5lakes energy

Clean energy and environmental consultants

The Potential for Hydrogen to Support Low-Carbon Industry in Minnesota

Use Potential Logistical Readiness, Barriers to Adoption, and Recommendations for Community Engagement

Prepared for: **Minnesota Department of Commerce, State Energy Office**

Prepared by: **5 Lakes Energy, May 2025**

Acknowledgements

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Why hydrogen?

- Hydrogen is a key ingredient (i.e., material feedstock) for a wide range of chemicals and fuels (including sustainable aviation fuel).
- Clean hydrogen could help **transform** several of Minnesota's economic sectors, including agriculture (ammonia), shipping (methanol/ammonia), and iron production.
- Clean hydrogen can play a key role in reducing emissions in certain hard-to-decarbonize industries.

Outline

- Introduction
- Use Potential
- Logistical Readiness and Barriers to Adoption
- Community Engagement
- Conclusions and Key Takeaways

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Minnesota's climate action framework

- In 2022, Minnesota released the first iteration of its Climate Action Framework, organized around six goals:

CLEAN TRANSPORTATION	CLIMATE-SMART NATURAL & WORKING LANDS	RESILIENT COMMUNITIES
CLEAN ENERGY & EFFICIENT BUILDINGS	HEALTHY LIVES & COMMUNITIES	A CLEAN ECONOMY

Minnesota's climate goals

- To support the CAF, the state's legislature updated its climate goals in 2023 to include:

50% GHG EMISSIONS REDUCTIONS BY 2030

NET-ZERO GHG EMISSIONS BY 2050

80% CARBON-FREE ELECTRICITY BY 2030

100% CARBON-FREE ELECTRICITY BY 2040

Hydrogen production and current use

- The United States annually produces 10 million metric tons (MMT) of hydrogen
  - 55% is used for crude oil refining
  - 35% is used for ammonia and methanol production

0.18 MMT

MINNESOTA'S ANNUAL H_2 PRODUCTION

CONSUMED BY

2 REFINERIES

	TECHNOLOGY	COLOR	ELECTRICITY SOURCE OR FEEDSTOCK	GHG FOOTPRINT
WATER-BASED	ELECTROLYSIS	GREEN	RENEWABLES	MINIMAL
		PINK	NUCLEAR	MINIMAL
		YELLOW	MIXED-ORIGIN GRID	LOW-MEDIUM
FOSSIL-BASED	PYROLYSIS	TURQUOISE	NATURAL GAS	LOW (Solid Carbon Biproduct)
	STEAM REFORMING + CARBON CAPTURE	BLUE	NATURAL GAS	LOW
	STEAM REFORMING	GRAY	NATURAL GAS	MEDIUM
	GASIFICATION	BROWN	BROWN COAL	HIGH
		BLACK	BLACK COAL	HIGH
GOELOGICAL	EXTRACTION (Passive Capture)	WHITE	IRON-RICH DEPOSITS	LOW
	WATER INJECTION AND RECOVERY (Stimulated Production)	ORANGE	IRON-RICH DEPOSITS	LOW

Hydrogen colors associated with different production pathways

Potential role for low-carbon hydrogen in Minnesota's industrial sector

- Hydrogen can be used as either a feedstock or energy carrier (fuel)
- Minnesota has three current manufacturing initiatives that could benefit from the availability of clean hydrogen:
    - Low-carbon ammonia
    - Low-carbon iron
    - Sustainable aviation fuel (SAF)
- Additionally:
    - Low-carbon methanol, a potential shipping fuel, could be produced using waste CO_2 from the state's ethanol refineries
    - Hydrogen could be adopted to replace fossil fuels in high-temperature industrial processes

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Low-carbon ammonia

- To meet the state's annual fertilizer demand, 900,000 tons of ammonia would be needed
  - MN is the 4th-highest consumer of ammonia-based fertilizer in the US
- Hydrogen production accounts for most of GHG emissions and energy requirements associated with ammonia synthesis
- Alternatively, the use of green hydrogen for ammonia production would significantly reduce the GHG footprint of Minnesota's agricultural sector

The production of ammonia to meet Minnesota's current demand for nitrogen fertilizer emits more than 1.6 MMT of CO_2e per year, out of state.

Low-carbon ammonia

AVERAGE IOWA
PRICE PER TON AMMONIA

U.S. Department of Agriculture

- Most ammonia today is produced at a small number of large facilities, far from its use site
- With no fertilizer produced in Minnesota, the state's farmers spend $500 million to $1 billion per year to procure it, with nearly all that money leaving the state

Low-carbon iron

- Iron and steel production accounts for ~7% of the world's GHG emissions
- Today, Minnesota's six active iron ore mines are owned by two vertically-integrated steelmakers
- All the ore they mine is shipped out of state for processing, eventually becoming value-added, high-quality primary steel

Minnesota supplies approximately 85% of the iron ore consumed in the United States.

