Transportation and Stationary Power Integration

WORKSHOP PROCEEDINGS

Phoenix, Arizona

October 27, 2008

US Fuel Cell Council
www.usfcc.com

Acknowledgements

This workshop was planned under the guidance of Marc Melaina of the National Renewable Energy Laboratory (NREL) and Fred Joseck of the Department of Energy's Hydrogen, Fuel Cells & Infrastructure Technologies Program. Workshop organization and facilitation was provided by Energetics, Incorporated in Columbia, Maryland. Breakout group facilitators included Shawna McQueen, Katie Jereza, and Richard Scheer. The proceedings were prepared by Shawna McQueen, Anna Domask, Katie Jereza, and Richard Scheer of Energetics. Special thanks are extended to the workshop speakers and participants, who contributed their time and knowledge to enrich and enliven the workshop discussion.

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INTRODUCTION

One of the key barriers to commercialization of hydrogen fuel cell vehicles is the availability of hydrogen fueling infrastructure, particularly in the early years when market volume (and hence hydrogen demand) is small. Previous feedback from industry has indicated that existing transportation fuel providers (oil and gas companies, retail gasoline station owners) will not be likely to assume the financial risk of building hydrogen fueling stations without an assured consumer demand for the hydrogen. On the other hand, vehicle manufacturers have indicated that they are unwilling to produce fuel cell vehicles in any significant quantity in the absence of convenient, publicly accessible hydrogen refueling stations.

To address this critical "chicken and egg" issue, the Department of Energy (DOE) is exploring options for enabling adequate hydrogen supply in the early stages of hydrogen fuel cell vehicle commercialization. One promising option is using stationary fuel cells in combined heat and power systems to co-produce hydrogen. These combined heat, hydrogen and power (CHHP) "trigeneration" systems can hypothetically be configured to provide (1) high quality, grid-independent electric power for stationary critical load applications, (2) additional electricity generating capacity for other applications including plug-in hybrid electric vehicles, (3) useful thermal energy for heating or cooling loads, and (4) hydrogen fuel that can be used for multiple fuel cell applications, including material handling equipment, backup power, and light- or heavy-duty vehicles.

While there are many potential CHHP deployment options, early targets might include facilities like military bases, postal facilities, and airports, and the hydrogen would be used either onsite in vehicles or for transport to nearby retail/fleet refueling stations. By leveraging the high efficiency of fuel cells and the multiple revenue streams offered by trigeneration, the CHHP strategy can potentially reduce the up-front capital costs and financial risks associated with hydrogen production for early vehicle markets.

The DOE is conducting a comprehensive techno-economic analysis of the feasibility, costs, and benefits of the CHHP strategy, working jointly with the National Renewable Energy Laboratory, Oak Ridge National Laboratory, Argonne National Laboratory, Sandia National Laboratory, Brookhaven National Laboratory, and others. Outside stakeholder input will be gathered at regular intervals (through workshops, web forums, or other means) to inform the analysis, critique methodologies and assumptions, and review results.

Purpose of the Workshop

The first *Transportation and Stationary Power Integration Workshop* was held on October 27, 2008, in Phoenix, Arizona, in conjunction with the *Fuel Cell Seminar*. The purpose of the workshop was to gather initial input and feedback from invited experts on the overall CHHP concept and proposed analysis approach. Input from participants will be used to guide and refine the analysis plan in the early stage of the DOE analysis project. Invitees were drawn from a broad range of organizations to assure a diverse range of expertise and opinions. As shown in Appendix A, more than 50 experts participated in the meeting, representing electric utilities, fuel producers, fuel cell manufacturers, automobile manufacturers, state and federal government, non-profit interest groups, national laboratories (analysts), and consultants.

Workshop Structure

The workshop format included a half-day of plenary presentations on the research project plan and analysis tools, followed in the afternoon by facilitated breakout group discussions to gather detailed feedback from participants (see full agenda in Appendix B). The plenary was divided into two sessions, as shown in Exhibit 1. The speakers represented a variety of organizations, including federal and state agencies, automotive companies, and fuel cell manufacturers. The presentations set the stage for the issues addressed during the breakout groups.

Exhibit 1: Plenary Presentations

Session 1: Project Overview and Federal Perspective

- **Transportation and Stationary Power Integration Analysis Scope and Approach**
  *Fred Joseck, **U.S. Department of Energy***
- **H2A Stationary Systems Model**
  *Darlene Steward, **National Renewable Energy Laboratory***
- **Facility Locations and Hydrogen Storage/Delivery Logistics**
  *Nicholas Josefik, **Construction Engineering Research Laboratory, US Army***
- **Potential USPS Involvement**
  *Ray Levinson, **US Postal Service***
- **California National Guard Sustainability Planning, Hydrogen Fuel Goals**
  *Lieutenant Colonel Reuben Sendejas, **California National Guard***

Session 2: State and Industry Perspectives

- **State Perspective: Connecticut**
  *Joel Rinebold, **Connecticut Center for Advanced Technology***
- **State Perspective: California**
  *Mike Tollstrup, **California Air Resources Board***
- **Fuel Cell Vehicle OEM Perspective**
  *Britta Gross, **General Motors***
- **Fuel Cell Company Perspective**
  *Pinakin Patel, **FuelCell Energy***

Following the plenary session, the group was divided into three parallel breakout discussion groups, all tasked with providing feedback on the potential of CHHP to contribute to early hydrogen fueling capacity and the DOE analysis approach.

Workshop Discussion Summary

The following sections present a summary of the plenary presentations and breakout group discussions. The detailed breakout group reports can be found in Appendix C.

