Hydrogen for Freight in Minnesota: Considerations for Technology Readiness and Policy Options

Elise Harrington & Karen Bridges

University of Minnesota
Driven to Discover℠

Multiple uses for hydrogen are driving new interest

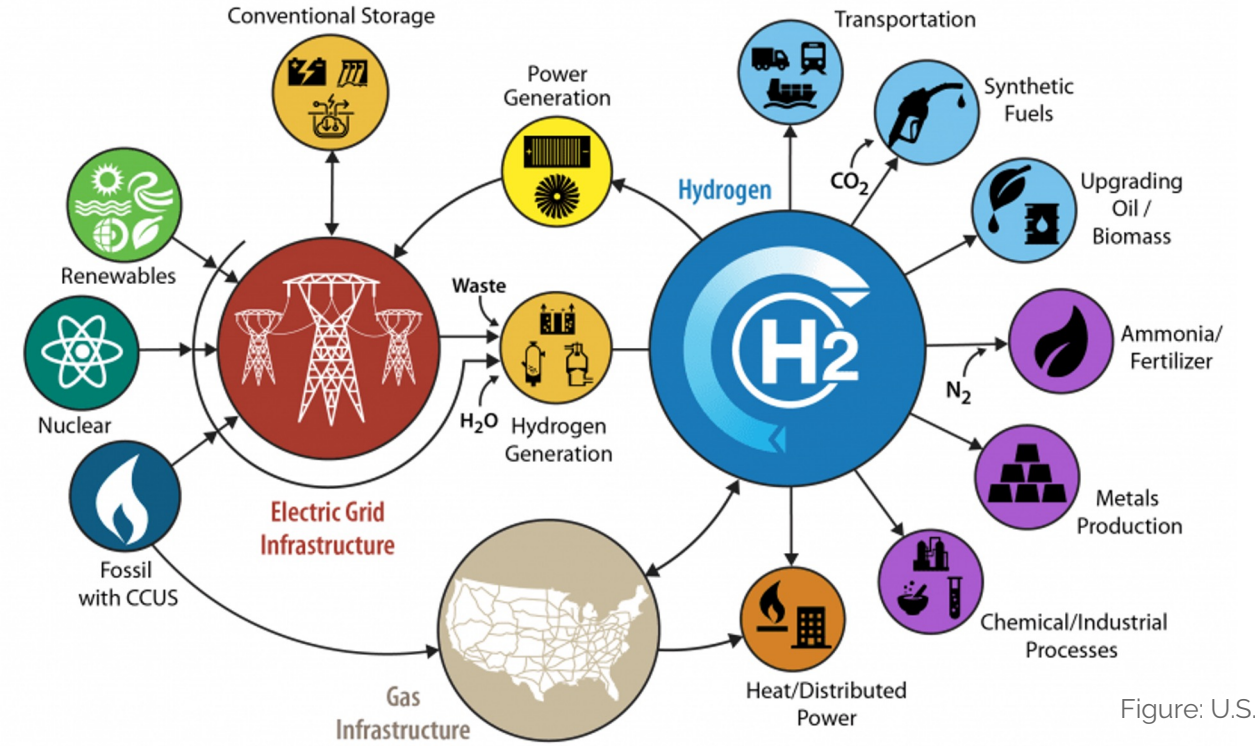


Figure: U.S. DOE (H2 @ Scale)