~

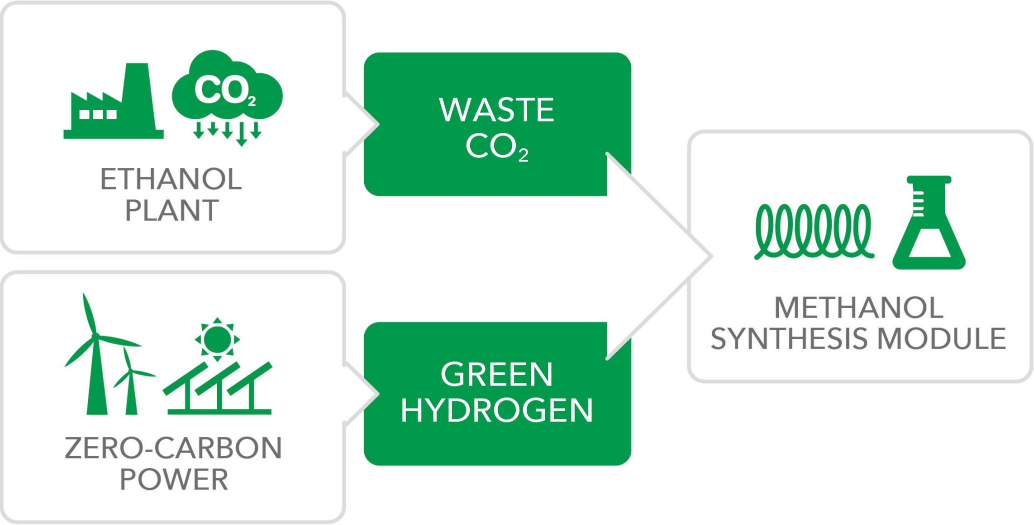
Global demand for iron and steel is projected to increase by more than one-third by 2050.

Sustainable aviation fuel

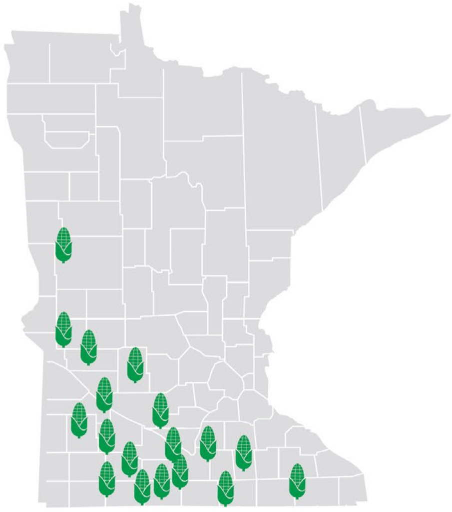
- Aviation accounts for 2.5% of GHG emissions in the United States (120 MMT CO_2e)
- Minnesota's annual jet fuel consumption is 350 million gallons
- SAF is the primary option to decarbonize aviation in the near future
- The various production pathways can yield SAF with 15-90% lower carbon intensity than petroleum-based jet fuel
    - Nearly all pathways require hydrogen

Minnesota's jet fuel consumption accounts for 4.4 MMT of 'well-to-wake' CO_2e emissions annually.

Low-carbon methanol



MINNESOTA'S 18 ETHANOL PLANTS



- Methanol is used as a building block to produce chemicals, materials, and fuels
- Global demand is projected to grow at 2-3% annually
- Low-carbon methanol is produced by reacting green hydrogen with CO_2
  - Concentrated waste CO_2 from ethanol plants is a potential resource

Low-carbon methanol

- Replacing fossil-based marine fuel with methanol could reduce marine fuel carbon intensity by >90%
- The Port of Duluth is the second largest (by goods tonnage) of 10 ports in the Great Lakes-St. Lawrence Seaway
- If half of the CO_2 from Minnesota's 18 ethanol plants were used for methanol production, the state could produce 1.3 MMT of methanol annually (equivalent to 1/10th of the country's annual methanol supply)

High-temperature industrial process heat

High-temperature industrial process heat accounts for an estimated 2.5 MMT of direct CO_2 emissions in Minnesota each year, predominantly due to natural gas and coal combustion.

- Minnesota's manufacturing sector emits >10 MMT CO_2 annually, much of which results from fossil fuel combustion to supply process heat
- High-temperature heat is difficult to electrify and is likely to be decarbonized by alternative fuels, like hydrogen
- An estimated 2.2 MMT annual CO_2 results from natural gas combustion to power the state's six iron ore pelleting plants in the Iron Range

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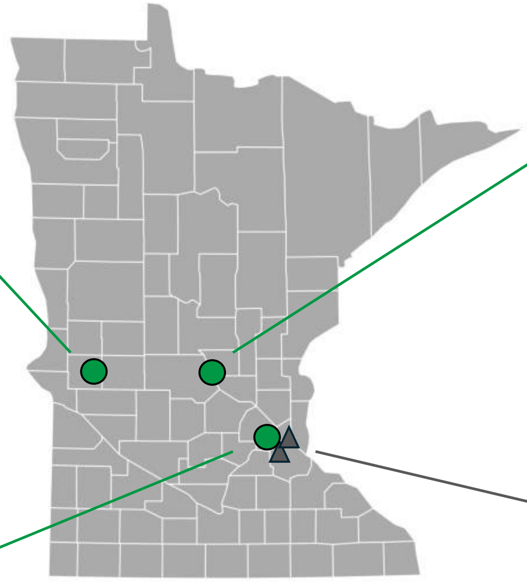
Systemic elements: Hydrogen production

