

## Sub-Program Comments Provided by Reviewers

### Hydrogen Production and Delivery Sub-Program Comments

#### Hydrogen Production

**1. Was the sub-program area adequately covered? Were important issues and challenges identified? Was progress clearly presented in comparison to the previous year? (Include information presented in the plenary and/or session overview presentations of the sub-program if appropriate.)**

- Yes, the sub-program was well presented.
- The sub-program area was adequately covered, along with important issues and challenges. Progress was clearly presented in comparison to the previous year.
- The sub-program was clearly covered, and in great depth.
- The sub-program area was well covered. Issues and challenges were well identified. Given the number of technologies in the sub-program, presenting these might have been a challenge, but slide 5 provided a concise description for each technology and related the challenges across technologies—well done. Progress during the current year was well presented, but progress during the previous year was not as apparent, so a comparison between the two could not be performed.
- Yes, the sub-program was adequately covered.
- The sub-program was more than adequately covered; the important issues and challenges were identified; and there was good evidence of progress.
- The presentation summarized the sub-program well. The sub-program’s 2012 accomplishments were clearly identified.
- The Hydrogen Production sub-program was well covered and clearly articulated. The goals, accomplishments, and plans were well presented and on target.
- The sub-program was adequately covered. All of the current pathways were presented, and their barriers were identified. Progress was clearly presented in comparison with the previous year.
- Very broadly speaking, yes. There was much greater focus on accomplishments than on challenges and issues, but the latter are very hard to cover in a talk of this length.
- Yes. The “develop distributed and central technologies to produce hydrogen (H<sub>2</sub>) from clean domestic resources within DOE Hydrogen Production sub-program” debrief did not cover the 2011 achievements in detail; however, the sub-program mainly focused on 2012 program goals. The sub-program’s near-term and long-term challenges with respect to distributed production and centralized and semi-centralized H<sub>2</sub> production were identified. The U.S. Department of Energy (DOE) prioritization of research and development (R&D) needs in H<sub>2</sub> production clearly identified a technologies development road map through 2030.
- The Hydrogen Production sub-program review was excellent. The presenter provided the right level of detail to highlight the accomplishments and challenges of the program. In particular, it was nice to see that several areas, such as the TDA Research Inc. H<sub>2</sub> cleanup system (which has broader commercial potential than use just for biogas organic sulfur removal), demonstrated significant progress. Also, the progress underway with high-pressure electrolysis from Giner and Proton presents a nice cliff-hanger for next year’s review in terms of associated costs and performance.
- Excellent program oversight. One need is to indicate which fiscal year dollar amounts are expressed in (i.e., are the funds defined in fiscal year [FY] 2002 dollars or FY 2012 dollars).
- There is a need to consider whether the short-term portfolio is sufficient with regards to well-to-wheel emissions. The sub-program should very much focus on cost!
- The sub-program area was adequately covered. However, capital cost and process efficiency challenges for thermochemical production were not addressed in the presentation.
- Significant progress is being made in those research areas targeted for continued funding in FY 2013. The elimination of FY 2013 funding in selective research areas is a reflection of the ability of these technologies to show progress or a path forward if a technical barrier has been identified.

- The sub-program seems to be spending a lot of effort on exotic pathways of H<sub>2</sub> production. However, it seems to put very little emphasis on a very promising technology—solid oxide electrolysis. In the eyes of this reviewer, this technology is the most promising for renewable H<sub>2</sub> production. This reviewer is not a developer of the technology and does not stand to gain from its development. The reviewer is very informed about all pathways from a technical and economic point of view. Solid oxide electrolysis cell (SOEC) technology should be placed under a microscope, and its economics should be outlined and encouraged according to its merit. This technology has the potential to consistently produce H<sub>2</sub> at over 80% efficiency (lower heating value), with zero apparent degradation (due to less than thermal-neutral operation). SOEC can also have an extremely low capital cost, because the material operates at very high current densities. Solid oxide ceramics are also very dense, thus producing H<sub>2</sub> of very high purity due to the low diffusion of impurities into the final product. Recent information on performance shows that this technology can respond rapidly to transients, which makes it feasible for integration with variable renewables. It would be prudent to spend some effort analyzing this technology's merit, and place it in the spotlight to stimulate industrial development for nearer term, affordable, renewable H<sub>2</sub> production.
- No. This activity has been funded for many years, especially during the previous administration. It does not appear to have had much advance in the state of technology. The only discussion was on the use and improvement of an advanced modeling tool, the Hydrogen Analysis (H2A) model. It was unclear if progress was delayed due to funding limitations or greater challenges that could be overcome, or whether funds were given to model development over R&D. This should have been discussed more thoroughly.

## 2. Are plans identified for addressing issues and challenges? Are there gaps in the project portfolio?

- A detailed plan for addressing issues and challenges was identified. There are no gaps in the project portfolio.
- There are no apparent gaps in the project portfolio.
- The Hydrogen Production sub-program plans capture main challenges associated with fuel production. The technologies road map reported the successful conclusion of both natural gas (NG) reforming and biomass gasification R&D efforts.
- Gaps are well defined and in line with the Office of Energy Efficiency and Renewable Energy (EERE) mission.
- There are identified plans and challenges. There are gaps, but these are probably the result of the availability of funds. The sub-program is doing a good job, given the funding.
- Plans were well called out in the presentation. The sub-program portfolio covered the area very well, given program funding levels and priorities.
- The plans of this sub-program will adequately address the issues and challenges, provided there is sufficient funding.
- Plans were presented for addressing barriers/issues. The portfolio encompasses many different technologies, and all require significant experimental work to address the very challenging barriers to obtain DOE's targets for efficiency and H<sub>2</sub> cost.
- There are clearly laid out plans to address gaps. One remaining question is why there is so little emphasis on improving bio-derived liquids. Also, more analysis related to the costs of biomass feedstocks should be undertaken prior to diminishing the budget in this area. For instance, now that excess NG is available in the United States for power production (i.e., renewable portfolio standards), there should be more biomass available at a reasonable cost for H<sub>2</sub> production. The increase in funding for photoelectrochemical (PEC)-related projects was unclear and it was unclear if this technology will meet the production cost targets at a commercial scale.
- This overview spent little or no time discussing plans. There is one (very well used) slide discussing challenges at a very high level. There are few gaps in the portfolio, although it was sometimes hard to tell if individual programs were properly addressing the most important gaps.
- There is a big gap on large central production technologies and small-scale renewable systems. The Office of Fossil Energy and the Biomass program have funded the construction of a number of demonstration projects, but the data from these projects has not been modeled and used to judge state of the technology.
- The main gap is trying to separate the different program components (production, delivery, and storage) without looking for synergies between them. The reviewer asked if, for example, the liquefaction process can be (partly) run with waste heat from the production process. The ultimate goal is not improving H<sub>2</sub> production, but rather enabling H<sub>2</sub>-based transportation.
- The program should be looking at large-scale electrolysis for central H<sub>2</sub> production.

- There should be some focus on rural America and other isolated sites (i.e., off grid and off road). Fuel generated at remote localities could make a huge difference in how things are done “out in the boonies.” Technology that enables relatively small and rugged units that can be used in remote areas is a great idea for the H-prize. For example, units comprising solar-powered water electrolyzers and compressors and accompanying H<sub>2</sub> storage systems could provide power on demand at remote locations where liquid fuels are difficult to obtain. The technology could also serve safety, disaster response, combat, humanitarian, and third-world needs. In the latter category, there are regions in India where electricity costs 60 times the rate that New Yorkers pay. These regions are ripe for “leapfrog” technologies because the cost could be recovered quickly by a family, provided that appropriately sized units could be made available by advances in the technology.
- A well-to-wheel analysis was not covered. The sub-program needs to very much focus on cost.
- The elimination of funding for bio-derived liquids for distributed production seems appropriate, given that none of the technologies being pursued have a clear path forward for meeting cost targets. Furthermore, these technologies are rather complex, and it is hard to image them being operated in a distributed fashion.
- Plans for active engagement of the Concentrating Solar Power (CSP) Program were not addressed. Solar collection and concentration reflects major capital cost components for solar thermochemical production, and coordination/collaboration with CSP is essential to this area of H<sub>2</sub> production.

### 3. Does the sub-program area appear to be focused, well managed, and effective in addressing the DOE Hydrogen and Fuel Cells Program’s needs?

- Yes.
- The sub-program appears to be focused, well managed, and effective. This program is more demanding than some of the other sub-programs, because much of the work is long term in nature.
- The sub-program is well managed and even includes collaborations between other DOE offices as well as other agencies.
- Yes. The sub-program is looking at how to reorganize aspects and options to meet future projected cost targets.
- The program is well managed, but its focus and effectiveness are hampered by inadequate levels of funding to achieve sufficient progress that would retain the interest of stakeholders and researchers.
- The sub-program area does focus on main technologies and does address the DOE Hydrogen and Fuel Cells Program’s (the Program’s) needs. It is important to recognize that some R&D technologies may offer some technical merits while not being practical. Sub-program management needs to weigh each technology’s practicality in many areas (e.g., mass productions/fabrications and end-to-end system practicality).
- The sub-program appears to be well managed, but it seems too broad in scope.
- Better facilities are needed for environmental testing, specifically for compressor materials at elevated temperature in H<sub>2</sub>.
- Yes, in general. But the portfolio needs the uniform application of techno-economic analysis to identify the specific targets that must be achieved to reach H<sub>2</sub> production goals. It would probably be advantageous to focus more effort on approaches that have a higher probability of success.
- While the sub-program appears to be focused and well managed, this reviewer suggests that the sub-program keep abreast of progress being made in the DOE Office of Science’s Office of Basic Energy Science (BES) Energy Frontier Research Centers and hub programs for a number of the technologies being funded in centralized production to leverage those R&D investments and to make sure that effort is not duplicated.
- It is not clear if the biological production approach being taken will ever yield cost-effective H<sub>2</sub> production. Perhaps this approach should be focused on fundamental work only, funded and directed by BES.
- The project was focused on developing a new tool, but it was unclear if the tool was validated by industry and through independent analysis. Although the current portfolio was well managed, the presentation failed to adequately give the audience an understanding of the real technology development issues, especially if there was limited funding.

