2011 — Systems Analysis
Summary of Annual Merit Review of the Systems Analysis Sub-Program

Summary of Reviewer Comments on the Systems Analysis Sub-Program:

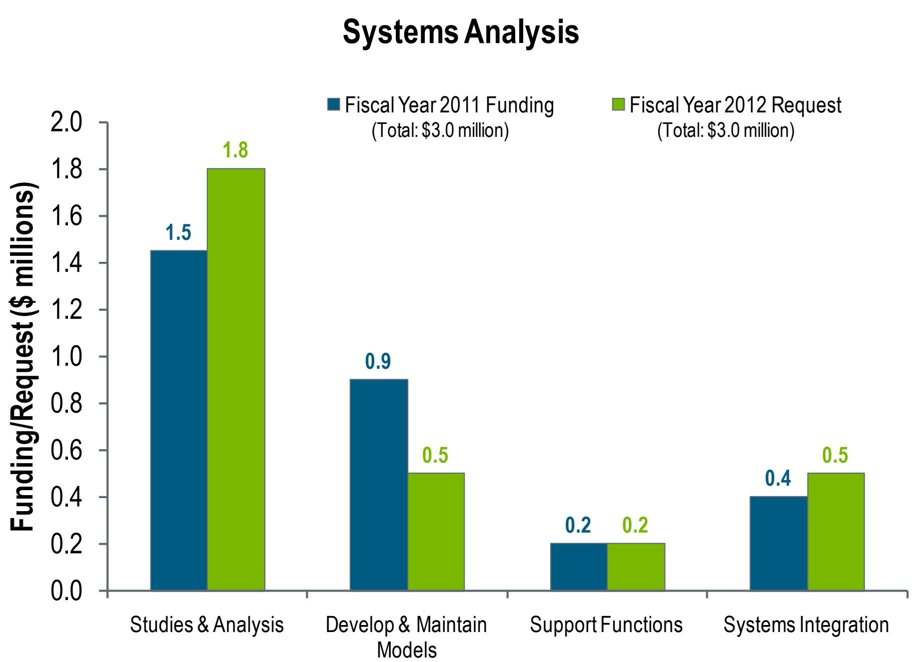
The reviewers considered the Systems Analysis sub-program to be an essential component of the U.S. Department of Energy (DOE) Hydrogen and Fuel Cells Program's mission. The projects were considered to be appropriately diverse and focused on addressing technical barriers and meeting targets. In general, the reviewers noted that Systems Analysis is well managed and has increased its focus on near-term fuel cell technology applications.

Some reviewers commented that the sub-program is effective in providing analytical support for the Program's research and development (R&D) efforts and that it is helpful in appropriately directing R&D efforts to address key barriers. Reviewers also commented that the analysis and model portfolio was complete and making good progress toward understanding the issues and opportunities to achieve the Program's technical targets. Some reviewers were very disappointed that the funding request for this critical Program activity was reduced from the fiscal year (FY) 2010 funding level of $5.4 million. They commented that the sub-program was high-quality and that it should be expanded.

Key recommendations for this sub-program included: (1) the sub-program should continue to identify unique benefits of hydrogen and fuel cells and provide results in terms of costs versus benefits and value propositions; (2) analysis projects should include more industrial collaboration; (3) analysis should include policy implications; (4) model validation and peer review should be emphasized, because they are critical for sound and credible analysis; and (5) a pictorial illustration should be provided showing the relationship of the analysis projects to the sub-program's goals and objectives.

Systems Analysis Funding:

The FY 2011 appropriation for Systems Analysis was $3 million. Funding for the sub-program has shifted from a focus on model development to a focus on conducting analysis using the models developed by the sub-program. In particular, analysis projects are concentrated on infrastructure development for early market fuel cell introduction, the use of hydrogen and fuel cells for energy storage, and the petroleum and greenhouse gas emission reduction benefits of the Program's technology portfolio. The FY 2012 request of $3 million, subject to Congressional appropriation, provides greater emphasis on analysis of hydrogen for energy storage and transmission, early market adoption of fuel cells, biogas resources, and infrastructure analysis.



Majority of Reviewer Comments and Recommendations:

The maximum, minimum, and average scores for the Systems Analysis projects were 3.6, 2.6, and 3.1, respectively. Reviewers noted that the diversity of the Systems Analysis project portfolio has shifted from basic model development with a narrow focus on transportation applications to a wider array of projects that investigate issues such as the diverse approaches to using hydrogen and fuel cells for energy storage and their potential benefits.

Model Development and Systems Integration: Four projects involving model development were reviewed, with an average score of 3.2. In general, these projects received very favorable reviews. The majority of the projects were regarded as well aligned with the current program goals and objectives. Reviewers continue to emphasize the need for collaboration, peer review, and validation with industry, academia, and the national laboratories. Reviewers recommended that models use a consistent set of inputs and assumptions and increase collaboration with industry to ensure that models are relevant to commercial applications.

Studies and Analysis: Eight program analysis projects were reviewed, with an average score of 3.1. In general, the reviewers felt that the projects supported Program goals, but they also agreed that the analysis projects need to: (1) involve more collaboration with industry to calibrate information with actual operation and experience; (2) be peer reviewed prior to issue and publication; and (3) use a consistent set of inputs and assumptions.

Energy Storage: The projects reviewed in this topic area included a study focused on the levelized cost of electricity generation from stored hydrogen and a study to examine the potential greenhouse gas emissions reductions associated with using hydrogen as an energy storage medium for grid electricity generation. The reviewers noted that energy storage is an important study area and good progress has been made toward understanding costs and greenhouse gas emission benefits. However, they also felt that these projects should draw additional resources from other activities within the National Renewable Energy Laboratory (NREL) and the DOE Office of Electricity Delivery and Energy Reliability. It was recommended that other storage technologies and other renewable generation technologies in addition to wind power—such as solar power—should be included in the hydrogen energy storage analysis.

Infrastructure: The projects reviewed in this topic area were rated favorably for assessing gaps with hydrogen infrastructure and understanding the infrastructure costs of near-term markets. Reviewers specifically appreciated the fact that the knowledge and insights of stakeholders were included throughout the project, but they also identified the need to include additional stakeholders—such as permitting officials—to make the group more diverse. Suggested next steps included: documenting the results and key findings, sharing the findings with key stakeholders, and engaging in dialogue to explain the implications of the results.

Market Analysis: The market analysis project assessed the impact of government funding and American Recovery and Reinvestment Act projects on reducing fuel cell cost. Overall, the reviewers felt the project was successful in evaluating the barriers, market dynamics, and policy needs to overcome barriers and stimulate the market. They suggested that future work should address 100–500 kilowatt backup power fuel cell systems and supply issues for hydrogen. In addition, it was suggested that follow-up studies should be conducted to determine the role that non-transportation fuel cell markets can play in the development of the transportation fuel cell market.

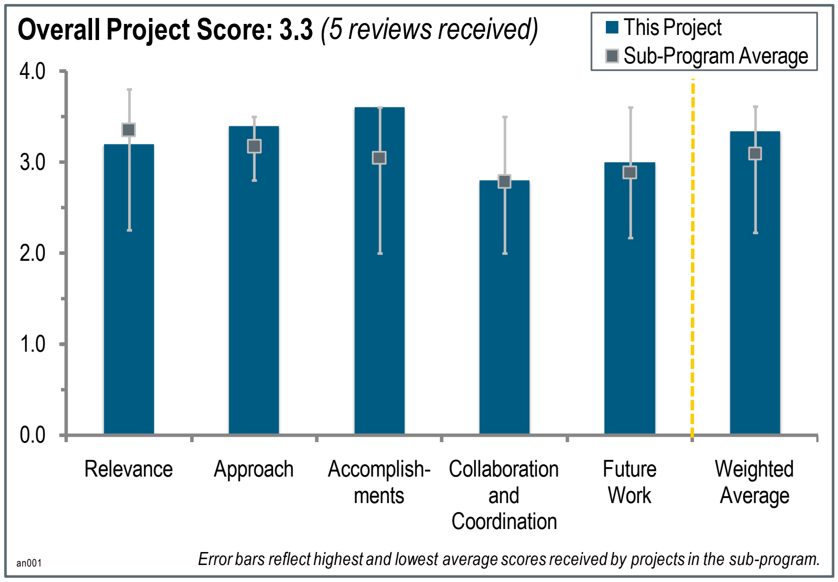
Programmatic Benefits Analysis: The reviewers commented that NREL's project to assess the Program's benefits (in terms of reducing greenhouse gas emissions and petroleum use) is relevant to the Program's objectives and provides valuable projections of the impact of fuel cell electric vehicles and hydrogen in the U.S. transportation mix. It was recommended that additional analytical work include competing automotive drive trains.

Scenario Analysis: This new analysis project examines the integration of various elements of the early hydrogen and fuel cell market such as fuel cell buses, material handling equipment, renewable biogas resources, stationary fuel cells, and light-duty fuel cell electric vehicles. Because the project is new, the primary emphasis of the reviewer comments was on the project's direction and scope development. The reviewers felt that the project is critical to help guide R&D and to understand the interaction of various early markets with the development of infrastructure. Strong emphasis was placed on getting a good cross section of stakeholders in the analysis project.

Project # AN-001: Infrastructure Analysis of Early Market Transition of Fuel Cell Vehicles

Brian Bush; National Renewable Energy Laboratory

Brief Summary of Project:



The Scenario Evaluation and Regionalization Analysis (SERA) model is a tool for studying regional build-outs of renewable energy infrastructures over time by optimizing the delivered cost of hydrogen. Project objectives are to: (1) expand the interoperability of SERA with tools such as Hydrogen Demand and Resource Analysis (HyDRA), including importing detailed cost models from the U.S. Department of Energy's (DOE's) Hydrogen Analysis (H2A) project; and (2) perform various hydrogen scenario analyses. The goals are to (1) determine optimal regional infrastructure development patterns for hydrogen, given resource availability and technology cost; and (2) geospatially and temporally resolve the expansion of production, transmission, and distribution infrastructure components.

Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.2** for its relevance to DOE objectives.

- It is very important to understand hydrogen costs under various conditions.
- Being able to geospatially and temporally investigate infrastructure development is key to understanding hydrogen and fuel cells' role in the near-, mid-, and long-term energy landscape.
- It is important to understand infrastructure cost trade-offs.
- A major purpose of the work (re: slide three) is to determine, through modeling (SERA), the least-cost build-out scenarios for providing hydrogen fuel to a community or geographic region (production and distribution). Similarly, SERA can be used to compare the costs of hydrogen production and distribution for specific, proposed scenarios. SERA adds depth and detail, especially geospatial mapping detail, to general knowledge about production and distribution costs. However, it is not clear what DOE programmatic decisions require this level of extra detail. (Over the course of this project, this reviewer wants to know what decision would have been different if the only information at hand had been the input data to SERA.) Ultimately, the private sector allocates the capital to build-out energy infrastructure (as the U.S. government does not provide central planning), and it is not clear how this project might usefully inform that process. (It is not clear how this project might provide individualized information to the many actors whose behavior the model seeks to capture.) SERA may help calibrate expectations about the impact of particular approaches to hydrogen production and distribution (through scenario analysis) and provide visualizations to demonstrate to locally based stakeholders how certain factors might apply specifically to them. However, it is hard to say that these goals make the project "critical" to the success of the DOE Hydrogen and Fuel Cells Program.
- The SERA models appear to have considerable relevance, although they are probably not absolutely critical to DOE objectives. The models appear to be broadly applicable and can provide meaningful predictions based on a wide variety of input data; therefore, they should be applicable to lots of different markets. The work appears to have made the system robust and versatile.

Question 2: Approach to performing the work

This project was rated **3.4** for its approach.

- SERA is an optimization tool that integrates well with other data analysis tools, such as H2A (as a source of data) and HyDRA (for data visualization). The emphasis in recent work has been on scenario analysis, which generates new information rather than merely adding features to the software. This is commendable. However, one important feature worth mentioning is the improved (and potentially more automated) data flow from H2A updates. (This is similar to the recent accomplishment on the HyDRA project; indeed, SERA may be gaining this advantage through HyDRA.)
- The approach seems hard to fault but, because the project is complete, perhaps it has evolved. At any rate, the final product seems to provide what DOE wants.
- It seems to be a solid model based on other DOE models.
- SERA is integrated with other analysis models and is also able to perform a range of scenario analyses depending on need. However, it needs more collaboration with other stakeholders, especially with industry stakeholders, who can provide more of a "real-world" perspective and point out real-world deployment issues.
- Integrating other models is good, but it appears that another vehicle choice model has been developed.

Question 3: Accomplishments and progress towards overall project and DOE goals

This project was rated **3.6** for its accomplishments and progress.

