NREL National Renewable Energy Laboratory
Innovation for Our Energy Future

H2A Delivery Components Model

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Project ID # PD_31_Sozinova

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)

BUDGET

Funding: 100% DOE Funded

- FY08: **$100K**
- FY09: **$200K**

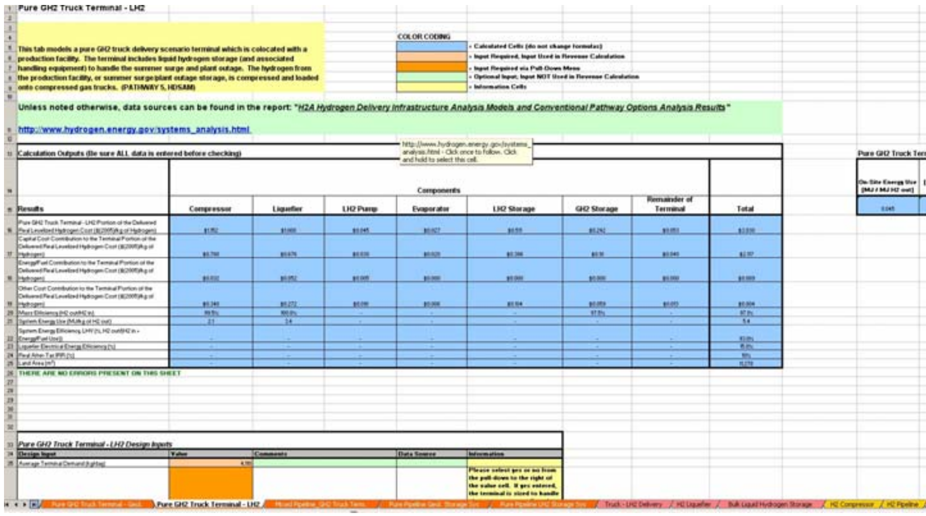
PARTNERS

- Argonne National Lab
- Pacific Northwest National Lab
- Nexant, Inc.
- TIAX
- GTI
- Chevron
- Air Liquide