### 4. Other Comments:

- It is a good and carefully planned sub-program.
- This is a very well run team; emphasizing longer term research that is appropriate given that steam methane reforming (SMR) will dominate this area for decades to come. The challenges are substantial, but not impossible.
- Large-scale production is needed.

- Progress in key cost factors are explained by using a model that was recently updated.
- The feedstock cost is a significant portion of the cost of H<sub>2</sub> in many of the technologies being developed within this sub-program. It is extremely difficult to project the cost of the feedstock in the future; the sub-program's cost estimates have increased significantly over the last year due to factors such as increased demand, which again is very difficult to project forward. As such, it is very difficult to judge to what extent improvements in technologies being developed reduce the cost of H<sub>2</sub> independent of the feedstock cost. Compared to the cost of gasoline, which is the basis for the DOE cost target, the majority of the cost is feedstock. Although the H<sub>2</sub>A is needed, the principal investigators (PIs) should be instructed to clearly show how their technology reduces the capital and operating costs independent of the cost of the feedstock. This way, reviewers will have a better way of judging the impact of the R&D effort on improving the technology.
- Funding levels for the Hydrogen Production and Delivery sub-program have fallen to subcritical levels. The most effective response is to significantly reduce the number of options being pursued in order to ensure effective progress in a smaller number of active investigations. It is interesting to note that two long-term technologies with much higher 2015 and 2020 production cost targets (biological and PEC) receive about five times the funding allocated to a third long-term technology, solar thermochemical hydrogen production (STCH), with lower 2015 and 2020 production costs, while at the same time, the STCH target embraces much higher central production capacity than PEC or biological.
- The presentation tried to give the audience the feeling that technology was moving forward to achieve the key cost drivers. However, it looked like it was using the Hydrogen and Fuel Cells Technical Advisory Committee as an independent panel to support the portfolio, rather than actually evaluating the work and the funding allocation to achieve the production targets. The presenter should more clearly describe the state of technology and the barriers to getting large-scale commercial systems into the market.

## Hydrogen Delivery

### 1. Was the sub-program area adequately covered? Were important issues and challenges identified? Was progress clearly presented in comparison to the previous year? (Include information presented in the plenary and/or session overview presentations of the sub-program if appropriate.)

- Yes.
- The sub-program was covered adequately. Important issues and challenges were identified, and progress during the past year was presented.
- The sub-program area was adequately covered, with all important issues and challenges identified. Good progress has been made compared to the previous year in terms of improving efficiency and cost reduction.
- Yes, the sub-program was thoroughly covered. The presenter provided a balanced view on technologies and commercialization challenges.
- The presentation on the Delivery sub-program was excellent—thorough and encompassing. Goals and challenges were well articulated. Progress was clear and impressive.
- Yes. All of the delivery elements were identified, and their 2011 status reported. Cost reduction goals were specified. The overview presentation was concise and relatively easy to understand.
- Yes. The speaker did a good job of describing the issues/barriers and then presenting how the accomplishments address the issues.
- The program was well described. Economic and technical challenges associated with delivery were explained.
- The sub-program area was well covered. Important issues and challenges were well identified. Progress was well identified. The presentation used a very nice format that described status and progress by technology area: the slide banner named the challenge and progress, and the body of the slide noted the past year's accomplishments, recent accomplishments, and future work.
- This was a nice, careful presentation that touched on all critical issues, progress, and changes from last year. It clearly and succinctly showed the organization of the sub-program, goals, accomplishments, the status of work, and future plans.
- Yes, the Hydrogen Delivery sub-program covered both the 2011 achievements and future work/goals. Major challenges with respect to H<sub>2</sub> delivery technical changes, transportation, liquefaction, and delivery were identified. 2011 milestones and progress were clearly presented.

- The sub-program was adequately covered, important issues were covered, and progress was delineated within budget constraints. The presentation should have mentioned the team members.
- This was an excellent overview of the program and its progress. Important issues and challenges were identified, with the exception of funding.
- Given the limited amount of funding in these programs, it appears that significant progress is being made and that the advancements from last year were clearly apparent.
- Yes. The reviewer would like to learn about any collaboration with other federal (e.g., U.S. Department of Defense, U.S. Department of Transportation, and U.S. Department of the Interior) and state programs, as well as other countries (e.g., India and Germany).
- The presenter covered the sub-program very well.
- The Hydrogen Delivery sub-program area is well addressed by the range of projects. High station costs are identified as a primary concern, and there is a reasonable focus on projects exploring compressor and storage costs. The range of projects is well justified and focused on areas where delivery cost reductions are possible and needed.
- The presentation adequately covered the barriers and challenges to reducing the cost of delivered H<sub>2</sub>. Progress could have been presented in a more direct fashion; specifically, why the approach has changed from the higher risk of developing adsorbents versus overwrapped conventional equipment. Similarly, the reviewer asked whether analysis or the lack of R&D results led to the change in direction.
- The content of the sub-program review was excellent in laying out the near- and long-term market scenario for H<sub>2</sub> delivery. Also, the new cost targets for H<sub>2</sub> production, delivery, and dispensing were introduced. Clear examples were given of how the delivery targets can be reached in the near term through the use of high-pressure tube trailers, which will allow minimization of high-cost compression at the forecourt and/or the use of fiber-reinforced pipeline systems. Also, challenges such as the regulatory hurdles for high-pressure tube trailers were highlighted. The sub-program accomplishments served as proof points that the delivery cost objectives can be met. For instance, the Lincoln Titan carries five large-cylinder glass-fiber-wrapped vessels with increased carrying capacity of 18% over the four-cylinder module that meets the 2015 target.
- Delivery is an essential component in the realization of the fuel cell electric vehicle (FCEV) market. The Delivery sub-program addresses long-term to early-market scenarios and involves technical pathway cost analysis. Each solution pathway (e.g., tube trailer transport, pipeline transmission, and so forth) has been systematically investigated from both an engineering and cost analysis perspective. Substantive collaborations among national laboratories and industry are strengths of the sub-program.
- The presentation needed additional focus on early market barriers (e.g., a pipeline seems to be a very long-term path).
- More work needs to be done to improve component reliability in delivery and dispensing systems. As the sub-program recently was reminded, the failure of components can be catastrophic to the industry. More testing of various valves, sensors, and electronic controllers needs to be performed in a controlled environment before systems are fielded (e.g., testing 1,000 valves of type A, type B etc.). This needs to be done so that reliability can grow without jeopardizing actual installations. The reviewer has heard from California installations that valves and fittings have been the weakest link for years, and that is something that DOE can address for the industry at large.

## 2. Are plans identified for addressing issues and challenges? Are there gaps in the project portfolio?

- Yes. The most important bases were covered.
- The plans presented appear to be adequate and realistic. No gaps were noted in the project portfolio.
- A detailed plan for addressing issues and challenges was identified. There are no gaps in the project portfolio.
- Concise plans were presented for addressing barriers.
- The gaps have been well identified. With the exception of applying more budget to get it done faster, the sub-program is doing a good job.
- The program has done a good job with limited funds to identify and address areas where DOE investment can facilitate and enable delivery. Gaps do exist, but they cannot be addressed with current program funding levels.
- Plans are well called out for addressing issues and challenges. For the given funding, the portfolio covers priority issues very well.
- There were no major gaps.

- All critical components were covered.
- Plans for addressing issues and challenges have been identified. Any gaps are attributable to the availability of funds.
- Plans are discussed. Long-range goals and objectives may need to consider materials science barriers.
- The Hydrogen Delivery sub-program plans capture main issues and challenges associated with fuel delivery. However, H<sub>2</sub> fueling stations, locations, fuel storage, and consumers' easy access were not addressed.
- Future plans are all well thought out. Given the significance, magnitude, and variability of the compressor cost, the two projects involved in the program need to be given priority and carefully administered and reviewed.
- The overall plan is excellent. The addition of some focus on early markets is very appropriate. A few useful additions to the plan could include clearer effort on the pros and cons of liquid vs. gaseous H<sub>2</sub> delivery, some clearer focus on cold gas delivery, and potential utilization of the Lincoln Composite Titan 4 ISO unit for storage at stations and terminals to reduce these storage costs.
- Plans were identified. Some strategic consideration needs to be given to setting priorities for delivery technologies and costs for near-term, intermediate-term, and long-term options. This strategic assessment should be executed in light of estimated H<sub>2</sub> consumption levels in the near term, intermediate term, and long term. Driving costs down through investments for options that might never be employed, or that might be employed for relatively brief periods, could supplant R&D investments for much lower cost and more extensively deployed delivery options.
- The plans presented address the key issues, but more information should have been presented on the economic characterization of the complete system to achieve the \$4 per gallon of gasoline equivalent (gge) target. It was not clear why there hasn't been more demonstrated success, especially given that this work has been in progress for a number of years.
- Key roadblocks of retail site costs for compression and bulk transportation were identified.
- A number of the technological and regulatory challenges were addressed. The portfolio seems to be addressing all of the key areas. This reviewer suggests obtaining data on the Lawrence Livermore cryo-compression unit with vehicle dispensing, because this seems like a viable approach for addressing delivery costs.
- The problem of H<sub>2</sub> delivery cannot be treated as a separate problem from the problem of storage. If the program focuses on minimizing H<sub>2</sub> delivery cost, the result may be a technology that increases the cost of vehicle storage, increasing the total cost of ownership. The program needs to look for synergies between production, delivery, forecourt, and vehicle storage, and concentrate on supporting those.
- There do not seem to be any real gaps in the portfolio of projects.
- There should be some focus on rural America and other isolated sites (i.e., off grid and off road). Fuel generated at remote localities could make a huge difference in how things are done "out in the boonies." Technology that enables relatively small and rugged units that can be used in remote areas is a great idea for the H-prize. For example, units comprising solar-powered water electrolyzers and compressors and accompanying H<sub>2</sub> storage systems could provide power on demand at remote locations where liquid fuels are difficult to obtain. The technology could also serve safety, disaster response, combat, humanitarian, and Third World needs. In the latter category, there are regions in India where electricity costs sixty times the rate that New Yorkers pay. These regions are ripe for "leapfrog" technologies because the cost could be recovered quickly by a family, provided that appropriately sized units could be made available by advances in the technology.
- The regulatory and public acceptance issues related to H<sub>2</sub> pipelines are likely to be a significant non-technical barrier.

