Hydrogen Transition Sensitivity Studies using H2Sim

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Project Overview

Objectives / Goals

• Create a tool robust enough to test the impact of different assumptions on the development of hydrogen infrastructure

• Exercise the tool under different assumptions to understand the infrastructure’s sensitivity to different scenarios

• Suggest to DOE areas of further research based on the parameters most influential in the infrastructure development
## Model Enhancements

<table>
<thead>
<tr>
<th>Feature</th>
<th>H₂Sim 1.0 “Old”</th>
<th>H₂Sim 2.0 “New”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pathways in Each Year</td>
<td>One pathway built in a given year.</td>
<td>Multiple build rounds considered, allows multiple pathways</td>
</tr>
<tr>
<td>Delivery Evolution</td>
<td>Delivery method is fixed to production plant “Pathway’s can’t change”</td>
<td>Production plant can change delivery methods (eg. Central plant that trucks H₂ initially, then switches to pipeline)</td>
</tr>
<tr>
<td>Stranding</td>
<td>Entire pathways</td>
<td>Strands individual portions (eg. Prod., Del., Disp.)</td>
</tr>
<tr>
<td>Dispensing Stations Build-Out</td>
<td>Disp. stations capacity = Prod. Capacity, all built in same year</td>
<td>Dispensing stations built as required by demand</td>
</tr>
</tbody>
</table>
## Model Enhancements, cont.

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<th>H₂Sim 1.0 “Old”</th>
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<tbody>
<tr>
<td>Dispensing Cost Algorithm</td>
<td>Lookup tables populated with H2A data</td>
<td>Discounted Cash Flow within model</td>
</tr>
<tr>
<td>Delivery Cost Algorithm</td>
<td>Lookup tables populated with city-specific H2A data</td>
<td>Delivery cost computed within model. Allows rapid modeling of different size cities.</td>
</tr>
<tr>
<td>Pipelines</td>
<td>Optimized Ring Structure used in HDSAM (Rev. 22 Apr 06)</td>
<td>Minimum Spanning Tree Approach as suggested by UC Davis</td>
</tr>
<tr>
<td>Ethanol</td>
<td>Not an available production option</td>
<td>Includes Forecourt Ethanol (1.5tpd)</td>
</tr>
</tbody>
</table>
Review of “Old” Results

Baseline Build-Out Plot

1.5tpd NG Forecourt SMR was selected every year. (Demand: Los Angeles 15% Penetration in 10 yrs.)

Legend defines which pathways are built in each year.

Evaluation & Selection Process is repeated for each year of the analysis. Forecourt SMR is seen to win every year.
Review of “Old” Results, cont.

Forecourt Sensitivity (1,500kg/day station)

Assuming “Upper Bound” Forecourt SMR, Central Coal with Pipeline became lowest cost pathway.

1.5 tpd NG Forecourt SMR beat all other options by >$0.50/kg.

“Upper Bound” Forecourt SMR has a higher cost than leading pathways and thus...

Forecourt SMR with “Upper Bound” capital cost raises cost substantially.
Baseline Case and Sensitivities Using the “New” Model ($H_2$Sim 2.0)
Baseline Assumptions

• City of Choice: Los Angeles
• DOE LA Demand Scenario
  – LA Scenario 1 is baseline (Scenario 2 examined in sensitivity analysis)
  – Curve has Vehicle Penetration of 5.8% in 10 yrs, 99% by 2050
  – Assumes MTA Population & Vehicles
• Initial Dispensing Station Penetration set at 0.5% (20 stations)
• Forecourt SMRs at “Lower Bound” capital cost estimates
  – “Upper Bound” capital cost assessed in sensitivity analysis
• Central Coal plants must use sequestration
  – CA: No power plant emissions greater than that from IGCC plants
  – Limited number of sequestration sites in California
• Coal plant in Wyoming becomes available in 2020
  – 1,000 mile pipeline from Power River Basin to LA (~$700k/mile)
  – Not fully optimized: will examine larger production/pipelines
• Urban Pipelines are not allowed until 2025 (Modeling practicality).
  – Costs are set at $1M/mi. (to represent urban pipeline cost)
Baseline Assumptions, continued

- **Step change in Dispensing Technology in 2020 ("DOE 2017 Delivery")**
  - Increase compressor efficiency from 65% to 80%
  - Decrease # of purchased compressors from 3 to 1
  - Compressor cost factor decreases from $6300 to $4100/(kg/hr)
  - Decrease storage tank costs from $818/kg to $300/kg
  - Maintenance & Repair cost factor drops from 1.8% to 1.5%
  - Output pressure increases to 10kpsi

- **New Delivery option in 2020**
  - Cold Compressed Gas Truck (CCGT) carries 1100 kg (previous HPGT carried 657kg)
  - Also applies to gaseous storage at Dispensing Stations & Terminals

- **Step change in Terminal Technology in 2020**
  - Decrease # of purchased compressors from 3 to 2
  - Decrease storage compressors from 2 to 1
  - Decrease storage tank costs from $818/kg to $300/kg
  - Compressor cost factor (NG to H2 compressors) decreases from 130% to 80%
Sensitivity Studies

- Increase the initial # of dispensing stations to 2% of city total
- Increase Forecourt SMR Capital Costs to Upper Bound Estimates
- Baseline Case (Los Angeles Demand Scenario 1)

- Same as previous but with higher pipeline costs ($2M/mi)
- View Baseline Case out to 2050
- Increase Demand (Los Angeles Demand Scenario 2)

- View Scenario 2 build out to 2050

Increase Forecourt SMR Capital Costs to Upper Bound Estimates
Baseline

Buildout (Pro.)

