2010
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 essential to the DOE Hydrogen Program's mission. The projects are considered appropriately diverse and focused on addressing technical barriers and meeting targets.

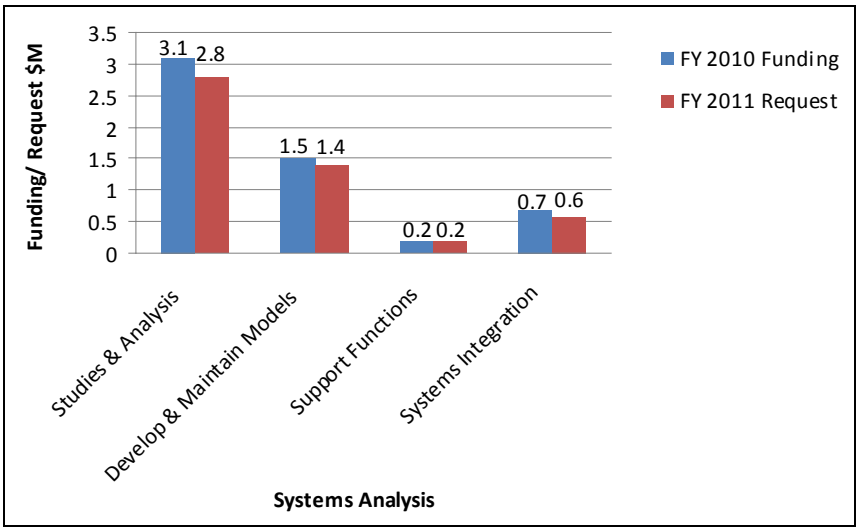
In general, the reviewers noted that the Systems Analysis sub-program is complex. Some reviewers commented that the sub-program is well managed and has adopted an organized approach for analytical support of the Program, which is appropriate for addressing the comprehensive list of barriers identified in the Fuel Cell Technologies Program's Multi-Year Research, Development, and Demonstration Plan (MYPP).

Recommendations identified by the reviewers for Systems Analysis were: 1) a common set of assumptions should be used for analysis projects; 2) analysis projects should identify collaboration; 3) fuel purity analysis should continue, with analysis of cost and performance tradeoffs; and 4) model validation and peer review is critical for sound and credible analysis. The Systems Analysis sub-program will continue to address these issues, and reviewer feedback will be incorporated in the sub-program's future plans.

Finally, the reviewers commented that the analysis and model portfolio was complete and progressing in addressing analysis topics. They stated that the MYPP barriers were being addressed by the Systems Analysis sub-program and put into the proper perspective.

Systems Analysis Funding:

Funding for Systems Analysis has shifted from model development to an analysis focus utilizing the models developed by the sub-program. In particular, analysis projects were concentrated on stationary fuel cell applications, infrastructure, early market fuel cell applications, and support for the Program's technology readiness goal to enable commercialization of fuel cell vehicles. The 2011 request-level funding profile, subject to congressional appropriation, provides greater emphasis on analysis of hydrogen for energy storage and transmission, and on transition, resource, and infrastructure analysis.



Majority of Reviewer Comments and Recommendations:

The maximum, minimum, and average scores by the reviewers of the Systems Analysis projects were 3.5, 2.6, and 3.1, respectively. Reviewers commented that the diversity of the Systems Analysis project portfolio addresses the "analysis and modeling gaps" of the sub-program, and the resource, infrastructure, transition, and early market analysis requirements. The major recommendations for the Systems Analysis projects are summarized below.

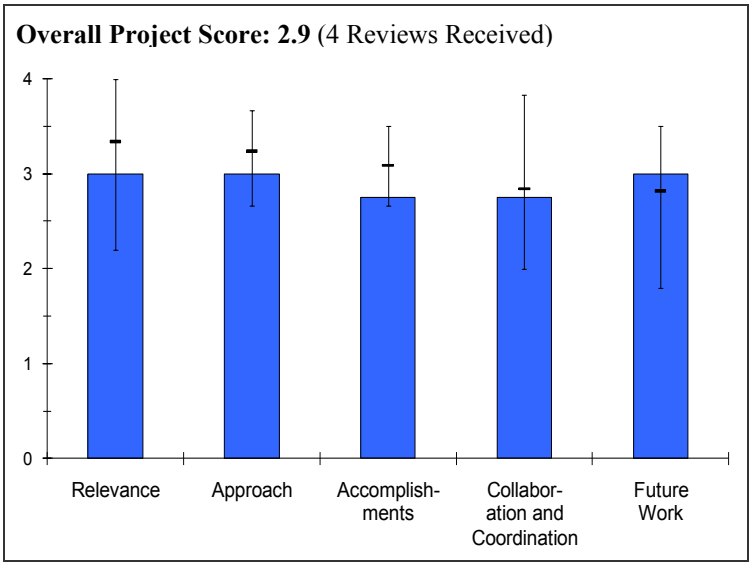
Model Development: Projects involved with model development received very favorable reviews. The majority of the projects were regarded as well-aligned with the current program goals and objectives. Reviewers consistently suggested that industry, academia, and the National Laboratories collaborate on model development and participate in the peer review and validation process. Reviewers recommended that models use a consistent set of inputs and assumptions, and that collaboration with industry be increased to ensure models are relevant to commercial applications.

Program Analysis: The analysis projects were ranked from average to good, and reviewers stated that the projects supported the Program's goals. In general, the reviewers concurred that the analysis projects should involve more collaboration with industry to calibrate information with actual operation and experience; analyses should be peer reviewed prior to issue and publication; and a consistent set of inputs and assumptions should be used. The reviewers felt that the Water Analysis project is important for hydrogen production but should be extended to include analysis of other critical issues such as water permitting. The resource and infrastructure analysis with the new Hydrogen Demand and Resource Analysis Tool (HyDRA) was well received by reviewers. The fuel quality for stationary fuel cells project received good reviews; its importance was recognized in addressing fuel cell cost and performance, but it was also suggested that air quality impacts be considered.

Programmatic Benefits Analysis: Reviewers commented that the Program's commercial benefits analysis project with PNNL, *Pathways to Commercial Success: Technologies and Products Supported by the HFCIT Program*, is a non-research project and should be removed from the merit review program. However, it was recognized that this project made progress and is an essential activity for the Program, providing information about the impact of federal R&D spending. The work provides an ideal communication tool to illustrate the benefits from the Program's research.

Project # AN-01: 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 on the delivered cost of hydrogen. The project's objectives are to: 1) expand the interoperability of SERA with tools such as Hydrogen Demand and Resource Analysis (HyDRA) and import detailed Hydrogen Analysis project (H2A) cost models into SERA 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 DOE objectives

This project earned a score of **3.0** for its relevance to DOE objectives.

- The purpose of the project matches the DOE's objectives, but it's not clear whether the output is meaningful or useful based on the input information.
- This project seeks to model an early market for hydrogen transportation fuel, the potential market evolution with time, and its implications on the infrastructure build-out. However, it is not clear how the results of this work are intended to, or had intended to, influence on programmatic decisions. In Q&A, the PI describes the purpose of the work as strategic (for high-level planning) rather than tactical, attempting to provide individualized information to the many actors whose behavior the model seeks to capture.
- The work is aligned to the objectives in the Multi-Year Program Plan (MYPP).
- The project is aligned with the program's objectives, but is not critical to the program's success.
- The project will provide a better understanding of what is required to make hydrogen sustainable.

Question 2: Approach to performing the research and development

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

- The technical barriers are more related to the model rather than its actual content. Overcoming these barriers will not result in a better output, but it would allow the computer models to work more smoothly together.
- The PI sees the relevance of the work as integrating the study model, SERA, with other models, such as HyDRA and H2A. This is an approach to the work rather than the end. The approach should follow from the questions that the project is trying to answer. Clarifying the questions the DOE's Fuel Cell Technologies Program needs answered for its strategic decision making could improve the project. On slide 4 of the presentation, the purpose of the work is described as "determining the optimal mix of hydrogen infrastructure … which pathways will provide least-cost hydrogen for a specified demand?" However, one would think that market participants will make these tactical decisions for themselves. It's also not clear how greater spatial detail, mentioned in slide 3, addresses a strategic need.
- The project's staged approach permits more efficient use of resources.

- The infrastructure growth appears to be very similar to the gasoline fueling station growth. That provides a check to indicate that the results are probably reasonable, but at the same time, it raises the question of whether it would have been easier to just look at gasoline station density.
- This project compares the cost of hydrogen produced from a combined heat, hydrogen and power (CHHP) system to the steam methane reformer (SMR) hydrogen production pathway which distinguishes this from the other projects.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.8** based on accomplishments.

- It's not clear that the model is capable of maintaining relevance to the latest technologies. The market is evolving and will constantly shift.
- The project has resulted in studies as listed on the right side of slide 8; however, the results and findings of these studies were not part of this review. These studies also were not delivered to the DOE separately. The presentation showcased the quality of the computer-generated graphics more than the lessons learned.
- The project is proceeding on schedule.
- The forecast of CHHP versus SMR is good and beneficial in understanding the role of CHHP.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.8** for technology transfer and collaboration.

- Several partners are listed, but the ability of these partners to provide meaningful feedback on the validity and approach of the model in real-world economic conditions is in doubt.
- The project appears to be in close collaboration with the DOE laboratories: National Renewable Energy Laboratory (NREL) currently, as mentioned in slide 18, and Oak Ridge National Laboratory (ORNL) previously, as mentioned in slide 2.
- Additional collaborations from outside of NREL would be appreciated since previous years had more outside collaborations).
- The project needs industrial involvement, such as fuel distributors available to assure decisions are aligned with their logical path.
- The project should be coupled with ORNL's consumer choice model for fuel cell vehicle (FCV) introduction and market growth.

