution not well understood



Sandia National Laboratory

Geologic Hydrogen, Defined

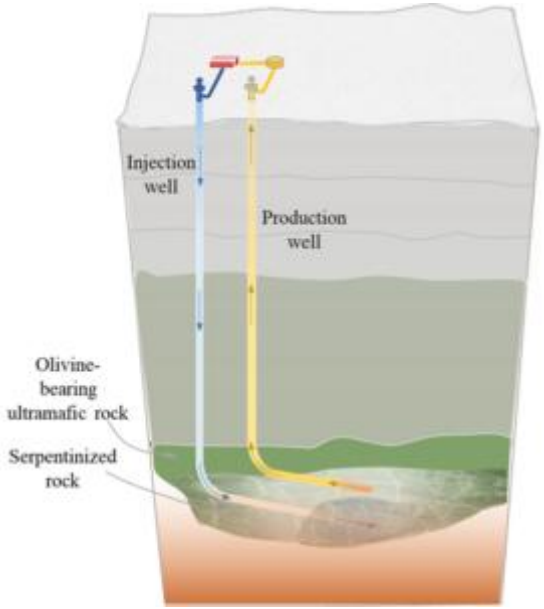
Stimulated

Artificial acceleration of water-rock interactions and fluid flow in ultramafic rock formations

Introduce water, catalysts, heat, and induced fractures to geologic formations to speed up reactions & flow

Uses technology applied in *Enhanced Geothermal Systems (EGS)*

- dynamic fracturing and injection of carbon-rich solutions to increase permeability and surface area for reaction
- electrical stimulation of fractured frameworks
- catalysis



Credit: LBNL

Geologic Hydrogen

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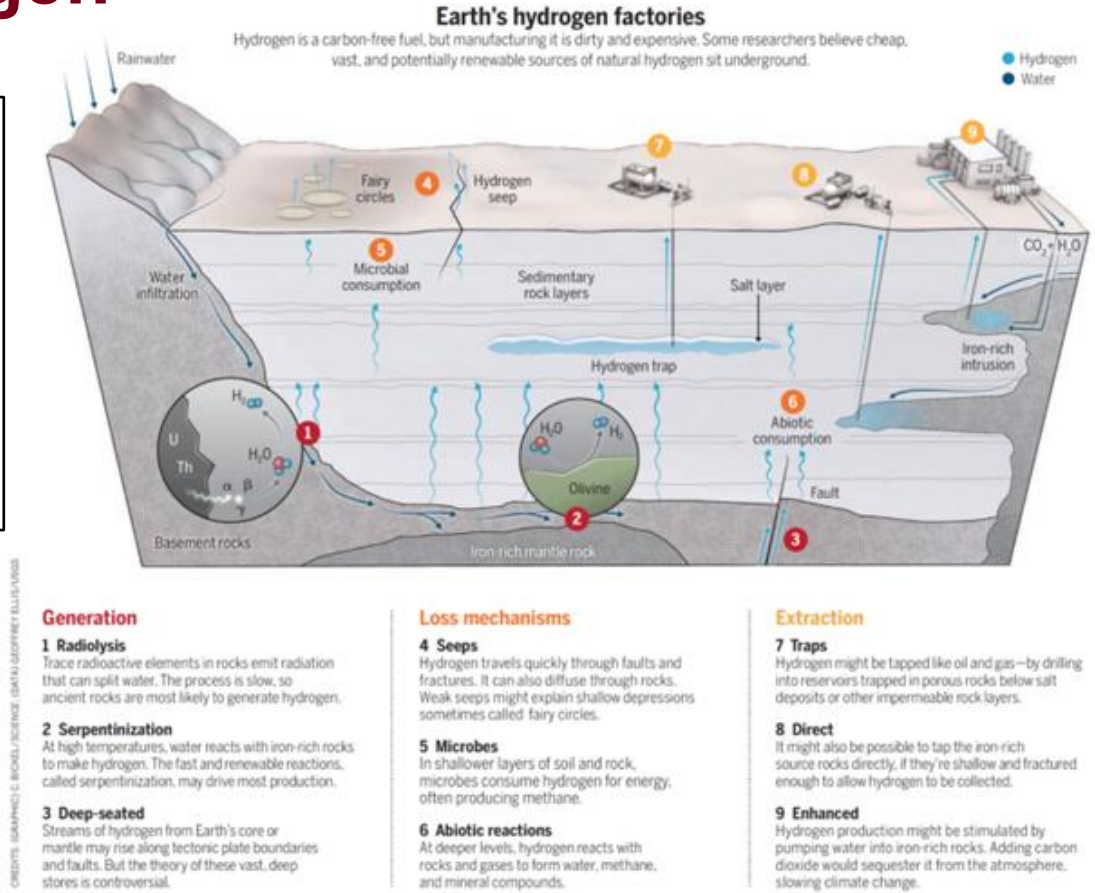
Early on the learning curve