- The principal investigator reported progress on several recent scenario studies, including combined heat, hydrogen, and power systems; biogas systems; and wind-power cost models. The presenter should be commended for putting increased emphasis, compared to last year, on the results and lessons learned of the studies performed.
- The project's progress and accomplishments appear to be satisfactory according to what was required by the project plan.
- Some interesting results are counterintuitive, such as the interaction of Annual Energy Outlook projections of electricity and natural gas prices, and the causes of the prices changes.
- The capabilities of the model have been considerably enhanced; now there is good focus on a range of scenario analyses to meet Program needs.
- The accomplishments and progress are reasonable.

Question 4: Collaborations and coordination with other institutions

This project was rated **2.8** for its collaboration and coordination.

- This project is inherently collaborative because it builds on data produced by others and generates scenario studies of interest to the Program.
- Direct collaboration is minimal, but obviously exists through the other projects to which it is connected.
- There is little evidence of any results due to collaboration.
- There has been more collaboration with others during the previous years, but not as much this year—especially as the model turns more to performing various scenario analyses. Closer collaboration with industry stakeholders, as well as other analysis efforts (such as the AN-018 effort) to look at early hydrogen infrastructure costs, will help validate model results and align them with market realities.
- Collaboration with potential users would be beneficial.

Question 5: Proposed future work

This project was rated **3.0** for its proposed future work.

- Going forward, the plan is to focus on "complex deployment scenarios."
- The project is complete, but it seems that it would have been worthwhile to propose applying the system to a wider variety of markets and test it on some more difficult ones.

- It is important to align future scenario analyses with findings of other analysis efforts, input from industry stakeholders, and Program needs and priorities. Future scenario analyses should focus on near-term market opportunities and barriers to overcome. Sensitivity analyses should also be initiated. Some future scenarios could look at the impacts of the different levels of and the presence or absence of supporting policies at the state and federal levels.
- It is appropriate to focus on new scenarios.

Project strengths:

- SERA is at its best when it is used to calibrate expectations about particular technologies and growth paths.
- SERA integrates results and data from multiple hydrogen analysis models and projects. It has geographic information system capabilities, and is able to incorporate updates from H2A cost models. The project has started looking at the impact of consumer preferences, which is an important variable often overlooked in many quantitative analyses.
- Scenario analysis will help guide and justify DOE research and development directions.

Project weaknesses:

- SERA is at its weakest when flashy visualizations obscure the state of uncertainty in the underlying data. One can easily lose track of the fact that this is a world of estimates and approximations, and that highly detailed geospatial maps and other outputs can overwhelm the extent of substance of the story. Furthermore, SERA is not, in fact, a critical element in determining allocation of capital for build-out of energy infrastructure.
- The project needs to be closely coordinated with industry stakeholders.
- There is a concern about developing another vehicle choice model, rather than using the Market Adoption of Advanced Automotive Technologies (MA3T) model.

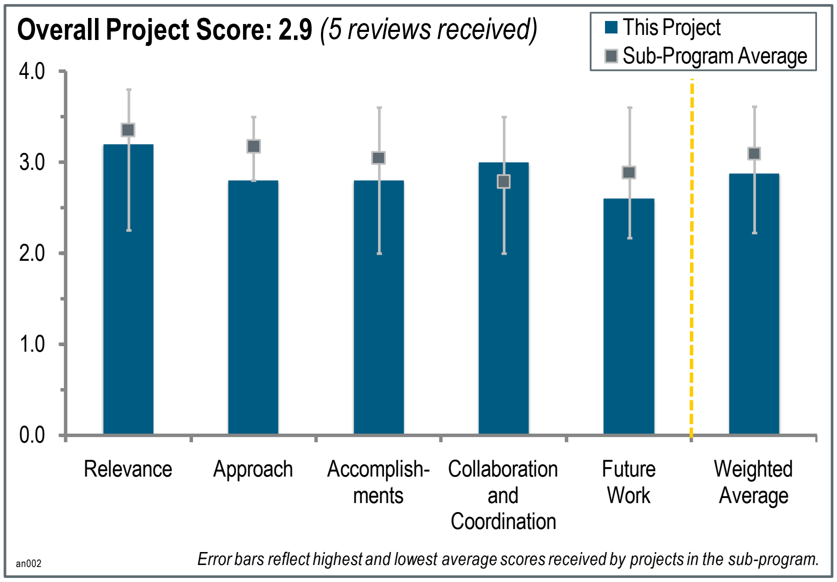
Recommendations for additions/deletions to project scope:

- A general nationwide scenario of infrastructure development could be developed and compared against the approach of developing infrastructure on a region-by-region basis. As the subject of integrating renewables into the grid becomes an important issue, more focus could be given to analyses looking at the impact of using curtailed renewable power in different regions of the country—in terms of both integrating renewables and developing a hydrogen infrastructure.
- The planned integration with MA3T is great.

Project # AN-002: Analysis of the Effects of Developing New Energy Infrastructures

Dave Reichmuth; Sandia National Laboratories

Brief Summary of Project:



The objectives of this project are to (1) use dynamic models of infrastructure systems to analyze the impacts of widespread deployment of hydrogen technologies; (2) analyze the contribution of stationary fuel cells that co-produce hydrogen to the early market penetration of hydrogen fuel cell electric vehicles (FCEVs); and (3) analyze competition between electric vehicles, efficient gasoline vehicles, and hydrogen fuel cell vehicles. Because the transition to hydrogen fueling is expected to rely on distributed steam-methane reforming and stationary fuel cells, the impacts of hydrogen vehicles and stationary fuel cells on the infrastructure must be understood.

Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.2** for its relevance to U.S. Department of Energy (DOE) objectives.

- This project supports the DOE Hydrogen and Fuel Cells Program's research, development, and deployment objectives, as it assesses environmental impacts, analyzes necessary infrastructure development, and analyzes long-term impacts of hydrogen fuel and vehicles.
- Analysis projects such as this one help to assess the environmental impacts, needed infrastructure development, and the long-term impacts of the large-scale deployment of FCEVs.
- Comparing other vehicle platforms and investigating new approaches such as combined heat, hydrogen, and power (CHHP) enhances the understanding of the development of hydrogen and fuel cell technologies and the related infrastructure, while also highlighting the value propositions.
- This project is important for understanding the factors that will influence fuel cell vehicle penetration.
- This project has not captured unknown alternatives, such as alternative hydrogen carrier technologies and other technology advances that may improve batteries (as an example). The infrastructure issues for hydrogen have not been adequately addressed.

Question 2: Approach to performing the work

This project was rated **2.8** for its approach.

- The model employs an easy-to-use front end with sensitivity analysis and has the ability to export to Excel. The model is cost-driven, based on appropriate regions and vehicle segments.
- The project considers the demand and price interactions between primary energy and fuels and between fuels and vehicles. Different regions and different vehicle segments are considered separately for each. One concern is that the model assumes that costs will drive consumer decisions. If that were the case, there would be no current market for hybrid vehicles at the higher costs of hybrid vehicles relative to their internal-combustion-engine-only variants. The fuel cost savings with hybrids would not have payback periods as short as three years, or even five years (slide 18), for example. The user interface shown on slide seven is convenient for conducting sensitivity

analyses by using slider bars for the different input parameters. It was not clear, however, whether these parameters were fixed or if others could be added by the user, if desired.
- It is good that the model is including "choice factors," such as vehicle range. This adds more depth and reality to the analysis.
- The approach is good and the methodology is sound, but unimaginative. The possibility of alternate technology advances is inadequately addressed.
- The model is intended to cover a complete loop of energy, fuel, and vehicles; however, it should have used the Market Adoption of Advanced Automotive Technologies tool for the vehicle choice model and it should look at the change in petroleum price when half the fleet is alternative fuel vehicles.

Question 3: Accomplishments and progress towards overall project and DOE goals

This project was rated **2.8** for its accomplishments and progress.

- It has been shown that carbon prices are important to the increased market penetration of FCEV, and that these vehicles will enable significant greenhouse gas (GHG) reductions. Policy is also shown to be significant.
- Progress is good within the parameters laid out.
- The following has been added to the model as recommended by the reviewers from the previous year: more powertrain and vehicle size options, more geographic regions, and low-carbon energy sources. The base case results in slides 12 and 13 are significant in that they show, subject to the various assumptions used in the analyses, that the FCEVs have a much greater market penetration rate than any of the plug-in hybrid vehicles (PHEVs) or battery electric vehicles (BEVs) beyond 2040. The corresponding effect on oil use and GHG emissions is also the greatest due to the penetration of the FCEVs (slide 19). These results hold only if crude oil prices increase over the years in excess of overall inflation. If crude oil prices do not outpace general inflation, then the analyses indicate only marginal penetration by any of the vehicle and fuel technologies considered, be it FCEV, PHEV, or BEV (slide 16).
- It is good to see that effort has been made to expand to regions outside California to analyze regional effects.
- The list of international collaborations is impressive, but it is not apparent that there are international contributions.

Question 4: Collaborations and coordination with other institutions

This project was rated **3.0** for its collaboration and coordination.

- This project has excellent international collaboration, part of a world-leading team.
- This project contributes to the International Energy Agency (IEA) task on Global Hydrogen Systems Analysis, including contributing to the IEA reports, World Energy Outlook, and Energy Technology Perspectives. The specific nature of the collaboration with Dr. Andy Lutz of the University of the Pacific was not discussed in the presentation.
- It is good that there is international-level collaboration.
- The project's collaboration is poorly explained.

Question 5: Proposed future work

This project was rated **2.6** for its proposed future work.

- The following improvements and additions to this work will be highly valuable: (1) a greater number of hydrogen production pathways to be added, (2) an increased resolution of energy source data, (3) a link to macro-system model, and (4) more detail on inter-regional energy and fuel transport to examine infrastructure costs and more complex carbon policies.
- More work on the infrastructure effects would be beneficial.
- The work described for the remainder of fiscal year (FY) 2011 and FY 2012 does not significantly add to the results already achieved. Along with the continuing model development work, perhaps it would be useful to analyze various cases of different policy options (e.g., the nature and magnitude of subsidies, tax incentives, or fuel prices).

- The first priority should be to establish realistic petroleum prices as a function of the number of vehicles in the fleet.

Project strengths:

- The project's strength is its world view.
- The project's strengths include the following: (1) the model offers a convenient means of conducting sensitivity analyses; (2) the base case results clearly point out the strong impact of fuel costs on the future market penetration of advanced vehicle and alternative fuel technologies; and (3) if the assumptions are validated, then the relative differences in market penetration rates of the different vehicle technologies (BEV, PHEV-10, PHEV-40, and FCEV, slide 13) and the corresponding effects on oil use and GHG emissions (slide 19) are important results.
- The project's strengths are (1) the model front end is user friendly, and the model is dynamic; (2) a sensitivity analysis is used to make up for the unknowns relating to costs and other factors; (3) FCEVs are compared with other vehicles and pathways; (4) the contribution of CHHP to early market FCEV development is investigated; and (5) the software can be expanded to other regions and countries.

Project weaknesses:

- This project needs more resources.
- The project is a bit unimaginative in trying to consider the effects of major, game-changing advances in the technologies. For policymakers, this would be good, as it would help them to decide on research and development investment.
- Some of the assumptions in the model should be revisited to ensure their validity. These include the following:
    - Distributed steam-methane reforming for hydrogen production: at least for the near future, the trend appears to be contrary to the assumptions made in this work (slide 10).
    - A 500 megawatt high-temperature stationary fuel cell with co-production of hydrogen (slide 10) represents a fuel cell size scale-up of approximately three orders of magnitude. There appears to be little effort at present to increase the size of the solid oxide fuel cell (SOFC), molten carbonate fuel cell, or the phosphoric acid fuel cell "building block" from the current 100–400 kilowatt size. It is hard to visualize 1,000 or more of these fuel cell units working in concert at one location, or any advantages of scale from such an installation.
    - Even if direct data are not available, some decrease in the effective fuel economy of FCEVs should be considered as the vehicle size increases from small car to large car to truck (slide 9).
    - The payback period is a critical parameter for FCEV sales (slide 18). While fuel economy is a consideration in vehicle purchases, payback period is typically much less important than other, perhaps emotional, factors in these decisions. The payback period may be a significant factor only for vehicles purchased for commercial or business use.
    - Some factors, such as vehicle range (important only for BEVs), may be more of a go/no-go decision factor than an equivalent cost factor (slide six).
- The project does not include other alternative fuels such as compressed natural gas and biofuels. The project only uses SOFC-related parameters and data from only one fuel cell manufacturer. It would be better to get parameters and data from several and compare and contrast to develop more representative and wide-ranging values.
- Portions of the work appear to be duplicative, i.e., another vehicle choice model.