### **3. Does the sub-program area appear to be focused, well managed, and effective in addressing the DOE Hydrogen and Fuel Cells Program's needs?**

- Yes.
- The sub-program looks to be in very capable hands.
- Yes, the sub-program is well managed. There is a focus on cost reductions, and the vendors are well on their way to meeting the goals. This is a mark of an effective program.
- This sub-program appears to be exceptionally well organized and managed considering that it appears to be relatively underfunded, considering the magnitude of the issues and potential showstopper capabilities of these issues.
- The program seems focused and well managed. Breaking the effort into near-term and long-term market scenarios is a valuable way for accelerating the development and deployment of the technologies being pursued.

- Yes, the prioritized path is well planned. The analysis conducted over the years has forced or tracked progress toward the goals.
- The sub-program administration and technical team are strong. Individual projects are steered toward DOE targets. The program has been very well managed. Research and technology priorities have always been identified and pursued systematically.
- The sub-program has been well managed. Outstanding analysis efforts have guided research efforts to ensure that dollars are spent in areas that matter. Despite limited funding, several projects have advanced to demonstration or commercialization, including trailers, centrifugal compression, and magnetic liquefaction.
- The sub-program appears to address major issues to reach the defined goals. It is good to see both liquefaction and compression solutions in the mix.
- The focus of the sub-program is good. The execution of roadblock items has been delayed due to funding. But there is good progress on compression, lightweight transport cylinders, and reduced-cost liquefaction.
- The sub-program managers have managed the program very effectively.
- The area is focused, but management appears to be more laboratory-directed than headquarters-directed. It is unclear whether the approvals for performance standards, for example, are leading the technology or lagging it. It is also unclear how much of a role each technology plays in achieving the final targets, and whether they are interrelated so that all must be achieved, or whether there are other sensitivities.
- The Hydrogen Delivery sub-program is focused only on the delivery of fuel and not on fueling stations and fuel storage.
- Greater priority is needed on the fiber-reinforced polymer pipeline technology, which could be a real winner.
- Better facilities for environmental testing are needed, specifically for compressor materials at elevated temperature in H<sub>2</sub>.

#### 4. Other Comments:

- It is a good and well planned program.
- This was a very nice, tight presentation.
- The sub-program has worked in areas where market pull from applications such as compressed NG has helped enable the early commercialization of products.
- The presentation should have included results from the California Fuel Cell Partnership refueling station designs and operating costs to give the audience an understanding of how much of an improvement this technology approach will make in reducing the cost. Currently, there are more than 5 years of actual operating data with incremental improvements in the technology. The reviewer asked how these results compare, and whether the development cycle takes as long to enter the market.
- Given the importance of H<sub>2</sub> infrastructure that supports a variety of applications (truly the most important crosscutting area), public investment should be prioritized on infrastructure challenges. The major automobile manufacturers will solve the design and production of vehicles, but they need infrastructure so that the public can use their vehicles. At least two major auto companies, General Motors and Toyota, plan to roll out their fleets in 2015. The major challenge they are facing is that the fueling infrastructure to support these fleets is not there yet. It is unrealistic to think that the car companies will set up the infrastructure. That should be a federal function, just like the interstate highway system. The reviewer noted that this program solves many of the technical problems, and asked whether it could do more with more funding. Dropping an already small budget from \$5.2 million (2012) to \$2.9 million (2013) is not going to get us there fast enough. This sub-program should be made a much higher priority.
- Some strategic consideration needs to be given to setting priorities for delivery technologies and costs for near-term, intermediate-term, and long-term options. This strategic assessment should be executed in scenarios of estimated H<sub>2</sub> consumption levels in the near term, intermediate term, and long term. Driving costs down through investments for options that might never be employed, or that might be employed for relatively brief periods, could supplant R&D investments for much lower cost and more extensively deployed delivery options. Whereas the targeted delivery costs are chosen to provide incentive for early deployment and commercialization, such costs should be targeted in concert with technology deployment in the areas of production and consumption. Cheaper is not necessarily better in the context of parallel capability development.
- It is unclear whether the cost targets are expressed in FY 2012 dollars or FY 2002 dollars. Pathway challenges are clear indicators of the direction forward, with the cross-modal common challenge.
- Model development of HDSAM has been and remains key to understanding the cost limitations of the scope of this sub-program.

## Hydrogen Storage Sub-Program Comments

### 1. Was the sub-program area adequately covered? Were important issues and challenges identified? Was progress clearly presented in comparison to the previous year? (Include information presented in the plenary presentation of the sub-program if appropriate.)

- Yes.
- The sub-program area was well covered and the challenges and progress highlights were presented clearly.
- The presentation summarized the program well. The 2012 accomplishments were clearly identified.
- Yes. Issues and challenges were clearly delineated for all types of H<sub>2</sub> storage. Progress was also clearly shown with examples.
- The sub-program area was well covered with a clear view of progress made in the current year. The presenter showed a clear understanding of the technical and programmatic details of the sub-program projects.
- All aspects were covered completely along with valuable information and examples.
- The presentation was clear and progress indicators were provided. A specific comparison with last year was not given, nor was it really needed given the way that the presentation was delivered.
- This was an excellent overview of sub-program activities and priorities. There was a good discussion of important issues and challenges. New R&D thrusts for 2011 and 2012 were introduced, and the impact of continuing projects on the overall program was highlighted. Overall, it was a very clear and illuminating presentation.
- Yes, definitely. The presenter did an excellent job covering the different ongoing activities and addressing the important issues and challenges of H<sub>2</sub> storage in both the long and short terms. The inclusion of applications beyond vehicular H<sub>2</sub> storage was welcome. The technical progress was clearly presented, especially in system modeling and system design.
- The presenter did a good job covering the status of the sub-program. The talk was verbally clear, but as usual, the slides were flooded with too much information to take in with a quick glance.
- The sub-program area was adequately covered. H<sub>2</sub> storage materials and the associated engineering are major issues, but the cost reduction of high-pressure cylinders is also an important issue to be covered in this sub-program. Some parts of the H<sub>2</sub> storage field are conducted with close coordination to related projects. International collaboration could not be found in the presentation.
- The goal seems to be to develop and demonstrate viable H<sub>2</sub> storage technologies for transportation, stationary, material handling, and portable power applications. There are four key elements of the storage sub-program: advanced tanks, materials development, engineering, and testing/analysis. Targets for each application area are pretty well addressed, but the vast majority of the work is focused on transportation and materials for transportation, with little work on portable power and stationary applications. This reviewer does not understand the value of close coordination with the DOE Office of Science's Office of Basic Energy Science (BES), because BES researchers make it clear that their work is focused on basic science and that they are not focused on practical application. Progress toward goals was highlighted well; however, progress of 2012 vs. 2011 was not highlighted. The sub-program areas were adequately covered and important issues and challenges were identified well.
- The cross section of storage activities was adequately represented. Progress in some areas was more apparent than progress in others. Some areas, such as spillover and improving the binding of H<sub>2</sub> in metal-substituted metal-organic frameworks, need more clear guidance as to what success looks like. These areas seem to be in the incremental phase, where little progress is being made, and are both far from attaining DOE targets.

### 2. Are plans identified for addressing issues and challenges? Are there gaps in the project portfolio?

- There is no gap in the project portfolio. The plan is well considered, considering the limited budget.
- The plans are focused on the DOE targets.
- Plans were identified for addressing issues.
- Clear plans and pathways for addressing the important issues and challenges in the different areas were presented. In addition, improvements over the current baseline materials-based systems were identified. Given the obvious limited funding, the project's portfolio is well balanced. The addition of performance targets for projects in areas other than vehicular applications closed a preexisting gap.



- Issues and challenges were adequately addressed. There are still some gaps in terms of meeting targets (e.g., DOE H<sub>2</sub>-storage system targets).
- Plans for reducing the costs of tanks appear to be well planned and executed. Boron-nitrogen-based organic storage materials appear promising. Two major gaps in this technology are off-board regeneration issues and the potential toxicity of the materials. Either of these has the potential to be a showstopper.
- Yes. A thorough description of projects and the issues the projects are addressing was provided. Also, a road map for the remainder of FY 2012, FY 2013, and FY 2014 was given. There are significant challenges with all chemical storage options. The costs for all storage systems will be very difficult to reduce. It seems unlikely, with a nearly 20% cut in funding for FY 2013, that any new work on the discovery of better storage materials can occur. It is also unclear whether other organizations such as BES, the National Science Foundation (NSF), and others will adequately support the critically needed fundamental research necessary for H<sub>2</sub> storage materials.
- Future plans were clearly identified. Due to funding constraints, the project portfolio is limited and has a focus on systems engineering, which may be premature. Current materials do not meet DOE goals. The program's level of effort on the discovery, development, and improvement of new materials does not match the needs of the program and country. Industry is capable and well positioned to address all engineering challenges if given viable storage materials. However, industry is not in the position to provide the resources, expertise, or risk associated with the development of a new and difficult technology based on materials discovery. This is a gap that should be filled by government-funded R&D and should be the focus of this sub-program.
- There are well-poised plans to address issues. There are gaps largely due to the ever-dwindling budget. The major requirements are still materials, especially now that the engineering center has made meaningful progress on system designs. Plans to address compressed tank costs are desperately needed. The economic success or failure of FCEVs will hinge on rapid cost reduction in fuel cells and (more relevant to this group) compressed gas tanks. Currently all of the material-based storage media fall short of the 2017 DOE targets and there is very scant resource available to create new materials. The plan to use NSF/BES and others to partly stop this gap is innovative, but insufficient. EERE is the only organization that drives to performance goals. As a result, it is the only one likely to deliver the needed storage materials.
- In general, plans to address technical obstacles were effectively summarized. However, in this reviewer's opinion, there is one important component that is missing from the overall portfolio. Nonreversible chemical hydrides (especially ammonia borane and alane) have emerged as important materials systems in the engineering development projects in the sub-program. However, very little effort is being directed toward the daunting challenge of efficient and cost-effective regeneration of the spent fuel. Development of an efficient onboard H<sub>2</sub> delivery process complete with contaminant mitigation is of paramount importance in the near term. However, finding a cost-effective process for regeneration could, at best, limit the timely introduction of a working system, or at worst, it could be a showstopper altogether. DOE management should take a close look at the regeneration issue and consider how the sub-program might be able to accommodate a more robust activity in that area.
- There does not seem to be an adequate plan for addressing the fact that there are not adequate H<sub>2</sub> storage material candidates for which a system can be engineered. The needs of portable power systems and stationary systems are not well addressed.
- A stage-gate review of spillover efforts and the sorption work needs to be considered very soon as those areas seem to have "hit their asymptote."