Question 5: Approach to and relevance of proposed future research

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

- The project seems to address making the model more flexible and useful.
- The proposed future work includes adding features and elements to the SERA model, including CHHP hydrogen production and biogas technology. Notably, they are "iteratively improving the detail and accuracy of the cost models" already in SERA.
- Market competition should be added to the model.
- The future work looks at competition among technologies as being useful, as long as they consider the total cost of hydrogen delivered to the vehicles.
- Work, like developing a vehicle introduction model, appears to be duplicating developments completed by, or being performed by, others. Future plans should be new work or expanding partnerships with others that are already performing the research.

Strengths and weaknesses

Strengths
- As a cost optimization model, SERA can be used to predict the mix of technologies that could be used (e.g., SMR and CHHP distributed generation of hydrogen and centralized production of hydrogen) given different pricing models for infrastructure costs such as capital and operating costs for generation and distribution.
- The project optimization over a five year period is taking into account the (likely) rapid changes in drivers (i.e., economic and environmental).
- The project is looking at technology competition.

Weaknesses
- It's difficult to validate whether the project output is realistic. There are many intangibles that are associated with siting and building fuel stations that don't seem to be taken into account.
- The project seeks to create detailed geospatial visualizations that have uncertain programmatic and decisional significance.
- Changes in supporting models that are used to determine inputs to SERA could make reported results less relevant, and it would not be obvious to the report reader.
- The project needs private sector input, especially for fuel distribution.

Specific recommendations and additions or deletions to the work scope

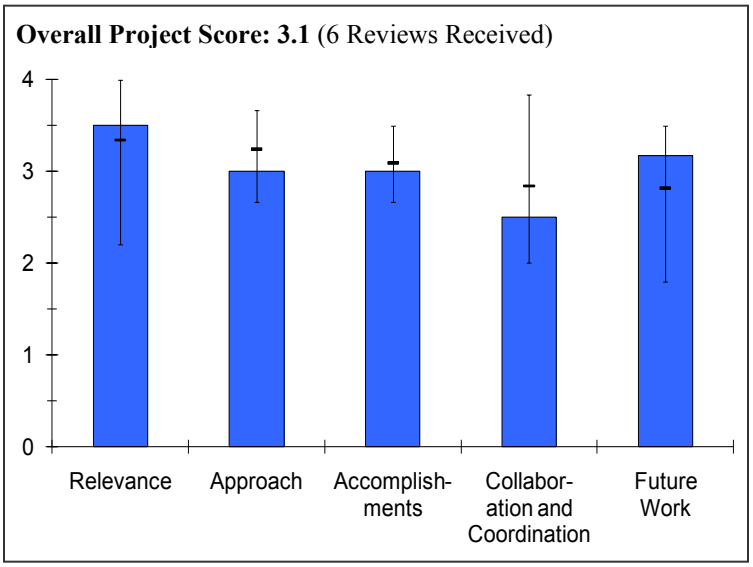
- It will be challenging to make the nominal economics work for the CHHP. It's also questionable if these stations would be practical for other reasons such as locations. It would be helpful if it was included in the analysis at a low level of effort.
- None.
- An analysis on the basis of a five-year moving window would be beneficial.

Project # AN-02: Analysis of Energy Infrastructures and Potential Impacts from an Emergent Hydrogen Fueling Infrastructure

Andy Lutz; 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, and 2) identify potential system-wide deficiencies that would otherwise hinder infrastructure evolution and mitigation strategies to avoid collateral effects on supporting systems. Since the transition to hydrogen fueling is expected to rely on distributed steam methane reforming (SMR) and stationary fuel cells (SFC), we must understand the impact of hydrogen vehicles and stationary fuel cells on the infrastructure.



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.5** for its relevance to DOE objectives.

- The project is useful in determining the most efficient ways to reduce emissions. It can be used to evaluate where the best reductions can be made with the least effort.
- The emergence of new technologies to generate power for industrial, residential, and transportation sectors requires careful analysis of their impact on emissions and potential to reduce consumption of imported fuels.
- The purpose of this project is to develop and use an economic model of energy systems to determine, under different influences of pricing and policy, the evolution of the energy infrastructure and changes in carbon dioxide emissions. By economic, the model attempts to capture the behavior of the public based on market prices. More specifically, the research sought to capture the effects that SFC might have on a generation of distributed power (electricity) and hydrogen fuel for transportation purposes.
- Analysis and understanding of the questions addressed in the project fully supports the DOE's Fuel Cell Technologies Program RD&D objectives.
- The project is relevant and can generate clearly useful information that can be used for policy decisions.
- The project is aligned with program goals.
- The project is well connected to DOE goals.

Question 2: Approach to performing the research and development

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

- Although the project has successfully identified the key barrier, the evaluation of future market behavior, that wasn't effectively addressed.
- The project's approach provides a tool to model the impact of different scenarios to predict potential improvements in reducing carbon dioxide emissions.
- The project's approach is to create a detailed systems model of fuel production and consumption and to use it to predict future behavior and market trends. This project is notable for its engineering detail.
- The project's approach is good and sensitive to the audience since the presenter defined all the acronyms.
- The project has a focused methodology, and the analysis is at an appropriate level of detail.

- The SFC penetration model needs to be more realistic. The Smart Grid Interoperability Panel and the impact of cleaner power is important.
- The combined heat, hydrogen and power (CHHP) can support a smart grid and that will be beneficial.
- There should not be any berating of electrical efficiency for CHHP since it, in fact, gets slightly better.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.0** based on accomplishments.

- Some of the project evaluation inputs seem questionable, especially the $4/kg hydrogen compared to $4.5/gal gasoline, the combined heat and power (CHP) heat output of a polymer electrolyte membrane fuel cell (PEMFC) , and reliance on distributed SMR generation.
- Significant progress has been made in modeling the impact of scenarios for the California market that relies on natural gas (NG) for electricity. Studies indicate the implementation of SFC in the California market has a limited impact due to strict California legislation. Other technologies, assuming they are successful, will compete against SFCs.
- Preliminary studies in other markets that rely heavily on coal to produce electricity show a bigger impact of SFCs to reduce emissions.
- There were several presentations this year on simulations of the effect of distributed hydrogen generation using CHHP. This project presentation stood out owing to its polish. Slides 12-19 indicate excellent progress toward their objectives.
- The project progress is acceptable, and perhaps more validation of the model results would be useful.
- The project is progressing according to schedule and presents good expansion of previous work.
- It's not clear if the hydrogen station is operated for public use.
- It's questionable whether heating or chilling could be sold when power and hydrogen are already sold.
- It's not clear whether the analysis would change if hydrogen is used for a smart grid to provide peak power.
- Criteria pollutant impact from fuel cell (FC) versus other options should be considered.
- The assumption of 85% hydrogen utilization is very high.
- The electrical efficiency reduction to 40% is not realistic since the actual efficiency should increase to more than 50%.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.5** for technology transfer and collaboration.

- There has been little interaction with other institutions so far. However, it is noted that involvement with a utility partner is scheduled for next year.
- Little or no discussion of collaborations was provided. Future work will explore working with NREL.
- The presentation did not discuss collaborations beyond participation in a workshop and reference to a potential utility partner in fiscal year 2011.
- They had a good response to last year's comments.
- Interactions with others doing similar or related work continues.
- There seems to be no collaboration with other organizations.
- The project could benefit from potential collaborations.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.2** for proposed future work.

- Future activities on coal-burning regions are critical to highlight the potential impact that SFCs could have by displacing high carbon dioxide emitters.
- Future work includes tighter coupling between the PI's model and other models (e.g., NREL's fuel cell power model). However, investigating SFC dedicated as PHEV charging would seem to be superfluous, because electricity is fungible.

- Future expansion plans beyond California are missing.
- The project provides a reasonable plan to continue expansion of the model and to improve its interaction and connectivity with other models.
- Supporting the project with a utility partner is a good idea.
- A CHHP partner is also recommended.

Strengths and weaknesses

Strengths
- It's useful to provide a clear pathway to emission reduction to assess most effective means.
- The project approach integrates production and demand to model impact of hydrogen technologies in complex energy sectors.
- The project can model the impact of legislative actions (e.g., carbon taxes) on the adoption of advanced technologies.
- The project presents high-quality, analytical work.
- The project was well presented and user friendly.
- The project's focused scenarios incorporating actual requirements make the results more compelling.
- CHHP analysis for co-products is an excellent idea.

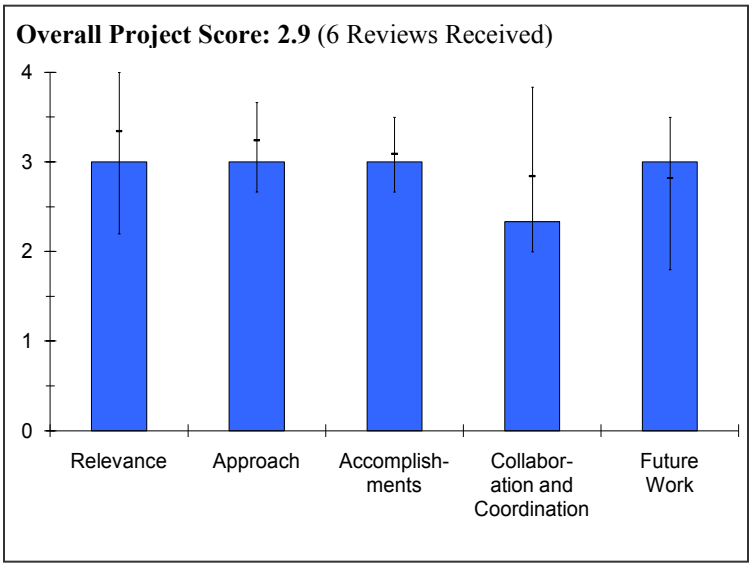
Weaknesses
- The practicality of co-locating a fuel station with power production is questionable.
- The project's assumptions might have overlooked some practical limitations for equipment siting, capital, and operating cost.
- The results of the project are highly dependent on long-range projections of legislative activities.
- None noted.
- The project scope was limited to California.
- The thermodynamic estimates for electrical efficiency and electrical hydrogen co-production efficiency estimates are very low for CHHP. Reconsidering the estimates is recommended.