Growth expected but uncertainty remains

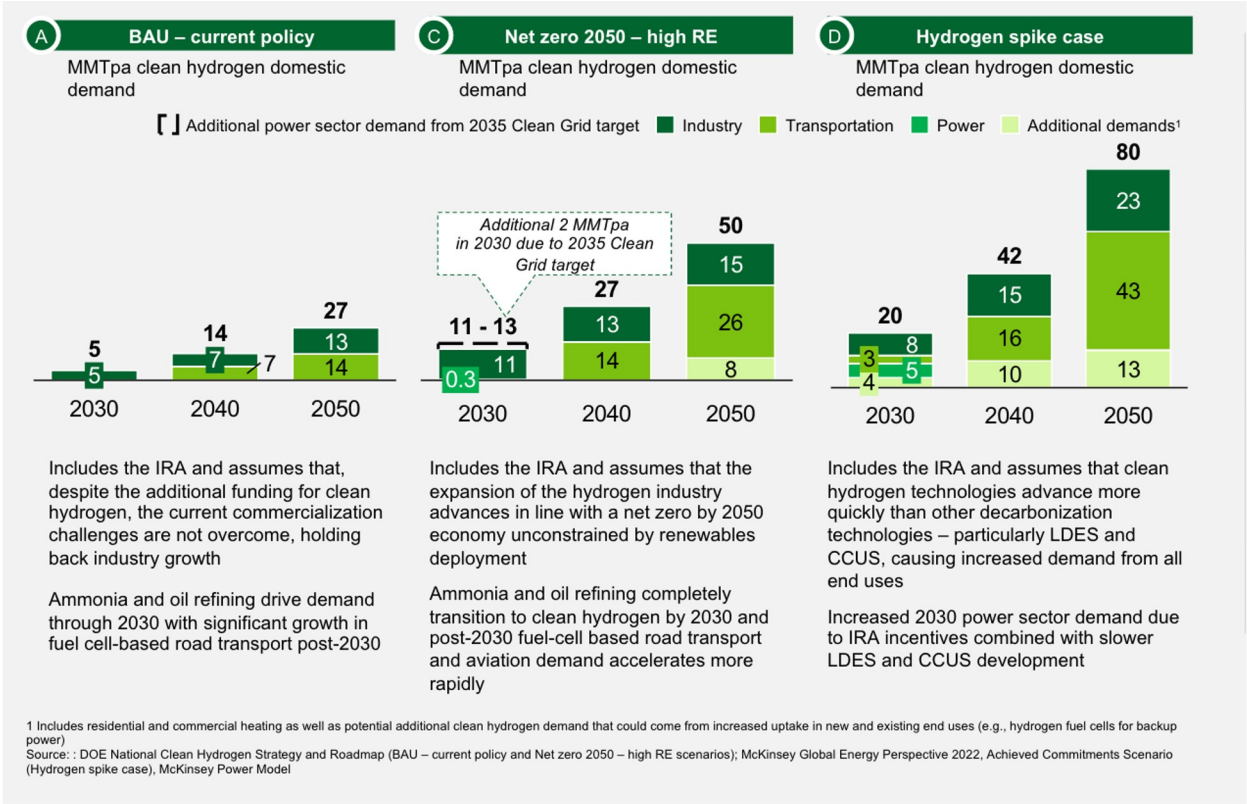
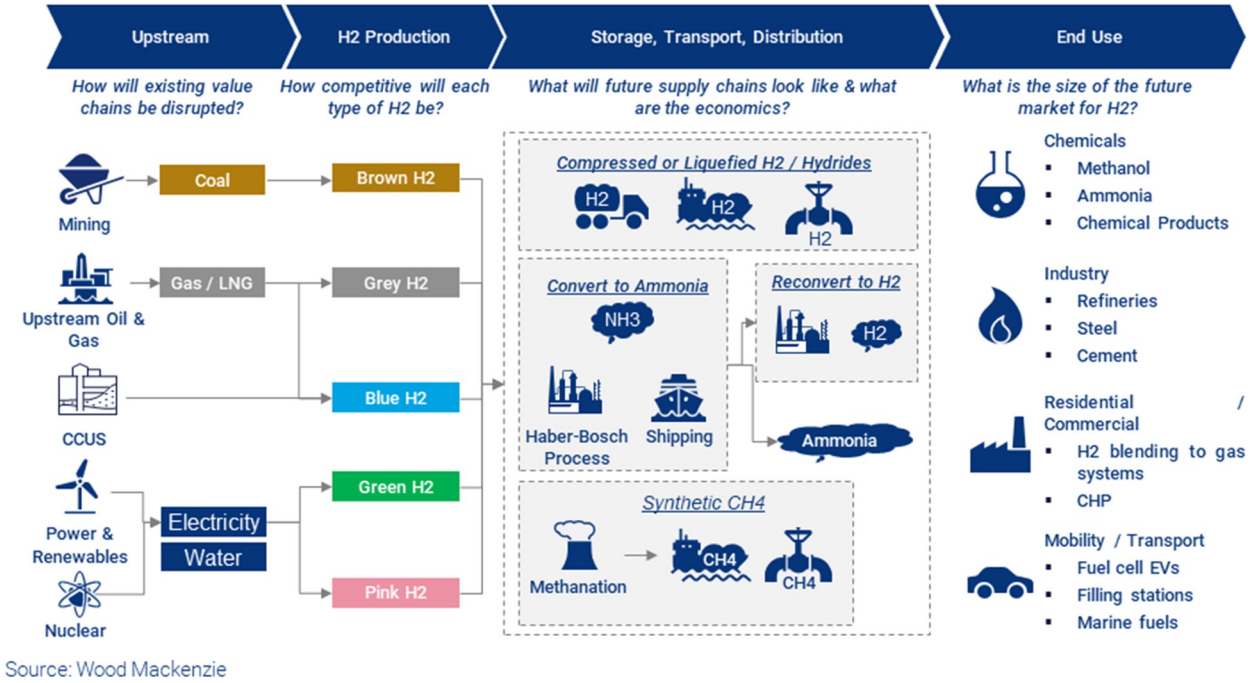


