Industrial Decarbonization Potential in MN:

MN as a Clean Energy Economic Powerhouse

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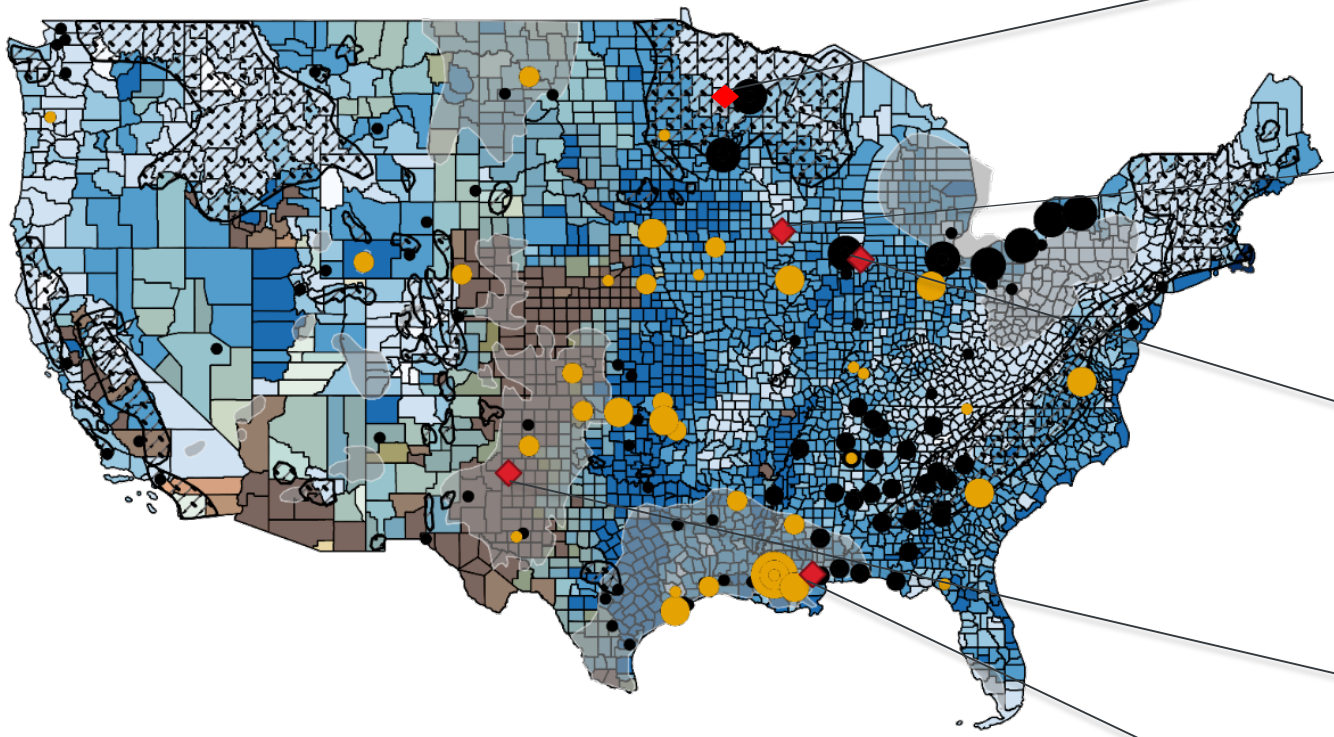
Approach: Four Land-based Locations for Phase I

- 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

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

Key Insights

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

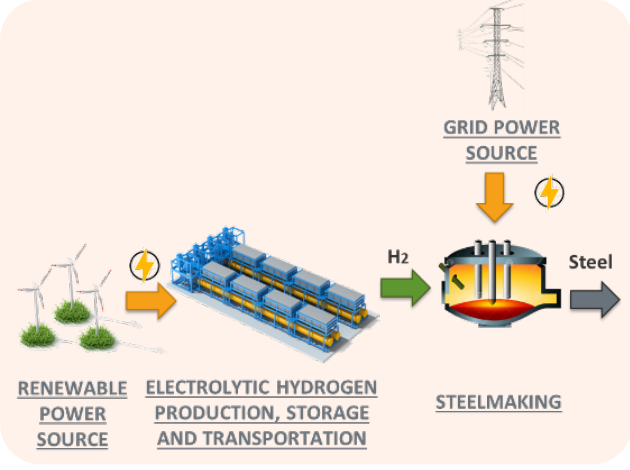
- Access to low-cost renewables, H2 geologic storage, existing infrastructure/raw materials