The UM West Central Research and Outreach Center produces 25 tons of **GREEN** ammonia (using solar power-generated hydrogen as a precursor) annually

St. Cloud is constructing a **GREEN** hydrogen project at its wastewater treatment facility, expected to produce 190 tons per year when operable

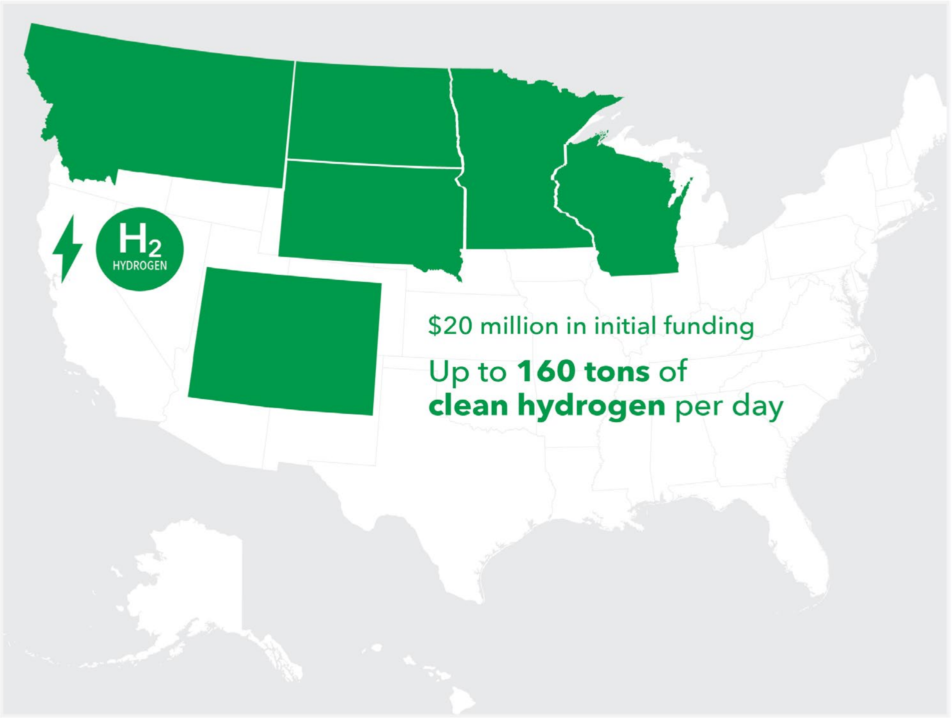


CenterPoint gas utility can produce up to 160 tons of **GREEN** hydrogen annually, blended into natural gas for distribution

Minnesota is home to two **GRAY** hydrogen facilities, producing an estimated 180,000 tons annually for the state's two crude oil refineries

Systemic elements: Hydrogen infrastructure

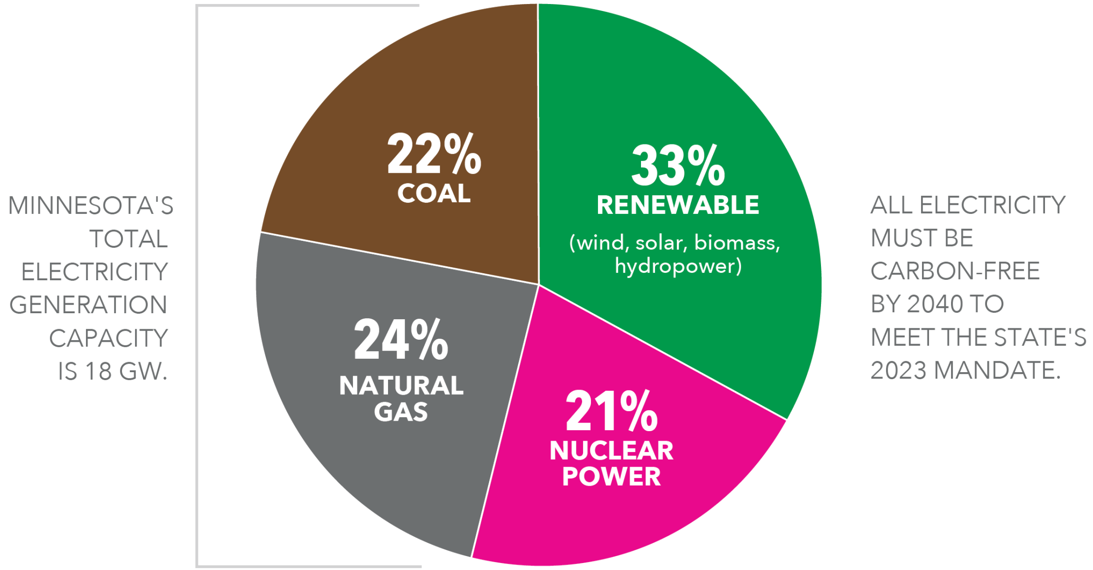
- Because Minnesota's current hydrogen producers store and use their hydrogen entirely on-site, the state has minimal hydrogen infrastructure (e.g., large storage facilities, pipelines)
- Research into optimal long-distance transport modes is still underway, with hydrogen posing special challenges for certain materials and repurposed pipelines
- Minnesota is a member of the DOE-funded Heartland Hydrogen Hub (HH2H)
  - The effort received an initial $20 million for Phase I planning activities
  - DOE is currently reviewing the H2Hubs program