### 3. Does the sub-program area appear to be focused, well managed, and effective in addressing the DOE Hydrogen and Fuel Cells Program's needs?

- Yes.
- Yes, with the current scenario of decreasing budgets.
- This is a well-managed sub-program.
- This sub-program is well thought out and properly focused on addressing the major issues and technical challenges of H<sub>2</sub> storage. The strong technical background and the experience of the sub-program manager in the field of H<sub>2</sub> storage are having a very positive impact on the quality and directions of the sub-program. The sub-program appears to be very well managed and rigorously coordinated and geared toward satisfying the DOE Hydrogen and Fuel Cells Program's needs.
- The sub-program is very well managed. The DOE Technology Development Managers are well respected by the project PIs and other participants, and they are doing a top-notch job of coordinating the efforts, anticipating program needs, and organizing new technology funding thrusts to support emerging areas. This reviewer

strongly supports their decision to maintain a high-risk/high-payoff component in the sub-program in addition to the engineering system development efforts. The sub-program management has done an excellent job of making a compelling case for continued support of the overall program in the face of difficult funding challenges.

- Yes. It is focused and well managed, and the managers are knowledgeable about the history and content of their program. It is focused on meeting the DOE targets in general, but there are a few projects out there that will be unable to achieve the targets and those projects should be reevaluated.
- The sub-program is both focused and well managed. They do a very good job with the funds allocated, but it is not likely that they will meet their goals at this level of funding. If funding cannot be expanded, the sub-program might need to focus further on compressed gas and one other approach (based on what was presented, adsorbent-based materials would be the most likely candidate). While the broad approach makes sense at the current level of progress, the budget is not sufficient to make real progress in all areas, and thus focusing on a couple of leading routes would be required for serious progress.
- The sub-program is focused and very well managed. However, budget reductions have left the critical area of materials-based H<sub>2</sub> storage development essentially unsupported. Because of this, a vital element of the Program's needs is not being sufficiently addressed. This is a gap in a long-term plan that significantly diminishes U.S. technology leadership. Hopefully, funding can be found to support a condensed and cooperative group of experts to make substantial progress on this challenging issue.
- The sub-program is well focused as far as the efforts of the Hydrogen Storage Engineering Center of Excellence (HSECoE) are concerned. Some of the peripheral projects, particularly ones at universities, could probably be dropped, because they are not addressing systems/approaches that have a chance of helping the HSECoE meet its 2014 objectives or the 2017 DOE H<sub>2</sub> storage system level targets.
- The sub-program area appears to be focused a little bit tightly. The materials for validation downselected by the engineering center of excellence are adsorbents and liquid-state chemical hydrides. Because there are no longer any materials centers of excellence, the only independent research is under EERE and fundamental research is under BES (which conducts advanced material research). More materials work may be needed to explore alternatives for downselected materials. Management of the sub-program is appropriate and the sub-program is effective in addressing the Program's needs.
- The major shortcoming of the storage program is that it is currently operated in isolation and focused almost entirely on the onboard issues associated with storage. By looking at onboard issues only, the sub-program has expended resources on suboptimal systems that appear promising on board, but have off-board issues that will preclude their adoption. A systems approach would have benefitted the program significantly and led to more efficient utilization of limited resources. Expansion to forklifts and portable power are good additions to the program.
- Some of the BES researchers need better focus. In more than one talk, the presenter clearly had not done proper prior literature review and was essentially repeating work already done very well in the materials centers of excellence, which ended in 2010. It remains a fact that "an [hour] in the library will save you a [month] in the lab." The engineering work going on in the HSECoE looks quite solid, with good decisions being made on go/no-go decisions. The research at the University of Oregon looks fabulous. There should be more projects like these.

#### 4. Other Comments:

- This sub-program is in many ways a "poster child" for how DOE programs should run. There is a proper balance between the needs of several industries with involved and interested industrial advice, world-class research projects, and active and effective program management. All the storage program needs is proper funding.
- The organization, planning, and execution of the HSECoE are exceptional. Savannah River National Laboratory is doing a great job running the center and the partners are making significant contributions. Thought should be given to extending the project through 2017 to give the center a better chance of meeting DOE's 2017 performance targets.
- Despite the continually decreasing funding, this sub-program remains at a high quality, is effective, on track, and continually focused on the real issues in H<sub>2</sub> storage. However, it is severely underfunded at this stage and it would really need more resources to get a real chance of advancing the storage technologies toward meeting the technical targets.
- This program should stay the course.

- The energy efficiency of the various storage options should probably be addressed more directly. Application-specific targets for storage systems should have been established. This reviewer fears that some materials that could be good for applications other than transportation could be discarded.
- The high cost and low efficiencies for alane and ammonia borane will prevent these technologies from ever being implemented. If the sub-program wants to continue work on these systems, it should reallocate resources to see if it is possible to improve these, rather than continuing work on onboard properties.
- The program seems to have a particular focus on cryosorbant material research (i.e., metal-organic framework). Because design ideas have resulted in several new materials, establishing H<sub>2</sub> storage trends as a function of material properties is recommended, as it aids in establishing the viability of overcoming challenges related to their intrinsic properties such as density, heats of H<sub>2</sub> adsorption, and so on. This may allow the program to focus more on the most promising materials.
- There is no comment on international collaboration in the presentation. Specifically, this sub-program's known current collaboration under the umbrellas of the International Partnership for Hydrogen and Fuel Cells in the Economy and the International Energy Agency Hydrogen Implementing Agreement were not adequately addressed. The budget for this subprogram has been reduced year by year; therefore, international collaboration becomes even more important to share the recent achievements conducted by other countries.
- The slides are sometimes a bit busy and hard to read from the back of the room.

## Fuel Cells Sub-Program Comments

### 1. Was the sub-program area adequately covered? Were important issues and challenges identified? Was progress clearly presented in comparison to the previous year? (Include information presented in the plenary and/or session overview presentations of the sub-program if appropriate.)

- Yes.
- Yes. The introduction was perfect.
- Yes. This presentation provided a broad, but brief, overview that highlighted both the outstanding challenges and some key results.
- Yes, clear and exciting progress from last year was clearly shown.
- The fuel cells area was clearly and comprehensively covered. Successful examples were described, and the remaining challenges were discussed.
- Yes. Given the short time for presenting such a large body of work/progress, the presentation seemed to summarize the program well.
- Yes. The Fuel Cells sub-program area was adequately covered in the presentation. The progress as compared to the previous year was clearly presented.
- The area was well covered, and the cost drivers were clearly articulated that inform the use of the available resources. Progress was demonstrated from prior years, and the steady improvements were documented.
- The Fuel Cells sub-program was well covered. The objectives, strategy, and challenges were highlighted, along with recent progress. Automotive, stationary, and portable applications were all well covered. These are all important markets for fuel cells.
- The description was good. Annual progress was presented, and at least some of it was described (there was a lot of progress to review, and not much time).
- Yes. The sub-program area was adequately covered, important issues and challenges were identified, and progress was clearly presented. The issues of cost, durability, and performance were highlighted, and progress was presented, covering a range of fuel cell types, including polymer electrolyte membrane (PEM) fuel cells, portable fuel cells, and solid oxide fuel cells (SOFCs).
- The sub-program area has been well covered, and the most important issues and challenges have been well identified. The project “A Total Cost of Ownership Model for Design and Manufacturing Optimization of Fuel Cells in Stationary and Emerging Market Applications” might have also been presented with the two other cost analyses, as the question of total cost of ownership is critical for fuel cell commercialization. The main progress since last year has been clearly presented.
- Yes, although it would be good to see overall goal charts and progress broken out by components.
- Yes. The sub-program usually calls out highlights, which is expected, but it would be interesting to see a table of all of the different catalysts studied (by catalyst type and project) and show side-by-side where they are at for various activity and durability metrics. The same could be done for membrane conductivity, water transport model fits (at various current densities, or under a specified transient condition), and so on.
- Highlights of the sub-program were adequately covered. Considering the length of the time for the talk, a comprehensive review is not possible. Some of the more important issues were covered—cost is always the most important. The need for fuel processor cost reduction was highlighted, as was the need for fuel cell durability to be enhanced. Progress on catalysts, portable power, and humidification (balance of plant) were covered.
- This was a very effective overview. One additional area that might be mentioned is the complementarity of fuel cells and batteries for transportation: batteries make more efficient use of renewable electricity but are limited in range and rate of recharging; fuel cells provide full-function vehicles with good range and rapid refueling but have lower overall efficiencies for utilization of the currently most practical forms of renewable energy. Fuel cells also require more fueling infrastructure than do (slowly recharged) batteries. Both still face cost challenges.
- The sub-program was adequately covered, and the primary challenge of cost for automotive and stationary systems was identified. The challenge with increasing durability was not addressed. Progress was clearly presented, with highlights demonstrating increased catalyst durability and increased direct methanol fuel cell and direct dimethyl ether fuel cell catalyst activity.
- The discussion on projected transportation fuel cell system costs, on slide 6, has many assumptions in it. It would be valuable to state some of the most major assumptions, such as the cost/performance being based on nanostructured thin film (NSTF) technology. Similarly, it would be nice to see this same discussion based on the

standard technologies that developers are actually using (e.g., dispersed platinum (Pt) on carbon supports) because to date, there is not an indication that developers have been successful in using the NSTF. Knowing where the program stands in terms of cost analysis with standard materials versus non-standard materials would be valuable.