#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

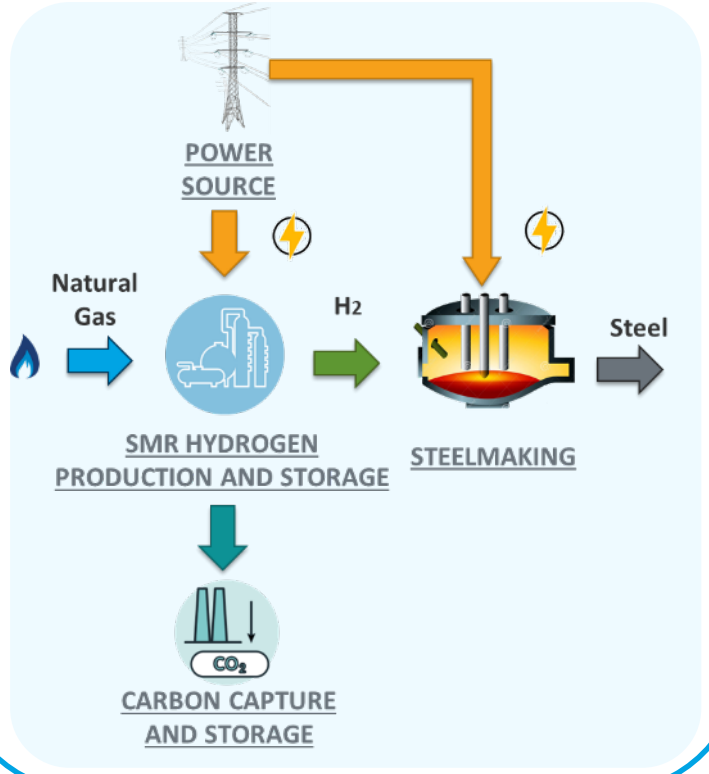
#4: Hybrid systems (wind+solar+storage) can substantially drive down costs.