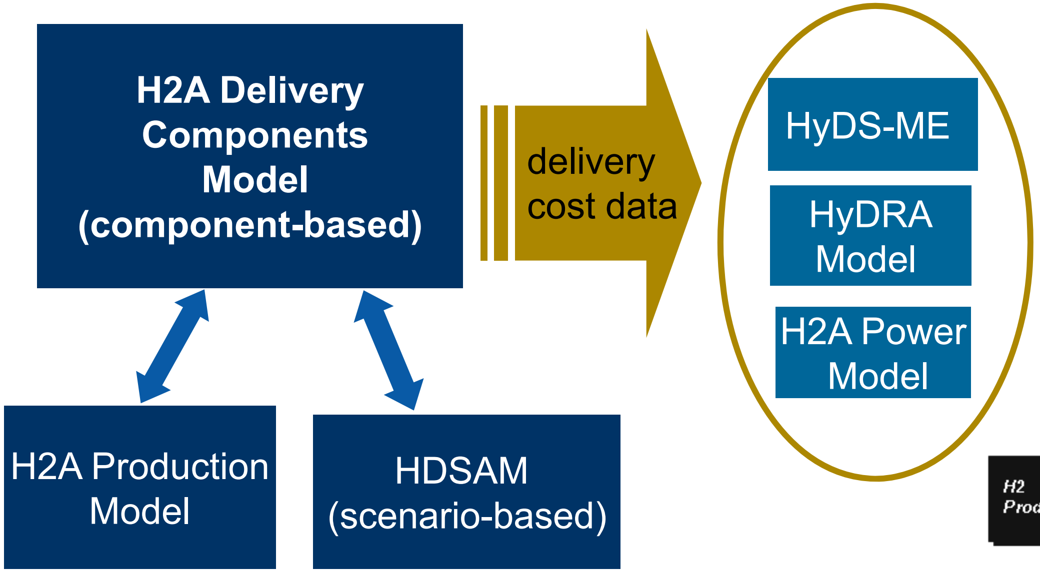
Relevance: *Components Model Overview*

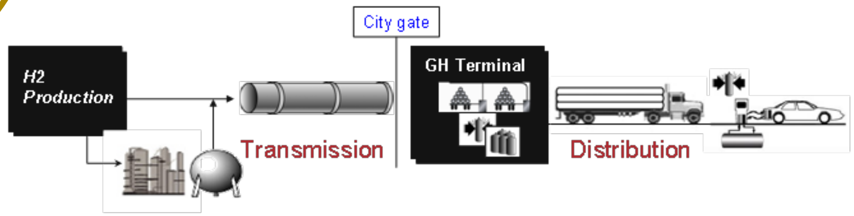
H2A Delivery Components Model provides costs for hydrogen delivery components

- includes 20 delivery components
- Excel based (availability to public)
- flexible
- can be used to provide inputs for spatially and temporally detailed models

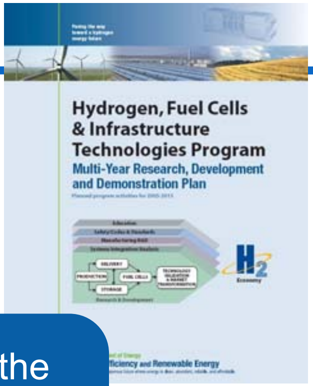


Relation to Other Models





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
"D3. Output to System Analysis and System Integration: Hydrogen delivery infrastructure analysis results, MYPP, 2007, p. 3.2-29"

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

Technical Accomplishments and Progress

H2A Components Model Update and Maintenance

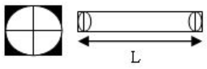
Example: Page from the Review Report

- **Review and Debugging**
  - *reviewed v. 2.0*
  - *fixed errors*
  - *sent Review Report to DOE*
- **Model Update (on-going effort)**
  - *GREET Data*
  - *Feedstock & Utility Prices*

List of Corrections to the H2A Components Model

- TRUCK-GH2 DELIVERY
- B32 – toggle button. Change color to orange.
- B71 – formula includes B46 "Time for Loading H2 into Trailer" can be empty if the user input in cell 31 is "no" B46 should be substituted to B62 instead, where time is calculated dependent on the answer in the cell 31.
- B53 – "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 B53. The formula in this cell
- currently locked in "Diesel (retail)".
- B18 – "System Energy Use". Again, the formula uses fuel type and currently is locked in "Diesel". It's not consistent with the menu cell B53 ("choose the fuel type").
- E14 – "On-site Energy Use". The Formula includes LHV and density for the liquid hydrogen instead of gaseous H2 (D49 and F49 from "Physical Property" Table). It should be substituted to D48 and F48, respectively (values for gaseous H2).
- Comment: Is there a reason in calculating H2 cost as a Trailer related cost and Truck related cost separately? Doing so overcomplicates the input. For example, all taxes, O&M costs, insurance are applied as fractions toward these components. It's not obvious how to estimate right away what fraction of taxes related, say to the truck, needs to be in the input.
- According to the cited in the GUIDE "Manual for the economic evaluation of Energy Efficiency and Renewable Energy Technologies" (Short et al., NREL 1995) we can do the following instead:
- FCR=CRF*(1-Tractor Cost*Tax rate*PV of tractor depreciation - Trailer Cost*Tax Rate *PV of trailer depreciation) +Property Taxes +Insurance Cost
- H2 Cost=(Initial Capital Investment + Replacement Costs)*FCR+O&M
-   Amount of H2 delivered
- This way we can eliminate at least a dozen of user inputs (fractions of taxes, insurance and O&M costs related to different components), which is quite hard to estimate right upfront.

