USDRIVE

DRIVING RESEARCH AND INNOVATION FOR
VEHICLE EFFICIENCY AND ENERGY SUSTAINABILITY

Fuel Pathway Integration Technical Team Roadmap

June 2013

This roadmap is a document of the U.S. DRIVE Partnership. U.S. DRIVE (Driving Research and Innovation for Vehicle efficiency and Energy sustainability) is a voluntary, non-binding, and nonlegal partnership among the U.S. Department of Energy; USCAR, representing Chrysler Group LLC, Ford Motor Company, and General Motors; Tesla Motors; five energy companies — BP America, Chevron Corporation, Phillips 66 Company, ExxonMobil Corporation, and Shell Oil Products US; two utilities — Southern California Edison and DTE Energy; and the Electric Power Research Institute (EPRI).

The Fuel Pathway Integration Technical Team is one of 12 U.S. DRIVE technical teams ("tech teams") whose mission is to accelerate the development of pre-competitive and innovative technologies to enable a full range of efficient and clean advanced light-duty vehicles, as well as related energy infrastructure.

For more information about U.S. DRIVE, please see the U.S. DRIVE Partnership Plan, www.vehicles.energy.gov/about/partnerships/usdrive.html or www.uscar.org.

Table of Contents

Table

Acknowledgements

FPITT Organizational Members
U.S. Department of Energy
ExxonMobil
Phillips 66
Shell
Chevron
National Renewable Energy Laboratory
Air Products and Chemicals, Inc. (Associate Member)

FPITT Roadmap Contributors
Fred Joseck, U.S. Department of Energy
Matt Watkins, ExxonMobil
Garry Gunter, Phillips 66
Herie Soto, Shell
Laura Verduzco, Chevron
Mark Ruth, National Renewable Energy Laboratory
Todd Ramsden, National Renewable Energy Laboratory
Darlene Steward, National Renewable Energy Laboratory
Brian Bonner, Air Products and Chemicals, Inc.
Melissa Laffen, Alliance Technical Services, Inc.

Mission and Scope

The Fuel Pathway Integration Technical Team (FPITT) supports the U.S. DRIVE Partnership (the Partnership) in the identification and evaluation of implementation scenarios for fuel cell technology pathways, including hydrogen and fuel cell electric vehicles in the transportation sector, both during a transition period and in the long term.

The FPITT reviews publicly available, ongoing and completed analyses of hydrogen and fuel cell technology pathways, with particular focus on techno-economic and environmental assessments of integrated hydrogen production, delivery, dispensing, and use pathways and comparison to other fuel pathways; identifies and bridges knowledge gaps that limit the ability to evaluate implementation scenarios for fuel cell technology pathways; identifies technical and institutional barriers to implementation of fuel cell technology pathways; and provides industry-based perspective on research and development (R&D) needs, targets, direction, and potential ramp-down for consideration by DOE in the management of the DOE Hydrogen and Fuel Cells Program. Activities are coordinated with the other technical teams of the Partnership to promote consistency between analysis and modeling efforts and to ensure effective use of resources.

The FPITT is aligned with the Partnership's goals, especially the second goal: Enable reliable fuel cell electric vehicles with performance, safety, and costs comparable to or better than advanced conventional vehicle technologies, supported by viable hydrogen storage and the widespread availability of hydrogen fuel.

This roadmap outlines an approach for achieving this mission.

Revisions to the Roadmap

The initial FPITT Roadmap was completed in December 2006 and has since served as a tool to communicate the team's responsibilities and activities within the FreedomCAR and Fuel Partnership (now U.S. DRIVE) as well as to guide the team in the prioritization of its activities. Since 2006, considerable progress has been made in addressing the goals and barriers stated in the 2006 roadmap.[1] The Partnership's evolution to U.S. DRIVE and technical progress necessitated an update to this Roadmap, so that it may continue to serve as a valuable tool for the FPITT and for the Partnership.

Goals

U.S. DRIVE is pursuing multiple options for hydrogen production, hydrogen delivery, hydrogen storage, and fuel cells. Technical teams for each of these technology areas have developed technical targets and identified barriers for their respective subsystems and components. The FPITT interacts across teams to enable a common set of assumptions and parameters, and the development of a consistent set of targets that can readily be used to evaluate integrated fuel pathways. In addition, barriers to implementation may require additional or modified goals. The FPITT will address these problems by pursuing activities that achieve the following goals.