- For the objectives, all areas were well covered. For micro-combined heat and power (CHP), only electrical efficiency was listed for 5 kW systems, while total efficiency >90% was listed for >100 kW CHP systems. It was unclear why total efficiency for micro-CHP/5 kW was not included. There are examples of 5 kW micro-CHP systems with >85% total efficiency, operating on NG. There were good examples of progress presented, such as 3M's work and GM's work on de-alloyed catalysts, meeting or exceeding DOE goals.
- The sub-program was not covered adequately. Select projects were highlighted, but it is not clear that the sub-program has a clear plan for how it will bridge the gap from its current status to ultimate targets. All of the important challenges were listed, but the budget breakdown suggests that only a few of these challenges are prioritized. The only quantifiable progress highlighted was a minimal reduction in the projected high-volume cost.

## 2. Are plans identified for addressing issues and challenges? Are there gaps in the project portfolio?

- Yes.
- Yes. There are no obvious gaps in the project portfolio.
- There is no gap in the project portfolio. All of the issues and technical challenges have been identified, and the strategies to address those issues and challenges have been planned.
- All plans address the issues. There are no apparent gaps.
- Yes. Cost and durability issues were emphasized, and the projects being funded are (mostly) aimed toward these key barriers.
- Plans have been made for addressing the remaining issues and challenges. The plans are a good use of the amount of funds allocated.
- The plan forward seems to be very adequate.
- Issues and challenges were well defined and identified.
- Some guidelines to address the challenges were discussed.
- Issues and challenges were identified as "targets." The plan for addressing the targets was clear.
- In addition to laying out component or modeling status versus target metrics, there could also be a very cursory description for each project of what gaps need to be addressed.
- Yes. With more resources, more catalysis, membrane, and alternative fuel cell research (e.g., for alkaline, reversible, and toward reduction-oxidation flow batteries) should be included.
- Good plans are in place for fuel cell systems.
- Plans are in place for most stack aspects, but balance of plant (BOP) is not sufficiently covered to make important progress. While not the biggest cost factor, it is an important one that can contribute to the eventual success of the FCEV economically. It is encouraging to see increasing manufacturing aspects.
- Plans were identified, which were largely more of the same for this past year. A major gap in the portfolio is in the membrane development area, particularly membranes that can handle liquid fuels. The use of liquid fuels as a long-term goal was also underrepresented.
- The membrane activities seem to be deficient. In addition, the new funding opportunity announcement (FOA) is vague—it should at least point out the major topics and emphasis.
- This program has many projects ending and almost all are ending in FY 2013. When those projects end, there are tremendous gaps, even if the DOE alternate projects are awarded, and certain areas were not included in the last solicitation. The major example is that there will be no durability projects after FY 2013, as the current projects will all end, and the subject was not addressed in the latest solicitation. Other areas that are not well covered include advanced membrane development (i.e., hydrocarbon and high-temperature) and mass transport, which was also not covered in the last solicitation.
- There is no funding for many of the focus areas listed in the presentation. This is a major concern going forward. Areas with little or no funding include membranes, electrolytes, gas diffusion layer (GDL), plates, seals, and interfaces. Meanwhile, there are numerous projects that seem to overlap in their focus (i.e., accelerated stress test development, nanowire catalyst, and transport modeling). Much better distribution of resources is required. Also, the strategic analysis can be misleading. For example, the analysis shows that stack power density is the single

biggest factor affecting fuel cell system cost. However, to enable higher power densities while simultaneously meeting thermal heat rejection targets, higher temperature operation will be required. Currently, there is no focus on higher temperature automotive systems or components.

- The importance of contaminants' effect on fuel cell performance and durability can be highlighted more. The plans for addressing issues and challenges are vague. More funding on lowering fuel cell cost and increasing durability and performance seem to be a more appropriate use of DOE funding, rather than developing low-cost BOP components.
- Plans for cost analysis were identified, and several future milestones relating to costs were presented. There are currently gaps in the portfolio, and the situation appears to be worse in the near future. One current gaps are high-temperature PEM and polybenzimidazole-phosphoric acid systems, both of which are receiving a lot of attention in Europe but are not represented in the current portfolio. Phosphoric acid and molten carbonate research is also a large gap in the portfolio. Another gap is PEM membrane research, where the current projects are ending but no new membrane projects are scheduled to start. Fuel processor work is currently underfunded. With a decreasing budget the last few years and the recent expanding scope to include an "all of the above" strategy encompassing all types of fuel cells, there is simply no way to avoid large gaps in the portfolio. Increased funding is needed to cover the expanded portfolio. With the majority of projects culminating in the next two years and no new FOA planned, the situation will worsen. It appears there will be gaps in crucial areas such as PEM catalyst work.
- Plans have been identified to address the issues and the remaining challenges. Bipolar plate developments are apparently not covered anymore, even if durability and cost issues remain. As it is now quite well accepted that coatings will be needed, investigations on it may already be useful, in particular for roll-to-roll and low-cost coatings. Investigations on fuel cell components and systems operating at medium temperatures (95°C–120°C) may be useful for automotive original equipment manufacturers.
- The plans on slide 12 address some, but not all, of the challenges faced by the industry. Key challenges remain on cost and high-temperature performance/durability, which will be the main impediments to widespread commercial scale-up. Additional funding should be allocated to a variety of approaches to increasing power density and materials that can support high-temperature operation and enable vehicle/application cooling systems to be successfully implemented. On the BOP side, additional funding for air compressor and humidifier development is important for the industry as a whole.
- The strategy slide lists a "technology neutral" approach, which this reviewer endorses. However, for areas such as stationary power that may span several different fuel cell technologies (e.g., phosphoric acid fuel cell [PAFC], SOFC, and high-temperature PEM), there may be specific challenges that do not cross all types. For example, the temperature ranges of high-temperature PEM, PAFC, and SOFC are roughly 160°C, 190°C, and 700°C, respectively. This span dictates different material challenges with regards to seals and BOP design/subcomponents. While cost is mentioned on this slide, there is no citation for manufacturing R&D. Manufacturing R&D is different than materials R&D. It addresses key needs to get to low-cost manufacturing. This appears to be a gap in the general fuel cell strategy, although it is currently addressed in the active portfolio.
- New awards were announced that appear to partially address the areas with issues. Some of progress reported also works towards addressing issues.

### **3. Does the sub-program area appear to be focused, well managed, and effective in addressing the DOE Hydrogen and Fuel Cells Program's R&D needs?**

- Yes.
- The program is intensively and well-managed.
- Yes. The sub-program is extremely well managed and clearly focused.
- This sub-program is well-managed, with the projects that it currently has. It has funding limitations that are responsible for any gaps.
- The Fuel Cells sub-program is well focused and is effectively using the allocated resources to solve the most pressing program needs.
- The sub-program has a much improved focus.
- Overall, the portfolio is focused and well-balanced to address needs.
- The sub-program is well focused and well managed. It is especially effective in addressing membrane electron assembly related issues, but it is soft on BOP aspects.

- Yes, although it is not clear what the relative emphasis is on reducing the overall installed costs of fuel cell systems for power.
- Yes, except for what appears to be a funding cliff. Many projects are ending, but new ones are not being funded. This reviewer asks whether all momentum will be lost.
- The sub-program is well managed and effective. In a time of diminishing funds, the sub-program appears to have been directed to broaden its scope to include all types of fuel cell systems, rather than maintain the focus it had on PEM systems. The strategy to increase the scope of the sub-program when funds are decreasing does not seem to be well thought out.
- Yes. For the future, a go/no-go decision and its stage gate should be more clear, and a basic and common philosophy of how to determine these needs to be defined.
- Yes. The sub-program has done a lot of work over the years to eliminate projects that did not show promise and reward those that have. Funding has swung dynamically from membranes to catalysts as the membrane suppliers began addressing performance and durability, but the catalysts remained a problem affecting both cost and durability.
- If based on the examples of success shown, the sub-program area is focused towards catalysts, with the exception of a humidifier. A chart showing simple progress toward goals in some of the other focus areas would help (stack components, system and BOP, and so on).
- The program seems to be taking a simplified approach to resource allocation. Cost and durability have appropriately been recognized as the biggest gaps to enabling fuel cell commercialization. The program puts most of its resources on non-Pt and low-Pt group metal catalysts (for cost reduction) and durability studies. The interdependencies of all components in the stack do not seem to be appreciated, and neither the cost nor durability targets can be met without advancement in the other subcomponents and understanding the interactions between these components. Also, with minimal funding available, it is puzzling that a large fraction of projects awarded this year are for cost analysis rather than technical development.
- The outcome of awards from the last FOA was a major disappointment across the industry. This FOA started with the best intentions to adhere to a tight schedule for submission, evaluation, and award. After a very long delay with no information on status, only a handful of awards were made, with little-to-no explanation of why. This reflects poorly on DOE and is disruptive to commercial organizations who must justify to shareholders substantial time spent preparing proposals with no visibility on timeline or status of decisions. Many in the industry are hopeful that the approach advertised by the recent Advanced Research Projects Agency-Energy FOA (i.e., a lightweight concept paper first, full proposal only after some indication of probability) will be more effective.
- Tornado plots seem to be a good mechanism for focusing research efforts where they would have the most impact on fuel cell costs. The sub-program area seems to generally be using them well. It is always difficult to get the right weighting between the areas that could produce the greatest cost benefits and the areas where major improvements are possible (e.g., whether much can be expected in improvements in compressors). Overall, management of the sub-program appears to be thoughtful, informed, and effective.