- COMPRESSED GH2 STORAGE
- B74 Single Vessel Capacity
- Volume=pi*d2 *L - pi*d3
-                                   12
- Where pi*d3/12 ~ 0.083 D^3, and is a volume of half a sphere .
- Tube volume is a cylinder volume – 2*volume of highlighted space
- volume of highlighted space= volume of the box (d^3)-volume of the sphere (pi^3/6)=
-                  = (6-pi)*d^3/6 ~ 0.48* d^3



Support Other Models

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

Milestone	Title	Date	Status
FY2009 – 2.7.1	Finalizing the changes to the delivery component model in collaboration with ANL	December 2008	Complete

Technical Accomplishments and Progress

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

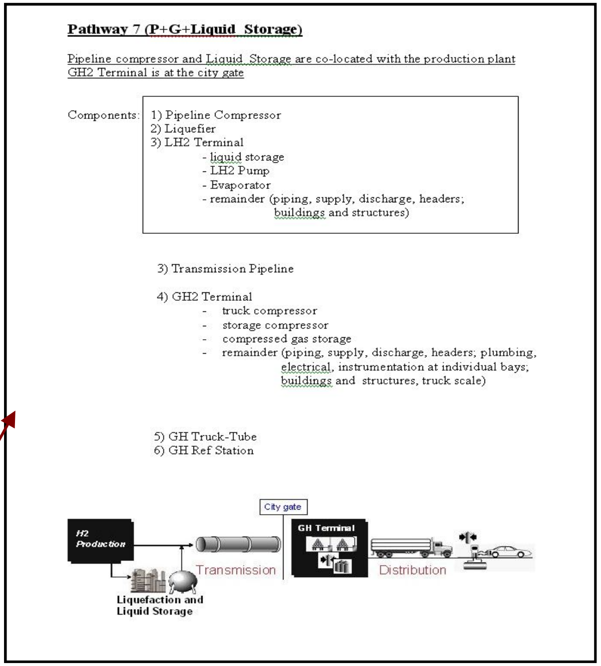
disaggregate cost
- storage, transmission, distribution
- fixed and variable

hundreds of thousands model runs

Solution

Designed "Delivery Components Composition. Short User Guide"

Created Automation Code (Ruby, Matlab)



Pathway 7 (P+G+Liquid Storage)

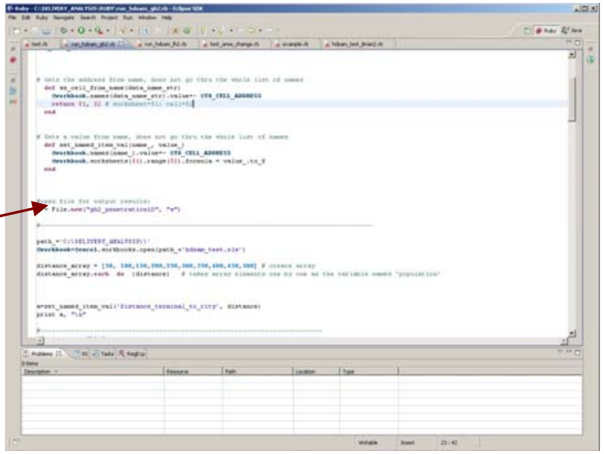
Pipeline compressor and Liquid Storage are co-located with the production plant
GH2 Terminal is at the city gate

Components:
1) Pipeline Compressor
2) Liquefier
3) LH2 Terminal
- liquid storage
- LH2 Pump
- Evaporator
- remainder (piping, supply, discharge, headers; buildings and structures)

3) Transmission Pipeline

4) GH2 Terminal
- truck compressor
- storage compressor
- compressed gas storage
- remainder (piping, supply, discharge, headers; plumbing, electrical, instrumentation at individual bays; buildings and structures, truck scale)