Adapted from heartlandh2hub.com

Systemic elements: Clean electricity

MINNESOTA'S ELECTRICITY GENERATION BY SOURCE



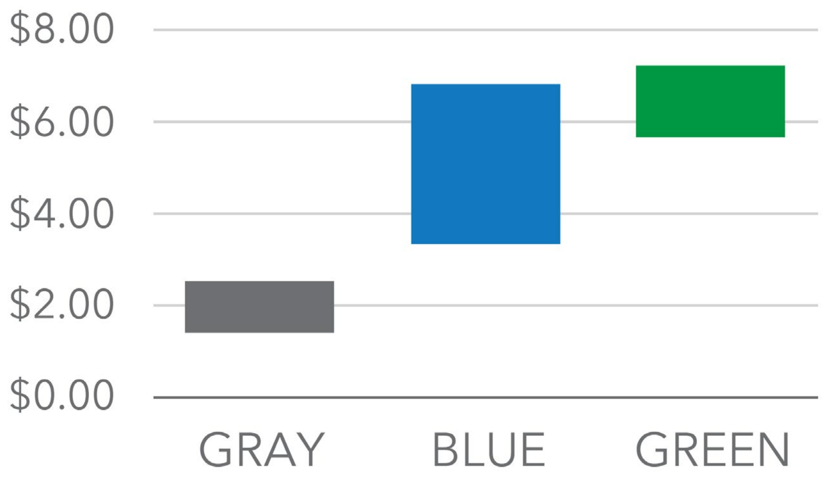
Source: U.S. Energy Information Administration

- Minnesota has a nuclear moratorium, but there have been initial conversations about the potential for nuclear at the legislature.
- Several initiatives have been designed to remove barriers to new clean electricity generation
- Minnesota grid-powered electrolytic hydrogen would, on average, have a carbon intensity (CI) exceeding that of methane-based hydrogen
  - The CI of electrolytic hydrogen will decrease as utilities work to meet the state's 2040 carbon-free electricity mandate
  - Electrolytic hydrogen production can take advantage of intermittent renewable power

Systemic elements: Cost

- **Gray** and **blue** hydrogen benefit from higher production capacities and centralized natural gas supply networks. The cost of **blue** hydrogen includes additional energy and infrastructure needed for carbon capture and storage.
- The costs of **green** and **yellow** hydrogen are driven largely by the electrolyzer costs and the high energy intensity of electrolysis-based hydrogen production.
- The cost of electrolytic hydrogen is less dependent than that of natural gas-based hydrogen on production capacity, making **green** hydrogen production more amenable to smaller regional production facilities.
- The major federal incentives that can subsidize clean hydrogen production are expiring in 2026 and 2027 under the new budget rules.

LEVELIZED COST OF GRAY, BLUE, AND GREEN HYDROGEN



Values were calculated using the NREL H2A-Lite tool for 50-200 ton per day capacity

Updates to Federal and Minnesota tax incentives for hydrogen and relevant industries

- **45V – Clean hydrogen production**
  - A tax credit of $0.60-$3.00 per kg of clean hydrogen available for 10 years after the facility is placed in service.
  - **Update:** To be eligible, facilities must begin construction by Dec. 31, 2027 (original date was Dec. 31, 2032) – *will have a negative impact on clean hydrogen project economics and is likely to limit interest in new project development.*
- **45Y and 48E – Clean electricity production**
  - 45Y: A tax credit of 0.3-1.5 cents per kWh of zero-emission electricity available for 10 years after the facility is placed in service. 48E: A tax credit of 6%-70% of project cost for clean electricity projects.
  - **Update:** To be eligible, wind and solar projects must begin construction by July 4, 2026, *or* if construction has already started, then developments must be placed in service by Dec. 31, 2027. Nuclear, geothermal, hydropower, and battery storage must begin construction by Dec. 31, 2032, to be eligible.

Updates to Federal and Minnesota tax incentives for hydrogen and relevant industries

- **45Q – Carbon capture**
  - A tax credit of $85 per ton of captured CO_2 for up to 12 years of operation.
  - **Update:** $85 per ton of captured CO_2 is available for both utilization and storage of the captured carbon (prior, up to $60 per ton of captured CO_2 for utilization was available).

- **45Z – Clean fuel production**
  - A tax credit of up to $1.75 per gallon SAF or up to $1.00 per gallon non-SAF fuels, such as methanol. Fuel carbon intensity must be <50 kg CO_2e per million BTU (calculated with GREET).
  - **Update:** Credit is available until the end of 2029 (original date was the end of 2027).

- **Minnesota SAF credit**
  - A tax credit of up to $1.50 per gallon SAF produced or blended in MN and sold for use in aircraft departing from MN airports. Credit is available for fuel sold before July 1, 2030.

Systemic elements: Permitting and regulatory frameworks

- Building new facilities requires a variety of permits. Establishing new industries could face additional permitting challenges due to the lack of relevant administrative experience and a regulatory framework.
- Uncertainty and delays in the current permitting process may hinder economic growth and project development in Minnesota.