#### 4. Other Comments:

- The team can be congratulated on their work and encouraged to continue to final success.
- Like the past reviews, this meeting remains the most important one in order to have an exact and updated state-of-the-art picture of fuel cell technologies. It also allows reviewers to have many exchanges with the different researchers and DOE people.
- Considering the unusual funding demands from Congress, DOE has done an admirable job keeping its focus and moving programs forward.
- The broad focus is appropriate for a national program and allows for some early success. That is probably a good strategy politically, too. That said, with the lower budget, it is critical that there are enough resources applied to the harder automotive program to ensure continued progress and keep the critical mass of researchers in the field.
- This was supposed to be a review, not a technical meeting. This reviewer was a little bit disappointed that most of the questions were about detailed technical issues, not direction and other macroscopic management-related issues.
- It was hard to read the slides. There were too many concerns on individual slides. Presenters should use big text (the rooms are huge, and there is just one screen). Also, the sound system was far from stellar. This reviewer had difficulty at times hearing what was said. It might make sense to school the speakers in public speaking.

- It is always nice to have presentations that are energetic and engaging. Most presentations at the Annual Merit Review are either monotone/boring or difficult to understand, mainly due to a lack of clarity. Perhaps presentation clarity can be part of the evaluation.
- Some of the durability data seems to have been generated under very controlled laboratory test conditions. These data should be validated under real-life fuel cell testing conditions to ensure their application in practical fuel cell operational conditions.
- As fuel cell cars are coming closer to deployment, infrastructure should be addressed more. No H<sub>2</sub> vehicle will be deployed without H<sub>2</sub> on the road, and few will be deployed if H<sub>2</sub> is just available for captive fleets. Other than hybrid cars, FCEVs depend on H<sub>2</sub> not only when deployed first. An H<sub>2</sub> infrastructure for captive fleets will allow for the first user to operate it, but no used car market can develop. That was one of the reasons why methanol never could make a breakthrough in California, when it was deployed in captive fleets. A transition to H<sub>2</sub> should involve at least the technical readiness of mass market infrastructure based on pipelines and road transport. This seems underrepresented in the existing infrastructure efforts. They look like they might allow for niche markets, but not for mass markets, at a time when vehicle development is geared toward mass markets.
- It was not specified whether the automotive stack is 80 kW net or gross.



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## Manufacturing R&D Sub-Program Comments

### 1. Was the sub-program area adequately covered? Were important issues and challenges identified? Was progress clearly presented in comparison to the previous year? (Include information presented in the plenary and/or session overview presentations of the sub-program if appropriate.)

- This is a well-managed and well-executed sub-program.
- The overall goals and objectives of the sub-program were clearly defined, and the projects in the sub-program were highly relevant to these goals and objectives. The important issues regarding manufacturing were clearly highlighted for this sub-program. The accomplishments of some key projects in the sub-program were highlighted, as were the results from a manufacturing workshop held last year.
- The manufacturing sub-program projects are rather mature, well conceived, and executed, and they are delivering quality results. The body of projects is broad (as it should be), encompasses the major challenges in this area, and is interrelated in many cases.

### 2. Are plans identified for addressing issues and challenges? Are there gaps in the project portfolio?

- There are plans in place for addressing key issues, including defining the current state-of-the-art and potential advancements that could be made with further investment. There are no significant gaps in the project portfolio, but additional projects could greatly expedite the advancement of these manufacturing technologies.
- The only gaps are due to the availability of funds.
- For this sub-program, the issues and challenges that remain have been clearly identified, and a plan exists, with the only limitation being the availability of funding. This program has a clear fit and path for expansion into other fuel cell types and applications if the Program had the funding to ramp up its focus in the area of manufacturing.
- There are no projects for low-cost, high-volume manufacturing of GDLs. There are no projects for high-volume assembly of stacks. This program concentrates only on component developments.

### 3. Does the sub-program area appear to be focused, well managed, and effective in addressing the DOE Hydrogen and Fuel Cells Program's R&D needs?

- Yes.
- This program seems well managed.
- The sub-program is clearly well managed, and the accomplishments from all of the programs have been remarkable. Many of the programs are seeing reductions in cost of more than 50% for the components, while others are demonstrating novel technologies that are directly applicable to fuel cell manufacturing. These advancements are necessary if the fuel cell industry is to grow domestically.

### 4. Other Comments:

- The DOE Hydrogen and Fuel Cells Program would greatly benefit from more projects like the ones found in this sub-program. Providing the funding necessary to drive the manufacturing technologies will be far more useful at this stage of fuel cell development than continuing to fund projects focused on fundamental understanding. The technology is adequate to penetrate the market today, but costs remain prohibitive to compete with technologies such as lithium-ion batteries and diesel engines. If the goal is really to drive the market adoption of fuel cells and reduce the impact to the environment, then the main focus has to be on reducing the overall system cost and pushing quality fuel cell products to the market.
- A few of the projects seem to have tasks that migrate away from manufacturing into areas such as membrane or electrode design, or durability studies. It seems like this sub-program has a disproportionately high number of projects that are beneficial only to the prime contractor.

## Technology Validation Sub-Program Comments

### 1. Was the sub-program area adequately covered? Were important issues and challenges identified? Was progress clearly presented in comparison to the previous year? (Include information presented in the plenary and/or session overview presentations of the sub-program if appropriate.)

- Yes.
- Yes, but there was no comparison with the previous year (one was not needed).
- Projects included in the sub-program were effectively summarized and highlights were presented. Slides 6 through 9 provide an overview of technology validation projects, with appropriate emphasis on those accounting for the bulk of resources expended since the sub-program was created, particularly the national H<sub>2</sub> FCEV and infrastructure learning demonstration, fuel cell bus demonstrations, and validation of an integrated energy station. There was no specific mention of issues and challenges. A “forward funding” approach is being adopted, but the implications are not clear to this reviewer based on information provided in the presentation. Time was not sufficient to follow up on that topic.

### 2. Are plans identified for addressing issues and challenges? Are there gaps in the project portfolio?

- Yes, there are plans for addressing issues and challenges.
- The presenter noted that the Technology Validation sub-program is in transition. The fuel cell applications being addressed by the sub-program are expanding. Important elements of the sub-program’s future portfolio will be determined in large measure by awards resulting from current DOE FOAs. The FOAs focus on light-duty FCEV validation and H<sub>2</sub> refueling station performance. They were discussed. Milestones relevant to the sub-program’s future are included in slide 10.

### 3. Does the sub-program area appear to be focused, well managed, and effective in addressing the DOE Hydrogen and Fuel Cells Program’s R&D needs?

- Yes.
- Yes, fairly well. Management has recently changed.
- Yes. The data from this sub-program are extremely valuable to demonstrate the readiness of H<sub>2</sub> and fuel cells.
- The positioning, purpose, and goals of the sub-program were clearly and succinctly articulated in slides 2 and 3 of the presentation. Some projects within the sub-program are outstanding, having been refined over a period of years and benefitting from superb management. An example is the National Renewable Energy Laboratory’s (NREL’s) data collection, analysis, and reporting in connection with the FCEV and infrastructure learning demonstration project. The primary focus of a few of the projects seems to be on work not consistent with the goals and described boundaries of the sub-program. Examples are NREL’s renewable electrolysis system development and testing (wind-to-H<sub>2</sub>) project, the Florida Hydrogen Initiative, and the Hawaii Hydrogen Power Park.

### 4. Other Comments:

- The activities within some projects are outside the positioning of the sub-program as indicated on slide 2. For example, NREL’s wind-to-H<sub>2</sub> project has elements of technology development, a test facility, a user test facility, and a technology development laboratory. Another example is the Florida Hydrogen Initiative, within which there are multiple types of activities, from basic materials research to H<sub>2</sub> education. Responsibility for such projects could logically be placed within each of multiple sub-programs. A challenge to be addressed by overall Program management is ensuring that there is effective communication about project plans, oversight, and results across relevant sub-programs. Expansion of the sub-program’s scope to fuel cell material handling equipment (MHE), stationary fuel cell installations, and fuel cell back-up power seems to be moving along well. DOE is encouraged to focus this sub-program on independent, objective analysis of data received from both DOE-sponsored and non-DOE projects. Conversely, activities not consistent with the positioning and description of the sub-program, such as technology development, testing, and education, should be minimized in planning the future sub-program portfolio.

## Safety, Codes and Standards Sub-Program Comments

### 1. Was the sub-program area adequately covered? Were important issues and challenges identified? Was progress clearly presented in comparison to the previous year? (Include information presented in the plenary and/or session overview presentations of the sub-program if appropriate.)

- Yes, the program is sufficiently covered, issues/challenges are identified, and progress is presented.
- Yes, the coverage of the program was adequate, and it demonstrated progress from the previous year.
- The sub-program was adequately covered, and important issues were identified. The projected reduction in funding is significant, and the across-the-board reductions in sub-program elements are proposed.
- This presentation described the program, its mission, direction, and key issues. A nice description of accomplishments from the program showed good relevance to the acceleration of deployment of these technologies, by providing solid, relevant information that goes directly to developing defensible codes and standards and by providing critical information that will enable fault-tolerant design.
- This sub-program area was adequately covered by the presenter. This portion of the DOE Hydrogen and Fuel Cell Program's budget has been [reduced] for a few years, but the sub-program team has done an exemplary job of getting critical issues addressed with the funding that they do have. The issues and challenges in getting the H<sub>2</sub> economy fully commercialized are well known to this sub-program team. They have forged productive alliances with industry members to accomplish common goals.
- The sub-program area was adequately covered, and the challenges were identified. Safety issues are of critical importance for public acceptance of H<sub>2</sub> and fuel cell technologies. It is absolutely needed to show that the H<sub>2</sub> and fuel cell industry is safe—even safer than other energy-related industries. Images like the Hindenburg accident and/or the nuclear bomb must be replaced in the public by safe and “green” applications.
- The work and leadership from the sub-program team have been critical to support standards/code development. This is greatly needed in new and emerging technologies. New technology areas benefit from coordination of the high-level industry, similar to the national template created in the early stages of the emergence of H<sub>2</sub> as a fuel alternative. While in traditional, established markets, standards maintenance could be considered routine work for a standards developer, the scenario is different in new and emerging technologies. Traditional standards products generate support through support services to established manufacturers. In new technologies, standards developers do not have any mechanism to generate financial support—they sink their money into research and product development. Safety standards are needed to help the industry evolve and demonstrate safety, but these evaluations cannot be done without a standardized method. The standards development organizations (SDOs) invest significantly in development of requirements to support developing industries. A mechanism through DOE needs to be identified to continue supporting the development of the safety standards until the industry is “launched.”
- Yes. However, this reviewer wishes that there was more funding made available to support the activities that were started but yet to be completed. Progress was clearly presented.
- By attending this session, the reviewer got tangible evidence of progress in addressing the sub-program objectives identified on slide 2, with the exception of the first bullet (safety in DOE-funded projects). It was easier for this reviewer to identify progress compared to the previous year from the information contained in the overview presentation than from the individual presentations in the session. To assess progress, it would be helpful to indicate the degree of completion/achievement of the “past” milestones identified on slide 17, as well as the current amount of progress towards reaching the future ones.