5) GH Truck-Tube
6) GH Ref Station

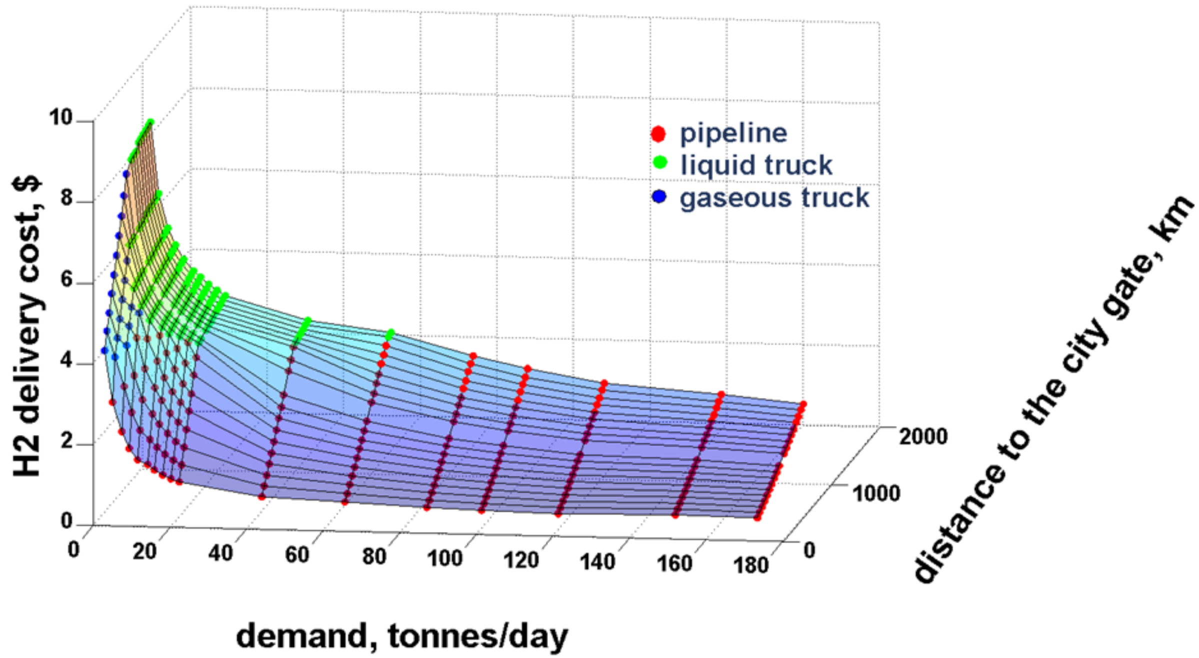


Technical Accomplishments and Progress

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:

B. Bush, M. Melaina, O. Sozinova, D. Thompson. "Hydrogen Deployment System Modeling Environment (HyDS-ME) Notional California Case Study". National Renewable Energy Laboratory, 28 Jan 2009.

B. Bush, M. Melaina, O. Sozinova, "Optimal Regional Layout of Least-Cost Hydrogen Infrastructure". National Hydrogen Association Conference & Expo 2009.