Recommendations and additions/deletions to project scope:

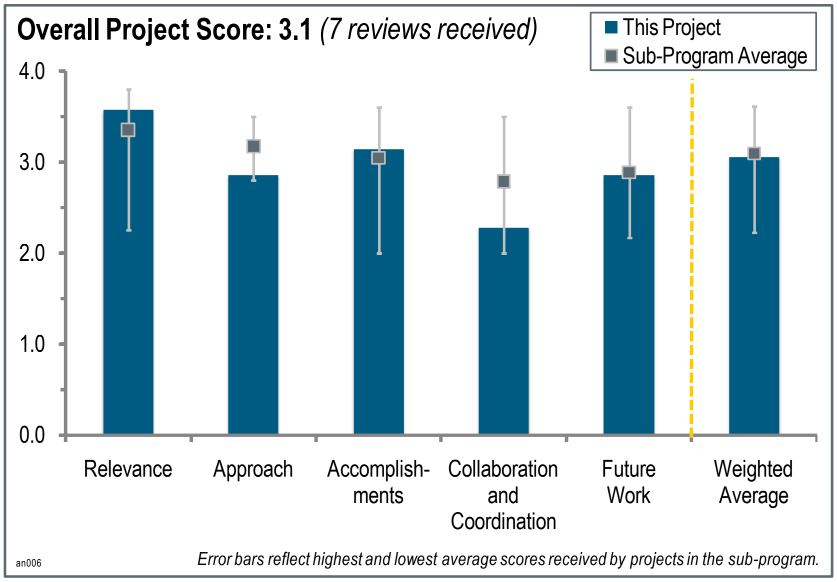
- Because the price of oil seems to be an important factor in determining the market penetration rates of the advanced vehicle technologies being analyzed in this work, it would be interesting to see what the effects would be of a significant increase in the base price of oil, such as doubling from $90 per barrel to $180 per barrel. This would reflect the "effective" price of oil in Europe and the Far East, and the results may explain the much higher emphasis being placed on these technologies in those parts of the world than appears to be the case in the United States. Another recommendation is to make the model available to the larger research community so that others may explore various fuel and vehicle scenarios.

- It would be beneficial to investigate the use of biogas, as that is a quickly expanding area of use and importance for stationary fuel cells. This project should also coordinate with Hydrogen Demand and Resource Analysis and Macro Systems Model related efforts. As conventional oil resources run out, the cost of extracting harder-to-reach resources will be higher—it might be useful to factor in these effects as well. Finally, the project could do more regional or granular analysis to analyze environmental implications of vehicle deployment and infrastructure development, such as the impact of distant production sites relative to where the energy is used and how to account for environmental pollution.
- The first recommendation is to stop the project. If it is continued, it should look at worldwide vehicle introduction and the impact on petroleum price.

Project # AN-006: Cost and Greenhouse Gas Implications of Hydrogen for Energy Storage

Darlene Steward; National Renewable Energy Laboratory

Brief Summary of Project:



Hydrogen has unique attributes as an energy storage medium, and could serve as a storage medium for electricity and as fuel for vehicles. The overall objective for this project is to find cost savings opportunities and other benefits of hydrogen energy storage and renewable hydrogen for vehicles by analyzing scenarios for using renewable electricity generation with hydrogen systems. Specific objectives of the project are to: (1) evaluate the economic viability of using hydrogen for utility-scale energy storage applications compared to other electricity storage technologies, including a simple energy arbitrage scenario, and analyze the potential for cost improvements over time; and (2) explore the cost and greenhouse gas (GHG) emissions impacts of the interaction of hydrogen storage with variable renewable resources, including hourly energy analysis of specific locations and wind profiles to capture detail.

Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.6** for its relevance to U.S. Department of Energy (DOE) objectives.

- This project sweats the details of a development scenario for producing hydrogen by electrolysis using "excess" (curtailed) electricity that is intermittently produced by a wind farm. The two possible reasons for doing this are to (1) help level the output of the wind farm by buffering the system with energy storage, and (2) produce hydrogen for use as a transportation fuel. This project creates value by carefully conducting a detailed analysis of these propositions to determine actual costs, both in dollars and, ultimately, in carbon dioxide (CO_2) emissions.
- This project evaluates the use of hydrogen storage to increase renewable electricity production.
- Storing energy effectively over relatively long periods of time is crucial to the widespread deployment of renewable energy, which tends to be highly variable in nature. Analyses such as these are essential in defining the potential role of hydrogen as an energy storage medium in these applications. This project also considers the dual use of hydrogen generated from renewable energy: (1) for energy storage, i.e., to provide electricity back to the grid; and (2) for use as a transportation fuel. The technical analyses are accompanied by life-cycle cost analyses, as well.
- This is a good match with DOE goals.
- Being able to store excess energy from wind turbines is critically important, and being able to store it as hydrogen, which could be used for vehicles, is even more important. The economic reality of this process is very relevant to DOE goals.
- This project is relevant to the DOE Hydrogen and Fuel Cells Program. It does support research, development, and deployment objectives.
- This project, as presented, only considers hydrogen production. A literature review of other technologies is mentioned, but is not discussed in detail.

Question 2: Approach to performing the work

This project was rated **2.9** for its approach.

- The strength of this project is its careful utilization of historical data from four geographically dispersed wind farms of different sizes. The approach is complemented by using the Fuel Cell Power Model for hydrogen generation, storage, and electricity regeneration.
- The approach is good and clearly presented along with the cost model.
- The project analyzes case studies using wind datasets and transmission line size constraints. For the case where some of the hydrogen is provided as a fuel for cars, the objective is to minimize the cost mix of electricity and hydrogen.
- Scenario analysis is a good strategy. Identification of barriers is done well. Studying wind farm locations in multiple states is a meaningful approach. Line losses and costs are important to identify value proposition.
- This is a continuation of a previous study. It seems that a more comprehensive approach would have been established by now with fewer limitations on the results. The approach is good, but should have been better.
- The literature review is still ongoing. The approach is based on realistic case studies. However, the criteria for selection are unclear. The reviewer wants to know how realistic they can be when renewable hydrogen storage is not yet practiced. The project uses hourly energy analysis using a fuel cell model.
- The approach needs to consider other electrochemical storage technologies that have better round-trip efficiencies. This study seems unrealistic.

Question 3: Accomplishments and progress towards overall project and DOE goals

This project was rated **3.1** for its accomplishments and progress.

- This project is progressing successfully and is generating results (e.g., slides 13–15). However, the results indicate, "Hydrogen can be produced from curtailed wind, but electrolyzer costs must come down for this option to be economical" (slide 17). This is not surprising, and it cannot be cited as progress toward technical goals. Nonetheless, a rigorous and detailed assessment of what costs must be in order to make an approach viable is a valuable contribution to the Program.
- Progress has been made toward objectives.
- Hydrogen storage needs for various wind farms have been calculated. The team has shown that electrolyzer costs must come down for wind electrolysis to be economical.
- Progress in the limited space is satisfactory.
- The analyses show that the needed hydrogen storage capacity varies seasonally and, even so, there may be periods of low wind energy and low amounts of hydrogen in storage. This suggests that for the case of a North Dakota wind farm, for example, energy storage as hydrogen may not be sufficient to make electricity from wind energy available at all times. The analyses clearly show that to generate hydrogen during high wind energy periods, and then to use the hydrogen for power generation using a fuel cell, the electrolyzer would need to be about five times as large as the fuel cell for an optimum system. For example, in one case, the electrolyzer would have a capacity of 700 megawatts (MW), while the corresponding fuel cell capacity would be 130 MW (to provide steady power output for more than 4,000 hours per year, i.e., a fuel cell capacity factor of 50%).
- Hydrogen cost analysis using the electrolyzer cost as a parameter is a good idea. The role of capacity factor for an electrolyzer is critical for economics. The reviewer asks how this can be maximized.
- The accomplishments seem to show that there is little hope for using hydrogen as a form of stored energy for later vehicle use (one of two scenarios presented), even if the electrolyzer was free. It seems that the parameters in the study should have gone beyond simply the cost of the electrolyzer to include other major cost drivers (e.g., the costs and maintenance of wind turbines, hydrogen storage, and the transportation of hydrogen).

Question 4: Collaboration and coordination with other institutions

This project was rated **2.3** for its collaboration and coordination.

- This project is inherently collaborative, as it adds value to historical and model data produced by others. Coordination within the National Renewable Energy Laboratory (NREL) project teams appears to be good. Apparently, the project does not suffer from lack of additional collaboration.
- While there is internal collaboration and collaboration with one industry partner, the project should seek additional collaborators from utilities, wind turbine producers, electrolyzer manufacturers, and geologists.
- Collaborations are too limited. Broader collaborations with more end users, utilities, and the original equipment manufacturers would have broadened the scope.
- In addition to the in-house NREL Strategic Energy Analysis Team, this project works with Xcel Energy, an electric utility serving several states in the Midwest and in the central United States.
- This reviewer asks how Xcel Energy has helped guide the study, and if the Electric Power Research Institute can be included in the study.
- There is only one entity beyond another national laboratory and NREL.
- Collaboration is not a big part of this project as presented.

Question 5: Proposed future work

This project was rated **2.9** for its proposed future work.

- The analysis in terms of CO_2 benefits is continuing.
- The proposed future work is reasonable.
- The analyses will be extended to solar installations, and they will add delivery of hydrogen for vehicles. Additionally, hydrogen storage costs will be refined and GHG emissions will be compared with alternative energy storage options.
- Solar does not need storage—it peaks with the load demand. Future work should analyze wind profiles and how to maximize capacity factor.
- The proposed future work could fill in some of the gaps, but there was no mention of changing the approach.
- The analysis of geologic storage needs input from a geologist—not all potential geologic storage scenarios are equal. The team should extend research to solar, hydrogen delivery cost, and impact on GHG.
- There is not enough emphasis on competing storage technologies.

Project strengths:

- A strength of this project is the utilization of historical data on the variability of a wind farm output to assess curtailment and the economics of hydrogen generation.
- This is a great study to examine viability of hydrogen storage.
- Even with the relatively limited funding, this project has made good progress. Working with Xcel Energy provides a real-world perspective on the practical feasibility of the options being analyzed. The project has analyzed four specific wind farms, each with a relatively high capacity factor of about 40%. The corresponding transmission line distances are 50, 300, 300, and 1,000 miles, a range of values that are useful in comparing the results of case studies.
- Two strengths include (1) an extremely important study area (the alternatives for the storage of energy from renewable sources as well as a potential source of transportation hydrogen), and (2) a great deal of background and talent that are available at NREL to accomplish the tasks.
- Using oxygen as a high-value product of electrolysis is a good idea

Project weaknesses:

- It appears that only one year's worth of wind data was used. Inter-year variability was not assessed. Also, the scenarios being examined can be expected to be uneconomical. While some detailed diagnosis is useful, prolonged examination would have diminishing returns.

- There are not enough resources.
- Only one 2009 publication was listed in the presentation (supplementary slides).
- The comparison criteria are not clear.
- This project had too many unknowns and too many limitations, which should not exist with a continuing project (which is approaching three years since its initiation). At this point, it is questionable whether or not the results are compatible with the funding. All of the slides were overmarked with "2010" and the title slide was dated "8 June 2010" with notes that the project "was expected to continue in FY11" and that fiscal year (FY) 2010 work was 75% complete. This is very confusing for a project with a May 2011 presentation. This reviewer did notice in the "supplemental slides" that the project was not reviewed in FY 2009. A clear explanation of the circumstances was not given. Also, this study could be a subset of AN-013.
- The analysis should include all of the emissions from the system, including from the combustion of natural gas.