- Assess techno-economic and environmental benefits of integrated hydrogen production, delivery, dispensing, and use pathways and compare to other fuel pathways.
- Identify and bridge knowledge gaps that limit the ability to evaluate implementation scenarios for fuel cell technology pathways.
- Promote transparency in all analysis activities by providing feedback on the communication of analysis parameters and results.

---

1 Accomplishment reports are available at http://www1.eere.energy.gov/vehiclesandfuels/about/partnerships/roadmaps-other_docs.html.

- Identify technical and institutional barriers to implementation of fuel cell technology pathways.
- Promote consistency between goals, analysis, and modeling efforts of various technical teams of the Partnership to ensure consistent overall targets and effective use of resources.

Key Issues and Challenges

Hydrogen transportation fuel pathways will need to compete against an existing fuel infrastructure that is well understood, highly efficient, and has widespread consumer acceptance. Though certain components of potential hydrogen fuel pathways are well understood, the costs, emissions, and operational requirements of complete hydrogen production, delivery, and dispensing systems have not been fully assessed. Furthermore, with the continual introduction of new vehicle technologies, the market conditions in which hydrogen must compete are continually evolving. One of the most important technical challenges in implementing hydrogen as a transportation fuel, therefore, is estimating the costs, benefits, and risks of potential hydrogen fuel pathways.

Gaps and Barriers

The following gaps and barriers describe challenges faced in the analysis of hydrogen fuel pathways.

A. **Inconsistent Data, Assumptions, and Guidelines for Communicating Parameters and Results.** Putting the results and recommendations from one analysis in context with other analyses and the overall objectives of the Partnership is difficult, as many of the assumptions and much of the data in existing analyses are not explicitly documented. The problem is compounded by the lack of reliable, up-to-date, real-world data on hydrogen and fuel cell technologies and deployment as well as a lack of understanding of the uncertainty within the data.

B. **Lack of Understanding of Fuel Pathway Impacts on Fuel Quality.** Hydrogen quality affects the performance, durability, and cost of fuel cells and of hydrogen production, distribution, storage, and dispensing components.

C. **Stove-Piped/Siloed Analytical Capabilities.** Analytical capabilities and resources have been largely segmented, both functionally by technology (production, storage, fuel cells, etc.) and organizationally (laboratories, specialized teams, industry/academia, etc.). Successful systems analysis requires the integration of analysis resources across all facets of the issue, including vehicle and fuel facets.

D. **Lack of Understanding of the Influence of Evolving Hydrogen and Fuel Cell Market Opportunities on the Transportation Sector.** Various niche markets for hydrogen and fuel cells, including forklift operations and backup power applications, are developing, but it is not yet clear whether or how these applications will impact efforts to implement hydrogen as a transportation fuel.

E. **Lack of Cohesion Between Temporal and Spatial Aspects of Analysis.** Analytical techniques available today do not address concurrently the temporal and spatial characteristics inherent in utilizing fuel cells and hydrogen fuel, limiting the ability to satisfactorily assess both transition and end-state issues.

F. **Lack of Understanding of Technological Progress and Technology Adoption and Learning Curves.** In the early stages of adoption, technologies exhibit high costs and highly variable performance. As dominant designs emerge, and as manufacturing volumes increase, costs decrease.

G. **Need for Component Goals That Meet Overall Targets When Aggregated.** Each component area (hydrogen production, delivery, fuel cells, storage, etc.) has its own goals. Without alignment, these cannot readily be used to evaluate integrated fuel pathways.

H. **Lack of Understanding of Supply and Demand Issues for Hydrogen as a Transportation Energy Alternative.** Understanding the behavior and motivations of potential fuel cell users is necessary to determine how the markets will respond in the long-term to fuel cell and hydrogen products. Market pull and the factors affecting it are important to setting targets and recognizing business-case barriers. In addition, the behavior in initial markets (i.e., of early adopters) is likely to be different than that of the mainstream markets (i.e., of average, pragmatic consumers and late-adopters), so multiple timeframes and penetration levels need to be considered.

I. **Lack of Integrated Knowledge Regarding Technologies, Markets, and Infrastructure Evolution.** Interactions between hydrogen and fuel cell markets and technology and infrastructure development will drive how and when technologies will be deployed. These interactions are difficult to predict and model. Further, external factors such as fuel pricing and natural gas supply, as well as consumer response to FCVs, are intrinsic to the regional selection of hydrogen transportation fuel pathways for implementation. These factors are non-deterministic and present modeling challenges as the correctness of the underlying model assumptions can only be determined over time.