Technical Accomplishments and Progress

Objective: Support Other Analysis

Calculating short-distance urban scenarios

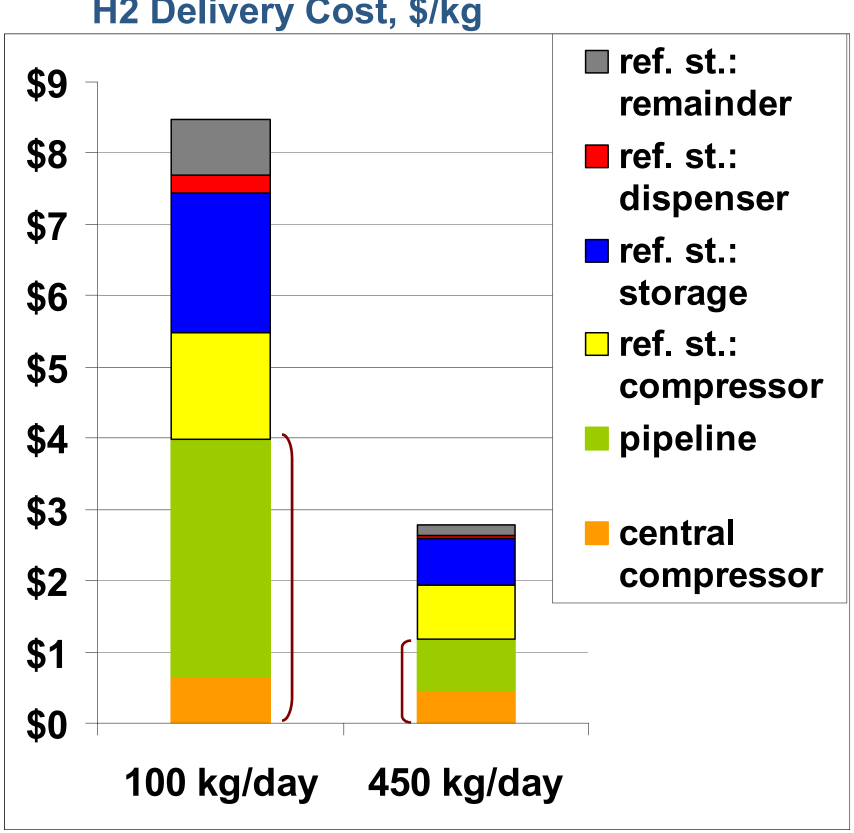
DOE specific scenario request

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

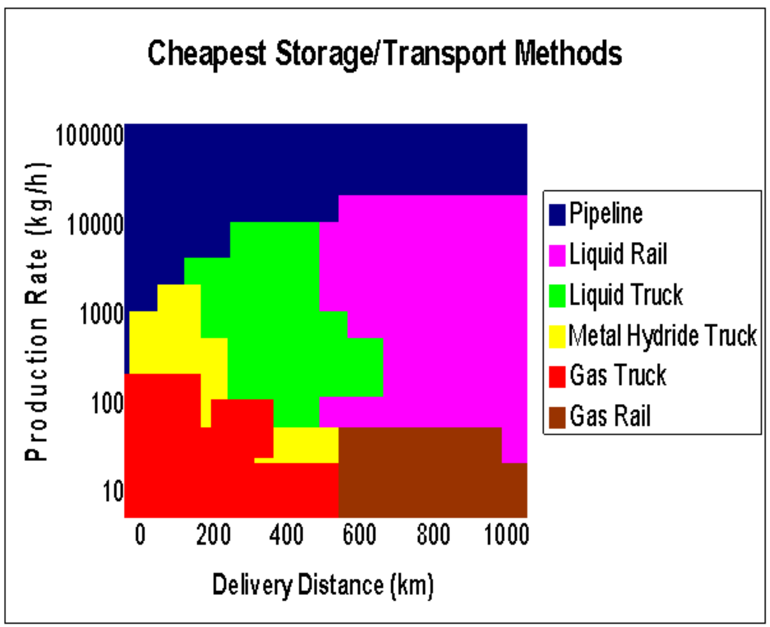


Technical Accomplishments and Progress

Objective: Expand Components Model

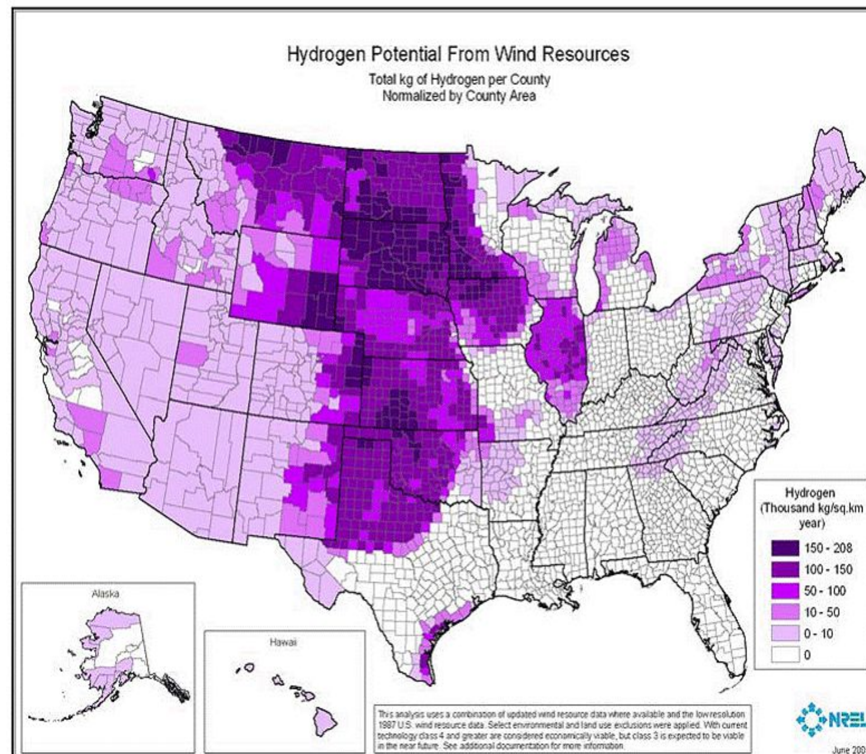
Interest in Rail Delivery

- 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.i., Midwest) to the East Coast large demands (e.i., New York)

  - rail and pipeline appear to be the most prevalent low-cost options for long distances and large demands