Plenary Presentations

Brief overviews of each plenary presentation are provided below. For more information, the full presentations can be accessed on line at
http://www1.eere.energy.gov/hydrogenandfuelcells/power_integration_workshop.html.

Plenary Session 1: Project Overview and Federal Perspective

Transportation and Stationary Power Integration Analysis Scope and Approach
Fred Joseck, U.S. Department of Energy
Mr. Joseck discussed the results of the Infrastructure Lessons Learned project and considered a number of locations for potential CHHP installation. He stressed the potential synergistic relationship between CHP and hydrogen fueling infrastructures, especially in early markets. He detailed some existing financing mechanisms to assist with the purchase of stationary fuel cells.

H2A Stationary Systems Model
Darlene Steward, National Renewable Energy Laboratory
Dr. Steward presented on her team's effort to develop a CHHP cost analysis model to enable the analysis of new transition strategies. The team is developing an H2A Stationary Model using the H2A discounted cash flow methodology, which will incorporate "trigeneration" case studies. Analysis methodology, initial assumptions, and preliminary results were presented.

Facility Locations and Hydrogen Storage/Delivery Logistics
Nicholas Josefik, Construction Engineering Research Laboratory, US Army
Mr. Josefik presented analysis of overall energy use in the Department of Defense (DoD) and some potential applications for fuel cells based on different defense facilities goals and requirements. He reviewed the energy legislation that applies to DoD and the current and planned DoD fuel cell power applications.

Potential USPS Involvement
Ray Levinson, U.S. Postal Service
Mr. Levinson presented the U.S. Postal Service (USPS) energy-use profile and noted some potential fuel cell opportunities. He spoke extensively on the fuel cell combined heat and power installation at the San Francisco Processing and Distribution Center and associated energy analysis. An outline of their current hydrogen fuel cell vehicle program and an overview of the use of fork lifts in the USPS infrastructure were also presented. .

California National Guard Sustainability Planning, Hydrogen Fuel Goals

Lieutenant Colonel Reuben Sendejas, California National Guard

Lt. Col. Sendejas provided information on the National Guard installations in California and discussed the Joint Forces Training Base at Los Alamitos, CA as a potential site for fuel cells.

Plenary Session 2: State and Industry Perspectives

State Perspective: Connecticut

Joel Rinebold, Connecticut Center for Advanced Technology

Mr. Rinebold presented a geographic analysis conducted as part of Connecticut's recent state roadmapping activity, which contrasted energy intensive industries, military facilities, alternative fueling stations, highways, and fleet locations to determine the ideal location for initial hydrogen infrastructure deployment. Mr. Rinebold described preliminary analysis of the seven military sites within the Bradley International Airport area for their feasibility as a location for a fuel cell installation.

State Perspective: California

Mike Tollstrup, California Air Resources Board

Mr. Tollstrup described various fuel cell sites in California and provided analysis of criteria pollutants. He summarized California regulations. The latest California-funded hydrogen fueling stations (some of which produce hydrogen from renewable sources) and various California fuel cell funding mechanisms were presented.

Fuel Cell Vehicle OEM Perspective

Britta Gross, General Motors

Ms. Gross compared electric and fuel cell vehicles. She spoke about the many milestones that need to be met to facilitate early commercialization by 2015. A large need for retail-like hydrogen infrastructure in advance of the deployment of large scale vehicle fleets was stressed.

Fuel Cell Company Perspective

Pinakin Patel, FuelCell Energy

Mr. Patel provided the developer's perspective on CHHP projects. He described direct fuel cell technology status and CHHP technology status and benefits, particularly focusing on renewable production. He concluded with strategic input to DOE including unique market drivers in California, suggestions for financial incentives, and research opportunities.

Breakout Sessions: Common Themes and Key Messages

During the breakout sessions, facilitators led the groups through a series of discussion topic areas, as shown in Exhibit 2. The questions in Exhibit 2 were provided as a reference, to stimulate discussion in each of the topic areas.

Exhibit 2. Breakout Group Discussion Topic Areas

Topic Area	Questions for Consideration
Benefits & Usefulness of Approach	• How and where can this integration strategy provide benefits? • Is this an effective or economical way to get the infrastructure jump started? • Is this useful only in the short-term or is there a long-term business case?
Practical Considerations for Deployment	• What barriers (technical or nontechnical) might inhibit or prevent this strategy? • Are there downsides or issues we have not considered? • Are we missing key perspectives?
Best Applications	• What buildings or operations offer the best applications for this strategy? • Are there niche applications that – have unique or special needs for CHP or electricity? – have unique or special needs or uses for hydrogen? – offer some advantage for producing and distributing hydrogen?
Configuration of Integrated Fuel Cell System	Any issues about the configuration of the integrated fuel cell system that need to be taken into consideration? • Is it correct to assume that these will NOT be PEM systems? • What's missing from the DOE analysis?
Analysis Emphasis	• How aggressive should the market scenarios be? • What elements or variations should be included in a scenario analysis of this strategy? – Suggestions for scale and extent of deployment? – How many of these will be needed and in what timeframe? – Suggestions for deployment strategies? • What's the definition of "early"? At what stage of market development might this be effective? First 1,000 vehicles? First 10,000 or million?
Next Steps	• ISSUES: what are the key issues for DOE to explore going forward? • RESOURCES: are there gaps in existing/available data or analysis tools? What are the sources for those data or tools? • NEXT STEPS: What would you like to see addressed at future workshops like this?