Strategy to Overcome Barriers and Achieve Goals

The FPITT provides critical industry feedback to the DOE Fuel Cell Technologies Office Systems Analysis activities that are aligned with the barriers and challenges listed above. The following sections outline strategies for achieving the goals of the Fuels Pathway Integration Tech Team, which are summarized in Table 1.

Table 1. Strategies for Achieving FPITT Goals

Goal	Barriers	Activities
Assess techno-economic and environmental benefits of integrated hydrogen production, delivery, dispensing, and use pathways and compare to other fuel pathways.	A, B, C, D, E, F, H	• Pathway Analysis* • Station Cost Reduction Analysis • Storage Pathway Analysis • Dispensing Pressure Analysis
Identify and bridge knowledge gaps that limit the ability to evaluate implementation scenarios for fuel cell technology pathways.	A, C, D, E, F	• Pathway Analysis* • Station Cost Reduction Analysis • Storage Pathway Analysis • Dispensing Pressure Analysis
Promote transparency in all analysis activities by providing feedback on the communication of analysis parameters and results.	A	• Pathway Analysis* • Technology R&D Rampdown • Review Models and Analyses
Identify technical and institutional barriers to implementation of fuel cell technology pathways.	A, C, D, E, F, I	• Station Cost Reduction Analysis • Technology R&D Rampdown • Dispensing Pressure Analysis
Promote consistency between goals, analysis, and modeling efforts of various technical teams of the Partnership to ensure consistent overall targets and effective use of resources.	A, C, G	• Coordination with Other Tech Teams • Review the Revisions/Updates to the Hydrogen Threshold Cost and Component Targets

* Pathway analysis involves levelized cost analysis coupled with well-to-wheels analysis and cradle-to-grave analysis. *Well-to-wheels (WTW) analysis* examines hydrogen fuel pathways, including feedstock recovery, transportation, and storage; fuel production, transportation, storage, and distribution; and vehicle operation. The reported energy use includes both direct and indirect use of raw materials (natural gas, coal, and petroleum). For feedstock recovery, direct use of raw materials involves those used to recover and refine the feedstock, and indirect use of raw materials involves those needed to produce electricity and materials that are used directly. *Cradle-to-grave analysis* expands upon WTW analysis and includes energy and emissions for production, maintenance, and disposal of the vehicles. Other life cycle assessment parameters may be added in the future.

Section 1: Analyzing Hydrogen Fuel Pathways

Goal: Assess techno-economic and environmental benefits of integrated hydrogen production, delivery, dispensing, and use pathways and compare to other fuel pathways.

Objectives:

Identify and, where possible, quantify the challenges associated with using a pathway on a large scale, e.g., primary energy input, land and water use, other infrastructures, scalability, and well-to-wheel (WTW) CO_2 emissions. Each hydrogen production, delivery, dispensing, and use pathway will have feedstock, supply, emissions, utility, land, and infrastructure issues that must be addressed and quantified. As the pathways are evaluated, these attributes will require definition to understand supply, peripheral infrastructure, and environmental impacts. These elements may increase the capital cost, impact timing, and require detailed technical and environmental assessment.

Identify related technologies not addressed in the Partnership's research goals that will be needed to successfully implement pathways. Related requirements will be identified as part of the evaluation of pathways and pathway technologies. This will enable related issues such as specific emissions and utility components to be identified and quantified (e.g., carbon capture and sequestration). Based on the results of this assessment, the FPITT will identify any additional research and/or analysis projects that should be explored and developed by the responsible DOE program or other entity to provide the technical solutions for the identified issue.

Refine approach to integrating hydrogen quality requirements into individual technical team roadmaps and analyses. Facilitate discussion. Hydrogen quality requirements have the potential to impact all fuel pathway components as well as fuel cells for various applications. The impacts of contaminants and the tradeoffs among performance requirements for individual pathway components, including fuel cells, require periodic assessment as technology is advanced and various fuel sources are considered. The FPITT will evaluate and refine the process whereby these issues are integrated into the relevant technology roadmaps.