Interesting supply of energy

Some pilot efforts under way

DOE supporting research; industry is leading investment



Credit: USGS

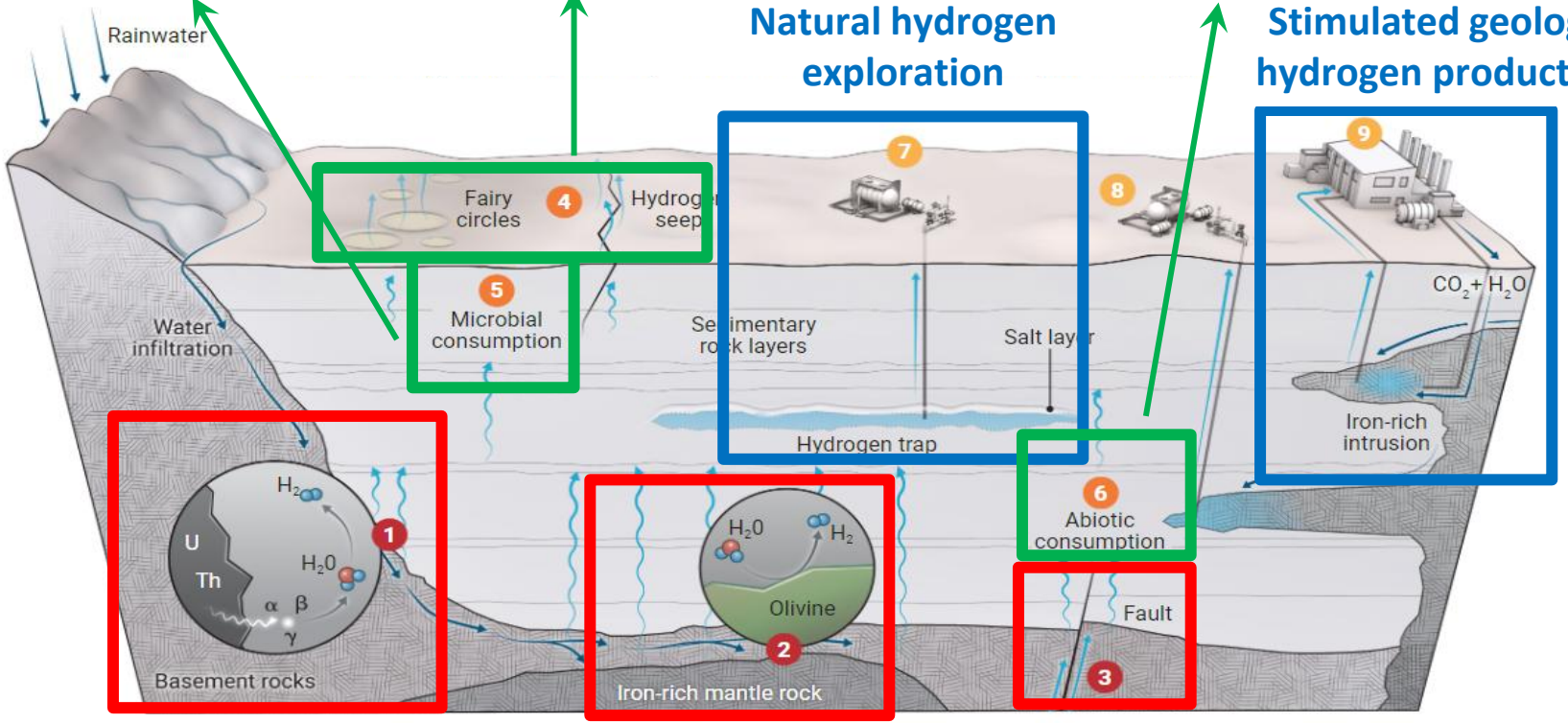
Consumption mechanisms #1:
Microbial activities

Consumption mechanisms #2:
Seeps and fairy circles (low conc.)