Technical Accomplishments and Progress

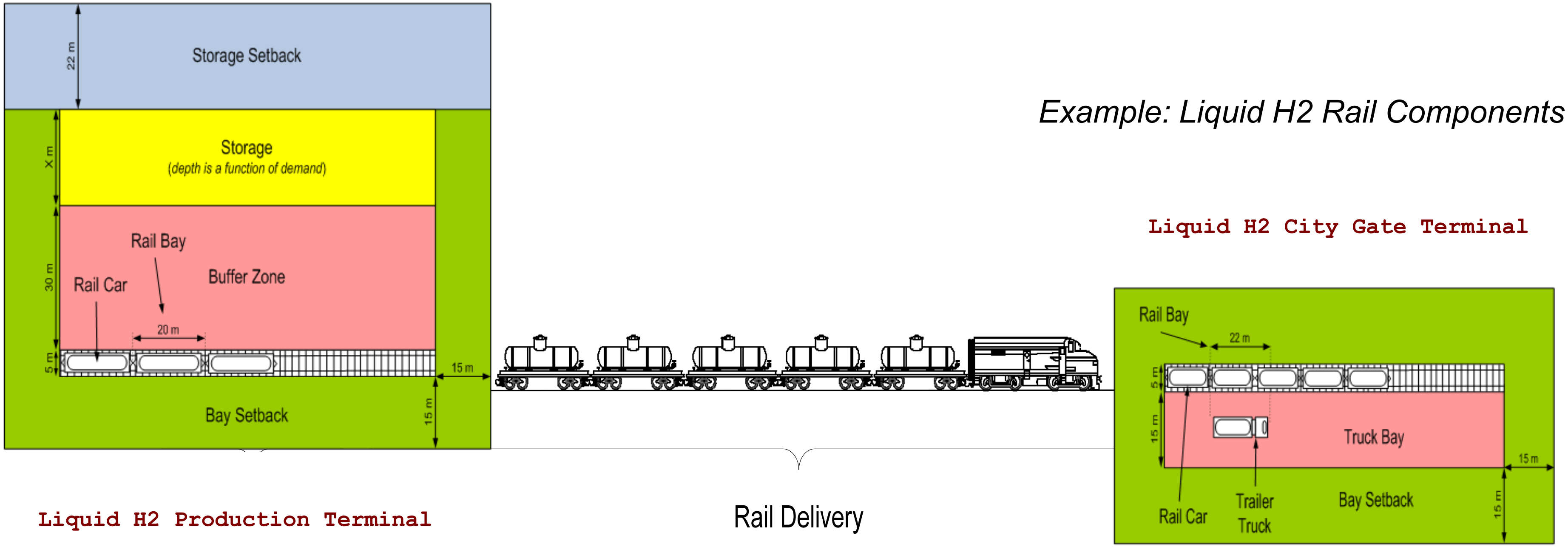
Objective: Expand Components Model

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



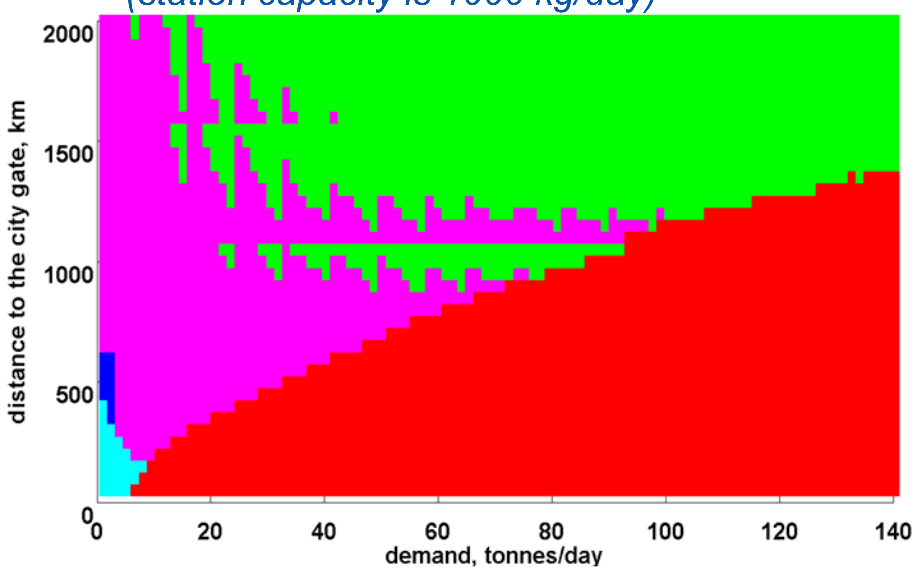