Clean Electricity to Industrial Production – Use Cases

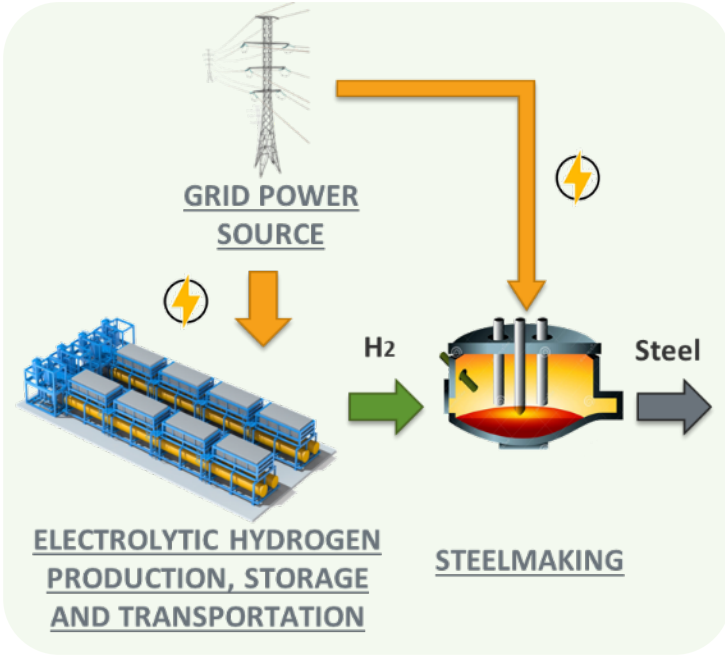
1

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



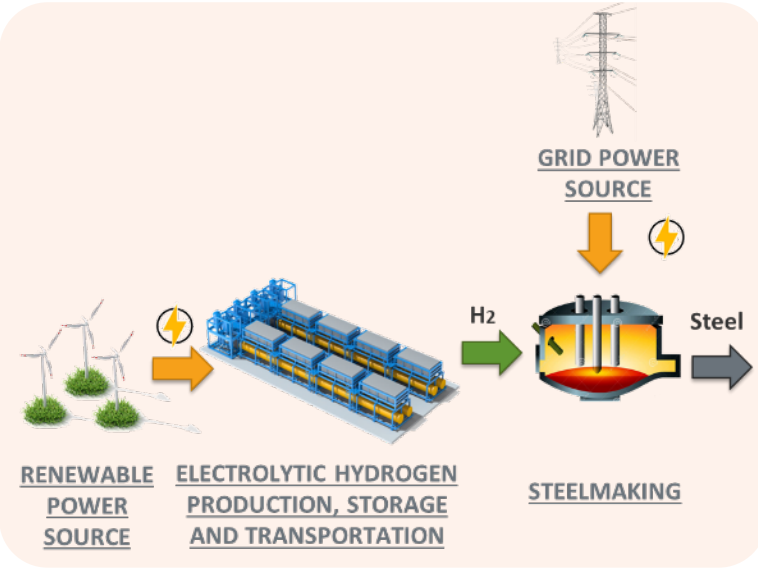
2

Grid Connected H2 Production co-located Steel/Ammonia



3

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

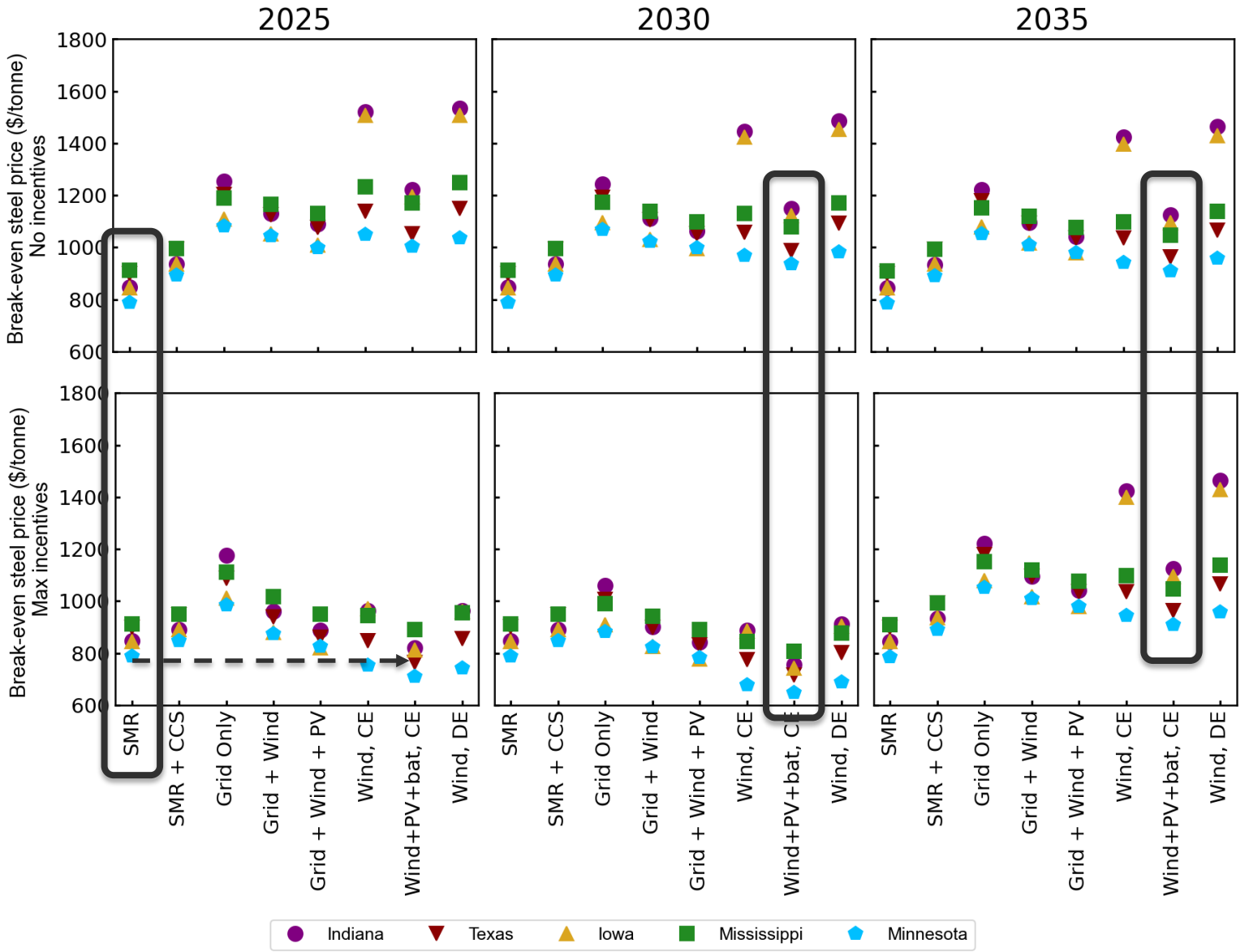


Determine the cost savings and potential advantages to off-grid, tightly coupled wind-H2-industrial end uses