Industry-specific elements: Low-carbon ammonia

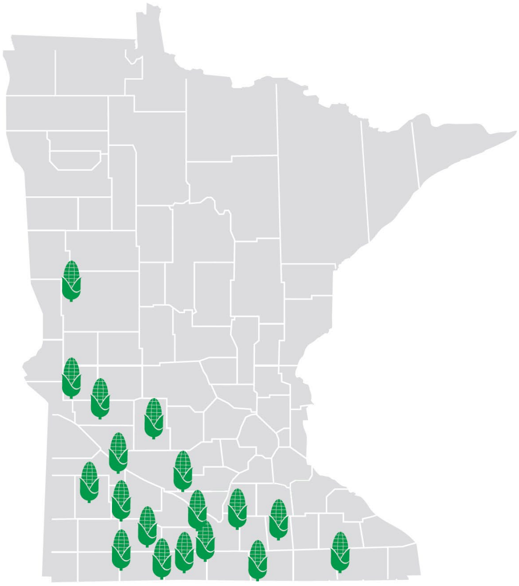
- Factors supporting the case for low-carbon ammonia production in Minnesota:
    - High fertilizer usage
    - Lack of in-state ammonia production
    - Significant renewable electricity generation potential
- Recent advances support economical small (<100k tons/year), modular production.
- A distributed production model has strong support within the farming community because it provides for local ownership and control.

Minnesota's potential ammonia demand to meet current fertilizer needs	900,000 tons/year
Hydrogen required[a]	160,000 tons/year
Water required[b]	860 million gallons/year
Electricity required[c]	8.9 TWh
Total electrolyzer capacity needed (100%-50% capacity factor)[d]	1.0-2.0 GW
CO_2e emissions associated with conventional ammonia production	1,600,000 tons/year

[a] Assumes 180 kg H_2/ton ammonia (Patricia Mayer, Adrian Ramirez, Guiseppe Pezzella, et al., "Blue and green ammonia production: A techno-economic and life cycle assessment perspective," iScience, 26: 107389, August 2023).
[b] Assumes 20 L water/kg H_2 (Kaitlyn Ramirez, Tessa Weiss, Chathurika Gamage, Thomas Kirk, "Hydrogen reality check: Distilling green hydrogen's water consumption," RMI, August 2023).
[c] Assumes 55 kWh/kg H_2 (Pathways to commercial liftoff: Clean hydrogen, 2024 update, U.S. Department of Energy, December 2024, accessed April 2025).
[d] To calculate electrolyzer capacity, total annual electricity required was divided by 8,760 hours per year and by the electrolyzer capacity factor. Capacity factor measures how much the electrolyzer operates relative to its maximum possible output. The calculated values assume the electrolyzers would run between half and full capacity, depending on the power source–close to 100% for grid power, and potentially below 50% for intermittent renewables.

Industry-specific elements: Low-carbon ammonia

- Locally produced low-carbon ammonia could help stabilize market prices for farmers over time, but project financing and cost of production are significant barriers
- 45Y and 48E tax credits could support project economics, as long as electricity generation occurs under separate ownership, but there is limited opportunity under new federal budget rules
- In December 2024, the MN Department of Agriculture launched a $6.7 million grant program to support investments in green fertilizer
- Notably, farmers prefer solid urea over liquid ammonia, which creates a synergistic opportunity to use waste ethanol CO_2 streams as the needed carbon feedstocks
    - The updated federal 45Q tax credit offers a **$85/ton** captured CO_2 incentive for carbon capture and utilization as a feedstock



CONCENTRATED CO_2 FEEDSTOCKS FROM ETHANOL PRODUCTION

Industry-specific elements: Low-carbon iron

- Minnesota's iron ore resources and mining industry supply most of the iron ore consumed in the United States.
- Low-carbon iron production in Minnesota would increase the in-state value that can be obtained from the state's ore resources, while supporting broader interests to reduce the carbon intensity and pollution associated with ironmaking, conventionally served by coal-intensive blast furnace production.
- UM's Natural Resources Research Institute is leading a feasibility study of a potential hydrogen-based direct reduction iron plant for possible development in the Iron Range.

Potential low-carbon iron production plant capacity	2 million tons/year
Hydrogen required[a]	110,000 tons/year
Water required[b]	570 million gallons/year
Electricity required[c]	5.9 TWh
Total electrolyzer capacity needed (100%-50% capacity factor)[d]	0.68-1.36 GW
CO_2 emissions associated with blue hydrogen[e]	280,000 tons/year

[a] Assumes 54 kg H_2/ton direct-reduced iron (M. Shahabudin, Alireza Rahbari, M. Akbar Rhamdhani, et al., "Process modeling for the production of hydrogen-based direct reduced iron in shaft furnace using different ore grades," Ironmaking and Steelmaking: 1, May 2024).
[b] Assumes 20 L water/kg H_2 (Kaitlyn Ramirez, Tessa Weiss, Chathurika Gamage, Thomas Kirk, "Hydrogen reality check: Distilling green hydrogen's water consumption," RMI, August 2023).
[c] Assumes 55 kWh/kg H_2 (Pathways to commercial liftoff: Clean hydrogen, 2024 update, U.S. Department of Energy, December 2024, accessed April 2025).
[d] To calculate electrolyzer capacity, total annual electricity required was divided by 8,760 hours per year and by the electrolyzer capacity factor. Capacity factor measures how much the electrolyzer operates relative to its maximum possible output. The calculated values assume the electrolyzers would run between half and full capacity, depending on the power source–close to 100% for grid power, and potentially below 50% for intermittent renewables.
[e] Emissions are associated with the production of blue hydrogen needed for 2 million tons of direct-reduced iron.