Conduct periodic assessments and updates for selected pathways. The issues associated with a pathway technology will be assessed periodically based on technology evolution or changes in external factors. The evaluation will provide direction to the Partnership on component research in a given pathway.

Barriers:

- A. Inconsistent Data, Assumptions, and Guidelines for Communicating Parameters and Results
- B. Lack of Understanding of Fuel Pathway Impacts on Fuel Quality
- C. Stove-Piped/Siloed Analytical Capabilities
- D. Lack of Understanding of the Influence of Evolving Hydrogen and Fuel Cell Market Opportunities on the Transportation Sector
- E. Lack of Cohesion Between Temporal and Spatial Aspects of Analysis
- F. Lack of Understanding of Technological Progress and Technology Adoption and Learning Curves
- H. Lack of Understanding of Supply and Demand Issues for Hydrogen as a Transportation Energy Alternative

Activities:

- Pathway Analysis
- Station Cost Reduction Analysis
- Storage Pathway Analysis
- Dispensing Pressure Analysis

Integration with Other Tech Team Roadmaps:

- Dialogue with the Hydrogen Production, Hydrogen Delivery, and Hydrogen Storage Tech Teams, as well as the Fuel Cells Tech Team, will be required to establish requirements for technologies needed to meet the pathway-independent hydrogen threshold cost.
- Integration with the Vehicle Systems Analysis Tech Team is required to assess WTW implications of hydrogen pathways and compare them to the WTW and cradle-to-grave performance of evolving internal combustion engine and hybrid electric systems.

Section 2: Identifying Analysis Needs and Gaps

Goal: Identify and bridge knowledge gaps that limit the ability to evaluate implementation scenarios for fuel cell technology pathways.

Objectives:

Review the DOE portfolio of non-policy related hydrogen analysis programs to identify current pathway analysis capabilities. In order to adequately provide hydrogen pathway analysis input to the Partnership, the DOE analysis portfolio needs to be periodically reviewed. Gaps in analysis capabilities will be identified, and observations on the breadth and depth of existing analyses will be developed. In addition, the ongoing analysis tasks that need to be modified to better integrate with other DOE analysis tasks will be identified.

Identify and prioritize pathway analysis needs for long term and transitional analysis. Upon the completion of any analysis portfolio review, gaps in analysis capabilities will be identified. These gaps will need to be prioritized with regards to analyses focusing on the long-term hydrogen transportation scenarios, along with analyses for transitional hydrogen transportation scenarios. The prioritization of these gaps will be used to plan future analysis activities.

Survey available literature and institutional knowledge of the U.S. DRIVE partners to identify knowledge gaps that limit the ability to evaluate hydrogen production, delivery, dispensing, and use pathways. The credibility of analytical efforts undertaken within the Partnership can be challenged when the assumptions are not transparent, well documented, and well supported. One objective of the FPITT, therefore, is to identify assumptions in Partnership-related analyses that require additional research or documentation, and to determine appropriate methods to fulfill the analytical needs. For some knowledge gaps, existing literature may provide needed information. For others, uncertainties may be addressed through risk analysis and sensitivity studies.

In coordination with other technical teams, suggest R&D directions to address knowledge gaps. Some knowledge gaps can be addressed through R&D projects funded by DOE or the industrial partners. Where appropriate, and in coordination with other relevant technical teams, the FPITT may provide input and recommendations for use by the Partnership on the direction of R&D programs to address knowledge gaps.

Communicate gaps and R&D suggestions to the relevant U.S. DRIVE operations groups. Decisions regarding R&D and analysis directions within the Partnership are made by various operations groups. The

FPITT will communicate analysis results, gaps, and suggestions for future R&D directions to these groups to inform decision-making.

Barriers:

- A. Inconsistent Data, Assumptions, and Guidelines for Communicating Parameters and Results
- C. Stove-Piped/Siloed Analytical Capabilities
- D. Lack of Understanding of the Influence of Evolving Hydrogen and Fuel Cell Market Opportunities on the Transportation Sector
- E. Lack of Cohesion Between Temporal and Spatial Aspects of Analysis
- F. Lack of Understanding of Technological Progress and Technology Adoption and Learning Curves

Activities:

- Pathway Analysis
- Station Cost Reduction Analysis
- Storage Pathway Analysis
- Dispensing Pressure Analysis

Integration with Other Tech Team Roadmaps:

- Coordination with the Hydrogen Production, Hydrogen Delivery, Hydrogen Storage, and Codes & Standards Tech Teams, as well as the Fuel Cells Tech Team, will be required to identify, bridge, and communicate analysis and knowledge gaps and resulting suggestions for R&D and analysis directions.
- Integration with the Vehicle Systems Analysis Tech Team is required to assess vehicle cycle analysis and knowledge gaps.