Specific recommendations and additions or deletions to the work scope

- It's recommended to consider real-world input from companies that would consider such investments and on what basis. If companies will not invest in the infrastructure assumed, then the model is not relevant.
- The PI should continue with consideration of the coal-burning regions. Include studies of nuclear and renewable (e.g., solar, wind, and geothermal) energy on SFCs.
- It's recommended to take the project scope beyond California.
- The project's technical analysis alone may lead to misleading conclusions. For example, hydrogen has a greater economic value in comparison to heat.
- A techno-economic analysis is encouraged.

Project # AN-03: Agent-Based Model of the Transition to Hydrogen-Based Personal Transportation: Consumer Adoption and Infrastructure Development Including Combined Hydrogen, Heat, and Power
Matthew Mahalik; Argonne National Laboratory

Brief Summary of Project



The objectives of this project are to: 1) explore the chicken-or-egg problem of "which came first?" through co-development of the hydrogen production and delivery infrastructure and the user base which supports it; 2) understand how the system works rather than provide one forecast of system development, including questioning how different policies affect the transition, how sensitive growth is to factors beyond the control of policy makers, and what role consumer attitudes and behavioral characteristics play; 3) consider, in a complex adaptive system, the interactions among hydrogen fuel producers and suppliers, consumers of hydrogen fuel and fuel cell vehicles, and manufacturers of fuel cell vehicles, and 4) extend the current agent-based model to include limited-service combined hydrogen, heat and power (CHHP) facilities as well as the regular distributed production hydrogen fueling stations currently modeled.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.0** for its relevance to DOE objectives.

- The use of CHHP for retail stations seems unrealistic and is not likely to support the fulfillment of the program goals. The premise is not promising. A hospital or other CHHP source will not necessarily be motivated enough by a small revenue stream with potentially significant distractions to their core business and assumed liabilities.
- The purpose of this project is to develop and use an economic model to simulate the market transition from personal vehicles that are petroleum-based to ones that are hydrogen-based. By economic, the model attempts to capture the behavior, presumably based on market price and other economic costs, of independent actors that might choose to produce hydrogen fuel, produce hydrogen-powered vehicles, and purchase hydrogen-powered vehicles. More specifically, the research focused on the effect that CHHP might have on-fleet deployment, as independent actors chose to produce hydrogen for transportation fuel using CHHP facilities. Analysis and understanding of this question fully supports the DOE's Fuel Cell Technologies Program RD&D objectives.
- The project's model will guide the hydrogen program's RD&D objectives.
- The project is relevant for assessing areas to focus efforts in development of hydrogen distribution network.
- The project provides information necessary for formulating policy plans.
- The project supports only a very specific scenario that has very little potential to make an impact on consumer behavior.
- The project's showcase of understanding interactions among producers, consumers, and manufacturers is important.

Question 2: Approach to performing the research and development

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

- Considering the given inputs, the project model stands strong. However, it will be challenging to evaluate the qualitative reasons for people's decisions, as opposed to making an assumption based on financial considerations.

- This project has some similarities with project AN004, especially in terms of purpose. However, this project is unique as it involves a market research firm (Synovate) to develop different scenarios using different driver personalities. This approach creates a risk that the personalities will behave in the model as they are defined, rather than as the public as a whole would in real life. In economics, varying prices cause people to alter their behavior, rather than to continue to behave according to a stereotype. Nonetheless, the project seeks to develop insights for the questions raised in slides 3 and 4. These are interesting questions, and the approach is given the benefit of the doubt.
- The project's agent-based approach and ability to vary their behavior and the effect of policy makes the model a strong tool for understanding a possible transition to the hydrogen economy scenarios.
- The Los Angeles study is a useful and important model but contrasts between other large metropolitan areas, such as New York City and Chicago, would be appreciated.
- The inclusion of CHHP to the model is valuable, but it mostly relies on unproven technology (on a commercial scale), so it seems somewhat of a distraction and needs to be clearly compared to other alternatives.
- The project's approach is appropriate given the timeline and funding level and should accomplish its goals. Success with this approach should provide a model on how to approach more complex situations.
- The project has a very structured approach to develop and exercise the tool.
- The project's approach will evaluate driver acceptance of CHHP dispensers. However, it will not provide information on whether CHHP owners would really be willing to sell small quantities of hydrogen.
- Few, individual, small transactions of hydrogen sales are not practical for an organization that is not in the business of fuel sales to consumers.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.0** based on accomplishments.

- The approach doesn't seem to match the relevance slides. It's not clear how the approach will answer the stated "chicken/egg" problem – whether users will decide to buy at hydrogen dispensing facilities (HDF), and whether CHHP prospects might actually make the decision to become fuel providers.
- The project is relatively new, as it started in March 2010 and has only had modest progress to date. (See data on slide 12.) However, the rate of progress could not be considered slow.
- The project's granularity of the model was increased to improve realism.
- The project used an original equipment manufacturer (OEM) agent to limit the number of vehicles available during early rollout.
- The model provided a more realistic simulation of driver agents.
- The project had limited progress to report on, since it just started when slides were submitted.
- The tool provides interesting graphics and visualization, but the question being answered is not particularly relevant.
- The progress is on par with the period of performance, but activities like increasing the granularity of the roadway are not particularly challenging.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.3** for technology transfer and collaboration.

- The project should consider actual CHHP prospects to identify what would drive a decision to sell fuel. They also need to work with actual FCV customers to identify whether they would shop at a non-traditional fuel station; only then can a model be viable.
- In addition to the subcontractor Synovate, the project uses the National Renewable Energy Laboratory's (NREL) power model. The project seeks to model consumer behavior in Los Angeles. It came out during the Q&A that the California Fuel Cell Partnership believes that they have data they would like to contribute to the project. Given the similarities between the objectives and methods of this project and AN004 (using HyTrans to get insights to similar questions), the two projects might benefit from the coordination of their efforts.
- The project presents collaboration with a national lab and a market analysis company. More collaboration with industry and government stakeholders is needed.

- The project could probably expand on what other organizations brought in, for example, the Department of Transportation (DOT).
- The project is interacting with appropriate experts.
- Enlisting an automotive market research firm is beneficial for characterizing drivers, but this reviewer questions how accurately they have characterized the CHHP owners. The project needs multiple current combined heat and power (CHP) owners and potential CHHP owners to assess and provide input to assumptions.

Question 5: Approach to and relevance of proposed future research

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

- The future work should be revised in an attempt to better match the work with the goals. The model is jumping ahead on the easier quantifiable aspects, but it is not understood if the qualitative aspects will have more of an affect. The project should identify whether CHHP sites have the room and interest to be fuel providers.
- The project's future work is basically to run the study as planned.
- The project should expand to California and other metro areas.
- The project should add the possibility of transition failures.
- The project plans are appropriate given the scope.
- There is no need to expand the project scope.
- The team needs to look over and consider the competitive pricing of hydrogen.

Strengths and weaknesses

Strengths
- The project seeks to develop insights into important questions of interest to the DOE's RD&D objectives (slides 3 and 4).
- The project's agent-based modeling approach can be calibrated to new market data.
- The project's limited scope allowed results to be obtained in a short amount of time and with limited funds.
- The development of a driver agent appears to be good and may help in forecasting vehicle sales.

Weaknesses
- The project is unable to assess how consumers and producers will actually make decisions on criteria other than price and location.
- It is hard to imagine how this project will be able to do a credible job on such a complex and data-hungry subject in only six months. Given the similarities between the objectives and methods of this project and AN004 (using HyTrans to get insights to similar questions), the two projects might benefit from coordinating their efforts. There is slight worry that the development of driver personalities might bias the results by the propagation of stereotypes through the model.
- The project has too much emphasis on Los Angeles and seems hard to integrate a very fine grid.
- It is unclear how their method could be adjusted for a broader range of factors.
- The accurate prediction of hydrogen availability is very much in doubt.
- The accurate accounting for the total transaction cost of an institution, like a hospital, selling hydrogen fuel to consumers is very much in doubt.

Specific recommendations and additions or deletions to the work scope

- The project should incorporate real-world input from CHHP prospect companies that would consider such investments and on what basis. If no one will invest in the infrastructure assumed, then the model is not relevant.
- None.
- The project should expand to other metro areas.
- The project should contrast all methods of hydrogen production.
- The project should incorporate more data from industry and government stakeholders.