Industry-specific elements: Low-carbon iron

- Project financing, cost competitiveness, and offtake agreements are expected to be the biggest barriers to developing a low-carbon iron industry in the United States, including in Minnesota
    - A recent RMI analysis estimated $2.1 billion to develop a 2 million ton/year green steel facility in Minnesota, to include construction of a suitable electric arc furnace mill for steelmaking – but not including the costs of additional renewable energy generation capacity
- Minnesota Power's High Voltage Direct Current Modernization Project will increase northern Minnesota's options for clean electricity supply
- Minnesota's Buy Clean program could support offtake by creating an early market pull for low-carbon steel products

Industry-specific elements: SAF

- Minnesota's goal of developing a local SAF industry could spur clean hydrogen production.
- The Minnesota SAF hub was launched in 2023, to bring together a variety of partners to help build a value chain.
- The hub's aim is 100 million gallons of SAF production per year by 2035.

Capacity of the announced DG Fuels SAF plant in Moorhead, MN	193 million gallons/year
Hydrogen required[a]	29,000 tons/year
Water required[b]	150 million gallons/year
Electricity required[c]	1.6 TWh
Total electrolyzer capacity needed (100%-50% capacity factor)[d]	0.18-0.36 GW
CO_2 emissions associated with blue hydrogen[e]	73,000 tons/year
CO_2 emissions associated with gray hydrogen[e]	320,000 tons/year

[a] Assumes 0.15 kg H_2/gal biobased SAF (Oscar Rosales Calderon, Ling Tao, Zia Abdullah, et al., "Sustainable aviation fuel state-of-industry report: Hydroprocessed esters and fatty acid pathways," NREL, July 2024).
[b] Assumes 20 L water/kg H_2 (Kaitlyn Ramirez, Tessa Weiss, Chathurika Gamage, Thomas Kirk,"Hydrogen reality check: Distilling green hydrogen's water consumption," RMI, August 2023).
[c] Assumes 55 kWh/kg H_2 (Pathways to commercial liftoff: Clean hydrogen, 2024 update, U.S. Department of Energy, December 2024, accessed April 2025).
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[e] Emissions are associated with the production of blue and gray hydrogen needed for 193 million gallons of bio-based SAF.

Industry-specific elements: SAF

- Most SAF production pathways require hydrogen. Large-scale SAF manufacturing projects could provide a robust and consistent market pull for regionally produced clean hydrogen.
- Projects can benefit from both federal 45Z tax credits and the Minnesota SAF tax credit.
- Because these incentives require specified reductions in carbon intensity of the final fuel product, they could help offset cost premiums for electrolysis-based hydrogen.
  - Hydrogen can have a substantial impact on the carbon intensity of the final fuel.
- Barriers include the reliance on emerging technologies, and potential challenges associated with second-generation feedstocks (i.e., biomass not otherwise consumed for food, such as wood matter).

Industry-specific elements: Low-carbon methanol

- Minnesota has no stated goals for low-carbon methanol production and no current methanol production.
- Modular methanol production technology is emerging and could provide a pathway to utilize waste CO_2 from the state's ethanol producers.
- The primary barrier would be cost-competitiveness, with unsubsidized green hydrogen-based methanol modeled to cost twice that of fossil-based methanol.

Capacity of a potential low-carbon methanol plant	50,000 tons/year
Hydrogen required[a]	10,000 tons/year
Water required[b]	53 million gallons/year
Electricity required[c]	0.55 TWh
Total electrolyzer capacity needed (100%-50% capacity factor)[d]	0.063-0.126 GW
CO_2 emissions associated with natural-gas based methanol	110,000 tons/year

[a] Assumes 0.2 kg H_2/kg methanol (Stafano Sollai, Andrea Porcu, Vittoria Tola, et al. "Renewable methanol production from green hydrogen and captured CO2: A techno-economic assessment," Journal of CO_2 Utilization, 68: 102345, February 2023).
[b] Assumes 20 L water/kg H_2 (Kaitlyn Ramirez, Tessa Weiss, Chathurika Gamage, Thomas Kirk,"Hydrogen reality check: Distilling green hydrogen's water consumption," RMI, August 2023).
[c] Assumes 55 kWh/kg H_2 (Pathways to commercial liftoff: Clean hydrogen, 2024 update, U.S. Department of Energy, December 2024, accessed April 2025).
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Industry-specific elements: High-temperature industrial process heat

- Minnesota has 13 large manufacturers with a predominant need for high-temp process heat.
  - Currently burn fossil fuels, emitting 2.5 MMT CO_2 annually.
- The Iron Range's six taconite pelleting plants are responsible for the lion's share of these emissions.
- Other facilities include producers of beet sugar (coal), pulp and paper, glass (natural gas), and building interior materials (coal).
- The cost of green hydrogen would need to fall to $1/kg before it would be cost-competitive for use as a replacement fuel for high-temperature industrial heat.