While there was significant overlap among the feedback and next steps proposed, each breakout group provided unique perspectives and comments during the facilitated discussions. A number of key messages and common themes emerged from the discussions, as summarized below. The detailed input from each breakout group is provided in Appendix C.

Analysis Needs

- DOE needs to carefully analyze the extra cost of the hydrogen fueling component at CHHP facilities. What is the cost of the excess reforming capacity and the cost of installing, operating, and maintaining the hydrogen purification, compression, storage, and dispensing equipment, land, and associated safety/liability requirements? What size market for hydrogen is needed to justify the additional expense?
  - Factor in enough storage to "guarantee" hydrogen availability for vehicle fueling even when power demand or power prices are high.
- Life cycle analysis of CHHP is needed to assess the complete economic, environmental, and energy security benefits (equivalent to well-to-wheels analysis for transportation applications). These models should also assess the impacts of state or federal financial incentives and carbon management or other policies (both existing and proposed). The relative merits of CHHP must be compared with the life cycle costs of incumbent heat

and power technologies and alternative near-term hydrogen production pathways (e.g., distributed methane or ethanol reforming at the forecourt, tube trailer delivery).

  - Include all value streams that can/could be monetized to reduce system capital or operating costs, including avoided energy costs, avoided emissions, carbon credits, learning by doing, etc.
  - When comparing alternatives, consider the non-monetary benefits to the system user, e.g., power reliability, sustainable operations, attraction/retention of employees.

- Consider the impact of increased distributed generation and renewable power: this could affect electricity prices and/or utility business models or cost structures.
- Conduct analysis of the costs and benefits of fuel cell CHP systems both *with and without* hydrogen production.
- Analyze the market introduction plans of the automakers to determine fueling station requirements and locations and overlay those results with possible locations of sites for CHHP facilities.
- Analyze the impacts of different configurations for utilizing the hydrogen, including sites that "harvest" hydrogen for off-site fueling stations, and sites that add hydrogen production capacity in a modular fashion as demand grows.

DATA NEEDS

- One of the best ways to fully evaluate the CHHP concept is through one or more learning demonstration projects to gather data needed to assess feasibility, refine system designs, get a better handle on installation and O&M costs, and assess the impacts of local policies and regulations, market structures, and geographic and weather conditions with regard to financial attractiveness, technical feasibility, and market acceptance.
- Real-world data from commercial installations is needed for the analysis.
- Assess the "lessons learned" from the experiences of distributed energy and CHP developers in addressing local regulatory and institutional barriers, environmental siting and permitting issues, interconnection with local power companies, and strategies for integrating CHP facilities with local, state, and regional electricity planning and grid operations.
- It may be difficult to get the types of electricity consumption and load-shape information for different building and facility types to assess the CHHP concept properly. Specific facility information is often proprietary but generic information may be available.
  - Data on electricity costs by time-of-day to assess the value of peak power production is available in those regions of the country that operate organized bulk power markets (e.g., New England, New York, Mid-Atlantic, Midwest, and California).

SYSTEM DESIGN/CONFIGURATION

- The fuel cell, compressor, PSA, etc. are sized for a particular rate of operation and most systems work best at steady state operation. Need to check with manufacturers on feasibility of varying production of hydrogen and/or electricity to meet real-time changes in hydrogen and electricity demand and/or pricing.
- Consider different configurations for utilizing the hydrogen, including sites that "harvest" hydrogen for off-site fueling stations, and sites that add hydrogen production capacity in a modular fashion as demand grows.

COMMERCIAL FEASIBILITY OF THE CHHP CONCEPT

- Consider whether the economics of CHHP support the production of hydrogen in quantities that hydrogen fuel cell vehicles (FCVs) will need as the demand grows. The choice of how to balance power, heat, and hydrogen production will be driven by the economics of each particular CHHP installation, and there is no guarantee that the systems will produce the amount of fuel that the vehicles will need. The automotive companies will need confidence in this strategy as a viable option for early fueling infrastructure.
- Consider how the timelines for CHHP deployment and early (2012-2015) transportation fueling needs match up. How will the addition of a hydrogen fueling component affect the timeline for project contract negotiations (which is already lengthy for fuel cell CHP projects, mostly due to the "newness" of the technology and the long process for getting incentive funds from state and federal programs)?
- Assess regulatory/safety/codes and standards/liability issues that could affect public access to fueling stations at CHHP sites, or that could impact ability to co-produce hydrogen for transport to off-site fueling stations.
- Define a vision/roadmap for how CHHP fits within the path from early hydrogen use to widespread, full-scale implementation of a hydrogen economy.

CHHP LOCATION/SITING CONSIDERATIONS AND PROMISING APPLICATIONS

- Increased use of renewable sources is a growing requirement across the nation, particularly in California and states located in the northeast, so hydrogen from renewable sources will be a strong selling point.
- Ideal siting criteria for CHHP include:
  - Site is ideal CHP candidate (site that already needs cooling and chiller replacement, electricity to gas price is high, net metering is available, and there is an opportunity to reuse the heat)
  - Stand-alone business case exists for CHP
  - Biogas or other renewable hydrogen feedstock is available
  - Located in a state with financial incentives
  - Fuel cell vehicles (FCVs) are being operated in the area
  - The site or nearby area offers multiple uses for the hydrogen (e.g., fuel cell, FCVs, fuel cell forklifts, and/or industrial feedstock)
  - Fueling station is accessible to the public and where the public *wants* to go

CHHP DEPLOYMENT STRATEGY AND CONSIDERATIONS

- All CHHP sites do not necessarily need to have a fueling station – some could simply produce and store hydrogen (e.g., in a tube trailer) and provide the fuel to an off-site fueling station. This could be especially important for CHHP sites that are not convenient or accessible to consumers, sites that do not have the land available for fueling stations, etc.
- The CHHP strategy needs to be driven by customer demands. Key issues include convenience and affordability for consumers to refuel vehicles and added value for CHHP system owners and operators, such as actual revenue increases and ease of

installation, operation and maintenance. The "voice of the customer" must be taken into account in developing siting criteria.