Recommendations for additions/deletions to project scope:

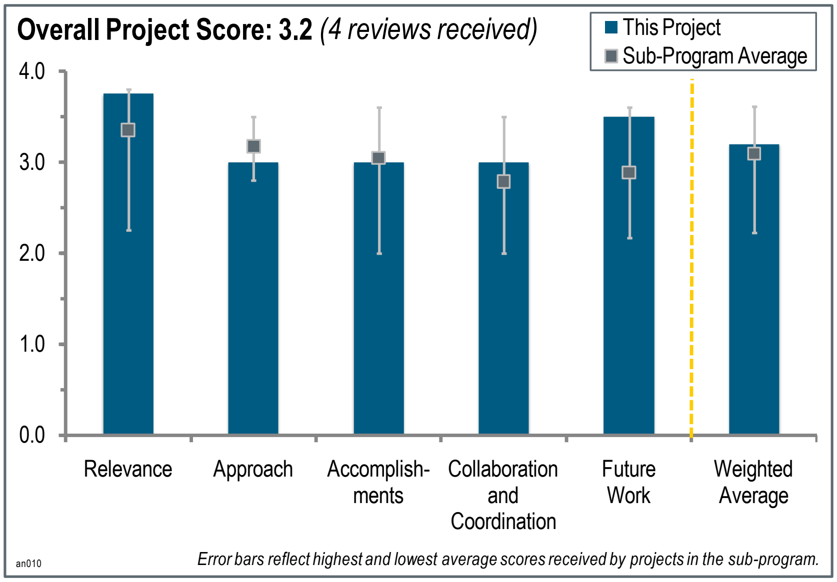
- It is not sufficient to draw a map showing all of the possible geologic resources for storage. For example, un-mineable coal seams are saturated with methane; depleted oil fields will not enable hydrogen to be stored cleanly; and some resources have unacceptable leakage rates. It is strongly suggested that the team collaborate with geologists so only viable geologic reservoirs are studied and included.
- The results should be published in the open literature.
- It is recommended that the project team connect with DOE's Office of Electricity Delivery and Energy Reliability to get more guidance. This reviewer wonders if waste biomass hydrogen could be considered as a least-cost option.
- If the project continues, and it should either on its own or as part of AN-013, there should be at least one additional major parameter considered to make the study more complete: namely, solar energy (which has already been proposed for inclusion in future work). Also, it is very important to know some detail concerning the assumptions associated with the costs and efficiencies of various technologies such as hydrogen storage above and below ground, gas turbines, pumps, compressors, fuel cell systems, etc. It would help if there was a page listing all of the major assumptions.
- This project should have collaboration with other institutions.

Project # AN-010: Fuel Quality Effects on Stationary Fuel Cell Systems

Shabbir Ahmed; Argonne National Laboratory

Brief Summary of Project:

The objectives of the project are to: (1) study the impact of impurities on fuel cell systems, including the components affected and performance loss, as well as degradation and cleanup strategies and their cost factors; (2) identify the system configurations that are most constrained by impurity effects; and (3) recommend research and development (R&D) that can mitigate the deleterious effects and provide alternative and less expensive cleanup options.



Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.8** for its relevance to U.S. Department of Energy (DOE) objectives.

- This is a critical study on the effects of impurities on the performance, life, and cost of stationary fuel cell systems.
- The work is clearly relevant, but seems to be a continuation of several years of study. About $1 million has been expended, and it is not clear what has been accomplished since last year.
- This is very relevant, since hydrogen from landfill gas and wastewater treatment plants is a promising approach to making renewable hydrogen.
- Understanding the impact of impurities is critical.

Question 2: Approach to performing the work

This project was rated **3.0** for its approach.

- An approach that gets to the cost tradeoffs is very good.
- The approach relies heavily on verbal and anecdotal input from some (but far from all) of the key players in industry. This is a very unreliable way of gathering data. For example, if two or more polymer electrolyte membrane (PEM) fuel cell producers were asked the same questions, they would give different answers.
- The approach is good but limited by the information available. Most bases appear to have been covered.

Question 3: Accomplishments and progress towards overall project and DOE goals

This project was rated **3.0** for its accomplishments and progress.

- A comprehensive database of likely contaminants is very good. It is nice to see consideration of a full set of sulfur, halogenated, and silicon contacting molecules. A system for further study has been set up.
- A lot has been accomplished, but there has also been a lot of funding involved. It is not clear what was previously accomplished and what has been done since last year.
- This project is establishing a very good understanding of impurity concentrations and their variability.

Question 4: Collaboration and coordination with other institutions

This project was rated **3.0** for its collaboration and coordination.

- This project shows good collaboration with industry partners. The reviewer asks why there is no interaction with all of the other groups at universities and national laboratories that are studying impurities on PEM performance. There are some obvious synergies and potential overlap there.
- There is collaboration with fuel cell manufacturers.
- While there are four non-government entities involved, there are also many key players in fuel cell production and fuel production and treatment who are not involved. If industry needs this database, is it unclear why they are all not involved and pushing for the results.

Question 5: Proposed future work

This project was rated **3.5** for its proposed future work.

- Future work should finish base case system and results validation. The reviewer asks if the base system will be easily modified as new impurities are identified.
- Proposed future work seems to be a continuation of what is being (or has already been) done. Helping to resolve the possible R&D to overcome various fuel and fuel cell issues could be an important addition.
- As long as the researchers accomplish a cost estimate of the gas cleanup system, it will be worthwhile.
- Tradeoff analysis is critical.

Project strengths:

- This project is a good, comprehensive evaluation of impurities.
- It is clearly a relevant project. Further, Argonne National Laboratory has repeatedly demonstrated that it has the personnel and background to perform excellent analyses.

Project weaknesses:

- It has already been continuing for years. It should not be a lifetime project. There are many major players who should be involved and anxious for results if there is indeed an industry need for the resulting database.

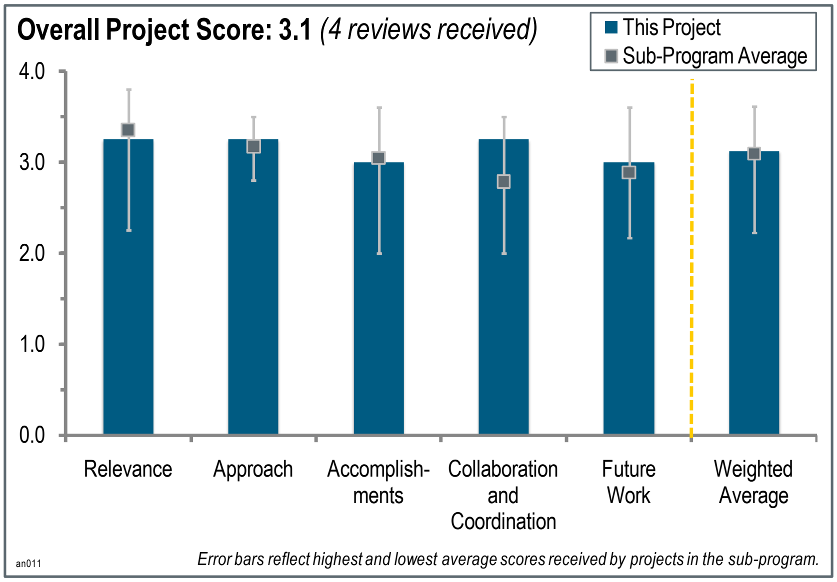
Recommendations for additions/deletions to project scope:

- The team should set some time limit on the project and try to get other major players involved (or at least expressing support).

Project # AN-011: Macro-System Model

Mark Ruth; National Renewable Energy Laboratory

Brief Summary of Project:



The overall objective of this project is to develop a macro-system model (MSM) aimed at: (1) performing rapid cross-cutting analysis, utilizing and linking other models, and improving consistency of technology representation (i.e., consistency between models); (2) supporting decisions regarding programmatic investments through analyses and sensitivity runs; and (3) supporting estimates of program outputs and outcomes. Objectives for 2010 and 2011 are to: (1) increase graphical user interface (GUI) functionality and capabilities; (2) utilize the MSM to compare hydrogen production, delivery, and/or dispensing pathways; (3) follow model upgrades (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model [GREET]-1.8d1, Hydrogen Analysis [H2A] Delivery Scenario Analysis Model [HDSAM] 2.2); (4) include vehicle cycle analysis from GREET-2 and the cost-per-mile tool; (5) integrate the Fuel Cell Power model; and (6) determine technical breakpoints in transition scenarios analysis.

Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.3** for its relevance to U.S. Department of Energy (DOE) objectives.

- It is absolutely critical to have one GUI from which all other models can be accessed and linked in order to fully analyze the impact of hydrogen and fuel cells and expedite their application.
- It is good to combine various tools.
- This project is relevant to those who are conversant with the acronym forest. This is one of several linked projects that are so acronym-laden that it is hard to tell what the purpose is.
- While the overall objectives of the MSM development were given in the presentation, its relevance to furthering the goals of the DOE Hydrogen and Fuel Cells Program was not very clear from the presentation. The actual work of the analyses appears to be performed by the component models, such as GREET or HDSAM. As such, the value added by MSM is not readily apparent.

Question 2: Approach to performing the work

This project was rated **3.3** for its approach.

- The approach of full model integration with a GUI is outstanding.
- The approach appears to be good, but the acronyms make it hard to tell just how good.
- The approach appears to be two-fold. One activity is to expand MSM capabilities by updating component models and improving the GUI's functionality. The latter makes more detailed inputs and outputs available to the user.

Question 3: Accomplishments and progress towards overall project and DOE goals

This project was rated **3.0** for its accomplishments and progress.

- The GUI now allows queries at the county level and allows even more data to be viewed as outputs. Additional models were integrated. Some impressive modeling has been demonstrated from this integrated approach. The user group sampled was a little small (i.e., 20) for a true user evaluation to be reported.
- The workshop shows responsiveness to the reviewer comments, indicating a willingness to consider the user. The model requires more work.
- The main accomplishments include the continuing enhancements to the GUI inputs and outputs and linking GREET-2 with MSM. The results of a case study on combined heat, hydrogen, and power for a large hotel in Los Angeles were presented, for example, but the significance of the results was difficult to discern.

Question 4: Collaboration and coordination with other institutions

This project was rated **3.3** for its collaboration and coordination.

- This project had good collaborations, but needs more stakeholder industries.
- The collaborations are mostly with other national laboratories. It is unclear who the other users are.
- This project is working with several different partners, including various national laboratories (primarily for component models), universities, U.S. DRIVE Partnership's Fuel Pathways Integration Technical Team, and several users. User feedback is being used to improve MSM.
- This project has a great mixture of partners.

Question 5: Proposed future work

This project was rated **3.0** for its proposed future work.

- Future work will put the project on track for full integration of other models.
- An extension of future work is reasonable given the expected future funds. Expansion of the outreach to users is necessary.
- The main planned activities are listed as (1) an update of component models (H2A, HDSAM, GREET, etc.) as new versions become available, and (2) an analysis and comparison of the effects of different vehicle and fuel costs, alternative hydrogen production and delivery methods, and hydrogen station build-out scenarios. It was not clear how the results of these analyses would be used.

Project strengths:

- A strength is the integration of other models into one GUI.
- The project has added considerable detail and transparency to the model inputs and outputs. The project has good collaboration and user feedback.

Project weaknesses:

- The project needs more resources so that the model can be used more.
- The value is in danger of being obscured by the acronyms and the complexity. It needs to be much more simply explained to the non-expert.
- The discussion did not offer examples of how the results from the analyses could be used.

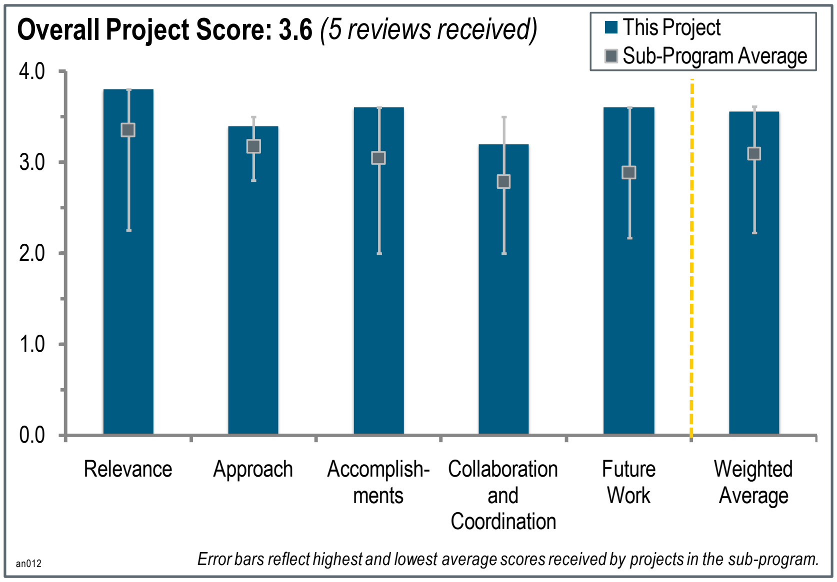
Recommendations and additions/deletions to project scope:

- It is not convincing that the GUI is ready for primetime—it needs to output data with units and at a precision that reflects the original data sources.
- This project should provide more significance and interpretation of the results. The project should highlight sensitivity analyses and discuss the important parameters.

Project # AN-012: GREET Model Development and Life-Cycle Analysis Applications

Michael Wang; Argonne National Laboratory

Brief Summary of Project:



The objectives of the project are to: (1) develop and update the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model (GREET) model for consistently assessing energy and emission benefits of hydrogen fuel cell electric vehicles (FCEVs) and other fuel cell systems; (2) conduct fuel-cycle analysis of hydrogen FCEVs with various hydrogen production pathways and early market fuel cell systems; (3) conduct vehicle-cycle analysis of manufacturing hydrogen FCEVs; (4) provide life-cycle analysis results for U.S. Department of Energy (DOE) Hydrogen and Fuel Cells Program strategic planning activities; and (5) support and interact with stakeholders to address energy and environmental benefits of hydrogen and fuel cell systems.

Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.8** for its relevance to DOE objectives.

- This is one of the most critical models being developed under the hydrogen analysis portfolio and is essential to DOE research, development, and deployment (RD&D) objectives.
- The GREET model provides needed analysis and information to DOE and other parties.
- In one reviewer's opinion, GREET has been a very successful effort. Even though a lot of money was spent, the result was an extremely useful tool, and enhancing it further has to be very relevant.
- This GREET model is one of the most valuable DOE models—the "gold standard" of greenhouse gas (GHG) calculations.
- The project's objectives align with the Program's RD&D objectives.

Question 2: Approach to performing the work

This project was rated **3.4** for its approach.

- Life-cycle analysis is critical and the approach of doing this openly and transparently is very powerful. Although it would be good if some of the critical industry data that is not open source was included, this would remove some transparency.
- This project is continuing to increase the number of technologies covered by the database. Development of a more user-friendly interface will increase the use of the tool by additional analysts.
- The work relies, at least partially, on data that is not readily available, such as fuel cell vehicle data. Further, the current study is apparently only partially responsible for the "new" GREET architecture.
- The approach is well thought-out and presented. The project is well designed, feasible, and integrated with other efforts.

Question 3: Accomplishments and progress towards overall project and DOE goals

This project was rated **3.6** for its accomplishments and progress.

- The project made great additions to the package including landfill gas to hydrogen, plug-in hybrid electric vehicles, and a greater emphasis on fuel cell vehicles.
- This project increased the range of use of the tool by adding additional case studies.
- It is hard to tell the progress because much of the current work is so intertwined with previous work.
- The GREET model represents a great accomplishment.

Question 4: Collaboration and coordination with other institutions

This project was rated **3.2** for its collaboration and coordination.

- This project team collaborates with the National Renewable Energy Laboratory and the Sandia National Laboratories, but it is hard to assess this question when the reviewers are only told that the collaborators are industry stakeholders; in general, more industry and government interaction would improve the data set.
- The stature of the team encourages unparalleled collaborations and access to data and information.
- It appears to be very limited in that no entities outside government except "industry stakeholders" (whatever that means in this context) were shown.
- The level of collaboration is not clear.
- The effort of collaboration and coordination with other institutions is outstanding.

Question 5: Proposed future work

This project was rated **3.6** for its proposed future work.

- The proposed future work includes the new version of GREET and documentation of combined heat and power.
- The project has a strong plan in a range of applications, including the new platform.
- There is clearly a need to make better projections for landfill gas emissions, as utilizing landfill gases is now an issue all over the country. Better analyses for fuel cell combined heat, hydrogen, and power systems are also very important. Presumably, a new platform for GREET could make it more accessible to more parties.
- The results for waste water treatment plants (WWTPs) are highly anticipated, as every municipality has WWTPs and this represents a diverse source of renewable hydrogen all across the country.
- The proposed future work is excellent.

Project strengths:

- The GREET model is an excellent life-cycle and GHG analysis tool.
- There is a large user community.
- This project is being built on an already successful program. In addition, Argonne National Laboratory clearly has the personnel and experience to be successful.
- This project sets the universal standard for researchers around the world.
- Developing a GREET model is excellent work.

Project weaknesses:

- This project may place too much emphasis on programming and needs more focus on all possible pathways to a diverse energy future.
- Obtaining some of the needed data in a consistent, reliable fashion could be very difficult. This project has gone on so long that it could become a money sink.

Recommendations and additions/deletions to project scope:

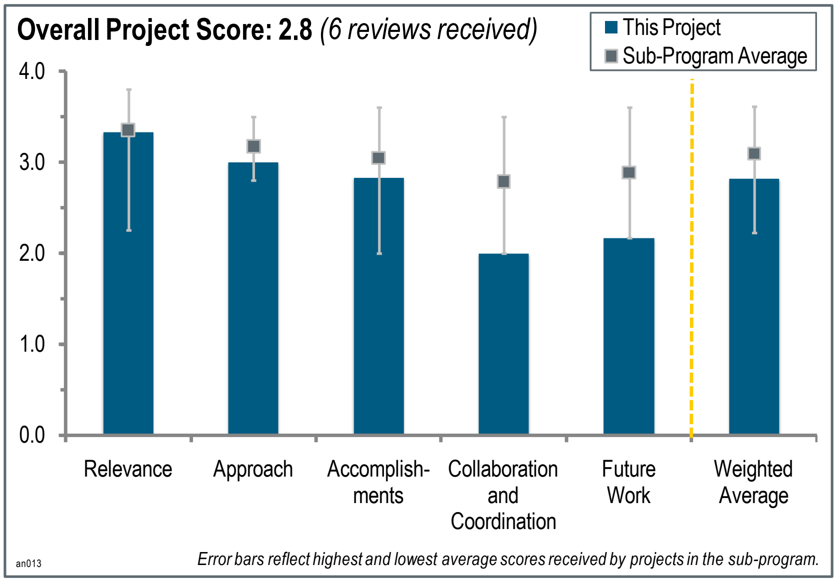
- This project could be more specific by attaching some kind of projected costs and timeline to each of the three tasks proposed for future work. At present, it is all very non-specific.

Project # AN-013: Emissions Analysis of Electricity Storage with Hydrogen

Amgad Elgowainy; Argonne National Laboratory

Brief Summary of Project:

The objectives of this project are to: (1) conduct life-cycle analysis of hydrogen as energy storage for integrating large renewable generation sources into the electric grid and alternative energy storage systems; and (2) support and interact with stakeholders to address the energy and environmental benefits of hydrogen for energy storage applications.



Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.3** for its relevance to U.S. Department of Energy (DOE) objectives.

- Hydrogen is clean. Its value proposition is enhanced when emission values are considered. This is a very important opportunity for fuel cells.
- This seems to be an outstanding project that could produce very useful results. It is clearly of interest to compare the relative merits and greenhouse gas (GHG) avoidance of different types of energy storage for any type of power generation, but especially for renewable sources such as wind or solar where storage is essential.
- This project is relevant to and supports DOE's Hydrogen and Fuel Cells Program.
- Energy storage is a key issue today, especially as renewables ramp up and the grid continues to have constraints. Integrating renewables into the grid has its challenges, and energy storage is an important solution to overcome some of these challenges. Hydrogen as an energy storage application can bring many benefits, but details need to be understood and communicated better. Thus, more detailed analyses and investigations on the subject matter, such as this project, are of importance.
- The project does not seem to be properly evaluating alternative technologies that may be on the horizon.

Question 2: Approach to performing the work

This project was rated **3.0** for its approach.

- Using hydrogen for energy storage is an emerging opportunity to deploy fuel cells in the smart grid. Life-cycle analysis is an effective tool.
- This approach is outstanding, if the models are valid. This reviewer asks if the models are single-valued (as implied) or whether they account for the large variations in efficiencies that actually occur during various processes involved in storing and recovering energy under different conditions. Actually, an optimization would probably be the best way to find the potential for different energy storage technologies.
- Considering this project is just an analysis task, the approach is good and clearly presented.
- The approach is OK, but limited. Literature searches seem to be perfunctory. The oxygen credit idea is not reasonable.

Question 3: Accomplishments and progress towards overall project and DOE goals

This project was rated **2.8** for its accomplishments and progress.

- Progress has been made toward objectives.
- The electrolysis method has been around for a long time. Low efficiency is very important. Alternative storage methods (batteries such as sodium sulfur) are not included. The value of oxygen is a good idea. This reviewer wonders how GHG can be allocated for hydrogen versus oxygen.
- Some very interesting results are shown, but there are some significant gaps. For example, little attention was given to the possibility of using the oxygen in hydrogen-oxygen fuel cells. They not only have much higher efficiencies than hydrogen-air, but should also be less expensive and have a longer life. Also, there was little attention to the costs associated with collecting and compressing oxygen, and there was no mention of the effect of costs associated with the collection and storage of oxygen (e.g., the effects of storage pressure and liquefaction).
- Progress is OK in a limited way.

Question 4: Collaboration and coordination with other institutions

This project was rated **2.0** for its collaboration and coordination.

- Collaborations are limited.
- No collaborations were mentioned. The project does not have any collaboration with utility, gas, or battery companies. Results will be more meaningful if appropriate industry partners are engaged.
- The project review only mentioned the National Renewable Energy Laboratory and "industry stakeholders" (but no specific companies).
- There is no evidence of collaboration.
- Collaboration is not a big part of this project.
- This project could also work more closely with utilities to both gain insights from them and also to communicate hydrogen's benefits.

Question 5: Proposed future work

This project was rated **2.2** for its proposed future work.

- Future work needs to be looking into the new systems that are arriving. For example, General Electric is opening a Zebra battery plant this year.
- DOE's Office of Electricity Delivery and Energy Reliability has determined that electrolysis hydrogen is not a near-term, cost-effective method. The study should include proper Environmental Protection Agency methods.
- Producing a report is valuable (although a report should be considered part of the present effort), but GHGs associated with facility fabrication would seem to be far less important than updating and improving the models.
- In general, looking at construction GHGs is minor. The project needs to consult with industrial gas companies on their outlook of capturing oxygen from an electrolyzer compared to the current industrial air separation unit (ASU) process.
- The proposed future work is reasonable and needs to be more detailed.
- It might also be worthwhile to not only look at emissions from energy storage facility construction, but also from decommissioning activities.

Project strengths:

- This is a good comparison of competing technologies for storage.
- This is a good project with good organization.
- This is a good analysis based on Argonne National Laboratory's excellent GHG modeling through the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model (GREET).
- Using oxygen as a high-value product of electrolysis in the analysis is a good idea.

- This project looks at effects in terms of impacts on different regions. It investigates the effects of by-product oxygen and compares energy storage via hydrogen to other common energy storage technologies.

Project weaknesses:

- The project is too limited in its consideration of competing technologies. The oxygen credit is not sensible.
- The project needs more quantitative data on emissions.
- Too many potentially questionable details are left unanswered. From what was presented (taking into account constraints on time and the number of slides), the quality of the models is unknown.
- This project does not show any collaboration with other institutions.

Recommendations and additions/deletions to project scope:

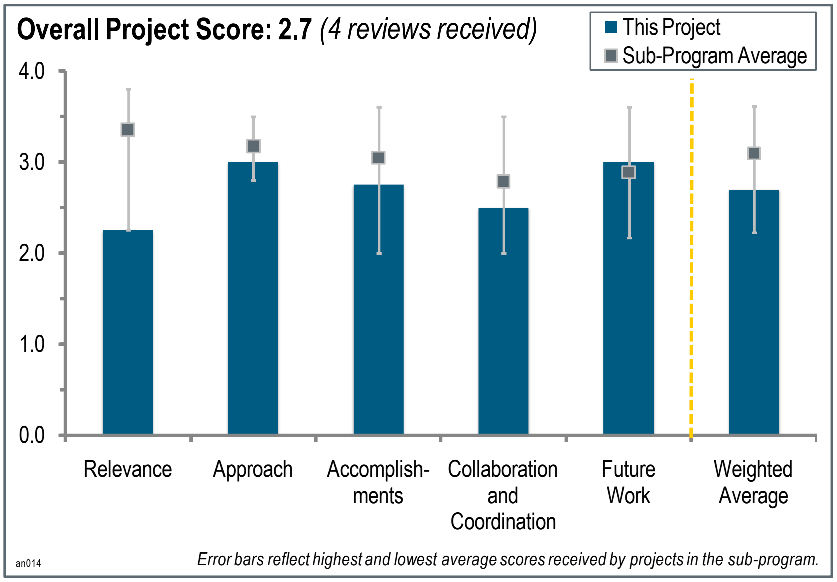
- This reviewer asks if this project can include biomass hydrogen.
- The project needs to consult with industrial gas companies on their outlook of capturing oxygen from an electrolyzer compared to the current industrial ASU process.
- Collaboration is very important for checking the analysis data, reducing efforts, and saving resources.
- This work could also be integrated with the Hydrogen Demand and Resource Analysis (HyDRA) model to provide a geographic information system that would benefit other pathway analyses.

Project # AN-014: Energy Informatics: Support for Decision Makers through Energy, Carbon and Water Analysis

A.J. Simon; Lawrence Livermore National Laboratory

Brief Summary of Project:

The objectives of this project are to: (1) complement geospatial visualization of energy statistics with a structural depiction of energy systems at multiple scales; and (2) aid local, national, and international decision makers with quantitative data tied to qualitative structural information about the state of their energy systems.



Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **2.3** for its relevance to U.S. Department of Energy (DOE) objectives.

- This project is enhancing the understanding of the current state of energy sources and use.
- This project is studying the quantitative visualization of data matrices: a vector of a variety of inputs, a vector of a variety of outputs, and the graphical illustration of the cross terms of the coupling matrix. The most famous of these diagrams begins with a vector of energy sources, by fuel type, and shows the utilization of each (in quadrillion British thermal units, or petajoules) by consumption sector. For the purpose of the DOE Hydrogen and Fuel Cells Program, the project has been commissioned to create new visualizations of water flow (hydrology) and carbon dioxide (CO_2) emissions, on both national and regional levels. Water resources are a potential issue in the local (regional) production of hydrogen fuel, and CO_2 emission reductions are a major driver for the Program. Nonetheless, to achieve "outstanding" relevance, the principal investigator (PI) should better articulate how these visualizations affect decision making. This is somewhat ironic because the classic "U.S. Energy Use" diagrams of this group provided crystal-clear motivation for the hydrogen work in the past decade, showing unequivocally that to reduce petroleum imports, the transportation sector must be addressed. This is a great success story in data visualization.
- This work appears to be potentially useful to state and local agencies. Its relevance to the Program was not clear.
- The project features nice energy and water flow charts, but there is no clear relevance to hydrogen and vehicles.

Question 2: Approach to performing the work

This project was rated **3.0** for its approach.

- A good chart and analysis were provided to characterize energy flow all in one chart.
- The Sankey diagrams produced by this group are nothing short of spectacular. Ultimately, the purpose of data visualization is to tell a story, and the visualizations produced by this group accomplish this exceedingly well. This project does great service to the Program, as well as other energy analysis activities.
- The major components of the approach appear to be data compilation, management, and presentation (primarily as Sankey diagrams). The correlation with water flows is nebulous, at best. For example, it is not clear how the information on slide four (U.S. geographical water availability) can be used along with the information on slide six (U.S. energy flow in 2009). It was stated that the latter was "one of the most often-requested information products," but there was no discussion of what use was made of the information in this Sankey diagram.

Question 3: Accomplishments and progress towards overall project and DOE goals

This project was rated **2.8** for its accomplishments and progress.

- This project has not made much progress from last time. The work should focus on generating information rather than developing individual geography Sankey charts. It would be beneficial to have a similar representation for the transportation sector only.
- The principal accomplishment reported was the generation of many state-level energy flow and water flow diagrams, and foreign nation energy flow diagrams. These are all useful for comparison, showing how easily states and nations differ in their energy and water consumption patterns. State-level CO_2 diagrams should be forthcoming. The presentation also indicated that the automation in which the diagrams are generated (slide 25) is improving. This is particularly encouraging because it should reduce the time lag between the availability of new data and its graphical representation.
- State-level energy and water flow diagrams were shown for California and Hawaii. An example was shown for how the initial water flow data had to be corrected as a result of visualizing it in the flow chart. However, this example also points out the potential unreliability of the data sources used in or available to the project. This uncertainty does not lead to a feeling of confidence, particularly for international data. The usefulness of the results from this work to the Program is not clear.

Question 4: Collaboration and coordination with other institutions

This project was rated **2.5** for its collaboration and coordination.

- This project needs to have a close industry partner.
- This project is inherently collaborative, as it functions to visualize data produced by others. The speaker pointed out, rightfully, that good visualizations can throw a spotlight on suspect data (as illustrated in the case of Hawaii water use), thus aiding the data producers and ultimately the data consumers as well.
- There appears to have been little or no collaboration with other organizations during the period under review. There has been collaboration in the past, and broader collaboration is planned for the future.
- There was no apparent collaboration this year.

Question 5: Proposed future research

This project was rated **3.0** for its proposed future work.

- This project does not face "barriers," "decision points," and "alternate pathways" as envisioned by the question. It merely—but significantly—provides a highly effective means for visualizing data matrices. The data sets to be addressed by future visualization may or may not affect the course of the Program, but some, such as the Manufacturing Energy Consumption Survey, should be highly informative.
- Residential and transportation energy uses will be compiled, including advanced technology scenarios. This information could be useful to analyze the potential future benefits of fuel-cell-based combined heat and power stationary systems and fuel-cell-based transportation systems.
- If by "transportation," the PI means "identifying energy use by fuel/vehicle type," that would be helpful to make the project relevant.

Project strengths:

- This work provides a highly effective means for visualizing data matrices. The diagrams on U.S. Energy Use, in particular, provide clear quantitative insight that can inform all concerned with energy issues.
- This work provides extensive data compilation and graphical representation on a variety of scales (local, state, country).
- There is good energy resource data at the Lawrence Livermore National Laboratory.

Project weaknesses:

- If possible, the project needs to better articulate how its visualizations have affected decision-making—for example, citations of reports and policy statements that have included the diagrams.
- Reliability of the data sources may be uncertain. The example of Hawaii water flows suggests that there may be numerous other errors in the data, minor or major. It is not clear how the results of this work support the activities of the Program, in either the transportation or the stationary applications of fuel cells.
- There is no clear vision of what this project contributes to the hydrogen and vehicle community. It is unclear who will use these data, and for what purpose.

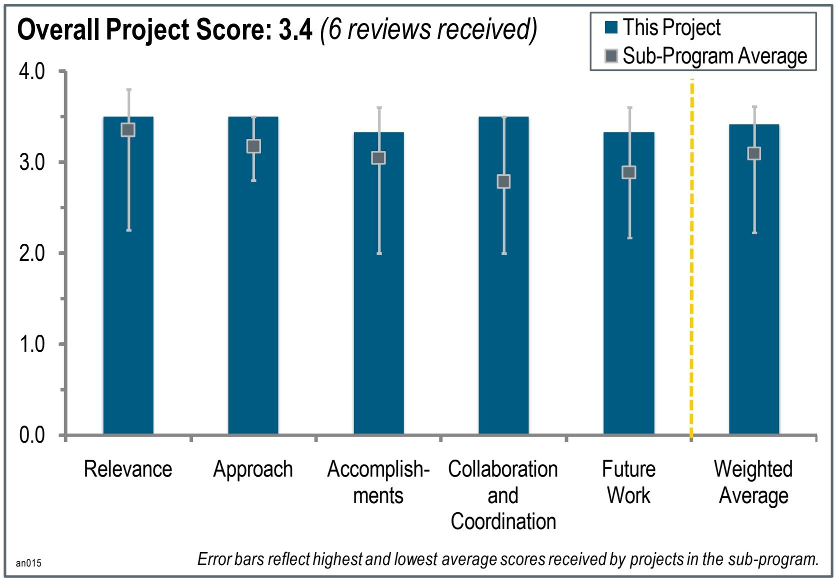
Recommendations for additions/deletions to project scope:

- It would be greatly appreciated if the tool set could be made available for others to use.
- The project should develop approaches for using the analysis results to directly support other activities of the Program.
- The project should estimate water and energy use by fuel and vehicle type.

Project # AN-015: Non-Automotive Fuel Cells: Market Assessment and Analysis of Impacts of Policies

David Greene; Oak Ridge National Laboratory

Brief Summary of Project:



This study contributes to the U.S. Department of Energy (DOE) Hydrogen and Fuel Cells Program's Systems Analysis sub-program goals by conducting an integrated assessment of the dynamic evolution of markets for non-automotive hydrogen fuel cells to improve the understanding of market barriers and risks and the role of policy in overcoming them. The research comprised interviews with original equipment manufacturers (OEM), literature review, development of an integrated market model, sensitivity analysis, and extensive peer review. The integrated market model represents learning-by-doing, scale economies, technological change, and (for proton exchange membrane fuel cells) buyers' choices among competing alternatives.

Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.5** for its relevance to DOE objectives.

- Non-automotive fuels cells should remain a critical part of future adoption plans for fuel cells.
- This study is very relevant, but seems to be overly focused on policy effects and unable to estimate the effects of competing technologies (e.g., improvements in battery technologies or availability of hydrogen).
- While this work is very important, vehicles, if produced, will be the primary drivers for the fuel cell market. If fuel cell electric vehicles are not produced, as the paper indicates, the market will probably collapse without strong incentives. Also, at present, the market for combined heat and power or combined heat, hydrogen, and power systems is very limited.
- This project shows that it is a critical part of the Program, and fully supports the Program's research, development, and deployment objectives.
- The near-term, non-automotive applications of fuel cells are an important market segment that will enable, in this transition period, the development of fuel cells for the transportation market. Thus, understanding the market dynamics, barriers, and effects of policies is important.
- This project provides an understanding of what is required to attain a sustainable industry.

Question 2: Approach to performing the work

This project was rated **3.5** for its approach.

- The pool of expertise polled was good, but interviews with OEMs do not necessarily mean access to crucial proprietary data that would benefit the study.
- The project was well designed with a good approach to overcome the barriers that could be encountered.
- Strong points of the approach include the following: evaluation and re-calibration of previous estimates, in-person interviews with fuel cell OEMs, development of an integrated model consisting of many factors, and expert peer review of work.

- The close interaction with industry is extremely valuable and makes the work very credible.
- The approach is adequate.
- Too much of the study is based on interviews, which are typically not very reliable.

Question 3: Accomplishments and progress towards overall project and DOE goals

This project was rated **3.3** for its accomplishments and progress.

- This is a good demonstration of the impact of policy and the immediate impacts of the American Recovery and Reinvestment Act funding. The conclusions are not overstated and the variability in estimates is accounted for.
- The project's progress is adequate.
- The range of results shown indicates a great deal of accomplishment. However, much of what was presented is based on information from interviews.
- The progress has been demonstrated well toward DOE goals.
- Overall, the project has done a good job in evaluating the barriers, market dynamics, and policy needs to overcome barriers and stimulate the market. Results will be strengthened by looking at some other factors, such as the supply of hydrogen and imports and exports, while reaching out to more fuel cell OEMs and fuel cell purchasers to validate findings.
- The addition of actual cost reductions is very impressive.

Question 4: Collaboration and coordination with other institutions

This project was rated **3.5** for its collaboration and coordination.

- This project has excellent collaborations, but this reviewer asks if these can be expanded to get mission critical proprietary information (that would be protected) that could lead to real conclusions or policy needs.
- Collaborations on this project are OK. One suggestion is to enlist more business schools to help with market evaluation work. Stanford and Berkeley routinely perform this type of work with their Master's of Business Administration classes.
- While information was gathered from many OEMs, the actual collaborators are very limited.
- The collaboration effort in this project is excellent.
- The project team contacted several fuel cell OEMs, and also received peer reviews of findings from a group of experts. This strengthens the results achieved. Reaching out to more OEMs as well as validating cost information received and calibrating the model by contacting key fuel cell purchasers will be important in moving forward.
- The close interaction with industry is a model that all projects should follow. Interaction effectively enables model validation as the project continues.

Question 5: Proposed future work

This project was rated **3.3** for its proposed future work.

- This project has great potential if critical information from industry and government can be obtained.
- This project needs more manpower for the market work. Business schools are a good resource.
- Future work seems to be a continuation of work already underway. One useful addition could be information from fuel cell system purchasers.
- The proposed future work is excellent and clearly demonstrates that the work plan can mitigate risk.
- There is mention of building on previous fuel cell market research to characterize and incorporate export markets. Perhaps the research team can also take a look at the import market, as both import and export markets are important dynamics. Meeting with other fuel cell OEMs, as well as fuel cell purchasers, will be key in fine-tuning and validating findings.
- If policies change, then a new forecast would be called for.

Project strengths:

- This is an area where better information is needed, and this group has the capabilities to do it well.
- This project features good progress in the first phase and a good planning for the second phase.
- Real-world insights were received from fuel cell OEMs. The integrated model considers various factors and the work was peer reviewed by experts. A new study acted as a fine-tuning and updating mechanism for previous work on cost estimates.
- This project shows close interaction with industry.

Project weaknesses:

- There is not enough manpower to conduct market surveys.
- As was stated in one of the slides, no one is likely to be able to predict markets. Without knowing markets, the results are necessarily based on “potential” sales. All of the results are tied to actual sales of various types of units.
- This study did not explicitly analyze limitations on the supply of hydrogen.
- It is questionable whether policy makers really pay attention to studies such as this, or if they even care.