Total annual high-temperature process heat consumed by Minnesota's manufacturing facilities	13 TWh / 4.5×10^7 MMBtu / 4.8×10^7 GJ
Hydrogen required[a]	400,000 tons/year
Water required[b]	2.1 billion gallons/year
Electricity required[c]	22 TWh
Total electrolyzer capacity needed (100%-50% capacity factor)[d]	2.5-5.0 GW
CO_2 emissions associated with current high-temperature industrial heat in Minnesota	2,500,000 tons/year

[a] Assumes 33.33 kWh/kg H_2 (the lower heating value of hydrogen).
[b] Assumes 20 L water/kg H_2 (Kaitlyn Ramirez, Tessa Weiss, Chathurika Gamage, Thomas Kirk,"Hydrogen reality check: Distilling green hydrogen's water consumption," RMI, August 2023).
[c] Assumes 55 kWh/kg H_2 (Pathways to commercial liftoff: Clean hydrogen, 2024 update, U.S. Department of Energy, December 2024, accessed April 2025).
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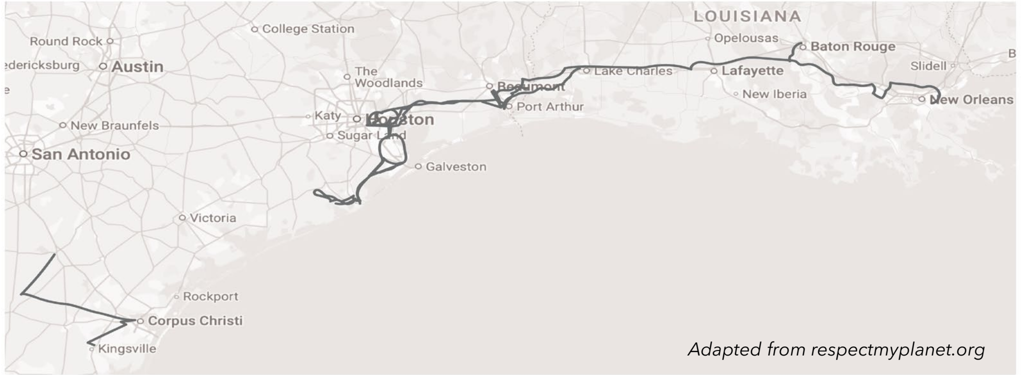
Earning social license through community engagement

- The major issues related to gaining social license for either new hydrogen or industrial projects in Minnesota include:
  - General skepticism
    - *Regular engagement opportunities, evidence-based education, transparency*
  - Safety
    - *Best practices, rigorous standards, clear communication*
  - Environmental and public health factors
    - *Maximize the use of renewable energy and gray water*
  - Benefits to the local economy
    - *Binding agreements, workforce development programs*
  - Opportunities for Tribal nations to engage
    - *Dedicated Tribal engagement forums, allow for preferred methods of engagement*

Lessons learned from Texas's 50-year-old hydrogen industry

- Federal OSHA, the Railroad Commission of Texas, and the Texas Commission on Environmental Quality all oversee hydrogen regulation in Texas, regulating hydrogen similar to refinery and petrochemical industries and hydrogen pipelines similar to natural gas pipelines.



- In 2023, the Texas Legislature created the Texas Production Policy Council to study the state's hydrogen industry and make policy recommendations to ensure effective oversight.
- The resulting report gave several recommendations:
  - Develop hydrogen-specific pipeline-related standards and regulations
  - Update leak detection and repair rules
  - Create centralized points of contact at state agencies to hold a specific focus on hydrogen
  - Develop hydrogen and training education programs and make available to the public
  - Streamline and standardize hydrogen project permitting processes

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Conclusions and key takeaways: Opportunities

- New clean industries could increase state revenue and add high-quality jobs, in line with the clean economy goal of the state's Climate Action Framework
- **Green hydrogen-based ammonia production could provide fertilizer price stability, reduce farmer overhead costs, and reduce the carbon intensity of the state's agricultural products**
- Low-carbon methanol could help decarbonize shipping in the Great Lakes
- **Both low-carbon urea fertilizer (derived from ammonia) and methanol could utilize the state's waste CO_2 from ethanol production as an input, leveraging the federal 45Q tax credit**
- **Low-carbon hydrogen could help Minnesota's emerging SAF industry meet the carbon intensity requirements for accessing additional state and federal incentives**
- Use of green hydrogen for industrial high-temp process heat could reduce industrial GHG emissions in Minnesota, as well as associated air pollution, especially critical for facilities still burning coal