Figure: Figure 13.2, Pathways to Commercial Liftoff: Clean Hydrogen, U.S. DOE (2023)

MMTpa = million metric tonnes per annum

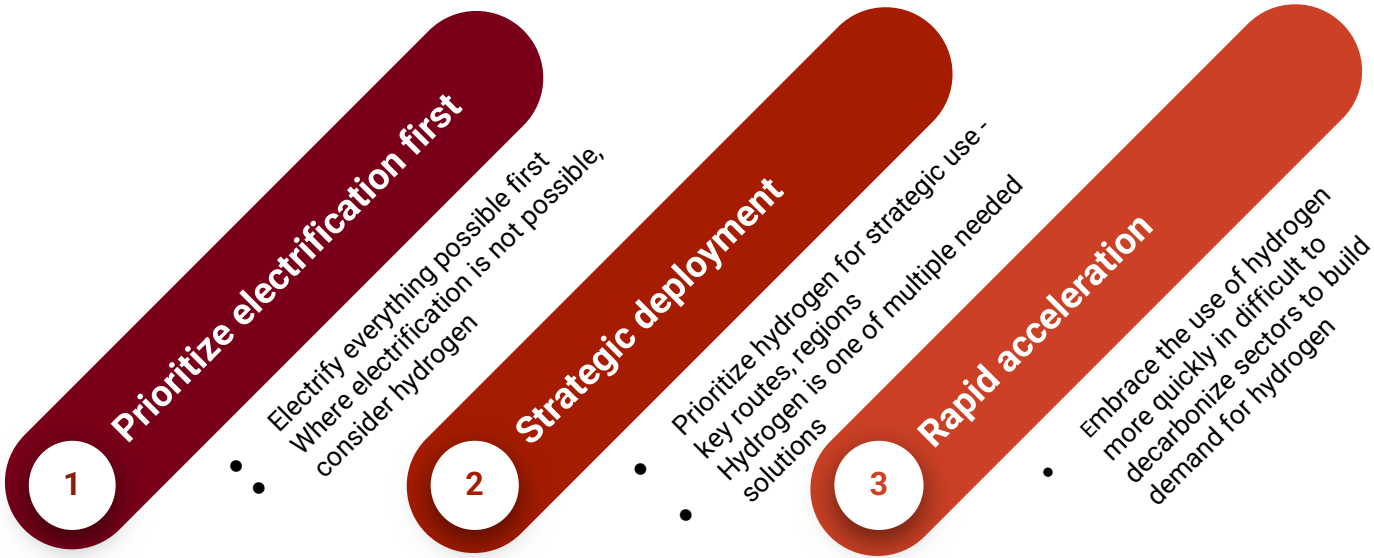
Near term efforts to clarify “colors”



Source: Wood Mackenzie

Figure: Wood Mackenzie

Proposed uses for hydrogen vary (scale, timing)