Recommendations and additions/deletions to project scope:

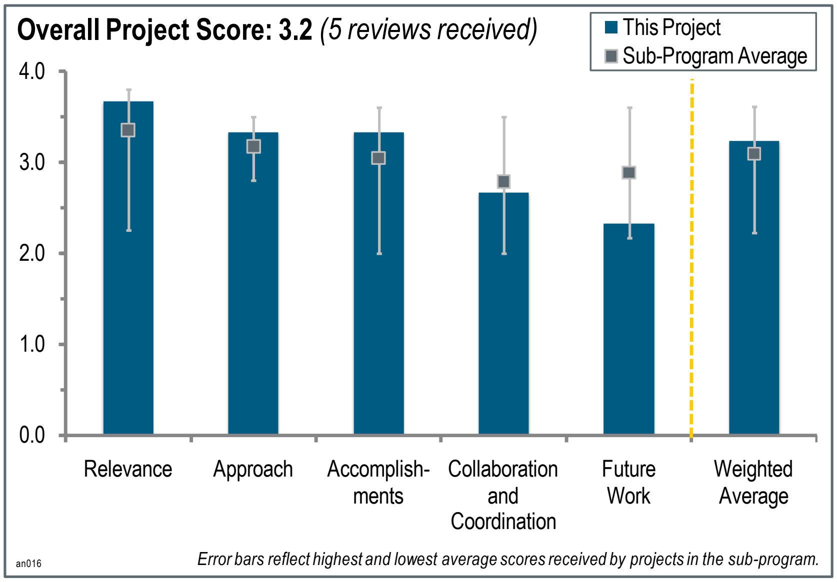
- The team should add 100–500 kilowatt backup units to the mix. These are, and have been, on the market for many years.
- The project team may need to look more into supply of hydrogen issues. A follow-on study might be to look at what role the market dynamics of non-transportation fuel cell markets play in developing a transportation fuel cell market. Try to delineate, for example, how decisions on some incentives (e.g., numbers of non-transportation units deployed, costs coming down to a certain dollar-per-kilowatt level, etc.) could impact the timeline and costs related to a full hydrogen fuel cell economy.
- The study should be updated as new data becomes available. Plans to integrate with the Scenario Evaluation, Regionalization, and Analysis (SERA) model are great.

Project # AN-016: NEMS-H_2: Hydrogen's Role in Climate Mitigation and Oil Dependence Reduction

Marc Melaina; National Renewable Energy Laboratory and Frances Wood; OnLocation, Inc.

Brief Summary of Project:

The objective of this project is to demonstrate the potential contribution of fuel cell electric vehicles (FCEVs) to meeting national goals of reducing greenhouse gas emissions and oil imports by: (1) using an economic framework with competition among vehicle and hydrogen production technologies; (2) analyzing the impact of alternative technology outcomes (e.g., hydrogen production and fuel cell vehicles); and (3) analyzing the potential role and cost of policies to accelerate adoption of fuel cell vehicles.



Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.7** for its relevance to U.S. Department of Energy (DOE) objectives.

- The relevance of this project's objective is quite good, as it projects the overall implications of FCEVs and hydrogen in the U.S. transportation energy mix.
- This project is an econometric analysis that attempts to model both supply and demand for hydrogen in a national energy model that includes competing alternatives. It attempts to predict consumer and producer behavior given free choice, the underlying prices and utilities of alternatives, and any subsidies that the U.S. government might offer to steer consumer or producer behavior toward a common purpose, such as reducing carbon dioxide emissions. The assessment of the effectiveness of FCEV technology as a technical means of advancing policy goals, and the nature of the subsidies that might be required to achieve such goals, provides important information as to whether or not to continue or accelerate the FCEV program.
- This project is a good match—the transition strategy for low-volume cases is very critical to sustain FCEV deployments.
- This is an excellent model for policy makers.
- Understanding the costs and benefits of various policy options is very important.

Question 2: Approach to performing the work

This project was rated **3.3** for its approach.

- It is unclear how the competition with other drive trains is handled in this model. The analysis needs to focus on a more market-driven approach as opposed to a "technology push" approach.
- This project builds on existing models (e.g., DOE's Energy Information Administration's National Energy Modeling System, DOE's Hydrogen Analysis (H2A) project, and the Macro-System Model). It segments hydrogen production markets by production method, vehicle markets by consumer preferences, and the United States as a whole by geographic region. Overall, it uses sensible approaches for performing the work.

- This project provides a good identification of barriers. This reviewer asks if the hydrogen market model includes the existing market plus the FCEV market. There is a reasonable list of hydrogen pathway options, but the reviewer wants to know about by-product hydrogen. This project provides a very good list of assumptions, which is important.
- Using the National Energy Modeling System (NEMS) as a basis for the analysis is very good, and it is refreshing that only portions of this model had to be tweaked.

Question 3: Accomplishments and progress towards overall project and DOE goals

This project was rated **3.3** for its accomplishments and progress.

- This project displays a relatively good amount of work in a short period of time. The analysis needs to be expanded to include the effects of competing drive trains (alternative).
- This project has analyzed a number of scenarios and identified the relative effectiveness of potential subsidies.
- This project provides a very good comparison of different parameters and their impact. This reviewer asks why biomass includes a penalty for carbon. This project also provides a good analysis of the impact of subsidy on market penetration.
- The scenarios analyzed in this work versus the amount of funding expended are appropriate.

Question 4: Collaboration and coordination with other institutions

This project was rated **2.7** for its collaboration and coordination.

- The project team needs to partner with a selected industry player.
- While this work relies on modeling efforts from other DOE projects, it seems to be comparatively insular. Additional interaction might provide contemporaneous peer review of the work.
- The project would benefit from some collaboration with original equipment manufacturers and hydrogen companies.
- The National Renewable Energy Laboratory is the only collaborator.

Question 5: Proposed future work

This project was rated **2.3** for its proposed future work.

- This project is concluding and future work is not planned.
- This work is complete.

Project strengths:

- This project builds on existing modeling efforts to provide forecasts of marketplace adoption of FCEVs under different incentive packages.
- This project uses the existing NEMS model to do the analysis.

Project weaknesses:

- The work appeared to be relatively insular. The lack of contemporaneous review and feedback increased the chance for error.

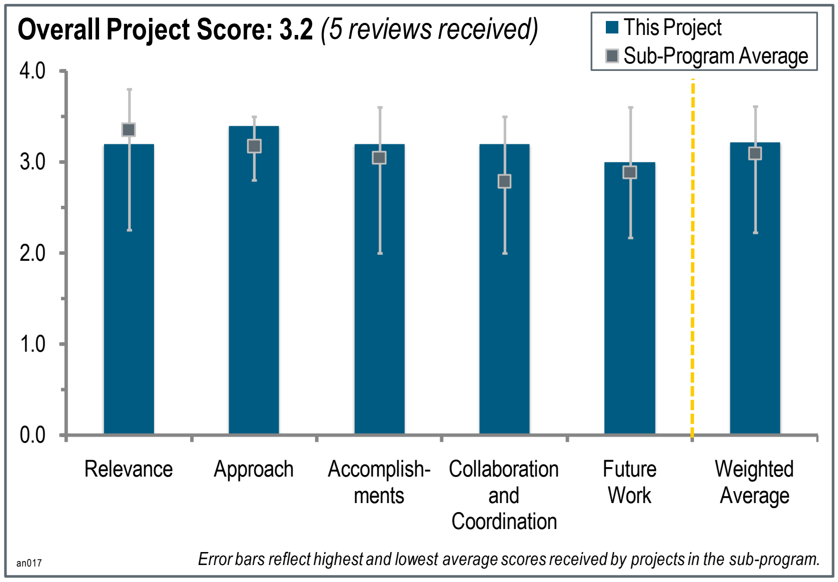
Recommendations for additions/deletions to project scope:

- Please consider waste biomass to hydrogen as a co-product from high-temperature fuel cells. The FCEV and hydrogen for stationary peak power can be a similar technology. This reviewer wonders if a mixed growth of fuel cells in both markets can be compared. It may improve some of the cost numbers.

Project # AN-017: Developments in the Hydrogen Demand and Resource Assessment (HyDRA) Model: Improvements in Data Interoperability, Availability, and Querying

Dan Getman; National Renewable Energy Laboratory

Brief Summary of Project:



The transition to hydrogen requires an understanding of the spatial relationships and interdependencies of a wide range of changing data sets. Estimating hydrogen demand; finding and organizing resources; and designing, building, and managing hydrogen production and distribution infrastructure all require spatial and temporal modeling and analysis that require and produce spatial and temporal data sets. HyDRA is a repository for spatial demand, resource, and infrastructure data related to hydrogen. Data are provided in maps and via model integration. In fiscal year 2011, HyDRA has focused on allowing users to answer questions with data and providing visualizations of the results. Development goals for 2011 include: (1) data interoperability—HyDRA is actively sharing data with multiple U.S. Department of Energy (DOE)-funded projects; (2) querying data—data in HyDRA can now be queried by their attributes and through spatial queries; (3) visualizing data—data in HyDRA can be viewed as maps or graphs; and (4) complex data sets that would require hundreds of maps loaded into a new visualization tool that allow users to explore, chart, and query those data.

Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.2** for its relevance to DOE objectives.

- This project shows good relevance to DOE Hydrogen and Fuel Cells Program objectives, applying mainly to the commercial and feasibility phase of implementation.
- This project focuses on the improvement and upkeep of HyDRA, a database and geospatial (mapping) visualization tool for hydrogen data, such as prospective demand, supply, cost, and means of production and distribution, that are functions of location. It provides query capabilities and graphical output as static maps and time sequences of maps, as well as digital data for other applications and models. It is neither an optimization tool nor a computational (modeling) tool, though it can spawn and function as a report generator for such tools (e.g., Macro-System Model). With respect to "relevance," it is clear that HyDRA adds a great deal of clarity and usability to complex data sets, which adds completeness to other projects charged with creating and compiling knowledge. However, to achieve "outstanding" relevance, the principal investigator should better articulate how these visualizations either affect decision-making or the course of the Program. A fairly impressive model that combines databases with spatial information will be critical to implementing the use of hydrogen and fuel cells.
- This project appears to be relevant, but it is very difficult to make sense of unfamiliar acronyms associated with the work. If the degree of connectivity and availability of data is correct, then it is a valuable tool. The acronym forest is likely to scare off users.
- This project is increasing the availability of data sets to a number of applications.

Question 2: Approach to performing the work

This project was rated **3.4** for its approach.

- Developing an open interface tool with a lot of customer-friendly features is a good approach.
- The presentation demonstrated that the HyDRA project is well thought-out, very well integrated with a large number of other DOE efforts, and very attentive to data standards. Together, these indicate an outstanding approach to the problem at hand that should continue to make HyDRA readily adaptable to future needs.
- The use of spatial data with large numbers of data sets and other models such as the macro-system model is outstanding.
- The approach is fine for those who are used to it. It is way too intimidating for new users. This needs to be more user-friendly or a HyDRA "light" needs to be developed for new users.
- Interoperability of applications and use of data through the model is useful.

Question 3: Accomplishments and progress towards overall project and DOE goals

This project was rated **3.2** for its accomplishments and progress.

- This project shows good progress toward the milestones.
- This project appears to have made significant progress over the past year in such areas as the automatic updating of core data (still in progress), the presentation of temporal data (still in progress), data integration with a suite of DOE tools, and query tools into the underlying database. The statement in the 2010 presentation (slide 18), "Automatic updates of data and prototyping the exploration of temporal and multivariate data sets are the core of remaining FY10 work" may indicate that this work is not yet completed. Lacking the personal knowledge and the history behind this, the concern is not great enough to down-score this element to "Good."
- The additional functionality added to the model makes it even more useful.
- This project's accomplishments appear to be satisfactory.
- The ability to exchange data between data repositories is useful.

Question 4: Collaboration and coordination with other institutions

This project was rated **3.2** for its collaboration and coordination.

- This project needs to identify one industry partner to work closely with. There can always be more industry stakeholders.
- This project is inherently collaborative, as it provides a means to visualize data produced by others, and it is open for use by hundreds of users (in academia, industry, and government) (from the 2010 project report).
- This project has excellent collaborations with other DOE agencies and developers of other relevant models. It needs more input from industry and government.
- Collaboration with other institutions is almost too much; it is hard to keep track of it all.
- Multiple sources of DOE funding at the National Renewable Energy Laboratory has been applied to this tool.

Question 5: Proposed future work

This project was rated **3.0** for its proposed future work.

- Future work should include identifying how to increase the usability of this model. It is a great tool, but with limited use in the industry.
- Among the most important proposed future work is the completion of the automatic update capability for core data, as well as the means of presenting temporal data.
- Future work should include continued improvements to the model and database integration.
- Future proposed work is acceptable.
- Improvements in data visualization should increase usage.

Project strengths:

- HyDRA is a great tool for sorting through and visualizing complex geospatial data.