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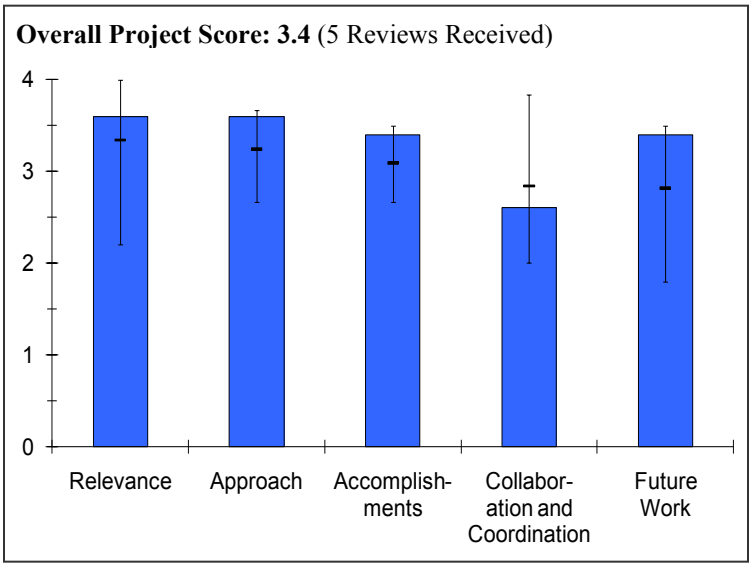
- The project work should be discontinued or refocused on a more relevant question.
- The project scope should be expanded to include competitive pricing, competitive uses of resources, and competitive technologies.

Project # AN-04: HyTrans Model: Analyzing the Potential for Stationary Fuel Cells to Augment Hydrogen Availability in the Transition to Hydrogen Vehicles

David Greene; Oak Ridge National Laboratory

Brief Summary of Project



HyTrans simulates the dynamic market transition from petroleum to hydrogen-powered vehicles. It represents hydrogen supply, vehicle production, and consumer demand for and use of hydrogen vehicles by 2050. For this study, the model was augmented to include a partial representation of the stationary fuel cell market. Fiscal year 2009-2010 research focused on inclusion of internal combustion engine and hydrogen plug-in hybrid electric vehicles and on analyzing the role that combined heat, hydrogen and power (CHHP) could play in increasing hydrogen refueling availability during the transition. The CHHP analysis contributes to understanding potential synergies between stationary and mobile hydrogen fuel cell applications.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.6** for its relevance to DOE objectives.

- The program is targeting real measures that can help subsidize the required initial investment, so it directly supports DOE efforts to figure out means for developing infrastructure.
- The purpose of this project is to develop and use an economic model (HyTrans) to simulate a market transition from a petroleum-based to a hydrogen-based transportation system. By economic, the HyTrans attempts to capture the behavior, based on market price and other economic costs, of independent actors that might choose to produce hydrogen fuel, produce hydrogen-powered vehicles, and purchase hydrogen-powered vehicles. More specifically, this year, the research focused on the effect that CHHP might have on fleet deployment, as independent actors chose to produce hydrogen for transportation fuel using CHHP facilities. Analysis and understanding of this question fully supports the DOE's Fuel Cell Technologies Program RD&D objectives.
- The project presents an important model to understand the transition from a petroleum-based economy to one based in renewables.
- The project appears to be relevant, but the use of multiple unexplained acronyms made it difficult to follow during the presentation.
- This project is looking thoroughly at hydrogen deployment scenarios, making it critical to the program and understanding of the distribution growth.

Question 2: Approach to performing the research and development

This project was rated **3.6** on its approach.

- The project seems to be well thought out with reasonable and practical assumptions.
- Presumably the PIs had tasks to further develop the HyTrans model to support new analysis of hydrogen ICE (internal combustion engine) vehicles, hydrogen PHEVs (plug-in hybrid electric vehicles), and CHHP-distributed hydrogen production. However, this was not emphasized. Rather, as the approach, the PIs describe developing three national CHHP deployment scenarios, and two methods of hydrogen delivery, as the framework in which to compare policy paths.

- The project presents a non-linear dynamic model that uses fuel supply, vehicle manufacture, and consumer choice agents.
- The project is integrated with other available models.
- The project's approach appears sound, but again the presentation is difficult to follow completely. This may actually be a problem related to the previous year's comments that energy industry collaboration and buy-in is lacking. The way the project is presented may be too difficult to fathom because of the nomenclature.
- Assuming that a CHHP owner will sell hydrogen to a fuel retailer is much more realistic than assuming that they will become a fuel provider.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.4** based on accomplishments.

- The project is progressing toward developing output that could be useful.
- The project accomplishments and progress are demonstrated in slides 8-18. They reached an interesting result (though one that follows from the design of the HyTrans model) that there is a fuel availability cost that affects vehicle purchase decisions based on the perception of the difficulty in obtaining hydrogen fuel when needed. That is, a cost separate from the actual cost of the fuel itself. Further, this phenomenon creates a situation where, while most of the fuel volume is produced by steam methane reforming (SMR, the least-cost method), the perception of fuel availability (i.e., the reduction in the availability cost) is mostly satisfied by CHHP (see slide 17). Such insights help to overcome barriers to deployment.
- The project emphasis this year was placed on CHHP using different amounts of government subsidies.
- There is no progress on energy industry buy-in and collaboration, and there should be. This should have been a high priority, and working on that would probably have made the project more understandable.
- The project recognizes the substantial subsidies required to make CHHP hydrogen happen.
- The project presents the most realistic scenario for CHHP deployment.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.6** for technology transfer and collaboration.

- The project has some good partners, but it could use more who could validate whether a small CHHP station is viable based on site and/or business constraints. It's not clear whether it is worth the effort and risk for an overall small amount of revenue, even if it's profitable.
- The project, by its nature, is highly collaborative. The PIs report seeking out information from other DOE labs (e.g., National Renewable Energy Laboratory or NREL, Argonne National Laboratory or ANL), academia (e.g., University of California, Davis or UC-Davis, University of Tennessee or UT), and the community of researchers that develop and utilize HyTrans.
- The project presents collaboration with other national labs and academic institutions.
- The project needs much more collaboration with industry and government stakeholders.
- The project should reach out to the energy industry.
- It is disappointing that industrial collaborators from earlier HyTrans work were not brought into this activity.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.4** for proposed future work.

- The project goal to publish in a peer-reviewed forum is a good one.
- Slide 20 lays out a particularly well-motivated description of the intended future work and its objectives.
- The project team will develop and test an integrated policy framework for the transition to hydrogen and disseminate the results widely.
- Energy industry collaboration and buy-in should have been on the slides presented, as they were promised to be addressed by the PI.
- Project plans are very good, especially integration into HyTrans and incorporating uncertainty in technology success.

Strengths and weaknesses

Strengths
- The project presentation was well done and explained in a simple, non-academic fashion with relatively plain English.
- The project seems well organized and practical, recognizing uncertainty and risk.
- The HyTrans model was enhanced to analyze the potentially important synergy between the stationary and mobile fuel-cell markets.
- The project presented a sophisticated model that includes all required components.
- The project's technical approach assumes CHHP owners will sell hydrogen to fuel retailers and that installation of CHHP will require subsidies.

Weaknesses
- Some of the project assumptions seem unrealistic. Using 1,500 kg/day distributed reformers are not a viable answer for forecourt. Also, the ability to produce and install 60,000 CHHP stations in less than nine years from a zero base seems aggressive. It is not clear if it will be justified at lower volumes.
- The PIs are upfront about the weaknesses in the project on slide 25. These include the need for more accurate quantification of data, the uncertainty as to the pace of technological progress and the course of world energy markets, and the lack of integration in the model between U.S. and international fuel cell markets.
- The project needs more emphasis in comparing all scenarios.
- The project needs additional input from industry and government stakeholders and their peer review.
- The unnecessary use of acronyms is very off-putting. The energy industry collaboration and buy-in is not a high enough priority.
- The project lacks stakeholder involvement.

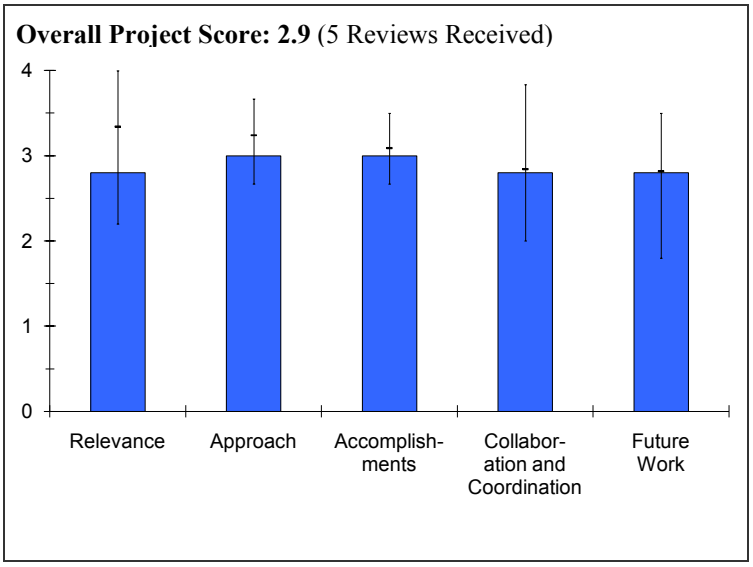
Specific recommendations and additions or deletions to the work scope

- None.
- There should be a comparison of all hydrogen generation possibilities.
- Present the project in a simpler language.
- Establish an advisory committee of representative stakeholders.

Project # AN-05: Biogas Resources Characterization
Ali Jalalzadeh-Azar; National Renewable Energy Laboratory

Brief Summary of Project

The objectives of this project are to: 1) develop a cost-analysis tool for bio-methane production from biogas based on the Hydrogen Analysis (H2A) Production model; 2) gather Geographic Information System (GIS) data on biogas resources in California and cost data on biogas purification systems, and 3) perform techno-economic analyses for various scenarios involving the production and utilization of bio-methane. The project can provide valuable insights and information to the stakeholders – utilities, municipalities, policy makers (at a macro level), and producers of biogas (at a micro level).



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.8** for its relevance to DOE objectives.