Conclusions and key takeaways: Barriers

- **High capital and production costs are major barriers facing large-scale, low-carbon hydrogen projects**
- Shifts in federal incentives since the change in administration have reduced economic competitiveness of these projects
- **This further emphasizes the importance of state-based incentive programs, such as tax credits, grants, and loans to help low-carbon hydrogen projects achieve liftoff**
- Careful planning will be needed to ensure Minnesota's ability to meet its carbon-free electricity mandate, especially if the state also incentivizes low-carbon electrolytic hydrogen production
- The permitting process in Minnesota is acknowledged as a major challenge for the development of complex industrial projects
- A robust regulatory framework for hydrogen may be needed to ensure safety and gain community trust, especially for large hydrogen projects

Conclusions and key takeaways: Social license

- Community concerns related to hydrogen projects focus on safety, as well as impacts on local economies, clean water resources, and the environment more generally
- **Successful hydrogen adoption in Minnesota will depend on public trust, which must be carefully and intentionally developed**
- Well-designed, robust, publicly available regulations and safety plans can help prevent accidents and build public confidence in the hydrogen industry over time
- Workforce development programs and binding agreements can help ensure that host communities meaningfully benefit from hydrogen and hydrogen-related industrial projects
- For projects that impact Minnesota's Tribal Nations, engagement should be tailored to the specific preferences and needs of the Nations involved

Thank you!

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General skepticism

Strategy	Examples
• Early and routine community engagement • Transparent project planning • Use of evidence-based education and publicly available educational resources	• Aligning messaging content with familiar energy concepts and reporting tangible benefits, through community and legislative engagement activities similar to those of the Minnesota Ethanol Producers Association and Minnesota Bio-fuels Association offer a framework for hydrogen • Adopting a public Q&A strategy similar to that of the Midwest Industrial Transformation Initiative

Safety concerns

Strategy	Examples
• Developing a robust safety plan and training programs, covering all workers who would likely interact with hydrogen • Ensuring all relevant safety measures are clearly communicated to the public • Providing publicly available documents and community engagement opportunities related to pipeline infrastructure projects	• Texas is home to a 50-year-old hydrogen industry, including most of the country's 1,600 miles of dedicated hydrogen pipelines, and the state records no major incidents • The state's regulatory framework could serve as an example for Minnesota • In contrast, North Dakota's oil boom of the 2000s highlights the consequences of insufficient early-stage planning and community engagement: inadequate safety protocols, multiple serious safety incidents, at least 74 fatalities

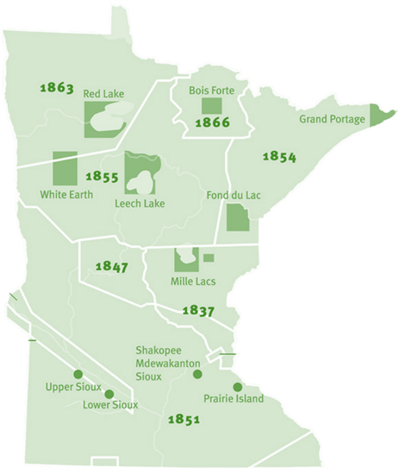
Environment and public health

Strategy	Examples
• Employ educational resources that clearly describe approaches and measures integrated into projects to minimize negative impacts • Use evidence and data counteract misinformation • Conduct life-cycle assessments, especially for low-carbon projects to demonstrate emissions reductions and pair with publicly available emissions tracking • Maximize use of local renewable energy • Practice community-appropriate siting and permitting related to water resources, while promoting the use of non-freshwater sources and ultrapurification practices • Consider the adoption of agrivoltaics methods to reduce pressure on Minnesota's farmland	• Mesabi Metallics, owner of the first new iron ore mine and pelleting plant to open in Minnesota in 50 years, plans to be the state's first zero-discharge mining operation, using only recycled water and stormwater • The mine will also employ higher-quality emissions controls for particulate filtration and stockpiles, and electrified alternatives to some equipment • The Big Lake solar farm in Sherburne county is a former potato farm that was converted into a solar array by US Solar, representing the developer's first agrivoltaics project • The developer started the project as a demonstration site, before opening it to community members

Local economy

Strategy	Examples
• Provide meaningful employment opportunities for locals • Leverage DEED's abilities to help align regionally available workforce pools with job demands for new projects and to evaluate direct and indirect economic impacts to host communities • Encourage use of DEED's Job Training Incentives Program and collaboration with the Department of Labor and Industry to create local union apprenticeship programs • Leverage opportunities through the Minnesota State Centers of Excellence • Use binding agreements to guarantee specific benefits to communities	• Southern Minnesota's ethanol projects were able to gain strong community support by leveraging cooperative ownership models involving local farmers • In 2022, Minnesota's ethanol producers purchased $3.1 billion of Minnesota corn, supporting 22,350 workers who earned $1.6 billion in wagers

Collaborating with Tribal nations



Strategy	Examples
• Proposed hydrogen projects should establish dedicated Tribal engagement forums • Create opportunities for Indigenous communities to define their preferred methods of participation • Appointment individuals to key positions who have a strong history of Tribal collaboration to effectively facilitate dialogue between Tribes and project developers	• MITI's green ironmaking feasibility study, which has encouraged and created a range of opportunities for Tribal participation, including Tribal-defined efforts • The project has also opened opportunities for Tribal economic inclusion • Changes to Minnesota law created an opportunity for Tribal-led clean energy development, culminating in the Red Lake Solar Project • This project further reflects how clean energy infrastructure can align with Indigenous values and self-determination