### 2. Are plans identified for addressing issues and challenges? Are there gaps in the project portfolio?

- Gaps are being addressed in the portfolio.
- Plans are identified for continuing with existing efforts.
- There are no obvious gaps in the project portfolio. Plans for addressing issues and challenges are identified.
- The challenges are clearly addressed. Safety is a crosscutting activity for which regulation, codes, and standards will help to maintain a good image in the public. Nevertheless, the building of standard answers, should a safety problem occur, is missing in the portfolio.

- Yes. The sub-program has a large task, and there is good “top-down” alignment of project goals to objectives, objectives to challenges, and challenges to current emphasis. The sub-program holds to two goals: safety implementation and applied R&D and leadership in standards development. The sub-program lacks cohesion between those two stated goals. The approach seems directed at the critical R&D pathway and does not suggest a collaborative effort with the development and implementation of safety practices and procedures. Standardization should ensure safety, but those standards, and the R&D activities that support their development, must begin and end with the end users, industry, code enforcement officials, and others. The reviewer asked whether there are opportunities to encourage sub-program participants to collaborate and leverage decreasing funding to advance both goals.
- Yes. There are still significant gaps in the programs. The level of detail in articulating the plans forward, given the changes in funding, has not been made clear. As a result, it seems like a “hurry up and wait” situation. The stakeholder voices have not changed in their expectations, but it seems as if DOE is moving the decision point out five additional years, from 2015 to 2020.
- Yes. The description of the international round robin is a good example of an activity targeted to work harmoniously with the international community to harmonize the test method protocol in measuring the physics necessary as dictated by SAE 2579, GTR, EHIP rev 12b, etc. The forklift tank cycling campaign is also an example of how the sub-program was able to rally resources to rapidly address a critical safety issue, which answered the original question (“Are these tanks being used safely in the current use domain?”), and the sub-program was able to get some good science out of the program. The sub-program is positioned to continue to advance the needs of the regulation, codes, and standards community and to respond to unanticipated, high-priority needs.
- As far as this reviewer understands, there is no major future change foreseen in the methodology that is followed in the sub-program. The “cases” covered are identified on the basis of need, such as “all the work related to the safe in-door deployment of forklifts.” As such, this reviewer cannot identify any major gaps in the overall scope of activities. On an individual project basis, the material coverage in the materials and components compatibility project seems too narrow, considering the fact that H<sub>2</sub>-compatible materials will have to be used and deployed worldwide. The sub-program should interact with and learn from other countries on their experience with steels of different composition from those used in the United States and with fiber-reinforced composites.
- The major gap continues in the funding of national standards efforts. DOE support has been critical and much appreciated by industry. The problem is the view that the industry has arrived, and there is no longer a need for this support. Standards are critical for existing and emerging industries. Industries are safe because of the checks and balances in the system. Safety codes and standards have been identified as a critical element for helping industries transition to commercialization. The approach with H<sub>2</sub> to address the standards early in the market development was revolutionary for reducing time to market. This also enabled the United States to be a leader in the standards area. It would be beneficial for all aspects of industry for DOE to investigate through stakeholder engagement and reconsider the need for supporting national standards development activities for areas critical to the DOE agenda and the national agenda.

### **3. Does the sub-program area appear to be focused, well managed, and effective in addressing the DOE Hydrogen and Fuel Cells Program’s R&D needs?**

- Yes.
- Yes. The sub-program’s communication with industry is excellent.
- This area is very well managed and has produced results that are useful.
- The sub-program area appears to be focused. International cooperation is absolutely needed in this field in order to achieve standards that will be adopted worldwide and that will address the Hydrogen and Fuel Cell Program's needs.
- Yes, the sub-program appears well focused and targets near-, mid-, and long-term objectives as well as coordinating the R&D activities with the standards development. The near-term needs are supported through the focus on related niche markets, such as forklifts through steel tank cycling and indoor fueling risk assessment. The mid-term needs for vehicle deployments are addressed by activities such as fuel quality, international harmonization, fast fill, tunnel safety, and first responder safety. The long-term needs are supported through fundamental applied science, such as sensor technology development, materials compatibility, and safety incident database development. The sub-program appropriately balances these R&D activities with the changing

landscape of market needs, immediate issues, standards document development schedules, and international harmonization.

- As indicated in slide 5, the sub-program will likely be affected by a non-negligible budget cut. All elements of the sub-program identified in slide 5 are presently endowed with sufficient resources to enable them to meet the majority of their objectives. However, the anticipated budget reduction casts this in doubt for the future, particularly in view of the facts that (1) sub-program learning from technology validation programs will have to be speeded up and (2) large-scale deployment of H<sub>2</sub> and fuel cell technologies is coming ever nearer.
- The sub-program seems to need to be redeployed to meet the new finding framework. There is clear competition among all of the alternative energy fuels. As a result, there seems to be a bit of a free for all. As a result, funding seems to be moving out of the R&D part and instead focusing on industries that are focused on near-commercial opportunities. There is not a clear plan, nor is there proper coverage for, stationary and portable fuel cells. They seem to be shadowed by the automotive industry. Also, with SDOs losing their funding for standards development, it will greatly reduce the pace at which new technology standards will be written. SDOs will work hard to finish what is already in play, but the new standards will be hard to get started.
- It is not clear how projects are selected. Unlike other sub-programs, this sub-program does not compete its portfolio. Competitive solicitations for all parts of this sub-program are recommended to ensure that the most qualified teams are performing the work. The use of consultants is extensive, and it may not be the best use of limited program funds.

#### 4. Other Comments:

- The importance of this program remains high, as H<sub>2</sub> and fuel cells (all applications) progress into commercialization.
- The DOE Hydrogen and Fuel Cells Program has been working hard to increase the exposure and acceptance of fuel cells and H<sub>2</sub>. This support is critical to the United States and to industry success.
- The leadership, R&D activities, and outreach parts of the sub-program are all performing excellently in spite of shrinking budgets. It is unclear how well these parts are coordinated. A feedback mechanism is implied in the approach overview; yet it is unclear how well that is working to improve the efficiency and guide the sub-program approach. It is also unclear whether the outreach programs are gaining “champions” from their audiences, and whether the industry is helping lead the identification of R&D priorities, gaps in codes and standards, or gaps between safety “best practices” and codes and standards.
- Regulations, codes, and standards (RCS) is a critical need area, not just to ensure the safe deployment of H<sub>2</sub> technologies (which is a must), but also to ensure that relevant national and internationally harmonized RCS are in place to accelerate the deployment and to ensure global commercialization of H<sub>2</sub> technologies. With the imminent rollout of H<sub>2</sub> fueling stations globally (in Germany, Japan, Korea, and the United States [particularly New York and California]), relevant RCS must be in place so as to not hinder the rollout and to ensure that H<sub>2</sub> technologies are deployed safely. The global leadership of this program in the international and domestic RCS community is clearly recognized. This is a critical and arguably a rate-limiting component to the deployment of H<sub>2</sub> technologies, and it should be funded at a much more robust level than the \$5 million U.S. dollars proposed in the 2013 request, particularly since the development of RCS is a critical path element to the rollout of H<sub>2</sub> fueling stations and the deployment of fuel cell technologies in the transportation sector. Relevant RCS work to ensure the safe deployment of these technologies is not just a market deployment issue, but one of safety. The original equipment manufacturers are on a path to deploy hundreds of thousands of vehicles in a very near time frame (2014–2017); commensurate with this is the planned infrastructure roll out (i.e., hundreds of refueling stations worldwide). Relevant RCS must be in place to ensure the harmonization and safe development of this infrastructure. This sub-program is not only on the critical path for deployment; it is also on the critical path for the safe deployment of these technologies. This sub-program should be given a much higher priority in funding allocation closer to its previous funding levels of \$15 million.
- Some attention must be devoted in order to avoid duplication of tasks between some projects. The role of DOE, in order to oblige fuel cell and H<sub>2</sub> projects to consider safety as an important issue from the start until their final implementation, should be considered not only for projects supported by DOE but also for projects that are privately supported. This will help to develop, from the start of the deployment of these technologies, a safe industry with an excellent image in the population.
- There is a visible trend toward funding national laboratories at the expense of support for SDOs. There are experienced individuals who make things happen within those organizations that may indeed not be funded in

the future. It would be a mistake to allow experience to go down the drain for the sake of consolidating reporting structures.

- Suggestions for slide 4: replace or otherwise correct the term “foundational” H<sub>2</sub> behavior (it is unclear whether the presenter meant “fundamental”). In addition, next to international harmonization (bottom box), there is also a need for collaboration between stakeholders (going beyond mere consultation) and for pooling of brain, infrastructural, and financial resources. This reviewer also has suggestions for the organization of the SCS session: effort should be paid to improve the sequence of the presentations in the session (e.g., for ease of comprehension, SCS-011 should have been presented before SCS-010, which should have immediately followed it).

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## Education Sub-Program Comments

### 1. Was the sub-program area adequately covered? Were important issues and challenges identified? Was progress clearly presented in comparison to the previous year? (Include information presented in the plenary and/or session overview presentations of the sub-program if appropriate.)

- Yes, the sub-program was well outlined and adequately covered. All significant issues and challenges were addressed. Annual progress was clearly identified and highlights were presented. Work and progress were clearly consistent with overall DOE goals and objectives.
- Yes, to all questions. The education element of the overall program is critically important to the successful adoption of these technologies. This is particularly relevant now, as infrastructure rollout is starting in preparation for the early stages of vehicle commercialization. A significant challenge facing this sub-program is funding. Interestingly enough, funding in this critical area goes a long way. The deployment of hydrogen technologies will only accelerate and benefit from a more robust funding of the Education sub-program.

