Modelling Optimal Hydrogen Transmission Network Infrastructure

FSR 10th Annual Conference

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CRA Charles River Associates

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Hydrogen is a fundamentally different energy commodity for which regulatory structures have yet to be developed

Supply	Demand
• Electric Power • Natural Gas • Coal • Industrial waste	• Transportation • Electric Power • Industrial End Uses • Others

Many commercially available models have been developed to understand midstream requirements for electric power and natural gas, but not for hydrogen

- Electric Power
  - Aurora
  - Plexos
- Natural Gas
  - GPCM and RBAC Suite

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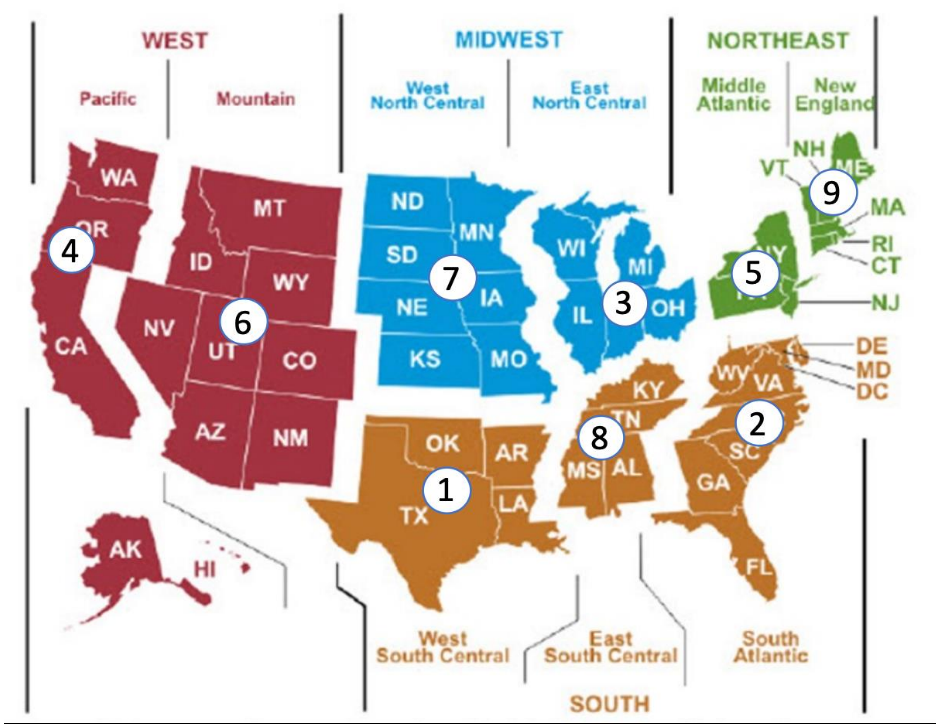
Methodology to Assess Hydrogen Infrastructure Build-out and Cost Impacts

Key Steps

1. Model 2050 hydrogen production costs within a given region
2. Estimate 2050 demand scenarios for hydrogen and allocate demand to each region
3. Model transmission costs associated with moving hydrogen via inter-regional pipeline
4. Optimize the hydrogen pipeline network to minimize total delivered cost of hydrogen across all regions



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Three sub-models underpinning broader optimization: (i) Production Cost, (ii) Demand, and (iii) Transmission

Production Cost Modelling

$$PC_{r_i} = \frac{OCapEx_{r_i} * CRF + O\&M_{Elyzr_{r_i}} + C_{Power_{r_i}} + C_{Water_{r_i}}}{S_{H2_{r_i}}}$$

Demand

$$Q_{H2_{r_i}} = \alpha_{r_i} * Q_{H2}$$

Transmission

$$T_{(r_i,r_j)} = \frac{\beta * \left(OCapEx_{Pipe_{(r_i,r_j)}} + OCapEx_{Comp_{r_i}} - D\right) + O\&M_{Pipe} + PP_{Pwr_{r_i}} * Q_{Power_{r_i}}}{Q_{Moved_{(r_i,r_j)}}}$$

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Objective Function and Model Formulation