Future cost of green hydrogen

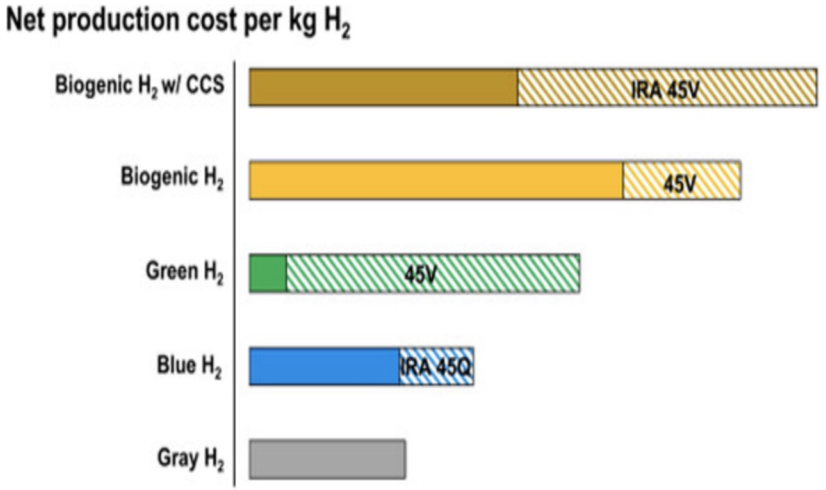


Figure: Cheng, et al. (2023)

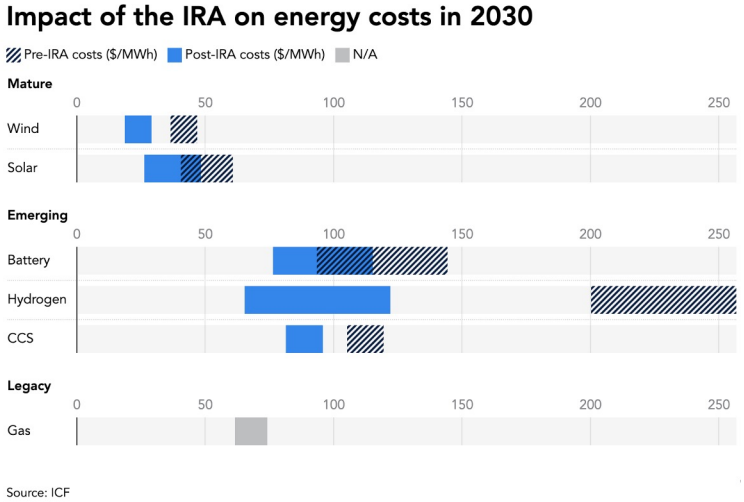


Figure: ICF International (2023)