Consumption mechanisms #3:
Abiotic reactions

Natural hydrogen exploration

Stimulated geologic hydrogen production



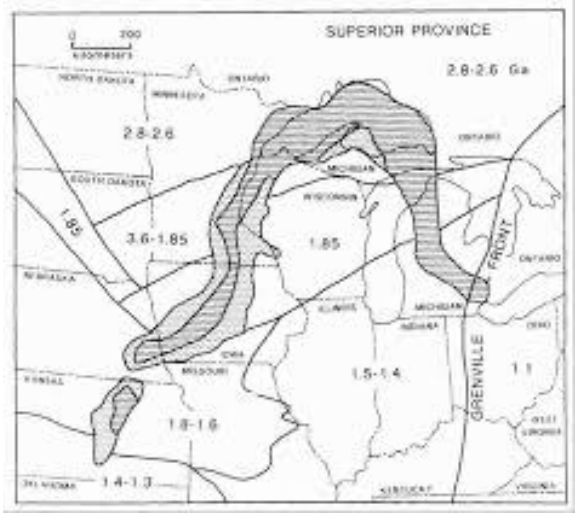
Production mechanism #1:
Radiolysis

Production mechanism #2:
Serpentinization

Production mechanism #3:
Primordial or magmatic H2

Modified from Hand et al., 2023

Geologic Hydrogen & Midcontinent Rift

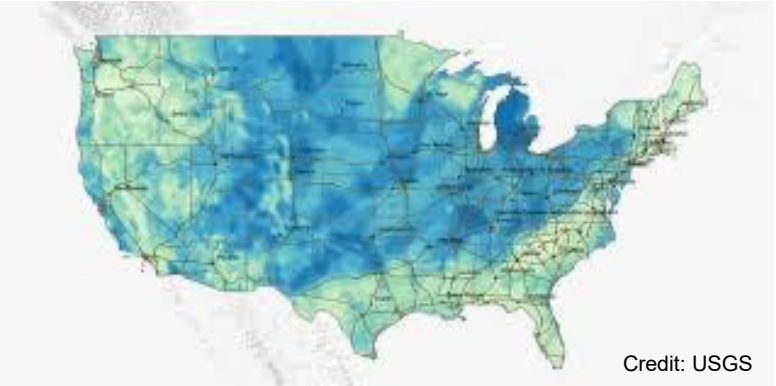


Credit: USGS

National models of natural hydrogen generation:

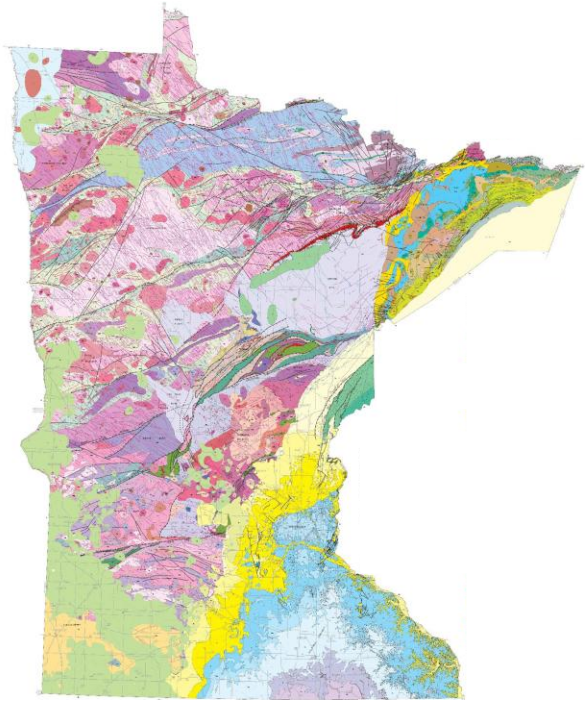
- States along the Midcontinent Rift: Michigan, Minnesota, Wisconsin, Iowa, Nebraska and Kansas
- States with olivine-rich rocks: Michigan, Washington, Minnesota, Oregon, Alaska, Hawaii and others
- States with U-Th rich granitic rocks: Wyoming, Idaho, Colorado, Virginia, Alaska and others

National Natural Hydrogen Potential



Credit: USGS

Geologic Hydrogen – MN potential



Minnesota Geological Survey

Geologic highlights

- Archean Granite greenstone in the north
  old rocks with high radioactivities
- Paleoproterozoic Banded Iron Formation
  high iron content and surface area from mining activities
- Mesoproterozoic Midcontinent Rift System
  naturally fractured systems for flow
- Duluth Complex and Tamarack intrusion
  high iron content