### 2. Are plans identified for addressing issues and challenges? Are there gaps in the project portfolio?

- Plans and methods to address challenges were identified, but future work remains uncertain due to the end of the state and regional program(s).

### 3. Does the sub-program area appear to be focused, well managed, and effective in addressing the DOE Hydrogen and Fuel Cells Program's R&D needs?

- Yes, this sub-program has made an important impact on the knowledge and comfort levels that the general public, educators, decision makers, first responders, and others have with these technologies. However, as the first deployments of hydrogen technology is upon us, improvement is required. Several current examples exist where, although responsible entities worked hard to educate the public and authorities having jurisdiction, events occurred where the impact could have been minimized with further education.
- Yes, the sub-program appears focused, well managed, and effective, from both a state and a regional level, and appears to increase exposure and impact.

### 4. Other Comments:

- Funding for this sub-program should be increased.
- The presenter has remained a steady and sound supporter of the sub-program, and has provided excellent managerial support. The sub-program should be funded in the future to include state and regional education efforts, partnership building, policy formation, and information management. Without these types of projects, deployment will advance at a much slower rate and there will be potential for missed opportunities.

## Market Transformation Sub-Program Comments

**1. Was the sub-program area adequately covered? Were important issues and challenges identified? Was progress clearly presented in comparison to the previous year? (Include information presented in the plenary and/or session overview presentations of the sub-program if appropriate.)**

- The 2011 activities were clearly presented. Challenges and important issues have not been explained very clearly. In addition, the link between the different projects is not very well established. However, the sub-program is very important for the success of H<sub>2</sub> implementation.

**2. Are plans identified for addressing issues and challenges? Are there gaps in the project portfolio?**

- Issues and challenges, and plans to address them should be presented clearly. The project portfolio is quite complete, but the overall structure could be better. The final objective, and how the projects fit into it, is unclear.

**3. Does the sub-program area appear to be focused, well managed, and effective in addressing the DOE Hydrogen and Fuel Cells Program's R&D needs?**

- There are a lot of different projects in the sub-program, but not all of them fit into a future perspective of a sustainable H<sub>2</sub>-based energy system. The financial resources are limited, so it seems even more important to focus on projects that fit into the future perspectives. Direct methanol fuel cells might not be part of this.

**4. Other Comments:**

- This is an important sub-program that has a lot of very interesting programs, but its overall structure could be improved.



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## Systems Analysis Sub-Program Comments

### 1. Was the sub-program area adequately covered? Were important issues and challenges identified? Was progress clearly presented in comparison to the previous year? (Include information presented in the plenary and/or session overview presentations of the sub-program if appropriate.)

- Yes, the sub-program area was adequately covered, issues/challenges were identified, and highlights of key progress were given.
- Yes, there was clear progress shown in every presentation.
- It is worthwhile to conduct studies on FCEV light-duty cars and trucks. However, these studies need to recognize the importance of the automakers' need to comply with a complex state and federal regulatory structure involving corporate average fuel economy, mobile source emissions, and zero emission vehicle mandates, which is not easy.
- This reviewer should have emphasized the results from the Technology Validation sub-program (183 FCEVs included in the test, 3.5 million miles, 500,000 trips, 25 H<sub>2</sub> stations, 35,700 refuelings, and so on) to emphasize that FCEVs are real and have been thoroughly tested (as opposed to battery electric vehicles [BEVs] and plug-in hybrid electric vehicles [PHEVs], which are just entering service and have not been similarly tested). Progress was not identified compared to previous years.

### 2. Are plans identified for addressing issues and challenges? Are there gaps in the project portfolio?

- Plans were given, and the sub-program is on the right track. Analyses, which have become more granular and specific (the reviewer especially liked the trend toward regional analyses), should continue to be so, and interaction between models and analyses should be integrated and increased.
- There are gaps in the portfolio, such as no analysis of what would happen if 120°C PEM fuel cells became reality or a really good, critical look at what it would take to do carbon capture and storage in the context of the rapid developments in the oil and gas industry.
- Researchers should conduct pathway modeling for the H<sub>2</sub> infrastructure cost upon reaching the dollars per gge target, which would be similar to the pathway established for PEM fuel cell stacks to hit the \$30/kW target.
- One gap is the lack of a dynamic analysis of intermittent renewable electricity (primarily wind, but also solar) compared to the dynamic electricity load in a given region, and quantifying the benefits of H<sub>2</sub> storage over battery storage and compressed air energy storage as a function of the number of days of storage provided. The analysis would include both the direct benefits of load management (storing off-peak electricity for use on-peak) as well as the benefits to the grid, such as frequency stabilization. The study would also compare the environmental benefits of H<sub>2</sub> storage to back up wind farms as opposed to using NG combined cycle (CC) plants for wind firming (one paper claims that using NG turbines to back up wind actually increases greenhouse gas emissions [GHGs]), because ramping up an NG turbine reduces efficiency, such that running the NG turbine 100% of the time produces less GHGs than the wind/NG CC turbine combination. This paper also claims that the wind/NG turbine system generated more nitrogen oxides (NO<sub>x</sub>), because ramping the turbine increases NO<sub>x</sub> emissions. H<sub>2</sub> storage would eliminate this conundrum and make wind a true zero-emission baseload electricity source.

### 3. Does the sub-program area appear to be focused, well managed, and effective in addressing the DOE Hydrogen and Fuel Cells Program's R&D needs?

- Yes.
- The sub-program is extremely well managed and focuses very well, considering its limited resources.
- The sub-program is focused and well managed, but this reviewer would encourage the modeling on H<sub>2</sub> infrastructure to be crisper. This reviewer applauds the sub-program for its nimbleness in addressing the implications of the substantive drop in the NG price as a result of hydro-fracturing. This reviewer also applauds the sub-program for addressing FCEV light-duty vehicles.

#### 4. Other Comments:

- In upcoming annual merit reviews, it might be helpful to add another slide at the beginning that PIs can use (if the project is not new) that summarizes the development of the project since it first started. For example, show the major additions/enhancements made to models, the types of issues that were covered, how the effort integrates with other Systems Analysis sub-program efforts, and where the project is going from this point on. This type of a summary could be provided at each project level and/or just the sub-program level. It is unclear what the role and outlook of the Systems Analysis sub-program is beyond 2015/2020 as commercialization nears, models are well-established, and a whole host of analyses have been conducted. Moving forward, it is unclear if the sub-program will provide more validation as more data is received from deployments or if it will conduct other types of analyses. This is something to consider, and perhaps give reviewers an outlook. It might be useful to consider the following together as a whole: typical H<sub>2</sub> refueling station development versus unconventional H<sub>2</sub> resources (e.g., biogas at wastewater treatment plants) and non-vehicle H<sub>2</sub> demand centers. Considering these together could provide insights about how they may help each other or how efforts could be leveraged.
- Slide 10 is misleading because it came from a third party that averaged data from various types of H<sub>2</sub> stations. As a result, the H<sub>2</sub> cost shown on slide 10 cannot be associated with any particular station type, but rather is an average of mobile refuelers, trucked-in gaseous and liquid H<sub>2</sub>, and a few on-site electrolyzers or SMR. In addition, because the station type is not identified, this graph does not include variable costs, because it is not known whether to add NG costs (for an SMR station) or electricity costs (for an electrolyzer). Thus, the capital costs are compromised by the inclusion of lower cost station options, and the variable costs are not even included. Slide 11 is also worrisome because it seems to imply that H<sub>2</sub> infrastructure costs per vehicle are similar to or even higher than BEV costs, while other credible studies indicate the opposite. For example, the McKinsey & Company report on alternative vehicles in the European Union estimated that BEV and PHEV electrical infrastructure costs would be five times higher than H<sub>2</sub> infrastructure costs. On slide 13, the presenter should include the range for the FCEV (e.g., FCEV-350) to contrast it with the BEV-100, with only a 100-mile range.

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## Comments on American Recovery and Reinvestment Act Activities

### **1. Were Recovery Act activities adequately covered? Were important issues and challenges identified? Was progress clearly presented in comparison to the previous year? (Include information presented in the plenary and/or session overview presentations if appropriate.)**

- This has been a well-executed sub-program. The commercial sales validate the worthiness of DOE funding.
- Recovery Act activities were well covered. Important issues and challenges were well identified. (Lessons learned were highlighted, which is especially commendable.) Progress versus the prior year was not apparent, but this did not harm the quality of the presentation.
- The overall status of all of the Recovery Act projects was provided, with a quantification of deployments, jobs, funds spent, and safety. Siting and permitting were identified as some of the major challenges.

### **2. Are plans identified for addressing issues and challenges? Are there gaps in the project portfolio?**

- The only weakness was the lack of a backup plan to replace the few projects that could not be started because of changes subsequent to award.
- Future activities and plans were not apparent. With only 14% of program funding remaining, perhaps they were not worth discussion. There was a good representation of follow-on (non-DOE funded) purchases of fuel cell material handling equipment (MHE); this is a great indicator of the program fulfilling Recovery Act goals.
- The project alluded to issues with the extended run-time project and stated that back-up strategies should be arranged in advance. In reality, this is very difficult to do, because these are, by definition, unanticipated events. However, structural mechanisms for dealing with this in the future can certainly be implemented.

### **3. Do these activities appear to be focused, well managed, and effective in addressing the DOE Hydrogen and Fuel Cells Program's needs?**

- Yes.
- The projects appear to be well managed, and they have successfully leveraged DOE's investments to result in many more private-party purchases of fuel cell systems for field deployment. This was the ultimate goal of the Recovery Act, so the efforts have been successful at addressing DOE's objectives in this area.
- It was a bit hard to agree to this, as all the projects were funded under the Recovery Act sources. It would be better that they not be so identified. Certainly they were good projects.

### **4. Other Comments:**

- The reviewer would like Composite Data Products for back-up power to be comparable to those for MHE.
- The Recovery Act appears to be successful in what it set out to do for fuel cells and H<sub>2</sub> technologies.

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