NEEDS AND OPPORTUNITIES FOR COLLABORATION/PARTNERSHIPS/LEVERAGING

- There is a strong need for improved collaboration between government and industry at the Federal, state, and local levels to align policies better, expand leveraging of resources, and improve information exchange to assist project developers to identify and evaluate promising locations for installations.
  - DOE could play a valuable role in this regard by providing "information clearinghouse" services enabling developers and others with a one-stop-shop for information on state and local incentives, rules, and regulations. DOE could also provide analytical support to public and private sector organizations that want to evaluate the technical and economic feasibility of CHHP at specific locations.

KEY NEXT STEPS

- Verify the hypothesis (using real world data and the H2A model) that the CHHP strategy can lower the cost of hydrogen production and delivery, particularly in the near term, and provide benefits for consumers and system owners.
- Verify system operating assumptions with manufacturers (e.g., assumed turn down ratios, equipment ramp rate, efficiencies, production levels of outputs, etc.)
- Develop **strawman business cases**, including modelled results from the H2A analysis, for various promising applications and review these with stakeholders at follow-on workshop(s) or web forums(s). Promising applications could include large, profitable corporations with sustainability goals, big box stores and supermarkets, military bases, universities, food processing facilities, and mail handling facilities.
- Invite broader participation in future workshops or webinars to begin forming the partnerships needed for commercial deployment of CHHP technology, including:
  - electric and gas utility stakeholders
  - current and future owner and operators of fuel cell systems ("voice of the customer").
  - safety and code officials
  - members of the project financing/project development community
  - representatives of state or federal regulatory and incentive organizations.

APPENDIX A
LIST OF WORKSHOP PARTICIPANTS

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Henkel

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Chevron

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Consultant

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URS/U.S. Department of Energy

Atsushi Yamamoto
Japanese Ministry of Economy, Trade, and Industry (METI)

APPENDIX B
WORKSHOP AGENDA

Transportation and Stationary Power Integration Workshop

Agenda

Phoenix Convention Center,
West Building, Room 211A
Phoenix, Arizona
October 27, 2008

MONDAY, OCTOBER 27, 2008

7:30 am **Registration and Continental Breakfast (Room 211A)**

8:15 am **Welcome and Opening Remarks**

8:30 am **Session I: Project Overview and Federal Perspective**
Moderator: Marc Melaina, NREL

1. **Transportation and Stationary Power Integration Analysis Scope and Approach**
   Fred Joseck, *U.S. Department of Energy*
2. **H2A Stationary Systems Model**
   Darlene Steward, *National Renewable Energy Laboratory*
3. **Facility Locations and Hydrogen Storage/Delivery Logistics**
   Nicholas Josefik, *Construction Engineering Research Laboratory, US Army*
4. **Potential USPS Involvement**
   Ray Levinson, *US Postal Service*

10:00 am **Morning Break**

10:20 am **Session II: State and Industry Perspectives**
Moderator: Pete Devlin, DOE

5. **State Perspective: Connecticut**
   Joel Rinebold, *Connecticut Center for Advanced Technology*
6. **State Perspective: California**
   Mike Tollstrup, *California Air Resources Board*
7. **Fuel Cell Vehicle OEM Perspective**
   Britta Gross, *General Motors*
8. **Fuel Cell Company Perspective**
   Pinakin Patel, *FuelCell Energy*

MONDAY, OCTOBER 27, 2008

12:00 pm	**Lunch (Provided)**
1:00 pm	**Concurrent, facilitated breakout groups (Rooms 201, 202, 205, & 206)**
	Transportation and Stationary Power Integration ▪ Opportunities ▪ Barriers ▪ Implementation Strategies ▪ Information Resources and Needs ▪ Suggested Next Steps
2:30 pm	**Afternoon Break**
2:45 pm	**Continue Facilitated Breakout Sessions**
4:30 pm	**Breakout Group Reports, Key Themes, and Next Steps (Room 211A)** **Moderator: Fred Joseck**
5:45 pm	**Adjourn**

APPENDIX C
DETAILED OUTPUT FROM BREAKOUT GROUP DISCUSSIONS

Breakout Group 1 Participants List

Name	Organization
Nicole Barber	Chevron
Nico Bouwkamp	California Fuel Cell Partnership
Bob Boyd	The Linde Group
Robert Byron	UTC Power
Whitney Colella	Sandia National Laboratories
David Cun	Honda R&D Americas
Pete Devlin	US Department of Energy
Anna Domask	Energetics Incorporated (Support)
Amgad Elgowainy	Argonne National Laboratory
Paul Friley	Brookhaven National Laboratory
Leo Grassilli	Navy
Britta Gross	General Motors
Paul Lemar	Resource Dynamics Corp.
Ray Levinson	US Postal Service
Shawna McQueen	Energetics Incorporated (Facilitator)
Reuben Sendejas	California National Guard
Darlene Steward	National Renewable Energy Laboratory
Ken Stroh	Sentech

FEEDBACK ON CHHP STRATEGY

BREAKOUT GROUP 1

● Indicates issue with the biggest impact on the feasibility of CHHP

Benefits & Usefulness of Approach	Practical Considerations for Deployment	Best Applications