- (2015) FC, NG-SMR, 1.5 @ 33 x 20
- (2018) FC, NG-SMR, 1.5 @ 33 x 5
- (2019) FC, NG-SMR, 1.5 @ 33 x 27
- (2020) FC, NG-SMR, 1.5 @ 33 x 36
- (2021) FC, NG-SMR, 1.5 @ 33 x 47
- (2022) FC, NG-SMR, 1.5 @ 33 x 56
- (2023) FC, NG-SMR, 1.5 @ 33 x 60
- (2024) FC, NG-SMR, 1.5 @ 33 x 68
- (2025) FC, NG-SMR, 1.5 @ 33 x 78

Volume (TPD)

<table>
<thead>
<tr>
<th>Year</th>
<th>Capacity</th>
<th>Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>2016</td>
<td>20</td>
<td>20</td>
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</tr>
<tr>
<td>2025</td>
<td>20</td>
<td>20</td>
</tr>
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Forecourt NG-SMR (lower bound) wins every time
Displays profited cost of H₂ if build new for entire demand

- **In general:** Biomass < SMR < Coal+Seq.

- **Central (Bio/SMR/Coal) with LT**
- **Central (Bio/SMR/Coal) with HPGT**
- **Existing LA with HPGT**
- **Existing LA with LT**

- **NG Forecourt SMR (0.100 tpd)**
- **WY: 2015 Coal+SEQ PL to CCGT**
- **Forecourt Ethanol (1.5 tpd) – DOE Target ~$3.00**
- **NG City Gate SMR (15 tpd) with HPGT**
- **NG Forecourt SMR (1.5 tpd) Upper Bound**
- **NG Forecourt SMR (1.5 tpd)**
Scenario 1: Upper Bound SMR

![Graph showing volume (TPD) over years from 2015 to 2025]

- **(2015) CG,EX @ 46 x 1**
- **(2020) C,NG-SMR @ 19 x 1**
- **(2015) CG,EX => 48**

- **Capacity:**
  - **Demand:**

- **Existing LA gaseous capacity + New Liquefier w/ liquid truck delivery (but HPGT is only slightly more expensive)**

- **Central NG-SMR w/ cold compressed gas truck (CCGT)**

- **Liquid truck technology stranded!**
Scenario 1 with 78 Disp. Stations in 2015

(2% initial station penetration)

- (2015) CG, EX @ 48 x 1
- (2020) FC, NG-SMR, 1.5 @ 33 x 12
- (2021) FC, NG-SMR, 1.5 @ 33 x 47
- (2022) FC, NG-SMR, 1.5 @ 33 x 56
- (2023) FC, NG-SMR, 1.5 @ 33 x 60
- (2024) FC, NG-SMR, 1.5 @ 33 x 68
- (2025) FC, NG-SMR, 1.5 @ 33 x 78

Capacity

Demand

Existing LA gaseous capacity + New Liquefier w/ liquid truck delivery

Forecourt NG-SMR
Scenario 2: Lower Bound SMR
(13.3% vehicle penetration in 2025)

2012 – 2017: Existing LA gaseous capacity + New Liquefier w/ liquid truck delivery

Forecourt NG-SMR wins every time (just like baseline scenario)

2012 – 2017: Existing LA gaseous capacity + New Liquefier w/ liquid truck delivery

Volume (TPD)

Year

Capacity

Demand
Scenario 2: Upper Bound SMR

(13.3% vehicle penetration in 2025)

Capacity vs. Demand

- Central Biomass/NG-SMR w/ cold compressed gas truck (CCGT)
- Liquid truck technology stranded!

Existing LA gaseous capacity + New Liquefiier w/ liquid truck delivery

Volume (TPD)

Year

Scenario 1: Baseline out to 2050

...then Central (Biomass/SMR/Coal) w/ Pipeline ($1M/mile)

Forecourt NG-SMR to 2032…
Scenario 2: Build out to 2050

2010 to 2050

- Volume (TPD)
- Year

Buildout (Pro.)

2012 – 2017: Existing LA gaseous capacity + New Liquefier w/ liquid truck delivery

2018 to 2030...

...then Central (Biomass/SMR/Coal) w/ Pipeline ($1M/mile)

Forecourt NG-SMR from 2017 to 2030...
Scenario 1: Higher Pipeline Costs

Forecourt NG-SMR wins every time
Questions?
Scenario 1 with 576 Disp. Station in 2015
(15% initial station penetration)

- (2015) CG, EX @ 48 x 1
- (2020) C, BIO-G @ 40 x 1
- (2015) CG, EX => 46
- (2023) C, BIO-G @ 40 x 1
- (2025) C, BIO-G @ 40 x 1

- Capacity
- Demand

Existing LA capacity w/ CCGT

Central biomass w/ CCGT

15% penetration still not reached in 2025!

Liquid truck technology stranded over a 2-yr. period

Year

Volume (TPD)
Scenario 1: Lower Pipeline Costs

Transition is 2 years earlier with $700K/mile pipeline than with $1M/mile pipeline

Forecourt NG-SMR to 2029...

...then Central (Biomass/SMR/Coal) w/ Pipeline ($700K/mile)