Levelized Cost of Steel (LCOS)

Key Takeaways:

- **MN has been identified as a place for low-cost green steel**
- LCOS cost competitive with SMR (steam methane reform) now.
- **IRA makes this possible in the near-term.**
- New builds will become more expensive than SMR after IRA expires.
- **Note:** IRA applies as long as plant is under construction by 2032



Preliminary results for presentation and not to be cited

Minnesota's Opportunity

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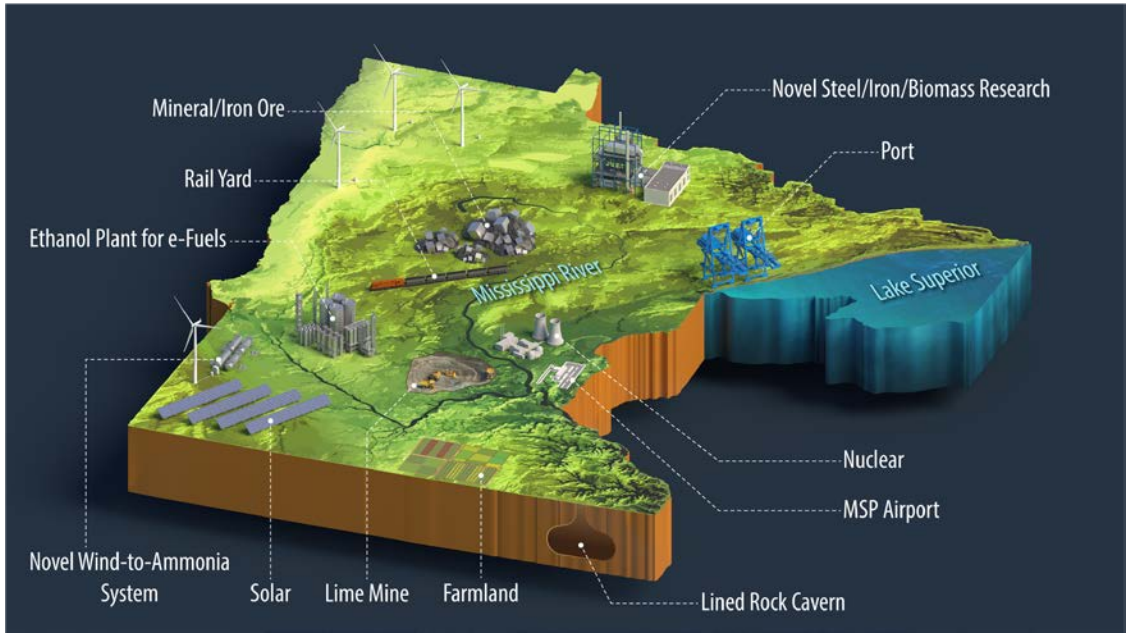
- ✓ MN occupies a *unique* position with key assets co-located in-state
  - Resources
  - Industry
  - Business
  - Communities
  - NGO's
  - Governments
  - Agencies
  - Infrastructure
  - Renewable Energy
  - Shipping



- ✓ The IRA provides a finite window of opportunity (2035)
- ✓ Requires the "Minnesota Community" to own it