Section 3: Achieving Transparency

Goal: Promote transparency in all analysis activities by providing feedback on the communication of analysis parameters and results.

Objectives:

On an ongoing basis, review and provide feedback for consideration in managing DOE-funded analysis projects regarding the communication of analysis parameters and results. DOE's Hydrogen and Fuel Cells Program develops standard and consistent analysis data, assumptions, guidelines, and scenarios for hydrogen transportation fuel implementation. The FPITT will provide feedback to these efforts to ensure that they support the FPITT's goals of enabling analysis of complete pathways and achieving transparency of analysis activities.

Barriers:

A. Inconsistent Data, Assumptions, and Guidelines for Communicating Parameters and Results

Activities:

- Pathway Analysis
- Technology R&D Rampdown
- Review Models and Analyses

Integration with Other Tech Team Roadmaps:

Coordination with the Vehicle Systems Analysis Tech Team is required to ensure transparency in vehicle cycle analyses.

Section 4: Identifying Barriers to Hydrogen and Fuel Cell Implementation

Goal: Identify technical and institutional barriers to implementation of fuel cell technology pathways.

Objectives:

Assess the impacts of technology advancement, refueling pressure optimization, learning curves, and station duplication on the costs of hydrogen fueling stations. Hydrogen fueling station costs now represent a greater portion of the hydrogen cost, as hydrogen production and delivery costs have been reduced through R&D. It is expected that high-volume manufacturing of station components, design standardization, and learning rates will significantly reduce hydrogen fueling station costs, but these impacts are not well understood. The FPITT will estimate potential hydrogen cost reductions possible through dispensing technology advancement, fueling pressure optimization, station installation learning curves, and station duplication.

Examine the resource requirements, including water, land, and feedstock requirements, for fuel cell technology implementation pathways, and identify resource limitations on both a national and regional level. Fuel cell technology implementation pathways require adequate long-term supply of various resources, for which other industrial, commercial, and residential activities also compete. The requirements change as technologies advance, specific pathways are selected and implemented, and the costs of various resources change in relation to each other. Resource limitations may arise due to supply challenges, contamination, environmental factors, cost escalation (e.g., from demand increases or resource depletion), or any of a variety of other issues. The FPITT will identify both the resource requirements and potential limitations of fuel cell technology implementation pathways and will incorporate this information into its analysis as appropriate.

Determine infrastructure requirements and potential infrastructure-related limitations, on both a national and regional level, for fuel cell technology implementation pathways. Infrastructure elements for fuel cell technology implementation scenarios include roads, railways, barges, pipelines, the electrical grid, and others to deliver feedstocks, process components, fuels, and hydrogen and fuel cell products. Individual installations have specific requirements for gas lines, electrical transmission and distribution, and water quality. Some elements of fuel cell technology implementation scenarios require manufacture of unique infrastructure components; inadequate supply of these components can limit the viability or timeliness of implementing particular pathways. The availability and cost of various infrastructure components and systems needed for fuel cell technology implementation will be studied, and insights gained will be used in FPITT analysis as appropriate.

Barriers:

- A. Inconsistent Data, Assumptions, and Guidelines for Communicating Parameters and Results
- C. Stove-Piped/Siloed Analytical Capabilities
- D. Lack of Understanding of the Influence of Evolving Hydrogen and Fuel Cell Market Opportunities on the Transportation Sector
- E. Lack of Cohesion Between Temporal and Spatial Aspects of Analysis
- F. Lack of Understanding of Technological Progress and Technology Adoption and Learning Curves
- I. Lack of Integrated Knowledge Regarding Technologies, Markets, and Infrastructure Evolution

Activities:

- Station Cost Reduction Analysis
- Technology R&D Rampdown
- Resource Analysis
- Dispensing Pressure Analysis

Integration with Other Tech Team Roadmaps:

- R&D off-ramping criteria will be discussed with the Hydrogen Production, Hydrogen Delivery, Hydrogen Storage, and Fuel Cell Tech Teams.
- Coordination with the Hydrogen Production, Hydrogen Delivery, and Vehicle Systems Analysis Tech Teams is required in the investigation of the optimum hydrogen working pressure for hydrogen powered fuel cell vehicles.

