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

Elise Harrington & Karen Bridges
Multiple uses for hydrogen are driving new interest
Growth expected but uncertainty remains

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

MMTpa = million metric tonnes per annum

Includes the IRA and assumes that, despite the additional funding for clean hydrogen, the current commercialization challenges are not overcome, holding back industry growth

Ammonia and oil refining drive demand through 2030 with significant growth in fuel cell-based road transport post-2030

Additional 2 MMTpa in 2030 due to 2035 Clean Grid target

Includes the IRA and assumes that the expansion of the hydrogen industry advances in line with a net zero by 2050 economy unconstrained by renewables deployment

Ammonia and oil refining completely transition to clean hydrogen by 2030 and post-2030 fuel cell based road transport and aviation demand accelerates more rapidly

Includes the IRA and assumes that clean hydrogen technologies advance more quickly than other decarbonization technologies – particularly LDES and CCUS, causing increased demand from all end uses

Increased 2030 power sector demand due to IRA incentives combined with slower LDES and CCUS development

1 Includes residential and commercial heating as well as potential additional clean hydrogen demand that could come from increased uptake in new and existing end uses (e.g., hydrogen fuel cells for backup power)

Near term efforts to clarify “colors”
Proposed uses for hydrogen vary (scale, timing)

1. Prioritize electrification first
   - Electrify everything possible first
   - Where electrification is not possible, consider hydrogen

2. Strategic deployment
   - Prioritize hydrogen for strategic use:
     - Key routes, regions
     - Hydrogen is one of multiple needed solutions

3. Rapid acceleration
   - Embrace the use of hydrogen more quickly in difficult to decarbonize sectors to build demand for hydrogen
Future cost of green hydrogen

Figure: Cheng, et al. (2023)

Impact of the IRA on energy costs in 2030

Figure: ICF International (2023)
Stacking IRA tax credits for transportation
<table>
<thead>
<tr>
<th>Freight sectors</th>
<th>Hydrogen fuel</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trucking</strong></td>
<td>~55% TCO Class 8 Sleeper Cabs = Hydrogen Fuel</td>
<td>- 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.</td>
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<td><strong>Maritime</strong></td>
<td>~87% TCO small container ship = Hydrogen fuel</td>
<td>- 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.</td>
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<td><strong>Rail</strong></td>
<td>~19% TCO MU commuter rail = Hydrogen fuel</td>
<td>- 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).</td>
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<tr>
<td><strong>Aviation</strong></td>
<td>~85% TCO regional plane = CAPEX + O&amp;M</td>
<td>- Sector less developed. - Technology early pilot stages. - No cargo planes tested/studied.</td>
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Long-distance, long-haul trucking


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

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.
Considering hydrogen alternative fuel corridors

Regional coordination is required

Figure: Hydrogen (AFC Rounds 1-7), U.S. DOT FHA; updated Nov 2023
Methanol and ammonia to dominate maritime

Cross-sector coordination is required

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

Figure: Hydrogen and ammonia production map (from National Clean Hydrogen Strategy and Roadmap, 2023)
Scaling infrastructure, Strategic Investments Key


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).


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