- The project uses bio-methane to produce hydrogen, which is an important pathway to renewable targets.
- The project addresses the development of an H2A tool to analyze the cost of implementing bio-methane production from landfills and agricultural waste. Such information is needed to evaluate the economics of bio-methane as an energy source.
- Opportunity fuels present a potentially valuable and under-explored hydrogen production pathway. This research appears to fill a gap in characterizing when and where these resources can be economically utilized.
- The project enables the understanding of the necessary steps and the potential costs needed to turn raw biogas into a usable fuel. While fuel cell is one of the potential uses of the upgraded biogas, it is not clear how this work supports the DOE's Fuel Cell Technologies Program. The upgraded biogas likely will have many other more feasible applications.
- Outstanding project for the abatement of greenhouse gas (GHG) and use of energy resources, but it has very little to do with the production of hydrogen.

Question 2: Approach to performing the research and development

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

- The project has developed a reasonable model to evaluate the biogas potential. However, the result suggests that it's not cost effective.
- The project does not mention that the largest source of biogas is landfills, and that landfill gas cannot be legally put into pipeline systems at this time in California.
- The project approach builds on the utilization of an H2A production tool and assembling a GIS database in the California market.
- The project uses an existing H2A model and approach to project biogas costs, energy use, and GHG emissions. It also entails collecting of GIS data related to the location of biogas resources. The H2A cost-modeling approach seems strong. However, the overarching goals and deliverables for the GIS analysis portion are not totally clear, particularly as they pertain to enabling a transition to a hydrogen infrastructure.
- The project would benefit from a more clearly articulated concept of the problems being addressed by the GIS component and associated scenario analysis. For example, it is not clear that the sample scenarios that were

presented require actual GIS data. The work could also use a more explicit focus on issues with bio-methane-to-hydrogen production, as distinguished from the current focus on bio-methane production. One example would be analysis of onsite hydrogen production.
- It's not clear the reason behind using H2A (a model used to look at hydrogen cost) to estimate the cost of upgraded biomass where some assumptions and basis might not be valid. Also, if only California data is used, it's not clear how it will be useful for other locations in the United States.
- The project realistically looks at biogas capture and distribution.
- The project's approach of injecting biogas into a pipeline is very logical.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.0** based on accomplishments.

- It's not clear if "cost" is being mixed up with "price". If this is a cost, then the price to justify the investment to get a return will make the economics worse. Also, the price $9.5/GJ for natural gas is a retail price, not a wholesale gas production number.
- They also need to evaluate the risk premium to an investor. To justify a long-term investment, a higher rate of return may be necessary.
- They have made good progress on assembling a model and identifying sensitivity studies. There is also good progress on cost versus size and/or capacity studies. Progress has been made in an analysis of the cost of constructing a piping network that would be required to interface to a NG pipeline.
- The project work is largely complete, with good progress towards the overall goals.
- The project has developed an initial biogas-costing tool that incorporates factors such as fuel quality and size of the facility. Biogas GIS data has also been gathered for the state of California and has been used to perform a preliminary scenario analysis.
- The costing tool appears to be strong. While it is understood that the scenario analysis is preliminary, the results seemed to lack coherence. For example, some interesting results were shown, but the overarching questions being answered and goals being addressed were unclear.
- The capital cost and operating costs need to account for the cost of waste handling from the upgrading process and the cost of monitoring upgraded biogas quality, which is more applicable if upgraded biogas is injected to an existing pipeline. Construction of a biogas pipeline must be justified by biogas availability and sustainability.
- Economics of the process are not going to be accurate until the process has been defined in detail.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.8** for technology transfer and collaboration.

- The project had no identified partners. Collaboration was mentioned, but no feedback was offered.
- The project inherently requires significant collaborations to develop a GIS map for California.
- The project appears to have successfully integrated feedback from industry and municipalities to gather and verify data and to review results.
- The PI should consider reviewing the study and results with key stakeholders to appropriately vet the cost numbers, including those in the gas industry.
- The project approach of soliciting input from stakeholders through workshops is good, but it would be better if they were more directly involved in the project.

Question 5: Approach to and relevance of proposed future research

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

- The project future work as identified will have limited usefulness. A better plan would be to find a vendor who is willing to build such a project to demonstrate the validity of the cost model and its conclusions. If the project had no adopters, then that will stand as final judgment.
- Potentially, the PI could develop a DOE-funded demonstration project to validate the costs, reliability, etc., of the equipment and pipelines.

- The project will address on-site utilization of bio-methane.
- The project is largely complete. It was mentioned that the PI would include analysis of on-site hydrogen production options, which is an important gap. There was also some discussion of characterizing the sensitivity of results to the resource quality (i.e., level of impurities). It is not clear from the presentation the depth with which these issues will be addressed, as there is limited time and funding remaining, but they are both important pieces of the overall analysis.
- Fuel cell (FC) use of biomass on-site is one of many options. It might be worthwhile to look into other monetization options. (It's not certain if this work should be done or funded by the Fuel Cell Technologies Program).
- The project should consider linking with other models to possibly develop a database of available biogas sources at various large municipalities throughout the United States.
- Including the tradeoff analysis for on-site use of bio-methane would be appreciated.

Strengths and weaknesses

Strengths
- The project presents a good model to understand sources and costs of biogas.
- The project addresses the utilization of bio-methane that is currently poorly utilized.
- The project analysis fills an important gap by characterizing a potentially cost-effective hydrogen production pathway.
- The project leverages previously developed tools and analysis (i.e., H2A) to insure consistency.
- The project demonstrates an economical process for eliminating a significant GHG.

Weaknesses
- The project identifies that the amount of biogas used is minor compared to the total gas used. So, there is a limited ability to affect the renewable target. The team focus seems to be on agricultural waste, but the amount available is small compared to landfill gas and total natural gas usage.
- The project conclusions are an attempt at straddling the issue. The model does not suggest that "biogas from farms can be cost effective."
- The project's current approach focuses on exporting bio-methane to a natural gas (NG) pipeline. Greater attention to on-site generation of bio-methane and generation and/or export of electricity to and electric grid would bypass the need to build feeder pipes to NG pipelines.
- The GIS component does not appear to be integrated with the rest of the project. It's not clear how the gap is being filled by this portion of the analysis.
- The project scenario analysis would benefit from identifying important questions.
- The project has limited relevance, if any, to hydrogen production and reducing hydrogen cost.

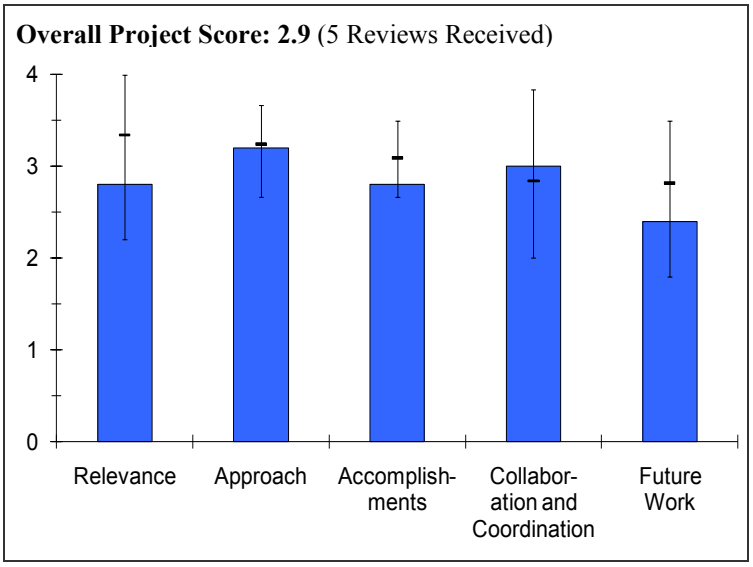
Specific recommendations and additions or deletions to the work scope

- The PI is encouraged to analyze an on-site conversion of bio-methane (fuel cells or diesel generators) to electricity versus the export of bio-methane to a NG pipeline.
- The team is encouraged to include parameters to characterize the cost sensitivity of gas to impurities. It has a strong effect on the price of fuel in other landfill gas-to-energy applications.
- It's recommended to consider the project economics taking into consideration a carbon tax.
- The PI needs to define the process to improve cost accuracy.

Project # AN-06: Cost and GHG 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. Hydrogen could play a dual role as storage medium for electricity and as a fuel for vehicles. The objectives of the project are to: 1) evaluate the economic viability of using hydrogen for utility-scale energy storage applications, in comparison with other electricity storage technologies (including a simple energy arbitrage scenario) and analysis of potential for cost improvements over time, and 2) explore the cost and greenhouse gas (GHG) emissions impacts of interaction of hydrogen storage and variable renewable resources, including specific locations and wind profiles and hourly energy analysis to capture detail.



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.8** for its relevance to DOE objectives.

- The project focuses on balancing renewable production with demand, which is important to optimize the utilization of intermittent renewable sources.
- The project addresses the economic viability of using hydrogen as an energy storage media integrated with wind power farms. The idea is that excess wind power would generate hydrogen via electrolysis. In return, excess hydrogen would subsequently be used to supplement electricity generation during periods of low wind power generation.
- This project has two primary tasks. The first analyzes hydrogen storage as a load-leveling tool for the electric sector; and the second looks at using hydrogen as an approach for optimizing the production of electricity and hydrogen transportation fuels. The second task is very relevant to meeting the goals of the DOE's Fuel Cell Technologies Program, as this offers an opportunity to leverage synergies between renewables and hydrogen, thereby increasing the competitiveness of both. However, while hydrogen storage (the first task) could be a useful tool for integrating renewables into the electric grid – and is both important and promising – it is not clear that this is directly applicable to the goals of the hydrogen program. It seems to relate more directly to efforts focused on deployment of renewables. To be fair, however, this is an area that does not fit neatly into any one compartment. In addition, it is likely that the work related to the first task is a useful adjunct to the second task.
- This project looks at options to maximize available wind power and manage variability in wind power and electrical demand.
- This project only partially supports the objective of reducing the cost of hydrogen for fuel cell applications.