Stacking IRA tax credits for transportation

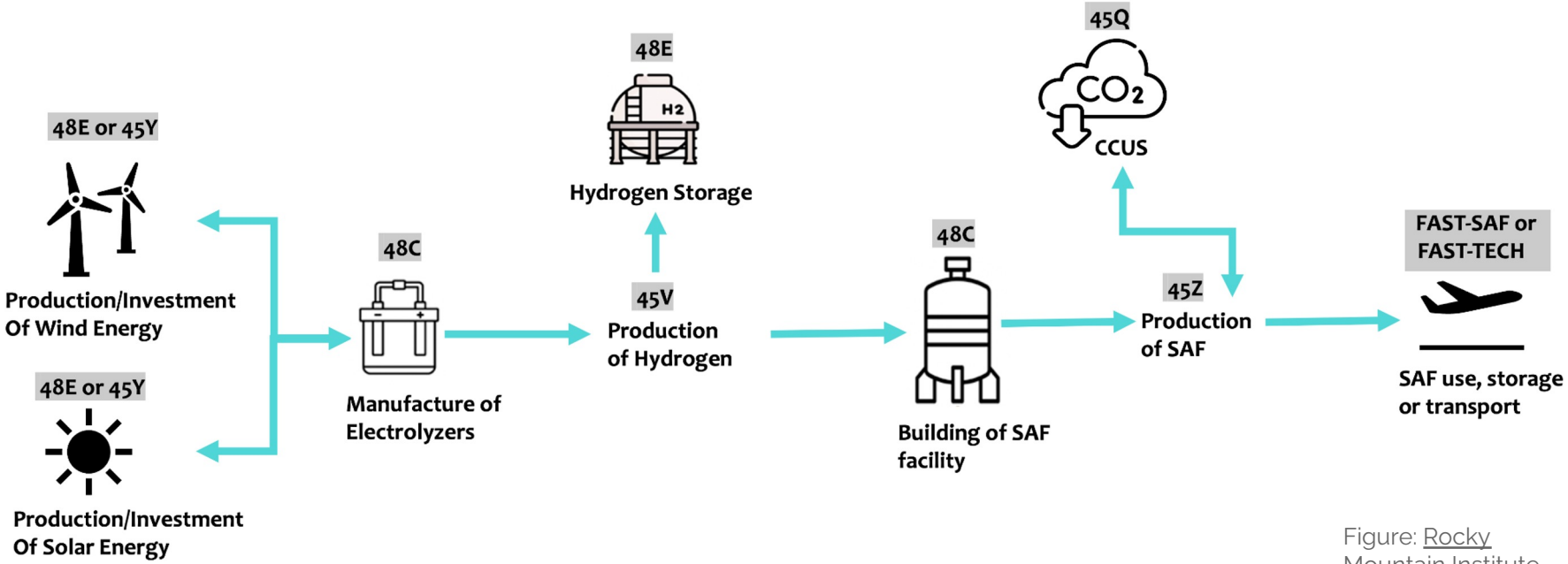


Figure: Rocky Mountain Institute

Freight sectors are sensitive to hydrogen cost

Trucking

~55%

TCO Class 8 Sleeper Cabs = Hydrogen Fuel

TCO expressed as Avg 10-year per mile cost of driving (excluding labor). Fuel costs for Diesel ICE = ~38% TCO; For BEVs, ~23% TCO.

- Diesel ICE = $1.03/mile; FCEV = $1.50/mile; BEV = $1.38/mile.
- Over life of sleeper cabs, fuel costs dominate vs upfront vehicle purchase cost.

Maritime

~87%

TCO small container ship = Hydrogen fuel

Fossil fuel cost majority of TCO for conventional ship; however, H2 costs need to drop by more than 50% for fuel cell to be competitive.

- H2 fuel storage requirements also increase CAPEX for small container ships; prohibitive for large ships.
- "Green" ammonia/methanol fuels as intermediate step, lower TCO but still higher than conventional fuels/technology.

Rail

~19%

TCO MU commuter rail = Hydrogen fuel

VS 8% TCO diesel equivalent = fuel cost. Vehicle and infrastructure maintenance costs = 50% TCO H2 fuel cell, 58% TCO diesel equivalent.

- Sensitive to regenerative braking assumptions.
- Assumed H2 cost of $7.50/kg (high).
- Breakeven H2 cost w/diesel for rail = $2.20/kg ($2.25/g)