Geologic Hydrogen – Concerns

Exploration permitting

Hydrogen safety

Groundwater impacts vs. fracturing

Coordination of regulatory and research to be competitive

Geologic Hydrogen – Opportunities

Significant role in industrial transformation

- Fuel (Hydrogen/NG mixtures; fuel cell generation)
- Energy storage (ammonia, hydrocarbon fuels)
- Reactant for production of iron, steel, critical metals/materials
- Reactant for production of hydrocarbon fuels (SAF, diesel)

Credit: Boundary Power

Investment in hydrogen infrastructure and adoption requires

DEMAND

MITI

MIDWEST INDUSTRIAL TRANSFORMATION INITIATIVE

Midwest Industrial Transformation Initiative

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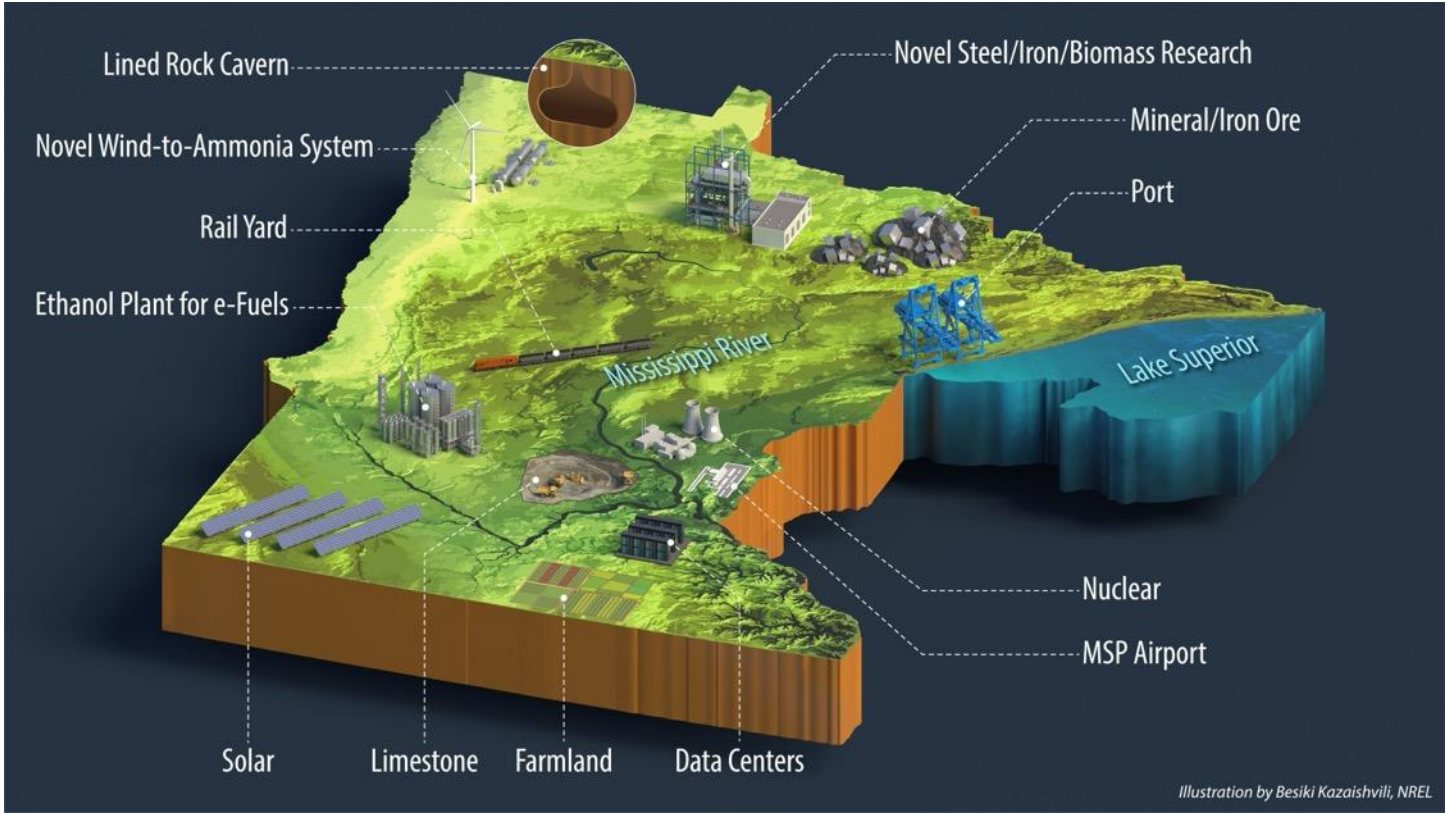
NATIONAL LABORATORY OF THE ROCKIES