• Give LEED points for facilities that deploy CHHP (fuel cells for combined heat and power and H2 fueling/production) ●●●●●●
• Focus on early stations, first 2-5 per regional cluster (with intention to avoid stranded investment) ●●
• Barriers: cost of grid electricity; retrofit cost ●
• In the short term, CHHP has potential to create more infrastructure faster. The long-term business case may be geared more towards applications with vehicle fleets or other unique energy needs at particular locations.
• Visible locations will help familiarize public with H2 as fuel
• Reliability of power can be a big deal – this should be promoted as a benefit
	• Sounds great IF we can achieve the perfect balance between power, heat and H2. But realistically, will economics support a balance that results in enough H2 being produced (a balance that will change over time as the vehicle fleet grows from 2 cars/day→20→2,000)? ●●●●●
	• Do timelines of stationary implementation and transportation fueling needs coincide? ●●●●●
	  – Contracts for fuel cell CHP currently take 1-2 years to negotiate (mostly due to lengthy state and/or Federal approval process for funding from incentive programs). Contracts are closely tied to incentives.
	• Location is critical - site must be acceptable to both users of heat & power and users of fuel (and people need to want to go there to fuel up) ●●●●
	• A stand-alone business case for heat & power will be a necessary condition for successful CHHP ●●●
	• Big challenge is finding initial niche installation opportunities that capitalize on all benefits and meet consumer needs for market acceptance. This includes finding location with anaerobic digester gas available, close to where consumers may want to buy H2 fuel, electricity to gas price is high, and there is an opportunity to reuse the heat. (Finding the "4-fer") ●●
	• Are the advantages of this approach significant enough(compared to conventional CHP apps) to offset the risk ●
	• AB118 is a funding challenge – unclear if it will support funding for H2 fueling infrastructure
	• Must have lots of vehicles on the road to make it work
	• Interaction with electric grid is key issue: timing of grid purchases and sales will be important to economics
	• Need to consider and prevent unintended consequences or behaviors in decisions to produce power vs heat vs hydrogen...making money is always the driver!
	• Under current regulations CHHP facilities (like CHP facilities) will be unable to export power or heat without becoming regulated as a "utility"
	• Don't slow down the process for siting CHP fuel cells by trying to piece together the timelines for stationary and transportation – CHP is here now
		• Do CHHP where CHP makes the most sense: look for sites that already need cooling and chiller replacement ●●
		• Consider utility scale storage of H2 (e.g., in geologic caverns) as a way to use curtailed wind and solar power, with fuel cell power generation from the stored H2 when the grid needs it ●
		• Look for alternative uses for produced heat, besides just hot water
		• Agriculture/dairy is a potentially good early application
		• Put the applications where people want to go, e.g., shopping centers
		• Food industry is a potentially good early application (and could use H2 in food processing)
		• CHHP for corporations pursuing "sustainability" as a goal
		  – to attract employees
		  – provide fuel for fleet of green vehicles that would be available to employees
		  – green image
		• Universities with on-site power generation and district heating systems
		• Prime siting criteria for CHHP:
		  – good CHP candidate
		  – biogas available as renewable H2 feedstock
		  – located in state with incentives
		  – FCVs in the area
		  – multiple uses for H2
		  – accessible to public
		• Locate CHHP at big box warehouse distribution centers where forklifts use H_2; transition to H_2 fueling stations at retail sites "within the family".

FEEDBACK ON CHHP STRATEGY (CONT'D)

BREAKOUT GROUP 1

● Indicates issue with the biggest impact on the feasibility of CHHP

<table>
<tr><th>Configuration of Integrated Fuel Cell System</th><th>Analysis Emphasis</th><th>Other Factors</th></tr>
<tr><td>

The fuel cell, compressor, PSA, etc. are sized for a particular rate of operation and system works best at steady state operation. Varying production of H2 and/or electricity may be unrealistic. ●●●●●●
Compression and storage are the biggest costs of the fueling station -- who absorbs?
Consider operating strategies that minimize the need to ramp the system up and down (baseload power generation + generation and storage of H2 at night) and utilize net metering to optimize value of electricity
It is too early to exclude PEM fuel cells from the analysis, particularly for distributed power applications without significant heat loads
Can do load following to cycle. Can ramp down immediately. Number of start-stops is the main problem to avoid.
Consider a configuration that uses a fuel cell for base load, solar for peaking power, and organic rankine cycle (powered by waste heat) for hydrogen production

</td><td>

Do a business case analysis both with and without H2 production ●●●●●●●●
Analysis should include values for avoided energy costs (electric, H2, heat), avoided emissions, carbon credits, renewable power generation, increased energy efficiency, and any other incentives that might apply ●●●●●●
Not all of the CHHP sites need to have a fueling station. Consider options in which some sites just produce and store H2 (e.g., in a tube trailer) that would be delivered to a local fueling station●●●●
especially for sites with limited or inconvenient public access
Utility cost structure and the way they do business will change in response to increased distributed generation and renewable power – need to consider how this could impact choices and economics ●●
Consider that as more storage and distributed CHP comes on line, this could lower peak prices for electricity and change the economics
Operating strategies must be practical and realistic (e.g., turndown ratios, ramp rate, etc.)
Use the H2A model as a screening tool to give insight into best technologies, incentives, configurations, etc.
Consider option for oversizing the fuel cell to enable production and sale of electricity into wholesale spot markets when price is high

