H2A Delivery Components Model

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Overview

**Timeline**
- **Start date:** FY 2004
- **End date:** On-going Project

**Barriers**
- Future Market Behavior (4.5 A)
- Lack of Hydrogen/Carrier and Infrastructure Option Analysis (3.2 A)

**Funding**
- 100% DOE Funded
- **FY08:** $100K
- **FY09:** $200K

**Partners**
- Argonne National Lab
- Pacific Northwest National Lab
- Nexant, Inc.
- TIAx
- GTI
- Chevron
- Air Liquide
Relevance: **Components Model Overview**

H2A Delivery Components Model provides costs for hydrogen delivery components
- includes 20 delivery components
- Excel based (availability to public)
- flexible
- can be used to provide inputs for spatially and temporally detailed models

**Relation to Other Models**

- **H2A Delivery Components Model** (component-based)
  - delivery cost data

  - **HyDS-ME**
  - **HyDRA Model**
  - **H2A Power Model**

  - **H2A Production Model**
  - **HDSAM** (scenario-based)
Relevance: Objectives

Project Objectives

- Update and maintain the Components Model
- Support other models and analysis that include delivery costs
- Expand Components Model by designing new components

MYPP

“Activities: Development of the H2A Delivery Components and Scenario Models, MYPP, 2007, p. 3.2-9”

“Analysis: Comprehensive cost and environmental analyses for all delivery options as function of demand, MYPP, 2007, p. 3.2-9”

Outputs

Relevance

To Hydrogen Program and Barriers, Targets, and Milestones

• **Hydrogen Delivery Program**
  “Hydrogen must be transported from the point of production to the point of use… Due to its relatively low volumetric energy density, transportation, storage, and dispensing at the point of use can be one of the significant cost and energy inefficiencies associated with using hydrogen as an energy carrier” (p. 3.2-1)

• **Barrier 4.5 A: Future Market Behavior**
  “Understanding the behavior and drivers of the fuel and vehicle markets is necessary to determine the long-term applications.” (p. 4-11)

• **Barrier 3.2 A: Lack of Hydrogen/Carrier and Infrastructure Option Analysis**
  “Additional analysis is needed to better understand the advantages and disadvantages of the various possible approaches.” (p. 3.2-18)

• **Milestone 12**
  “By 2017, reduce the cost of hydrogen delivery from the point of production to the point of use at refueling sites to < $1/gge” (p. 3.2-26)
Approach

• Collaborate to improve the model

(addressing barrier 4.5 A)

• Analyze various delivery scenarios to identify least-cost pathways. The parameters to vary:
  – choice of a pathway
  – distance
  – demand
  – refueling station size
  – geographic location and resource availability

(addressing Barrier 3.2 A)

• Explore new delivery options
Technical Accomplishments and Progress

Objective: Update and Maintain
- Reviewed The Components Model v. 2.0
- Developed Short Guide to the Delivery Components

Objective: Support Other Models & Analysis
- Created delivery costs database for use in HyDS-ME
- Enhanced capability of HDSAM and the Components model: automation codes for multiple runs
- Calculated delivery costs for short-distance, urban delivery scenarios
- Created first draft of the Refueling Station Tab for the H2A Production Model for forecourt cases

Objective: Expand Model
- Designed 6 new (pilot) rail delivery components for the Delivery Components Model

Output
- 3 Reports and 1 NHA poster presentation
H2A Components Model Update and Maintenance

- **Review and Debugging**
  - reviewed v. 2.0
  - fixed errors
  - sent Review Report to DOE

- **Model Update (on-going effort)**
  - GREET Data
  - Feedstock & Utility Prices

Support Other Models

- **H2A Production Model**
  - designed first draft of the Refueling Station Tab for the H2A Production Model (forecourt cases)

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**Example: Page from the Review Report**

- List of Corrections to the H2A Components Model
- TRUCK-GO DELIVERY
- B32 - biggest button. Change color to orange.
- B71 - formula includes E404 “Time for Loading H2 into Trailer” can be empty if the user entered in cell E1 = “The H2 should be substituted to B63 instead, where time is calculated dependent on the answer in cell E1”.
- B52 - “Type of Diesel” - designed as a drop-down menu button, but currently has only one choice of diesel type: “Conventional Diesel”.
- B126 - “Fuel Cost” has to reflect the cost of fuel chosen in B52. The formula in this cell
- currently reads in “Diesel (retail)”.
- B16 - “System Energy Use”. Again, the formula uses fuel type and currently is locked in “Diesel”. It’s not consistent with the menu in B52 (I choose the fuel type).
- B14 - “On-site Energy Use”. The formula includes LHV and density for the liquid hydrogen instead of pseudo-H2 (O&M and F&M from Physical Property Table). It should be substituted to D46 and F46, respectively (values for pseudo-H2).
- Comment: There is a problem calculating H2 cost as a Tractor related cost and “Truck related cost separately”. Doing so complicates the input. For example, all taxes, O&M costs, insurance are applied as fractions toward these components. It’s not obvious how to allocate right away what fraction of taxes related, etc to the truck, needs to be in the input.
- According to the cited in the NREL/DE/2006-014 “Manual for the Economic Evaluation of Energy Efficiency and Renewable Energy Technologies” (Shafie et al., NREL, 1995) we can do the following instead:
  - PCs (CR/FT): - Tractor Cost + Tax (rate) x PV of tractor depreciation - Tractor Cost + Tax Rate x PV of tractor depreciation + Property Taxes + Insurance Cost
  - H2: Overhead + Capital Investment - Replacement Costs x TR/FT