Three Lenses of Success

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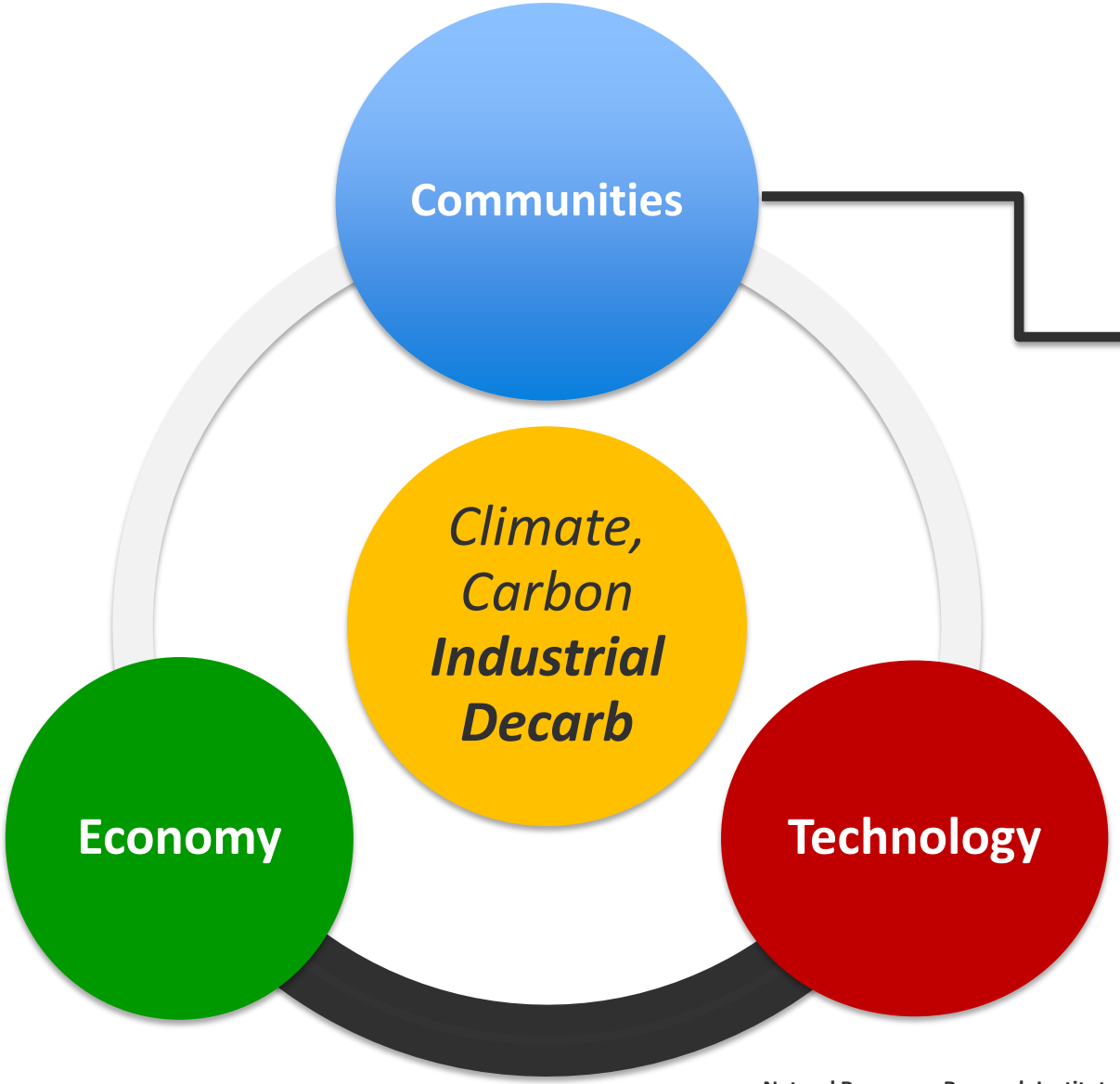

Environmental/Social Justice

- Tribal Governments
- Disadvantaged Communities
- Marginalized Communities
- Rural vs. Urban
- Business & Industry
- Agriculture
- NGOs
- State/Local Governments
- State/Federal Agencies
- Healthcare
- Education/Workforce
- More…

Iron & Steel Highlights

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Today:

- Minnesota iron/National steel industries fully engaged in CO_2 reduction (energy, fossil carbon).
- Majority of Minnesota iron leaves as taconite pellets to serve blast furnace (BF/BOF) market
  - Utilizes oxygen and fossil carbon
  - Produces high volumes of specific quality steel products for use by automotive, appliance customers

30% US Production

70% US Production

Tomorrow:

- Refined iron oxide/metallic iron products for BF/BOF ***and*** electric arc furnace (EAF) markets.
- Emerging ore-to-iron/steel producers
- Industry decarbonization

Green Steel Scenarios

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❖ ***Reduce/eliminate CO_2 emissions from global industry***

A) Blast furnace conversion to hydrogen blending

- Taconite to metallic iron units introduced to BF/BOF using green hydrogen reductant