</td><td>

EPRI-like organizations missing (from this discussion) ●●●
A big challenge Is obtaining accurate measured or projected data for electricity, heating, and hydrogen demand over time coupled with real-time pricing data for these products over time by location in the locations where it is hypothesized that there is a market demand for H2, and considering how demand and pricing for these changes over the years ●●
Federal/national energy plan is needed to guide efforts ●●
There is a need for a seamless interface with renewable portfolio standard (RPS) databases to enable investors to evaluate opportunities across state/region lines ●
Long time horizon for projects requires stable regulatory environment/incentives
Carbon offset credits should apply to H2 production as well as on-site power generation
Consider options for third party financing, e.g., power purchase agreements, with tax credit to the investor
Are there learning effects that should be applied (e.g., effects that will lower cost of H2 production or automotive fuel cells?)
Can we find a way to increase the incentives for projects that impact two sectors (transportation and stationary)?
Better coordination and communication is needed between those who manage transportation and stationary energy within government and companies

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</table>

Suggested Next Steps

Breakout Group 1

Invitees for Future Workshops	Next Steps	Issues to Explore	Resource Needs
• Financial representatives, project planners, and energy service companies • California Energy Commission, New York State Energy Research and Development Authority, Self Generation Incentive Program (California Public Utilities Commission), Connecticut Clean Energy Fund, Ohio New Frontier, Hawaii program • Electric Power Research Institute • Utility companies • Private sector organizations who are operating CHP fuel cells • National Hydrogen Association • National Fire Protection Association	• Put together strawman business cases (including results generated from H2A) and hold workshop or web forum to discuss – target to particular applications (e.g., corporate sustainability case, military base, university, supermarket, etc.) – include all value streams (monetary and non-monetary) • Get European, Asian (etc.) perspectives • Evaluate distributed reforming (e.g., H2Gen) type business case vs. CHHP business case for early hydrogen production • Explain value proposition -- Why would a building that doesn't have fleet vehicles install CHHP? – To bring in traffic: big box stores, supermarkets – Provide the CHP now and move to H2 as demand builds, adding capacity as needed – CHP stands on its own in near term and does not necessarily need H2 fueling – Existing filling stations could possibly install CHP and provide some H&P to neighbors (would require change in regulations for energy export) – LEED (or non-LEED) buildings that "harvest" H2 for sale to a local (or distant) fueling station – Use H2 for things other than vehicle fueling and power (e.g., in food processing) • Consider a focus on L.A. and New York (metro and surrounding areas) -- where the incentives are (CA, CT, NY, NJ and MA) and where the FCVs are	Does CHHP make sense as a short term strategy for H_2 production? **Arguments for** • Less risk by having more products earning revenue • Marginal costs of additional equipment for H2 production is less than if built from scratch • Lowers siting barriers for H2 stations, especially in urban settings where space is at a premium • Reduces uncertainty over hydrogen demand and stranded assets (a big impediment to building early vehicle fueling stations) **Against** • Need to show what the H2 fueling piece really adds—why not just CHP? • Need to prove that this strategy will really lower H2 production & delivery costs • Need to assess the system's sensitivity to turndown and verify ability to operate at varying rates What is "early market"? • 2012-2014 (California timeline is important) • on the order of 7,500 FCVs	• Baseline data on outputs (quantity and quality) from different fuel cell types in these different applications – (kW, H_2, thermal energy) – Bob Bryon (UTC) has specification sheet for CHP; could provide 10% of H_2 production for fueling • Business case analysis needed on applications that make the most sense

Breakout Group 2 Participant List

Name	Organization
John Christensen	Consultant
Bill Elrick	California Fuel Cell Partnership
CJ Guo	Shell
John Hansen	Haldor Topsoe
Ali Jalazadeh	National Renewable Energy Laboratory
Fred Josek	US Department of Energy
Nick Josefik	CERL, US Army
Ray Levinson	US Postal Service
Zhenhong Lin	Oak Ridge National Laboratory
Jean Lee	Apple Computers
Greg Moreland	Sentech
Pinakin Patel	FuelCell Energy
Mark Ruth	National Renewable Energy Laboratory
Sunita Satyapal	US Department of Energy
Eileen Schmura	Concurrent Technologies Corporation
Atsushi Yamamoto	Japan Ministry of Economy, Trade and Industry
Rich Scheer,	Energetics Incorporated (Facilitator)

Feedback on CHHP Strategy

Breakout Group 2

● Indicates issue with the biggest impact on the feasibility of CHHP

Configuration of Integrated Fuel Cell System	Analysis Emphasis	Other Factors
• Yes. Internal reforming. Direct and indirect useful. Fuel choice? ● • Can power be easily diverted from building energy to create hydrogen fuel? • Timeline: At present PEM is most completed and has perfect durability. Lifetime of SOFC/MCFC?	• What is optimal balance of power, thermal energy, and H2 production ●●●● • Analysis of overall energy utilization for various buildings to identify the best candidates ●●●● • Business case needs to be assessed for integrated stationary/transportation application with transportation as secondary application ●●● • CHP facilities and H2 fueling locations likely not the same - How much to transport H2 from CHP sites and how far ●●● • It may be worthwhile to assess the benefits/penalties of decoupling H2 production from fueling. The best applications for H2 production probably aren't the best locations for H2 dispensing ●● • Who is the owner of these CHP/ H2 facilities? ●● • Offsetting investment risks of H2 transition ●● • Conduct total life/fuel cycle analysis of all options ●● • What is the economic/financial value of backup power from CHP/ H2 facilities? ● • Analysis emphasis shows benefit • Future analysis should in part become tactical. Apply new H2A model against FCV OEM early market regions, USPS, national guard, and other federal/state facilities in those regions • PHEV versus 700 bar H_2 – PHEV as transition	• More cooperation between Federal and state policies and incentives ●●●●● • Stronger government leadership (including local and community levels) for CHP ●●● • Government leadership needed ●●● • Include carbon credits in the analysis – who gets them? Utilities? Owners? ●● • This concept is primarily a short term transitional strategy – long term will involve centralized H2 production ● • What about heavy duty vehicles other than buses? ● • Good idea but no near-term driver for FC makers to invest heavily in this type of device • Are developers and others aware of the DOE loan guarantee program ($10B available) • Large government program to decrease dependence on foreign oil • Safety needs to be addressed • Large central production has advantage if carbon sequestration is required