- Amount of H2 delivered

- This way we can eliminate at least a dozen of user inputs (functions of taxes, insurance and O&M costs related to different components), which is quite hard to estimate right upfront

**Milestone** | **Title** | **Date** | **Status**
---|---|---|---
FY2009 – 2.7.1 | Finalizing the changes to the delivery component model in collaboration with ANL | December 2008 | Complete
Objective: Support Other Models and Analysis

Creating Delivery Cost Database for HyDS-ME

Goals

- vary parameters
  - city demand
  - distance to the city
  - refueling station capacity

- disaggregate cost
  - storage, transmission, distribution
  - fixed and variable

- hundreds of thousands model runs

Solution

- Designed "Delivery Components Composition. Short User Guide"

- Created Automation Code (Ruby, Matlab)
Technical Accomplishments and Progress

Objective: Support Other Models and Analysis

Analysis performed with the help of the Delivery Cost Database

Analysis of the lowest transmission (to-the-city-gate) cost

California Hydrogen Deployment Study

Optimal Infrastructure Analysis for Hydrogen produced from Wind

Output:

Objective: Support Other Analysis

Calculating short-distance urban scenarios

**DOE specific scenario request**

Use **flexibility** of the Components Model

**Input Parameters:**

- dispensing rate 100 kg/day and 450 kg/day
- 6 cases:
  - short pipeline (2 miles)
  - liquid truck (70 miles)
  - gaseous truck (70 miles)
- no labor cost
- no land cost
- no central compressor capital cost

**Example:**

Short pipeline

**H2 Delivery Cost, $/kg**

- 100 kg/day
- 450 kg/day

- ref. st.: remainder
- ref. st.: dispenser
- ref. st.: storage
- ref. st.: compressor
- pipeline
- central compressor
Technical Accomplishments and Progress

Objective: Expand Components Model

Interest in Rail Delivery

Previous study by Amos (1998) identified rail delivery as a least-cost option for a significant range of volumes and distances.

Wind study: long distances from the wind site (e.g., Midwest) to the East Coast large demands (e.g., New York).

- Rail and pipeline appear to be the most prevalent low-cost options for long distances and large demands.
Technical Accomplishments and Progress

Objective: Expand Components Model

Design of Hydrogen Rail Delivery (Pilot Version)

The H2A Components model framework has been used to develop 6 new components:

- Production Terminal (Gaseous and Liquid)
- Rail Delivery (rail cars and rail tankers)
- City-Gate Terminal (Gaseous and Liquid)

Example: Liquid H2 Rail Components

Liquid H2 Production Terminal

Rail Delivery

Liquid H2 City Gate Terminal
Technical Accomplishments and Progress

Objective: Expand Components Model

Examples of scenarios where rail may prove to be the lowest-cost delivery option

“High” FREIGHT CHARGES
Lowest Delivery Cost Pathway Map
(station capacity is 1000 kg/day)

“Low” FREIGHT CHARGES
Lowest Delivery Cost Pathway Map
(station capacity is 100 kg/day)

*The costs do not include refueling station cost
**Distribution transport from the Gaseous H2 City Gate Terminal – by Gaseous H2 Truck
***Distribution transport from the Liquid H2 City Gate Terminal – by Liquid H2 Truck
Objective: Expand Components Model

INPUT:
City Demand = 140 tonnes/day
Distance to the city = 2000 km
Distance within the city = 21 km
Ref. Station size = 1000 kg/day

Comparative Components Cost
for rail and other delivery options

ACRONIMS:
GH2-rail – Gaseous H2 Rail Delivery
LH2-rail – Liquid H2 Rail Delivery
LH2-truck – Liquid H2 Truck delivery

Legend
- Prod. Terminal
- Transport/Transmission
- City Gate Terminal
- Distribution Transport

* The cost of the refueling station is not included
Collaborations

Marianne Mintz - ANL (Delivery Analysis)

Amgad Elgowainy – ANL (HDSAM)

Brian Bush - NREL (HyDS-ME)

Daryl Brown - PNNL (Model Review)

Darlene Steward – NREL (H2A Production Model)

Mike Penev – NREL (H2A Power Model)
Proposed Future Work

- **Components Model Maintenance and Update**
  - Add high pressure (700 bar) refueling station
  - Dispensing from cascade or booster compressor
  - Cryo-compressed pumps

- **Support Other Models and Analysis**
  - Expand delivery costs database for HyDS-ME (add rail delivery costs)
  - Develop delivery database for the use in HyDRA
  - Update and improve Refueling Station for H2A Production Model
  - Continue support DOE on specific delivery cost requests
  - Design delivery options for CHHP system (H2A Power Model)

- **Expand Components Model**
  - Continue developing rail components
  - Perform analysis on rail delivery to find the least-cost scenarios
Summary

• **Relevance**
  – Identify options to reduce hydrogen delivery costs

• **Approach**
  – Conduct techno-economic analysis of specific delivery pathway components

• **Accomplishments**
  – Reviewed H2A Delivery Components Model v 2.0
  – Maintained and updated the Components Model
  – Created Delivery Costs Database for use in HyDS-ME
  – Identified least-cost hydrogen delivery options to the city gate
  – Designed six new (pilot) rail delivery components

• **Collaborations**
  – Partnerships with ANL, PNNL, Nexant, TIAX, and active collaboration with the H2A Production Model, H2A Power Model, HDSAM and HyDS-ME teams

• **Future Work**
  – Update H2A Delivery Components Model with the high pressure cryo-compressed refueling station
  – Improve Delivery Cost Database for HyDS-ME and HyDRA
  – Complete Design of Rail Delivery Components
  – Continue to support DOE on specific scenarios analyses
  – Design delivery options for CHHP systems