Question 2: Approach to performing the research and development

This project was rated **3.2** on its approach.

- The project's approach seems reasonable and effective.
- The project utilizes a suite of economic analysis models and tools to examine the cost effectiveness of integrating two (hydrogen and wind) technologies.

- The overall approach, the questions being answered, and the experimental design are well constructed. It would be helpful to more explicitly identify the approach for the storage and transmission constrained cases (slide 17). It would be beneficial if this could be presented as a range of results rather than a single point.
- It's not clear how vetted the hydrogen combustion turbine data is. These numbers seem very good but additional verification and/or validation aside from the single source mentioned during the question and answer session is recommended.
- The project's option of 12,000 kg/day excess hydrogen storage is unrealistic, since wind farm and geologic storage will likely not be available in many locations.
- The project should consider future technologies, such as lithium ion (Li-ion) battery storage, where the round trip efficiency is going to be closer to 90% than the 60% cited for nickel metal hydride (NiMH) batteries.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.8** based on accomplishments.

- The project suggestion of exporting hydrogen for vehicles only works in select geography where there is a need for hydrogen in close (economic) proximity. This would greatly narrow the applicability and potential advantages that it could offer.
- Competing technologies have probably better understood operating and maintenance (O&M) costs. O&M for hydrogen might be higher than indicated.
- The project's modeled cost of different storage routes relative to hydrogen storage is a sign of good progress being made.
- The project results for the first task were presented, which showed that hydrogen is potentially cost competitive as an energy storage medium. They also showed preliminary results related to several cases for the second task. In general, it seems good progress has been made toward meeting the project goals.
- The cost to run a dedicated transmission line from a wind farm and/or storage to a grid center must be realistically accounted for as this cost could be very significant.
- The project needs a more thorough understanding of the data inputs for competing technologies to really assess the accomplishments. Battery efficiency looks too low but is probably reasonable for NiMH. Turbine efficiency might be on the high side; although it might be reasonable with a good bottoming cycle. Hopefully, these have all been covered in a more detailed peer review.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.0** for technology transfer and collaboration.

- The project has a good partner, Xcel Energy, to comment on real-world feasibility. During the project, the PI worked with Xcel Energy, Pacific Northwest National Laboratory (PNNL), and National Renewable Energy Laboratory (NREL) hydrogen teams.
- The project collaborations are adequate, since they included internal collaboration with other analysts and received data and feedback from Xcel energy.
- There are good collaborations with various modeling groups and NREL.
- The project needs a utility or several utilities participating.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.4** for proposed future work.

- The project's future work seems pointless unless there is a credible path to this being competitive against grid power (e.g., worth the capital) and against competing technologies.
- It's suggested to work on better technology than to continue analysis. The areas needed for improvement ought to be clear from the data.
- The project's future work will incorporate greenhouse gas studies.

- The work is largely complete. Future work entails further optimization of the hybrid electricity and/or hydrogen production case and analysis specific to solar resources. These are important questions and will continue to improve the work.
- In addition to comparing the round-trip efficiencies and leveled outputs of electricity among various technology options, the PI should consider looking at the payback period and technology maturity and risk of each option, with and without carbon consideration. Ultimately, the decision to install a certain technology will be largely based on how quickly the technology pays for itself.
- Future plans will improve results, but it still won't make a critical contribution.

Strengths and weaknesses

Strengths
- The project presents good analysis that shows the competitive position of the different technologies.
- The project recognizes the need to incorporate energy storage technologies into renewable energy production (solar and wind). Such approaches are critical to reducing the cost of solar and wind power, which must often build in significant levels of excess capacity to compensate for the wide variability on power production.
- The project's strong experimental design approach fills a gap in the overall knowledge space.
- The project makes a fairly good case for pairing fuel cell and electrolysis technologies with wind farms.

Weaknesses
- The project data seems to indicate that hydrogen is not cost effective as a storage means, but the conclusions do not directly indicate that.
- Electrolysis to hydrogen to electricity has a poor round-trip efficiency, which will be difficult to overcome.
- Hydrogen storage is a relatively immature technology compared to alternatives. Projections are subject to large uncertainties in projected costs of hydrogen storage compared to more mature energy storage routes.
- The project may not be acknowledging the strongest competitors to hydrogen technologies.

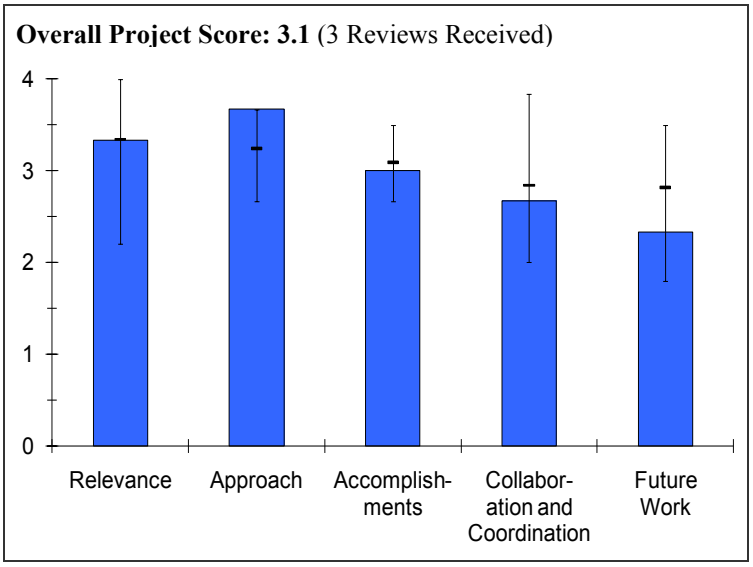
Specific recommendations and additions or deletions to the work scope

- The project's future work should not be considered until there is a pathway to lower the capital costs or increase efficiency to make it competitive with other storage methods.
- It would be interesting to focus more in depth on where and when hydrogen storage could actually be used (i.e., what resources, cost of electricity, etc.).
- The project should consider adding other energy storage options, such as Li-ion batteries to the study.

Project # AN-07: Hydrogen and Water: Engineering, Economics and Environment
A.J. Simon; Lawrence Livermore National Laboratory

Brief Summary of Project

The overall objective of this project is to quantify the impact of water on the future hydrogen economy, including the economic impact of water prices on hydrogen production and the regional impact of hydrogen production on regional water resources. The project addresses feedstock issues of the energy-water nexus and future market behavior regarding the timing and magnitude of hydrogen water stresses.



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.3** for its relevance to DOE objectives.

- The project provides analysis on the impact of water treatment technologies and clean-up on the cost of hydrogen.
- It is critically important that the DOE understands the impact of any future hydrogen economy on water resources.
- Water resources could be critical to hydrogen production.

Question 2: Approach to performing the research and development

This project was rated **3.7** on its approach.

- This project utilizes the Hydrogen Analysis (H2A) tool.
- The project integrates other program models effectively.
- The project compares water resources with future hydrogen demands and suggests technically feasible approaches based on water resources.
- The project's approach is thorough and well thought out.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.0** based on accomplishments.

- Although the project is nearing completion, the level of results seems to be marginal. The project compares centralized steam methane reforming (SMR) with distributed electrolysis and water treatment options.
- The project clearly shows water stress based on hydrogen rollout. However, the model needs refinement since issues such as the Great Lake water resources were not taken into account.
- The project presents a very good sensitivity analysis. The table indicates the preferred approach versus water price.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.7** for technology transfer and collaboration.

- The project coordinates with National Energy Technology Laboratory (NETL) and Sandia National Laboratories' (SNL) Energy-Water Nexus group.

- This project needs to collaborate with industry and government water resource stakeholders. It's not clear what the effect will be on future policy and legacy water rights.
- The project's biggest challenge appears to be securing permissions in highly stressed areas; therefore, the PI should consider bringing permit issuers into the project.

Question 5: Approach to and relevance of proposed future research

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

- The project should continue integration of other program models.
- The PI should consider expansion to international water resources.
- The project scope should expand to other hydrogen generation methods.
- The significance of adding this to H2A is in doubt.

Strengths and weaknesses

Strengths
- The project recognizes and/or addresses the potential impact and/or barrier of water availability and the cost of water treatment on the cost of hydrogen production.
- The project takes water resources into account, which must be a critical component of any analysis on the future rollout of technology.
- Understanding what will be required to obtain water permits for hydrogen production on a regional basis could be equivalent to a go/no-go decision on hydrogen production facilities.

Weaknesses
- The PI presented limited information.
- The project needs to drill down and make sure that all water resources are included.
- The project needs to take into account legacy water rights that may restrict the use of water in certain regions.
- The project needs to expand its methods of hydrogen production.
- This project will have little impact on the price of hydrogen.