Aviation

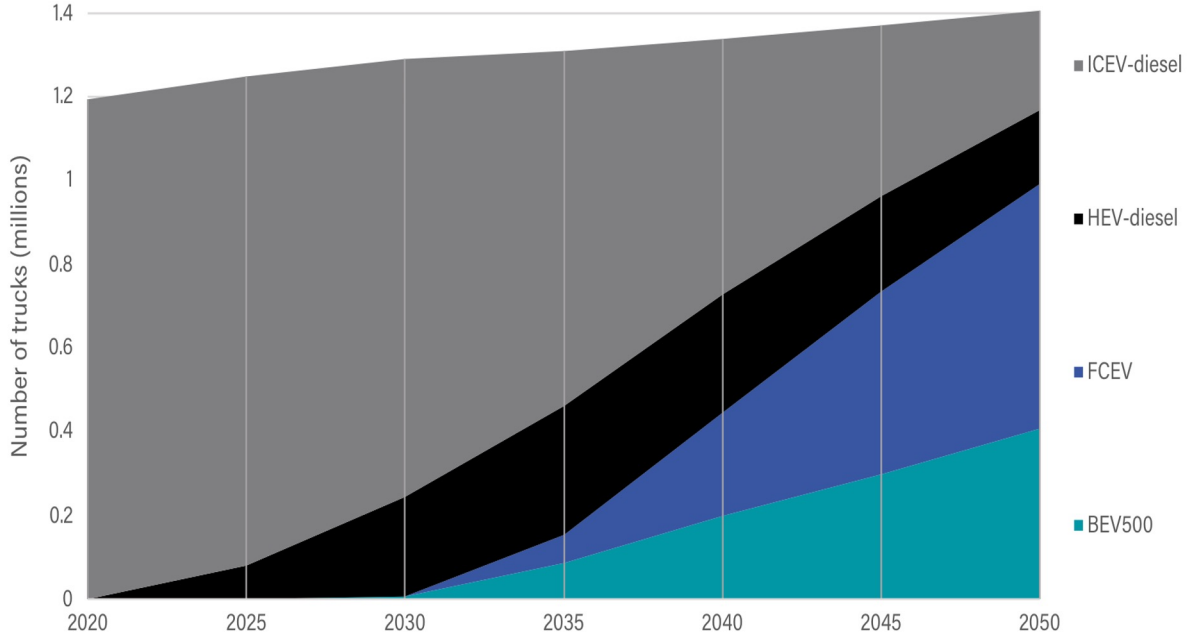
~85%

TCO regional plane = CAPEX + O&M

One application where fuel costs do not dominate. Fuel cell planes may achieve efficiency advantage over piston engine/lower TCO.

- Sector less developed..
- Technology early pilot stages.
- No cargo planes tested/studied.

Long-distance, long-haul trucking



Notes: ICEV-diesel = internal combustion engine diesel vehicle; HEV-diesel = hybrid electric diesel vehicle; FCEV = fuel cell electric vehicle; BEV500 = battery electric vehicle with 500-mile range.

FCEV: Mature tech for long-haul trucks. Fast refueling times and lower weight vs BEV. Promising alternative to diesel ICE over medium to long-term. Potential game-changer for hydrogen demand in US (US DOE 2023). Trend towards diesel-cost parity by 2035 (NREL 2022).

Figure: Projected long-haul heavy duty US truck stock through 2050. Source: Feldman et al. 2023.