➢ **MN role:** provide designed iron feedstocks

B) Green Iron Product(s) + Electric Arc Furnace

- DRI (direct reduced iron), HBI (hot briquetted iron), pig iron, scrap iron

➢ **MN role: produce green iron products**

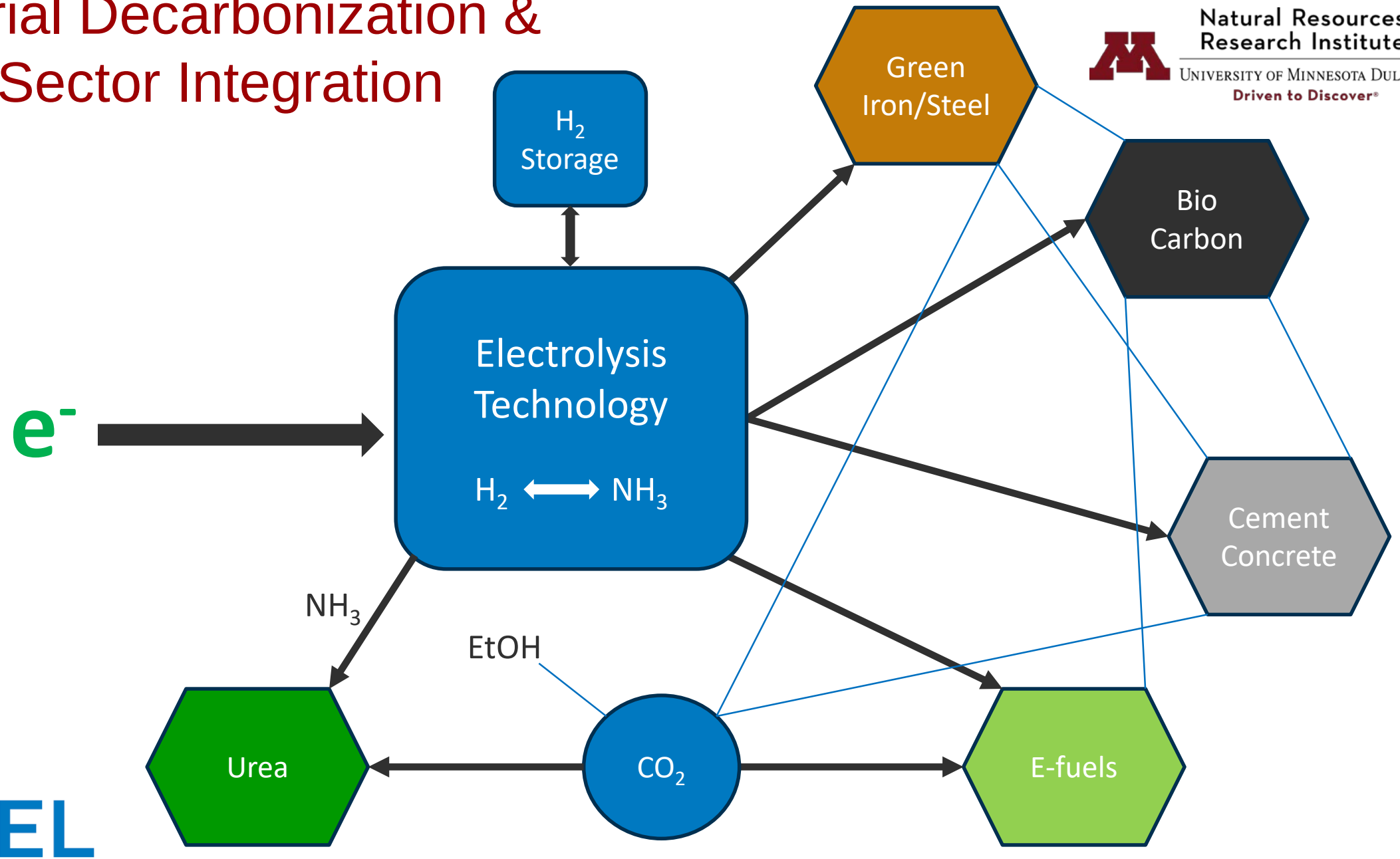
C) One-step conversion of Ore to Green Iron Units/Green Steel

- Uses green energy with/without green hydrogen to convert ore to product
- Can utilize poor grade ores
- May be amenable to renewable power availability

➢ **MN role:** engage opportunities, support development

- SSAB, H_2 Green Steel, others

Industrial Decarbonization & Cross Sector Integration



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Next Steps

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- ✓ Embrace the Integrated Industrial Decarbonization conversation **today**
- ✓ Engage in state-wide discussions & planning **tomorrow**
- ✓ **Own the opportunity**; partner across Federal, State, Industry and Community stakeholders

What can we accelerate by working together?

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