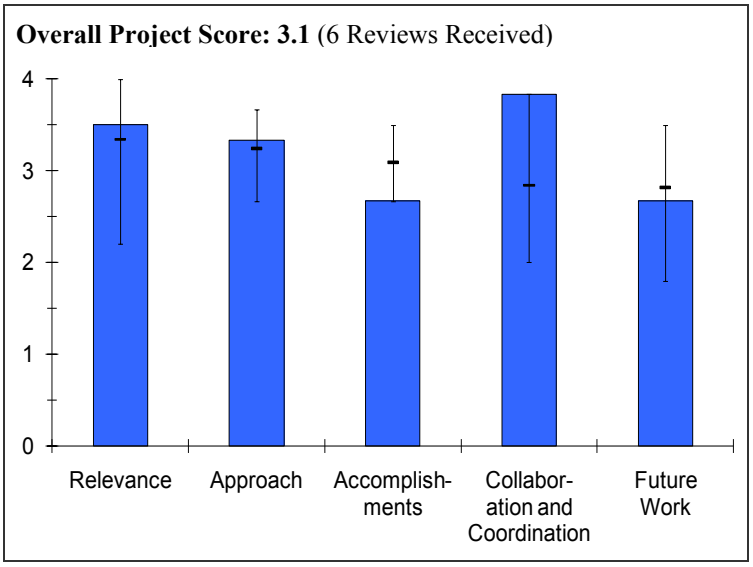
Specific recommendations and additions or deletions to the work scope

- Place your emphasis on water resources, and make a database of water resources that accounts for all available water, as well as restricted water by legacy water rights and local regulations.
- Continue to focus on the issues that are critical to hydrogen production, such as working with those that issue water permits to assure they understand the water and hydrogen impacts.

Project # AN-08: Analysis of Business Cases with the Fuel Cell Power Model
Marc Melaina; National Renewable Energy Laboratory

Brief Summary of Project

The objective of this project is to revise the Hydrogen Analysis (H2A) Fuel Cell Power model to suit the needs of business and finance decision makers and model end-users. To meet this objective, a Business Case Tab will be developed. This tab will not replace in-house financial models, but it will extend the capability to do financial and business analysis within H2A. This is especially valuable for tri-generation systems due to multiple revenue streams. Understanding this objective will require stakeholder feedback.



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.5** for its relevance to DOE objectives.

- The project is determining business case and defining deployment opportunities that are very relevant to assessing success of the program.
- The project is supporting stationary power, which is a good and relevant opportunity to reduce fuel cell (FC) costs and increase utilization.
- The project is critical to the determination of scenarios for introduction of hydrogen-powered vehicles.
- The project is offering business-oriented end-users a tool for quickly and transparently evaluating the economic aspects of combined heat, hydrogen and power (CHHP). This focuses on addressing a specific gap in the current analysis capability and could help in initiating early stage hydrogen infrastructure rollout.
- It's not clear the immediacy of this project. Given the current commercialization status of hydrogen and fuel cell technology and infrastructure, a tool like this might be premature.
- The project provides a useful tool for the potential end-users to evaluate the feasibility of CHHP, but the usefulness of the one-size-fits-all characterization in making the decision to adopt the technology is in doubt. Different end-users have different business models, evaluation tools, and drivers for adopting new, unproven technologies.
- The project has a very well-identified set of key stakeholders.
- The model being developed is very well focused and is needed to meet DOE objectives. The project is building on CHHP, which is a unique opportunity.
- There seems to be an assumption in many presentations that the supply of natural gas (NG) is endless. With the new production techniques, much more is expected to be available. However, with the pressure to convert coal-burning power plants to NG and the limitations on distribution, this may not continue to be true. There is little doubt that a better picture of economic issues involving relative productions of heat, power, and hydrogen (especially using biogas) is highly relevant.

Question 2: Approach to performing the research and development

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

- The project has a good approach of developing a model to help analyze the business case from perspectives of various end-users and decision makers.
- Including stakeholder feedback is crucial to get the required accuracy and relevance and make the model more user friendly in the end.

- The project identified the right set of stakeholder groups. Perhaps the PI should include more relevant industry players who will be using the model.
- The PI should try to ensure commitment from stakeholders. In the future, at minimum, the model users should share their findings.
- This project expands the usefulness of the FC Power Model.
- The project expands the scope of the analysis to reach new audiences. This will be critical.
- The project approach entails extending the H2A model based on feedback and ongoing review from both targeted and broad-based stakeholder interactions. The approach addresses a well-defined gap, leverages existing tools, and, through stakeholder interaction, determines what functionality is most useful to the target audience.
- Given the project focus is on addressing stakeholder needs, it would be useful to put a straw man working version of the proposed tool in front of prospective users to help facilitate feedback (i.e., determine whether it meets their needs.) There is potential for getting more fruitful feedback if users have something concrete to which to respond.
- The project approach of extending the capability of H2A is good. It is a good start to utilize both internal National Renewable Energy Laboratory (NREL) resources and external stakeholders.
- The project's considerations of all economic and financial parameters are well organized.
- The California stakeholder list is good. Adding Electric Power Research Institute (EPRI) may increase the project's strength.
- The role of IDC Energy Insights (IDC) needs to be better defined in terms of value proposition.
- The project estimates hydrogen cost by default or internal rate of return (IRR). This is a very useful feature.
- The project is heavily dependent on stakeholder feedback. It's not clear how much feedback has been received to date, and if the stakeholders have an incentive to do so. Also, it was not clear how much depth would be involved in dealing with biogas, and how the independent review is going to be accomplished.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.7** based on accomplishments.

- The project presents a good alternate business case calculation scenario. It's very relevant for analysis from different perspectives.
- The project received good feedback from the NREL MBA team, and all of it should be included as design features of the model. Another financial criteria used by industry and useful to calculate is VIR (Value to Investment Ratio) = NPV (Net Present Value)/NPC (Net Present Capital).
- The project problem formulation is adequate at this point. The key issue is there are multiple connected users of this approach, and it would be nice to get all of them on the same table to discuss how this can be best used.
- The project reviewed H2A model structure with the intent to identify possible extensions.
- The project collected feedback from the internal NREL MBA review team, NREL Technology deployment team, Federal Energy Management Program (FEMP), and Strategic Energy Analysis Center.
- The PI outlined the theoretical tab format and the to-do list of potential external revisions.
- The project is largely complete with limited concrete results to date. Since the H2A modifications were not presented, the implementation in H2A is in doubt. The project to date has focused primarily on identifying needs based on stakeholder interactions.
- The project appears to be behind schedule with respect to implementing the feedback after presenting the model and numbers to key stakeholders.
- The project's co-product cost estimates and user-friendly approach are quite good and efficient.
- The project approach of linking technology to strategy is very useful to new applications and users.
- State versus federal tax credits and ownership organization impact on economics will be valuable to add to this project.
- The utility side of economics, such as benefits to a smart grid, should be added to strengthen the model's value proposition.
- It appears that relatively little, beyond planning (which is certainly an important part of the process) and the workshop, has actually been accomplished. The International Partnership for the Hydrogen Economy (IPHE) workshop was an important step forward.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.8** for technology transfer and collaboration.

- The PI presented a good list of reviewers and stakeholders.
- The PI needs to get a list of first practical end-users.
- The PI presented very good collaborations with NREL.
- The PI presented good international collaborations.
- The PI presented good interactions with industry.
- The PI presented very strong and extensive collaborations with a diverse array of stakeholders throughout the project.
- As mentioned, the project appears to have strong collaborations with internal NREL resources and external stakeholders.
- The project interfacing with the fuel cell and hydrogen stakeholders is very productive.
- The PI should consider adding self-generators and distributed generation-type users.
- The project's actual formal collaboration seems to involve only NREL and IDC. However, it is assumed that there will be enough interaction with many stakeholders that they can also be considered collaborators.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.7** for proposed future work.

- Most of the work the PI presented set the requirements for the proposed future work and next steps.
- The project's future work seemed more focused on presentations. One would like to see more actual use of the model to expand the scenarios investigated.
- The PI should focus on continuing stakeholder interactions and actually implementing changes to H2A. As discussed in the "approach" comments, it seems like it would be useful to get the changes to the H2A in front of users prior to project completion. It was not clear from the presentation whether this is intended or not.
- The project should continue to collaborate with the Hydrogen Utility Group (HUG), California Fuel Cell Partnership (CaFCP) and IDC to verify and update the models. The team should talk to entities that have installed fuel cells to validate the model with real-world data. They are not CHHP, but lessons learned going through the process should be helpful.
- Very good work has been proposed by this group.
- Future work appears pretty vague at this point and highly dependent on more stakeholder feedback.

Strengths and weaknesses

Strengths
- The PI, Marc Melaina, is a good leader for this type of work.
- The project presents good coordination and approach to getting extensive feedback.
- This is a great new project.
- The project was designed to address a well-defined gap in current capability and has incorporated extensive collaboration with internal and external stakeholder groups.
- The project's outreach strategy is very good.
- The project is presenting what could be a very useful tool.

Weaknesses
- The project needs to identify how this would work for the end customer when there are multiple customers (station owners versus building owners) sharing the overall costs. It might be useful to think about a simultaneous Web-based interface to allow for negotiations.
- Ideally, a straw man version would be distributed to stakeholders for comment with some opportunity to respond prior to the project's conclusion. It is not clear given the timeline and funding whether this is feasible at this point. This could perhaps be included as a future additional scope.

- The project opportunity is to show how to improve the value proposition by adding relevance to a smart grid. This can help reduce the cost of hydrogen.
- The tri-generation fuel cell is not realistic. It's not clear at this time what hardware or costs would be involved in having the capability to choose the relative output distribution among heat, power, and hydrogen. This is especially true in dealing with biogas.