GREAT PLAINS INSTITUTE

West Central Research and Outreach Center

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**

Evolved Vision: **Industrial Transformation Hub**

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

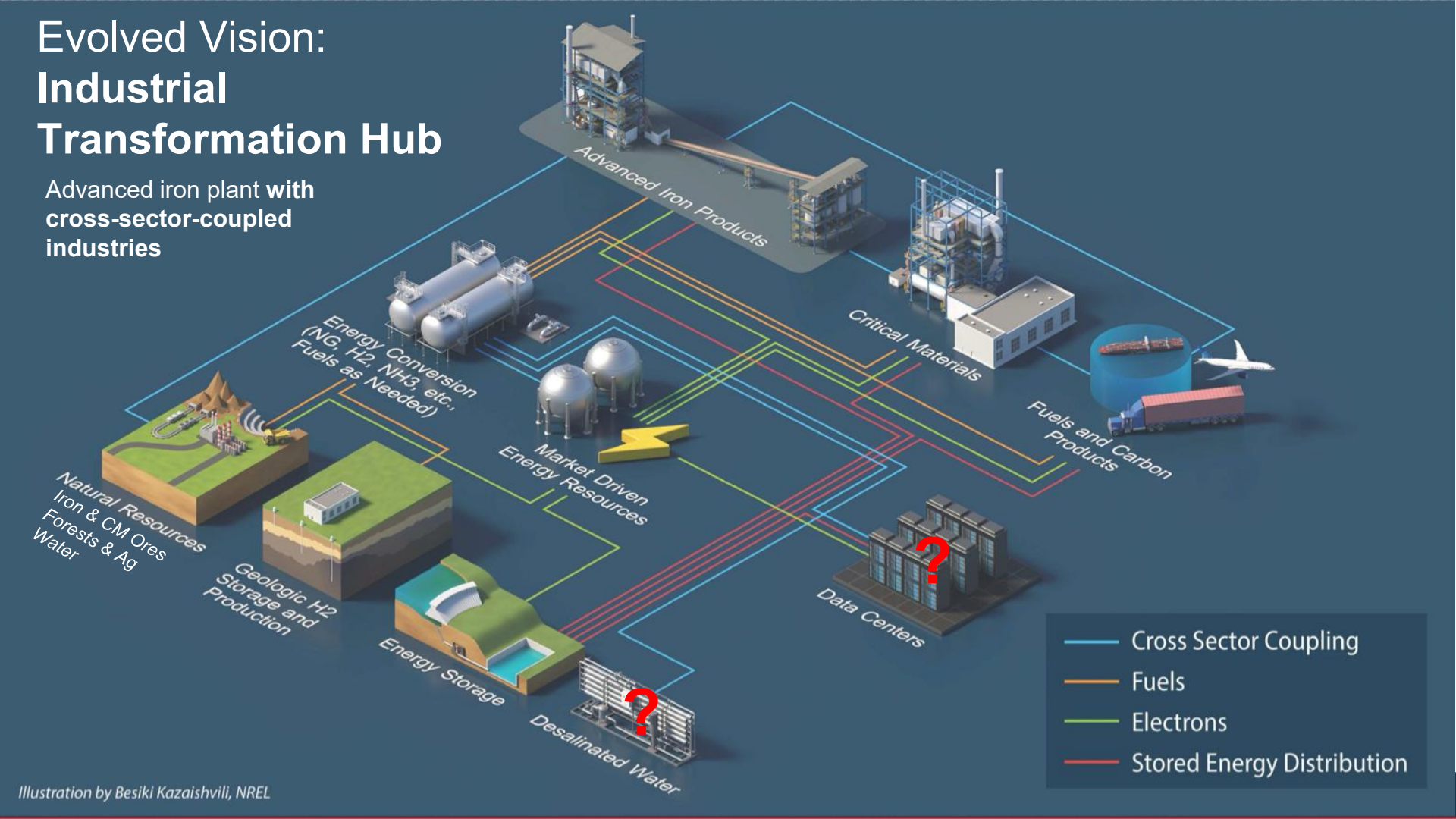
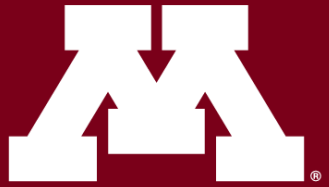


Illustration by Besiki Kazaishvili, NREL



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