FEEDBACK ON CHHP STRATEGY (CONT'D)

BREAKOUT GROUP 2

● Indicates issue with the biggest impact on the feasibility of CHHP

Benefits & Usefulness of Approach	Best Applications	Practical Considerations for Deployment
• Short-term = CHP, long-term = direct H2 to backup power • If nothing else, this dialogue will serve as a "shot across the bow" to the energy companies and industrial gas suppliers that the H2 infrastructure status quo is unacceptable	• Focus on residential and commercial locations to maximize power and vehicle fueling applications, i.e., post offices, shopping malls, etc. ●●●● • To make economics work we must have high CHP utilization, high grid electricity prices, and nearby use for the H2 ●●● • Net metering is important because it defines a high value site – allow sale of electricity to grid; greater value for peak power sold ●●● • Connecticut presentation represents a good model for a region, state. or local area (e.g., Southern California) to identify the best applications for CHHP. Important to identify best business cases for these applications ●● • Multi-use of H2 is very important: near-term = on-site use; long-term = fuel cell vehicles ●●● • Big box retailers; truck stops; energy security • Expand to include landfill gas for heavy duty vehicles or H2 for garbage fleet • Transit bus depot – CHP for building and H_2 for fleet	• Have a "Champion" onsite to make project most efficient ●●● • Who absorbs costs for high pressure (70MPa) dispensing, etc. ●● • 3rd party ownership- cost ● • Is natural gas infrastructure sufficient to support development ● • Gas expansion turbine (turboexpander) can be used to recover energy from gas compression/expansion • Need to consider codes and standards; compression requirements for high pressure dispensing; permitting ● • Concerned about viability when facing competition from off-peak grid power and CO_2 issue ● • Psychological barrier to H2 fuel adoption: many people concerned about safety. Need strategies to overcome this barrier to mass adoption of H_2 ● • Systems have not been proven- there is still technology risk to address ● • Limited number of fuel cell vendors who are able to produce systems • Centralized fueling for fleet vehicles required. Public access may be problematic. • How to deal with insurance and safety issues • Significant marketing and positioning to accomplish to sell this idea

Suggested Next Steps

Breakout Group 2

Next Steps	Issues to Explore	Resource Needs
• More detailed analysis of CHHP systems including a pilot project to refine system design and operating and maintenance costs • Develop costs for compression and storage requirements • Workshop to report on lesions learned, best practices • "Peel the onion" workshop – specific roll out of CHHP in targeted applications – Regional opportunities: CARB, NY – NJ, Connecticut • Find a way to communicate this opportunity to the new administration • Tie into LEED certification	• No design yet for full synergy of CHHP systems • After design there needs to be a demonstration for technology validation • Need a single clearinghouse (e.g., DOE) for information on incentives for fuel cell stationary and mobile projects – Information about both Federal and state – Basic information about stationary and mobile • What is the business case for users? – get value stream for peak power production and increased energy security • Need to find "sweet spot" target market and technology configuration for niche markets • Consider other markets for H2, even non-fuel cell applications and portable power • Consider ways to deliver H2 from distributed CHHP facilities that don't have fueling stations • H2 production from CHHP facilities must compete with existing H2 production • Educating facility managers is critical • Energy consumption patterns in buildings to match with output from CHHP facilities • How will building standards and commercial sites affect size and design of CHHP facilities • Is Federal support for H2 vehicles a long term prospect – If not why invest in CHHP?	• Get results from stationary fuel cell program in Japan – 1-kW systems • Get summary of lessons learned from similar programs from around the world • Expertise from CHP industry and distributed generation industry to determine best practices and lessons learned • Life cycle assessment and carbon footprint from universities and labs to businesses (Apple) who want to install • Simple analysis tools for calculating carbon footprint • "SWAT" teams of analysts to provide assessment of both Federal and commercial sites – FEMP support is limited – need supplementary, real time analysis of value propositions • Load profiles vary by facilities (electric and heat). For analysis, where does load data come from? – Proprietary or shareable for analysis – Sometimes available if sources "masked"

Breakout Group 3: Participant List

Name	Organization
Larry G. Christner	LGC Consultant LLC
Catherine Dunwoody	California Fuel Cell Partnership
Katie Jereza	Energetics Incorporated (Facilitator)
Jay Keller	Sandia National Laboratories
Paul N. Leiby	Oak Ridge National Laboratory
Marc Melaina	National Renewable Energy Laboratory
Michael Penev	National Renewable Energy Laboratory
Joel Rinebold	Connecticut Center for Advanced Technology, Inc
Eric Simpkins	IdaTech, LLC
Jinichi Tomuro	Engineering Advancement Association of Japan
Mike Tollstrup	Air Resources Board
Puneet Verma	Chevron