Technical Accomplishments and Progress

Objective: Expand Components Model

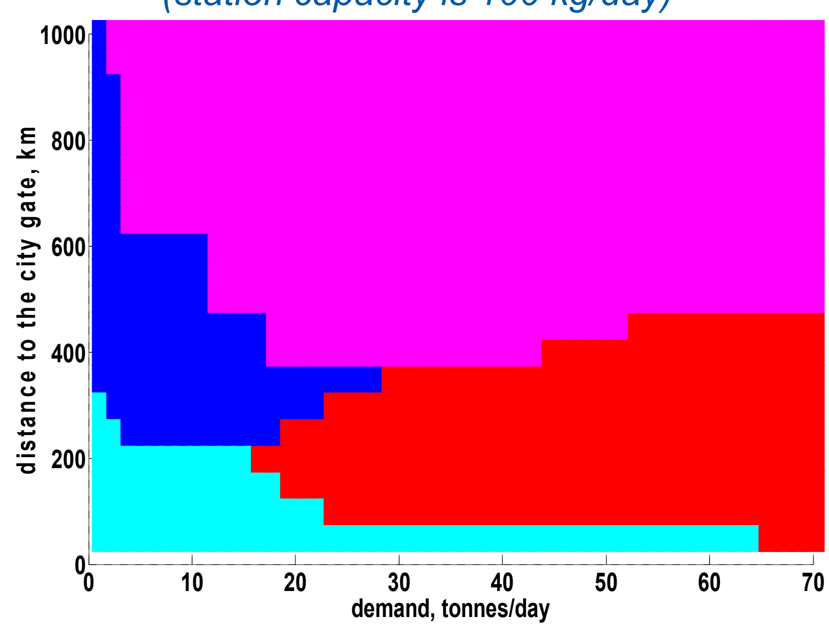
Examples of scenarios where rail may prove to be the lowest-cost delivery option