Project weaknesses:

- If possible, the project needs to better articulate how its visualizations have affected decision-making—for example, citations of studies, reports, and policy statements that have included HyDRA output as illustration for points made or conclusions drawn. Given the large user base, there could be many examples from which to draw.
- The acronym forest is intimidating to the casual users.
- There is a low awareness of the tool with external users (there is a pretty low level of use at this point).

Recommendations for additions/deletions to project scope:

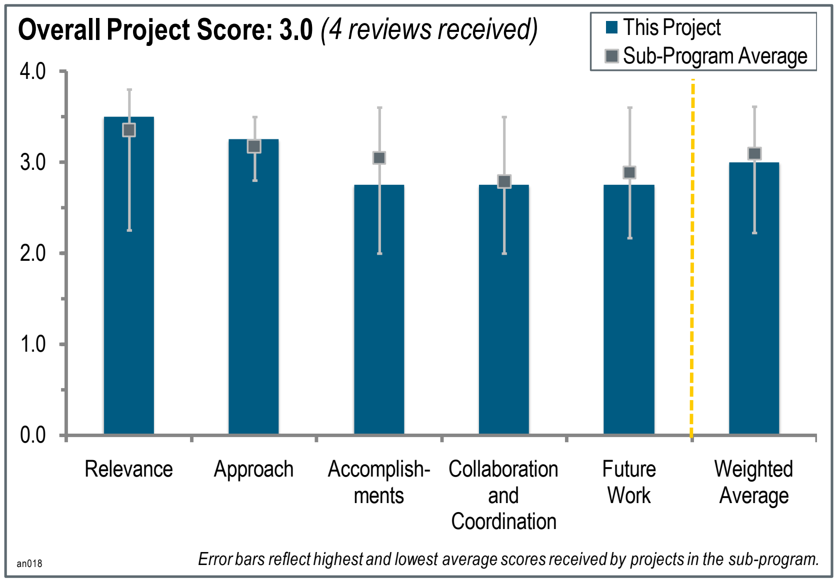
[No recommendations were offered by the reviewers.]

Project # AN-018: Hydrogen Infrastructure Market Readiness Analysis

Marc Melaina; National Renewable Energy Laboratory

Brief Summary of Project:

The objective of this project is to identify and collect feedback from key stakeholders on the following: (1) cost reduction opportunities from economies of scale (e.g., station standardization, number and size of installations) and learning-by-doing resulting from growth in material handling equipment (MHE), backup power, transit bus, and light-duty vehicle markets; (2) cost reduction opportunities from focused research and development (R&D) areas and priorities; and (3) specific examples through which early markets, such as MHE, backup power, and transit buses, can increase demand and reduce hydrogen infrastructure costs.



Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.5** for its relevance to U.S. Department of Energy (DOE) objectives.

- This project is very relevant to assessing the gaps with the hydrogen infrastructure.
- This project is relevant in its design and objectives, but its relevance may be compromised by the makeup of the workshop participants, the list of which was dominated by government, national laboratory, and academics. Only one utility participated.
- Having accurate cost estimates of near-term markets is critical, as assumptions of costs that are not realistic can skew analyses in the wrong direction. Cost estimates for the transition period are especially important, as they help improve the understanding of the development of a hydrogen economy. Making use of real-world experiences and realities to the extent possible is valuable, which is what this project aims to do.
- Reducing the cost of hydrogen refueling stations is critical to increasing hydrogen availability.

Question 2: Approach to performing the work

This project was rated **3.3** for its approach.

- There needs to be better coordination with key infrastructure industry stakeholders regarding the current and actual costs. The project team needs to identify a way out to enhance usage and application of the calculator.
- The approach is fine; the execution may not be.
- It is good that the approach involved both a qualitative component (workshop discussions) and a quantitative component (cost calculator). It is also good that multiple types of stakeholders were involved in the discussions, but it would have been better to include fewer participants from the government and national laboratory categories and more from key stakeholders such as local permitting officials. There was good coordination with other planning efforts (e.g., the California Fuel Cell Partnership [CaFCP] Roadmap).
- Using a workshop to identify cost reduction opportunities can be very effective.

Question 3: Accomplishments and progress towards project and DOE goals

This project was rated **2.8** for its accomplishments and progress.

- Good progress was made in developing the station cost calculator in a reasonable amount of time.
- The mix of participants does not seem to be right. It would be interesting to try another workshop with more utilities and energy companies. In this situation, government and academics are invisible.
- This work has developed good preliminary categories of cost reduction opportunities. As the cost calculator and compilation of the results is distributed via independent third parties, consistency and anonymity is preserved. Consistency and accurate understanding is provided by engaging stakeholders in clarifying the meaning of "early commercial" stations.
- Cost reduction opportunities look very promising.

Question 4: Collaboration and coordination with other institutions

This project was rated **2.8** for its collaboration and coordination.

- This project needs to have a close industry partner, rather than the industry being stakeholders.
- A weakness of this work is the mix of participants. It does not seem to have enough of the right kind of industrial participants.
- This project has good collaborations going on with the CaFCP and the workshop planning committee.
- The workshop had good participation from the industry, but not great participation. The project needs more people in the chain of designing, building, owning, and operating refueling stations.

Question 5: Proposed future work

This project was rated **2.8** for its proposed future work.

- It would be good to propose more workshops in different regions of the country to get a better mix.
- This report is necessary, but it is not apparent if there are benefits of the work beyond that.

Project strengths:

- This work uses both qualitative and quantitative approaches to obtain the knowledge and insights of the stakeholders. It coordinates with other efforts such as the CaFCP roadmapping efforts.
- Identification of cost reduction opportunities is extremely important.

Project weaknesses:

- Participants of the workshop included too many government and national laboratory participants and not enough (or any) key participants, such as local permitting officials.
- It is not clear what will be done to stimulate cost reductions. The cost calculator would be more beneficial if it were used to guide DOE-funded R&D.

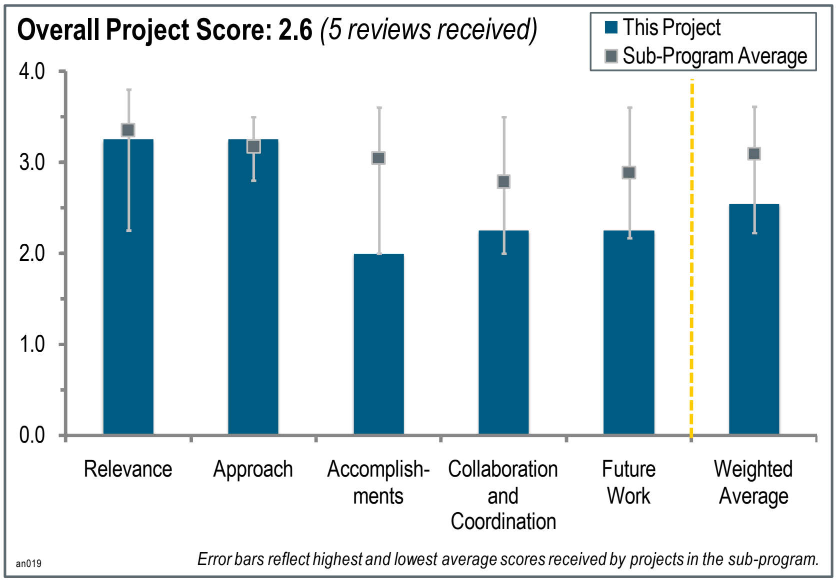
Recommendations for additions/deletions to project scope:

- This project should probably be more closely coordinated with AN-015 (Greene), as the insights gained in this project with regard to early market hydrogen infrastructure issues will help connect the dots to the early market fuel cell issues studied in AN-015. Findings from AN-018 might help supplement AN-015, as this project had not looked into the supply of hydrogen explicitly. This type of workshop and related efforts should probably be repeated every few years, especially around years that have critical research milestones, to keep track of changes in technology, demand, priorities, etc., so as to update R&D priorities and efforts accordingly. Results from this project should be widely shared with relevant key stakeholders, especially local permitting officials; they should be engaged in dialogue to explain the implications of the results achieved and the remaining needs.
- Unless DOE is going to stimulate implementation of cost reduction measures, this project should end with the documentation of opportunities.

Project # AN-019: Rethinking U.S. Hydrogen Infrastructure Transition Scenarios: What comes next?

Marc Melaina; National Renewable Energy Laboratory and David Greene; Oak Ridge National Laboratory

Brief Summary of Project:



The study will incorporate recent technology cost, market, and performance data from stakeholder outreach activities. The study will combine results from multiple scenario analysis models, including Hydrogen Transition (HyTrans); Market Acceptance of Advanced Automotive Technologies (MA3T), Scenario Evaluation, Regionalization, and Analysis (SERA), and Fuel Cell Power (FCPower). Significant advances and experience have been achieved and collected by supporting early markets (e.g., forklifts, buses, and telecommunication) with hydrogen fueling. In addition to spillover, some synergies may be achieved with light-duty vehicles as markets expand. A Station Cost Reductions Workshop was held to better understand early station cost reductions priorities.

Question 1: Relevance to overall U.S. Department of Energy objectives

This project was rated **3.3** for its relevance to U.S. Department of Energy (DOE) objectives.

- The analysis of transition scenarios will be critical to future goals of the DOE Hydrogen and Fuel Cells Program.
- It is not clear what specific Program goals and objectives this project supports.
- This is an extremely important issue. Establishing a hydrogen infrastructure is monumental and must be done in an orderly fashion.
- This is a clearly relevant project that is determining a group of good transition scenarios to introduce fuel cell vehicles in a cost-effective manner.
- This project is critical for research and development decisions and understanding the impact of those decisions.

Question 2: Approach to performing the work

This project was rated **3.3** for its approach.

- This project combines results from scenario models and updates with recent analyses.
- The approach is generally sound, but because the objective and milestones for the project are not well defined, it is not clear how the approach is aligned with achieving the objectives and milestones.
- The approach looks fine, but so little has been done that the practicality is still unknown. It could be, for example, that there is little interest and participation in the workshops.
- Combining the talents at the National Renewable Energy Laboratory with those at the Oak Ridge National Laboratory is an excellent approach to get the maximum value, as budgets for hydrogen and fuel cell electric vehicles have been reduced by the Secretary.
- This work's integration of high-caliber models is excellent.

Question 3: Accomplishments and progress towards overall project and DOE goals

This project was rated **2.0** for its accomplishments and progress.

- The project has not really had long enough for an opinion to be voiced at this time.
- This project is said to have started in January 2011, but has very little identifiable accomplishments to date.
- While it is not necessarily the fault of the researchers, virtually nothing has been done to date (estimated to be 5%).
- This project is just starting, but the team is properly reaching out to stakeholders to design the project.
- This project is just getting started, but plans are headed in the right direction.

Question 4: Collaboration and coordination with other institutions

This project was rated **2.3** for its collaboration and coordination.

- Stakeholders have not been fully identified, so it is hard to comment.
- No specific collaborators were identified, other than a general reference to stakeholder and workshop participants.
- None are known at this point in time.
- Collaboration between the two leading modeling groups is ideal.
- Getting a good cross-section of stakeholders will be critical, but the researchers are not at that point yet.

Question 5: Proposed future work

This project was rated **2.3** for its proposed future work.

- The future work plan is too vague to evaluate.
- It would be difficult to find a project that is more ill-defined and has poorer milestones. The project lists only one milestone in fiscal year (FY) 2011 ("scope of project"). It appears that the project has started without a clear idea of what it hopes to achieve. The project needs a better definition of what it plans to do, a better plan for achieving that, and some realistic milestones.
- There is no future work proposed; the group is only trying to get the present study underway.
- Future plans to hold workshops to help set the direction of the project are good.

Project strengths:

- The study is worth doing and the researchers have the capabilities to do a good job with it.
- The project includes two leading modeling groups.
- This probably should have been the first and only infrastructure project.

Project weaknesses:

- It would be difficult to find a project that is more ill-defined and has poorer milestones. The project lists only one milestone in FY 2011 ("scope of project"). It appears that the project has started without a clear idea of what it hopes to achieve. The project needs a better definition of what it plans to do, a better plan for achieving that, and some realistic milestones.
- It is too early to know.
- Insufficient funding is probably due to the "reckless cuts in hydrogen and fuel cell electric budgets by the Secretary."

Recommendations for additions/deletions to project scope:

- Following are several recommendations: (1) consider city (e.g., Los Angeles), state (e.g., California), and region (e.g., Pacific Southwest) and compare results; (2) wind energy seems to be "hanging," make sure it is tied to hydrogen production and compare transmitting electrons versus transmitting hydrogen to population centers; and (3) it would also be useful to compare electric vehicles to fuel cell vehicles at selected cities, states, or regions.
- This model must include all competing vehicle types and comparable infrastructure growth, which should require additional funding from the DOE Office of Energy Efficiency and Renewable Energy's Vehicle Technologies Program.