Objective Function

- Minimize the sum of hydrogen expenditures across all regions in 2050
  - Subject to the fact that all supply produced within the year must also be consumed in that same year

$$\min \sum_{(r_i, r_j)} P_{(r_i, r_j)} * Q_{H2_{r_i}}$$

$$subject\ to \sum_{r_i} S_{H2} = \sum_{r_i} Q_{H2}, \forall\, i, j$$

• Key Model outputs

- Connection between each region
  - Measured in terms of power capacity
- Total electrolyzer capacity required within each region
- Total cost incurred within the country with network and without network

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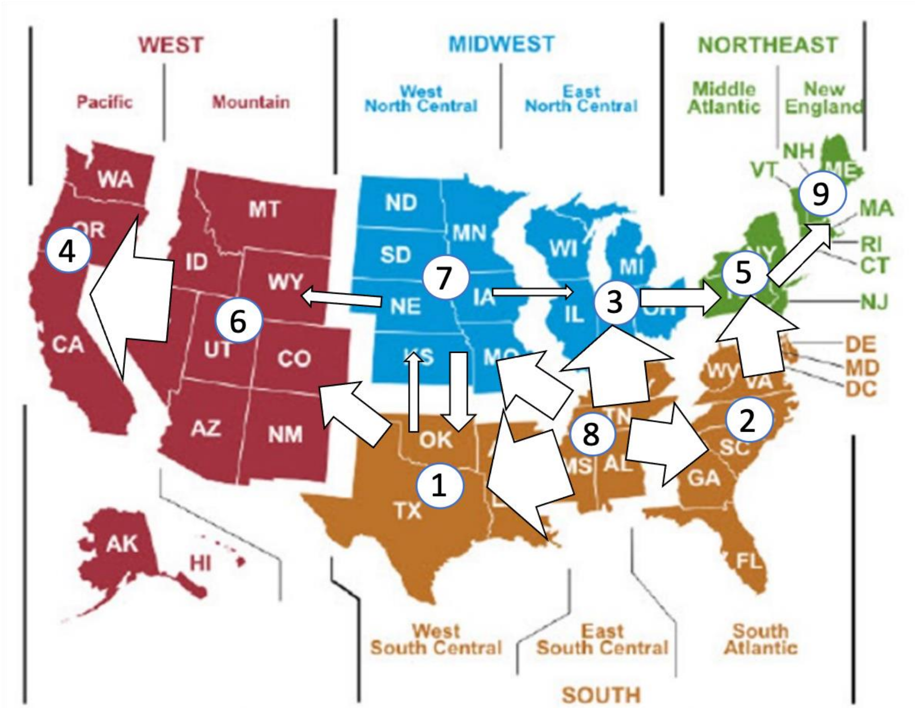
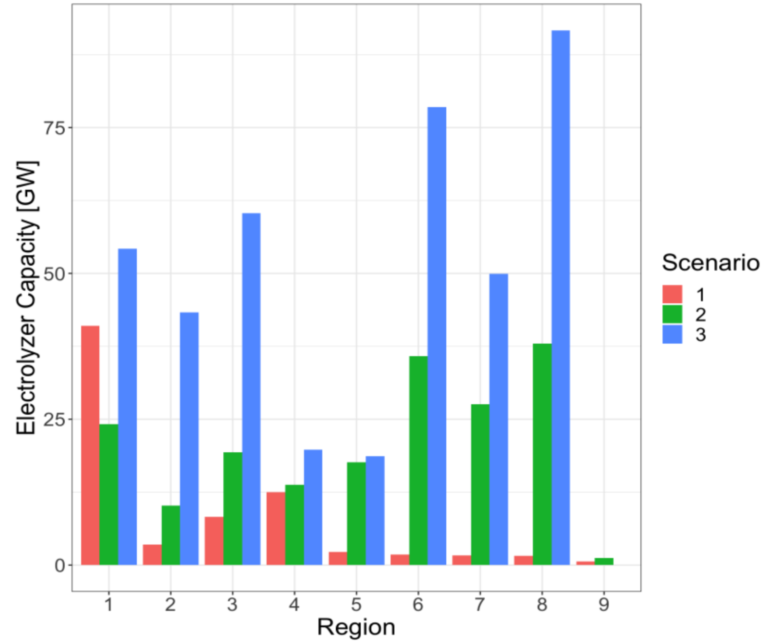
Example Model Results





	1.6 Quads	4.1 Quads	9.1 Quads
$0.01/kWh	1	1	1
$0.05	1	0.99	0.88
$0.12 (AEO Base)	0.99	0.96	0.91

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