Feedback on CHHP Strategy

Breakout Group 3

● Indicates issue with the biggest impact on the feasibility of CHHP

Benefits & Usefulness of Approach	Practical Considerations for Deployment	Best Applications
• Environmental benefits (emissions, efficiency, etc) of the proposed strategy are not well defined, but are critical to demonstrating viability of approach ●●●● • Decentralized H2 and CHP can offer economic and environmental value when implemented early without established infrastructure and 3rd party involvement and can continue to offer value once infrastructure and 3rd parties are established ●● • The business case for building new H2 fueling stations for vehicles is difficult to justify due to the initially low H2 demand. Stationary systems can use excess reformer capacity to produce and export H2, thereby avoiding additional capital costs and adding potential revenue streams to the stationary owner/operator; another advantage of these systems is their ability to be upgraded annually ● • Good approach for accelerating early development/adoption of H2 fleets; recommend following fuel cell sales to identify potential sites ● • CHHP could be rapidly implemented by using existing CHP market • Deployment plan should be phased/staged to optimize utilization of energy products and enable long-term assessment of costs • Significant environmental benefits can be realized when using "renewable" gas to make H2 (this is essential in California!) • Use of CO2 from the direct fuel cell can reduce greenhouse gas impact and bridge gap to using renewable sources of H_2	• Evaluate the economic viability of a CHHP facility●●●●●●● – The major barrier is financial. A clear financial plan is necessary to make this happen quickly – Calculate the extra cost to a CHHP facility for retailing "spare H2" (How spare is it? Quantify the excess reforming capacity and the costs of installing, operating, and maintaining H2 purification systems, compression, storage, and dispensing (CSD) equipment, land, and safety – Address the number of vehicles required to justify CSD expense – Validate the business case for early adoption of a CHHP facility (Is it really "free" or "low-cost"?) • Ensure H2 fueling is convenient for drivers (i.e., real consumers) -- siting is critical to success ●●●● • Need to better define "renewable" and determine whether a renewable element should be included in the program to provide additional benefits (Can efficiency count?) ●●●● • Determine CHP site owner/operator interest in managing a public refueling operation (may need 3rd party operator) ●● • CHP site should focus on PEM • Resolve disconnect between conventional refueling stations and CHHP systems to enable deployment ● • Address issues with differences in growth rates—the number of refueling station is 6x vehicle rate ● • Is renewable feedstock available in volume? Does this feed into renewable hydrogen?	• Installations that are willing to invest in H2 fuel station for the long-term while reaping benefits of CHP today ● • Military sites and airports are ideal, but commercializing integrated systems beyond these applications must be determined • Government sites have risk aversion, but insurance problems may be difficult to resolve

FEEDBACK ON TSPI STRATEGY

BREAKOUT GROUP 3

● Indicates issue with the biggest impact on the feasibility of CHHP

Configuration of Integrated Fuel Cell System	Analysis Emphasis	Other Factors
• Evaluate all fuel feedstocks to determine technical feasibility, availability, consumer and producer preferences, renewable benefits; keep in mind cost is major driver • Develop fuel cells systems that are modular (e.g., PEM) or monolithic (e.g., MCFC, SOFC)	• Analyze CHHP balance; pro forma with known return on investment; internalize environmental values ●●●● • Compare CHHP to other alternatives in "early" transition ●●●● • Understand fragmented stakeholders with varied perspectives and objectives: determine who customers are, listen to voice of customer, and plan according to customer needs ●●● • Identify which applications are best suited to maximize benefits (understand differences with niche vs. mass applications) ●● • Need "big picture" analysis to include: consumer perspective; overall fuel usage; build out rate ●● • Key analytical issue: can we get/will there be any positive spillovers to transportation sector other than early fuel availability (i.e., scale economies and technology learning [learning by doing] for fuel cell reformer, storage, other components) ● • Clearly identify the problem CHHP is intended to solve (early small scale availability of H2) and determine if it is the most practical solution • Determine if CHHP approval will result in building an unnecessary infrastructure	• Federal and/or state government incentives (i.e., financial credit) could increase the number of direct fuel cells to supply CHP at small towns across the nation and create the base infrastructure for supporting hydrogen delivery systems ● • Codes and standards ● – weights and measures

Suggested Next Steps

Breakout Group 3

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• Invite broader participation in future workshops, including:
– electric and gas utility stakeholders; determine utility value proposition to encourage participation
– current and future owner and operators of fuel cell systems (“voice of the customer”)
– safety and compliance experts
• Develop and circulate TSPI Workshop meeting summary report
• Develop and circulate a TSPI research plan to address key issues
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• Gather and apply real world data as input for near-term decision making
• Capital data
• Operational data
• Develop siting criteria at the local level
– Where does the vehicle customer want to fuel, are there other customers who could benefit from this location, and who would want to own/operate this CHHP system?
– In this case, siting criteria refers to customer/supplier needs rather than environmental footprint
• Determine timing for CHHP (and needed roll out rates?)
• Achieve consensus on alternative solutions to understand where CHHP fits in developing a hydrogen economy
– Compare with other ways to provide small-scale early fuel availability
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• Obtain real world data from existing fuel cell installations, such as:
– Fountain Valley Project (see http://www.fountainvalley.org/documents/OCSD_Aug2008_Newsletter.pdf)
– International Energy Agency (IEA) Task 18: Integrated Systems Evaluation – could form collaborative working group to evaluate the CHHP option (see http://www.ieahia.org/page.php?s=static&p=task18)
• Pursue TSPI system demonstration systems
• Collaborate with the Interagency Working Group on Hydrogen and Fuel Cells (see: http://www.hydrogen.gov/interagency_task_force.html)
• Use realistic economic and technology-based assumptions established by DOE H2A Analysis Group (see: http://www.hydrogen.energy.gov/h2a_analysis.html)
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