Considering hydrogen alternative fuel corridors

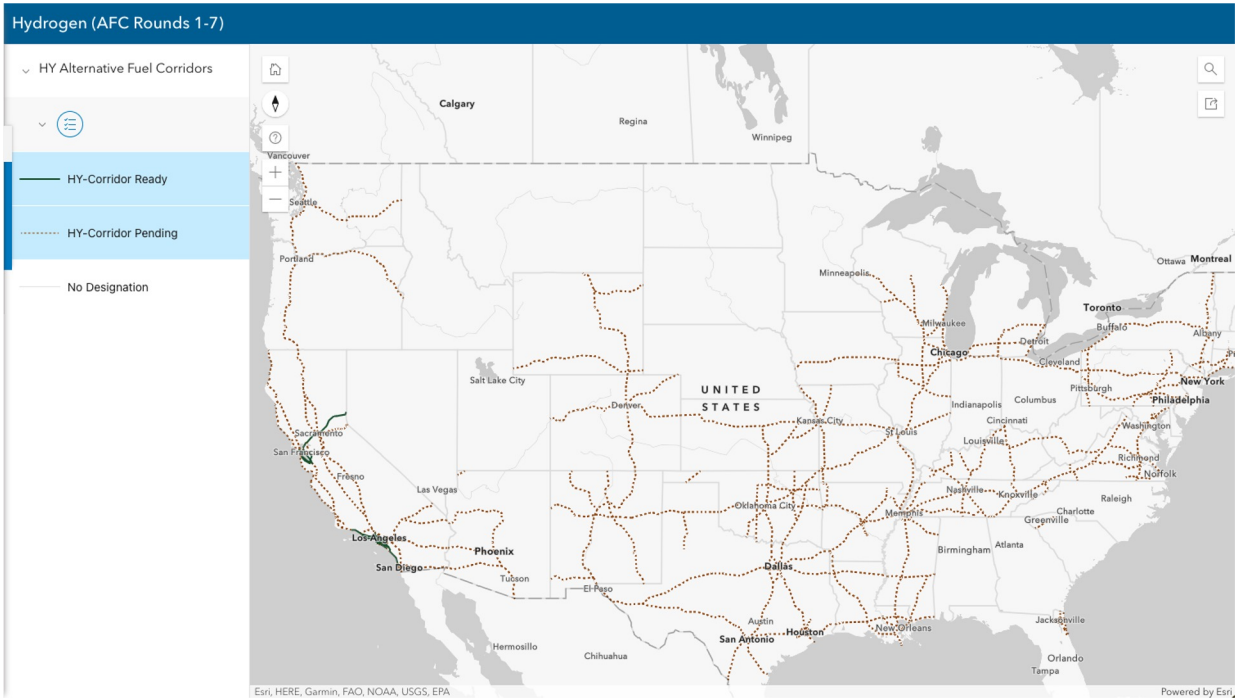
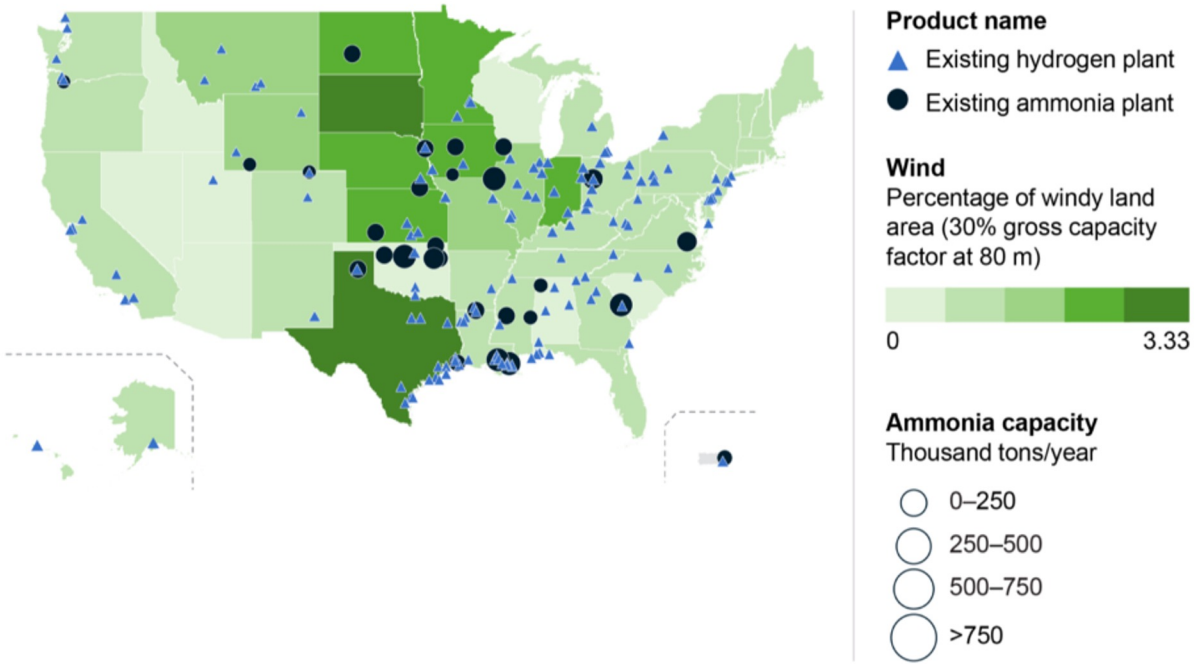


Figure: Hydrogen (AFC Rounds 1-7), U.S. DOT FHA; updated Nov 2023

Regional coordination is required

Methanol and ammonia to dominate maritime



"Green" ammonia = green H2 plus nitrogen from air (using renewables).

Figure: Hydrogen and ammonia production map (from National Clean Hydrogen Strategy and Roadmap, 2023)

Cross-sector coordination is required

Scaling infrastructure, Strategic Investments Key

No more hydrogen trains | Rail company that launched world's first H2 line last year opts for all-electric future (2023).

Mapping of Zero Emission Pilots and Demonstration Projects, *Getting to Zero Coalition and Global Maritime Forum* (2023).

First in the Americas: Alstom's hydrogen train enters revenue service in Charlevoix in Quebec (2023).

FCEV Drayage Trucks Prove Themselves in LA Port Demonstration Project (2022).

Central Washington airport hosts first test flight of hydrogen-powered airliner (2023).

Learning from pilots