Section 5: Review Hydrogen Threshold Cost and Component Targets

Goal: Promote consistency between goals, analysis, and modeling efforts of various technical teams of the U.S. DRIVE Partnership to ensure consistent overall targets and effective use of resources.

Objectives:

Provide input to the Partnership on setting goals for full pathways and pathway components. Goals aimed at enabling commercialization must ensure that the resulting pathways are at least economically equivalent to competing technologies expected to be available. The DOE hydrogen threshold cost is based on anticipated future market conditions and is pathway independent. It is expressed as a range, in dollars per gasoline gallon equivalent, untaxed at the pump. The hydrogen threshold cost is periodically reassessed in light of changes in vehicle system energy efficiency characteristics, competitive technologies, and gasoline price projections.

Develop "pathway component" goals that are consistent with the high-level goal and can be used to identify those components that should be the primary focus of R&D. Provide the results of that analysis to the Hydrogen Production, Hydrogen Delivery, and Hydrogen Storage Tech Teams as input to their goal setting processes. Operating from the high-level, pathway-independent hydrogen threshold cost, individual pathways must be sub-divided into components. The development of component goals will consider the contribution of the component within and across pathways. An integrated hydrogen fuel pathway will include some or all of the following components depending on location of the production facility:

- *Feedstock*
- *Production:* Processes that convert an energy source to hydrogen
- *Delivery*
  - *Purification*
  - *Production storage:* For central production processes, storage necessary to ensure uninterrupted flow of hydrogen to the distribution system
  - *Distribution preparation:* Process for preparing hydrogen from the production process and/or storage for introduction to the distribution system, e.g., compression, liquefaction, charging solid carrier
  - *Terminals:* Facilities that buffer capacity between production and retail and have the capability to change the state of the hydrogen (e.g., liquid-to-gas, liquid-to-solid)
  - *Distribution:* Facilities used to transport hydrogen between production, terminals, and retail locations (e.g., pipeline, compressed tank truck, liquid tank truck)
- *Local storage:* Storage capacity needed at the retail site to handle peak demand periods and ensure an uninterrupted flow of hydrogen to consumers
- *Compression:* Includes vaporization and compression if needed to interface between local storage and the vehicle
- *Dispensing:* Facilities needed to transfer hydrogen from local storage to vehicle tanks

Ensure consistency between pathways. The establishment of consistent goals requires commonality in the bases and assumptions used to develop component goals. In particular, all pathways must assume that hydrogen is delivered to the vehicle at the same level of purity. Likewise, all central plant cases will be evaluated on a common scale, as will all distributed production cases; furthermore, the central plant and distributed cases will be based on a common scenario to the extent possible.

Identify pinch points. Barriers that make attainment of a component goal difficult will be identified, including possible mitigation via trade-offs with other goals. An example is hydrogen quality: in addition to understanding the impact that it has on the hydrogen pathway component cost, it will be necessary to coordinate with the Fuel Cell Tech Team to evaluate the impact of a lower/different quality on fuel cell operation.

Periodically update to capture improvements in technology outlooks and future fossil fuel costs. Due to the uncertainty involved in the development of future fuel costs and technology projections, the hydrogen threshold cost will be reviewed when there are significant changes in the outlook for vehicle technologies or the outlook for gasoline prices. The cost review will be used to determine whether the magnitude and certainty of the change require an update of the component goals. Note that such changes should be infrequent, since R&D activity requires a reasonable level of certainty in the goals.

Barriers:

- A. Inconsistent Data, Assumptions, and Guidelines for Communicating Parameters and Results
- C. Stove-Piped/Siloed Analytical Capabilities
- G. Need for Component Goals That Meet Overall Targets When Aggregated

Activities:

- Coordination with Other Tech Teams
- Review revisions/updates to the Hydrogen Threshold Cost and Component Targets

Integration with Other Tech Team Roadmaps:

The hydrogen threshold cost developed by the DOE Fuel Cell Technologies Office will be communicated to the Hydrogen Production, Hydrogen Delivery, Hydrogen Storage, and Fuel Cell Tech Teams for evaluation of their feasibility and comparison with “bottom up” goals. The FPITT will obtain feedback from these other technical teams to refine the full pathway analysis.