GH2 Truck
LH2 Truck
Pipeline
LH2 Rail
GH2 Rail

"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 He City Gate Terminal – by Gaseous H2 Truck**

*****Distribution transport from the Liquid H2 City Gate Terminal – by Liquid H2 Truck**

Technical Accomplishments and Progress

Objective: Expand Components Model

INPUT:

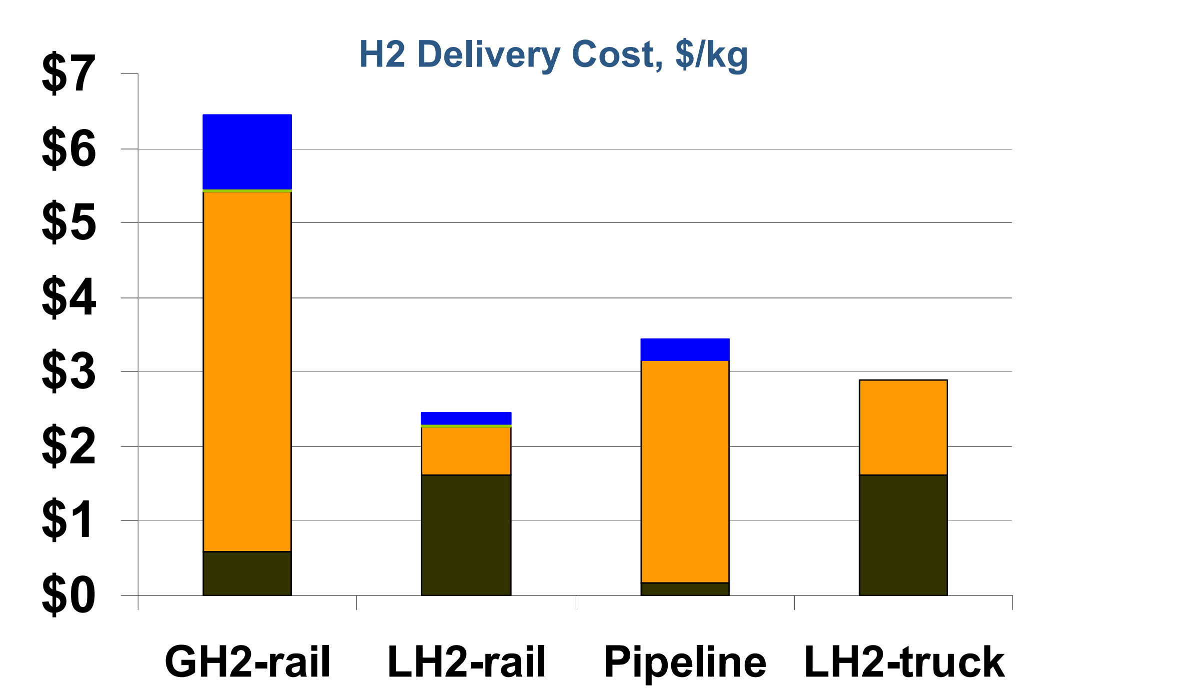
City Demand=140 tonnes/day

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



Legend

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

*** The cost of the refueling station is not included**

ACRONIMS:

GH2-rail – Gaseous H2 Rail Delivery

LH2-rail – Liquid H2 Rail Delivery

LH2-truck – Liquid H2 Truck delivery

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