# Joint Meeting on Hydrogen Delivery Modeling and Analysis

**FreedomCAR and Fuels Partnership Hydrogen Delivery, Storage and Fuel Pathway Integration Tech Teams**

May 8-9, 2007 ♦ Energetics Incorporated, Columbia, MD

## Discussion Session Highlights, Comments, and Action Items

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### *Overall Plan*

1. Complete and publish V2 HDSAM and components with documentation by end of 2007
   - Pre-publication version by about August, 2007
   - Hardwired to H2A energy efficiency and emissions tabs
2. Add carrier pathways and other enhancements (to be prioritized) by mid-2008

### *H2A Delivery Model: Discussion Items, Comments, and Follow-up Actions*

1. Pipeline Pressures: Transmission, Trunk, and Distribution lines
   - Early on it may be difficult to do anything different than is currently approved for gas pipelines from a regulatory perspective. Gas pipelines typically run at 700-1,000 psi for transmission, 100-300 psi for trunks/mains, and 1-125 psi for distribution/service lines. Odorants are used within city limits for non-industrial use gas service.
   - The current capital costs for the hydrogen pipelines in the model are based on 1.1X the price of steel natural gas pipelines.
   - Current defaults: 700-1,000 psi for transmission, 400-600 psi for trunks/mains, and 300-400 psi for distribution/service lines vs. 500-2,000 psi for transmission, 100-500 psi for trunks/mains, 30-125 for distribution/service lines.

   Follow-up: We will leave the current defaults. Anyone could insert alternative pressure ranges to see the sensitivities. (Care must be taken to recognize that the refueling station default compressor capital costs are based on a 300 psi inlet pressure.)
2. Current, Advanced (2015), Longer Term (2025), and R&D Target "Cases"

   Follow-up: We agreed that only Current and Target "cases" are needed. (2017 R&D Targets ≈ 2025 commercialization.)
3. Number of truck deliveries to refueling per day: 1, 2, or 3?
   - Two is the maximum that is acceptable to station operators; most operators would prefer one. Unattended (when closed) deliveries are unlikely.

   Follow-up: We will use up to 2 truck deliveries per day realizing this may be a stretch.
4. Refueling site compressors: how many and what reliability?

Follow-up: Change to 3 @ 50% especially considering we are now using the same compressor(s) for low pressure storage as well as the cascade charging system.

5. 1 vs. 2 gaseous hydrogen (GH2) trucks at the refueling station at any time?
   Follow-up: Will need 2 GH2 truck bays in the design so one truck can be getting hooked up while the other is being used in the drop and swap.
6. Refueling station operation (for urban): 18 hrs vs. 24 hrs
   - Early in transition, with a fewer number of stations, 24-hour operation may be needed to ensure availability. At higher market penetrations, this could be could cut back to 18-hours. The vast majority of current urban gasoline stations are only open 18 hours.

   Follow-up: Will stay with 18 hrs as the default.
7. Hourly/daily fueling site demand profile—ok as-is?
   Follow-up: Agreed that Chevron supplied data is robust and results in a robust/conservative design basis. Agreed that designing the fueling site to run at the maximum rate for the first 5 minutes of every hour is very conservative. We need to look at the sensitivities to this default.
8. 10,000 psi fills
   Follow-up: Will incorporate as part of H2A-V2, if at all possible
9. Cooling at the refueling station
   Follow-up: Will incorporate as part of H2A-V3 or H2A-V2
10. Cryo-gas transport
    Follow-up: If attractive, will add in H2A-V3
11. Final purification at the refueling station
    Follow-up: Will incorporate as part of H2A-V3 if deemed appropriate at that time.
12. Tube Trailer options
    - Current 2650 psi, ~340 kg
    - Advanced: 5000 psi, ~500 kg
    - Target: 1100 kg capacity
13. Gas Tube Trailer (2650 psi) Current H2A Capital Cost: $165k vs. DTI/HyPro $225k
    Follow-up: Will adopt $225k
14. Truck Driver Labor: H2A at $25/hr vs. DTI/HyPro at $40/hr
    Follow-up: Reconcile this difference. Does the H2A Delivery G&A rate account for most of the difference?
15. Truck Tractor Capital Cost: H2A at $100k vs. DTI/Hypro at $75k
    Follow-up: Will adopt $75k.
16. Truck Deliveries: H2A at 24 hrs/day vs. DTI/HyPro 12 hrs/day
    Follow-up: Will go to 18 hrs/day.

***H2A Delivery "Plus:" Discussion Items, Comments, Gaps, and Follow-up Actions***

1. Need enhanced Geographical Region modeling in HDSAM
   - Model as a function of population density (series of doughnuts?)
   - Rural? Interstate?

- City clusters?
- Look at the CTC, HyTrans and NEMS-H2 approaches

Follow-up: All of these will be considered and one or more will be incorporated into HDSAM V3

2. Add H2A production to HDSAM?
   - Distributed at refueling sites
   - Central Production

   Follow-up: This will be discussed with System Analysis
3. Refueling Station Size Distribution?

   Follow-up: It was believed that this would not substantially improve/change HDSAM results and will not be done.
4. Minimum percentage or other criteria for number of refueling sites at low market penetrations

   Follow-up: An approach to this will be added to HDSAM-V2 or -V3. (Note: if this is done by allowing the user to specify a minimum number or percentage of stations, and an option to allow to design the entire infrastructure to meet the station average daily demand capacity, one could get a cost at high underutilization.)
5. Documentation of Nexant project and update of H2A user guides

   Follow-up: Include documentation for how we model the pipeline networks and the truck delivery systems/schedules (algorithms, etc.)
6. Need sensitivity analysis/tornado charts in the H2A Delivery Models

   Follow-up: This will be incorporated in some manner.
7. How well do the models capture demographic information (personal income, etc.) to determine demand for fuel cell vehicles? Is Margo and Cory's work at NREL and agent-based modeling (RCF/ANL) enough?
8. More tornado diagrams would be useful to help understand the key variables and degree of impact (including conventional technologies) for all models.
9. Low-cost production technologies are differentiated by small amounts – in reality, it is difficult to pick winners
10. Ensure that the purpose, intended use, and customers of the models is made clear
11. What is the best way to characterize delivery costs on a regional basis in all the models?
12. If/when should we incorporate new H2A model results into the models that depend on it?

    Follow-up: This is a Systems Analysis call.
13. It is important to document all the models: H2A, HDSAM, HyPro, HyTrans, etc.
14. Add to HyPro results: total investment by major pieces of the pathway; well-to-wheel efficiencies, $CO_2$ emissions, geologic storage?
15. HyTrans & HyPro: create learning by doing tornado chart; add sensitivity for learning in central plants for production and delivery costs; add learning from international efforts?; include additional vehicles (PHEVs, biodiesel, etc.); add sensitivity to higher real estate costs.
16. Use of greenfield sites to build additional capacity is questionable—additional capacity will more likely be added at existing sites as long as these plants have the available land.

17. How does land availability affect pipeline costs?
18. Water– how much water is used in the different pathways?
19. Carbon sequestration– develop curves that include different costs depending on region, feedstock, separation technology, etc.
20. Utility corridors, and how these relate to siting issues?