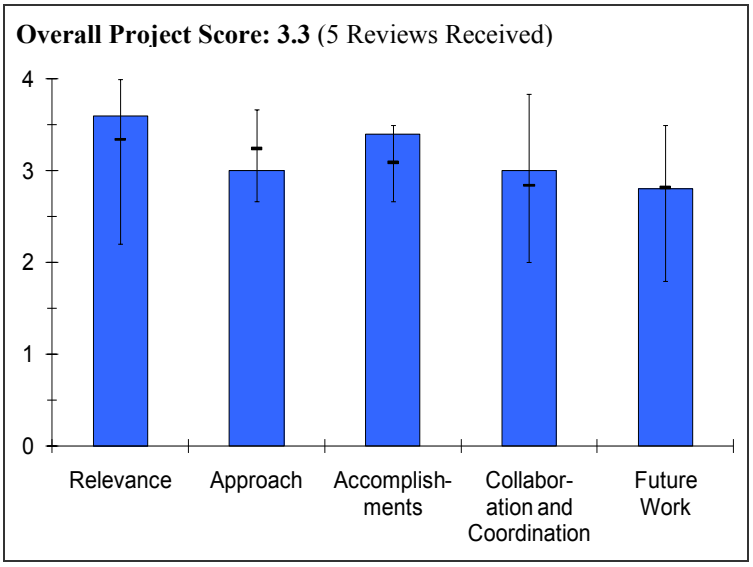
Specific recommendations and additions or deletions to the work scope

- The PI should consider adding a tool or interface to allow for simultaneous negotiations among various end-users.
- The PI should consider involving some good-level business school to develop a cost-effective business model, which could provide valuable input.
- EPRI may also be a beneficial partner for the project.
- The PI should try to incorporate, and make provisions for updating, some realism regarding the tri-generation fuel cells.

Project # AN-10: Fuel Quality in 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 effected, performance loss, degradation and clean-up strategies, and their cost factors; 2) identify the impurity through system configurations that are most constrained by impurity effects, and 3) recommend research and development that can mitigate the deleterious effects and provide alternative and less expensive clean-up options.



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.6** for its relevance to DOE objectives.

- The project is a necessary activity that is essential for deciding on the value of research into impurities and system design that will allow fuel cells (FC) to have sufficient lifetime in the field. The work is very relevant and covers most of the potential fuels. The weakness lies in addressing new fuels and perhaps developing a more general approach to impurity impact. The lack of good data from industry might be an issue that could be better addressed.
- The project helps identify the bad actors in hydrogen fuel for fuel cells, as well as identify the impacts and recommend approaches to deal with the bad actors. This work has more value by broadening the scope to look beyond natural gas (NG) and look at biogas and coal-derived syngas. With more R&D focus on bio-derived hydrogen production pathways, perhaps the scope needs to expand further to look at impurities for these bio-derived feed stocks.
- The project's focus on impurities is key to understanding the capital and operating costs and is very important to DOE goals.
- Impurity, system approach, and clean-up technology are very important to the success of fuel cells.
- The project is very relevant since hydrogen will likely be supplied from many sources for many types of fuel cells.
- It is critical that we have an understanding of the impurities and their impacts.

Question 2: Approach to performing the research and development

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

- This is an excellent project that is perhaps constrained by the data from industry.
- Two good approaches they have taken involve researching through literature review and working with those in the field. A possible recommendation would be for the team to look into the Tech Validation sub-program and the experience and data they obtained from their look into the impurities in a hydrogen feed and fuel cell vehicle operational data. Obviously, there are many factors that affect fuel cell performance. A good way to determine the cause of these problems would be to analyze the compiled composite data to see if there are any correlations.
- The project's hydrogen pathway list is pretty good.
- Combined heat, hydrogen and power- (CHHP) based hydrogen may have superior quality. The PI should consider including that if possible.

- This project has been going on since 2007 with nearly $1 million invested, and there are relatively few results. There must be a better approach than depending on responses from various organizations. The chart of results shows little new information. There is obviously value in knowing the content of landfill gas, but even here, there is such a wide range (both species and concentration) of possible contaminants that the results shown are clearly limited. A different approach for obtaining information should be considered.
- The project presents a very thorough review of impurities.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.4** based on accomplishments.

- The project has made progress toward the objectives outlined. The problem of data availability has impeded progress.
- The project database set up to document the impurities, its removal strategies, and their effects difficulties appears to be extensive and should be very useful for fuel providers and fuel cell developers and operators.
- The oxygen may have an adverse impact on the system and should be studied further.
- The list of contaminants presented by the PI is a good one.
- The project's coal gas contaminants analysis is very good.
- The project's analysis of the impact of multiple contaminants and their interactions is very comprehensive.
- The project resulted in few results relative to the time and funds invested.
- They have speciated the gases down to compounds that are present at the parts per million (ppm) level.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.0** for technology transfer and collaboration.

- The project encompasses some collaboration with industry, but there is not much coordination with other national labs who work on the effect of impurities. It is recommended to use the other fuel cell research groups in the program as a source of information and data mining.
- The project has good collaborations with fuel cell companies. The PI needs to consider collaborating with more fuel providers. All the work should be shared with those working on establishing a hydrogen purity standard. The cost to make purer fuel must be balanced with the cost to make fuel cells more tolerant to certain impurities.
- The PI developed a good outreach strategy.
- Many other organizations are involved in the project, and it is likely that the work will include collaborative efforts.
- The project collaborators are the right organizations to identify which impurities will impact fuel cell performance, but it may not be the best for establishing how clean the fuel really needs to be.

Question 5: Approach to and relevance of proposed future research

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

- Future work should be focused on finishing the project.
- The PI needs to have more discussions with fuel providers. The collaborations with fuel cell developers also need to look into longer term effects of impurities.
- This is very good work, especially considering that the topic is very complex.
- The project does not have a focused plan and has a slim chance of success.
- For future research, it would be great if the project could identify the key impurity that is limiting life.

Strengths and weaknesses

Strengths
- The project is very necessary.

SYSTEMS ANALYSIS

- The project's comprehensive strategy for all fuel cells and multiple fuels is very good.
- It is a project where the right kind of results could be very useful to many entities. Very capable personnel and facilities are involved.
- The project is conducting a thorough analysis on impurities.

Weaknesses

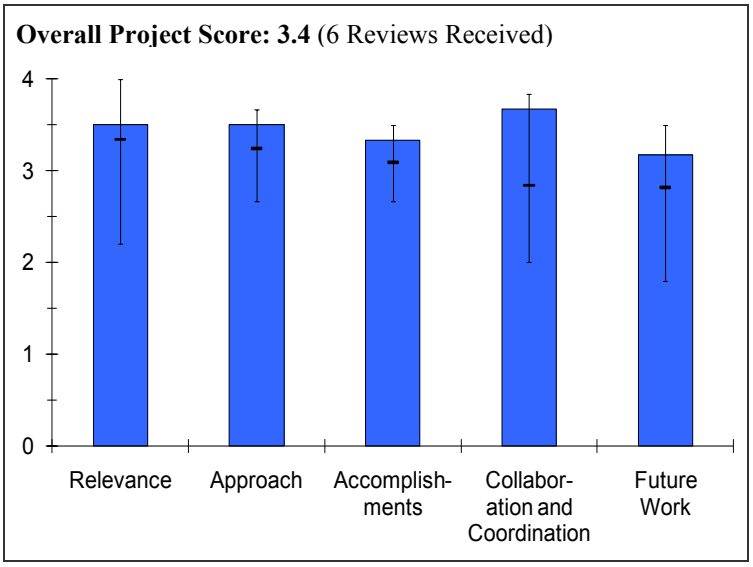
- Data acquisition appears to be a critical limitation of the project.
- Past DOE reports from 1970 to1990 have lots of data that could be beneficial for the project.
- The Gas Research Institute and Electric Power Research Institute (EPRI) also have some good data that could be beneficial for the project.
- The project isn't getting done relative to the time and funding.
- The project is unable to determine how clean the fuel really needs to be.

Specific recommendations and additions or deletions to the work scope

- The PI should attempt to obtain better data from the industry for future use.
- It will be very beneficial if the PI would perform capacity measurements in the presence of multiple contaminants.
- The PI should consider contacting biogas companies such as the American Biogas Council (ABC).
- The PI should consider an end date instead of an open-ended timeline. Additional funding should be based on getting certain results from current funding, in addition to having regular updates on progress and roadblocks.
- The project should consider air quality and its impacts.
- The project should consider trade-off analysis of cleaning the fuel versus sacrificing life and performance.

Project # AN-11: 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 a rapid, cross-cutting analysis, utilizing and linking other models and improving consistency of technology representation such as consistency between models, 2) supporting decisions regarding programmatic investments through analyses and sensitivity runs, and 3) supporting estimates of program outputs and outcomes. The objectives for 2009 and 2010 are to: 1) increase graphical user interface (GUI) functionality and capabilities; 2) utilize the MSM to compare hydrogen production, delivery, and dispensing pathways; 3) develop MSM links to the Hydrogen Demand and Resource Analysis (HyDRA) spatial data and visualization tool; 4) develop MSM links to the Directed Technologies, Inc.'s hydrogen production model (HyPRO) to analyze build-out scenarios, and 5) improve a pathway analysis by incorporating a vehicle cycle.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.5** for its relevance to DOE objectives.

- The project is very relevant since it converts all the models developed under this program through one interface. That increases their usability significantly.
- The project relevance will be established once there is sufficient proof of industry use of the model.
- Integrating all the available models into one GUI allows important powerful analytical capabilities for addressing issues with the transition to the hydrogen economy.
- The project represents a very necessary policy-making tool.
- The project is providing a central link between hydrogen analysis tools and the enabling of consistent cross-cutting analysis, thereby filling an important role in the DOE Fuel Cell Technologies Program's systems-level analysis.
- The project's MSM model does a good job of linking various models to force consistency so end-users have one central basis.
- The project is very relevant, especially for planning future research and funding.

Question 2: Approach to performing the research and development

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

- The project approach is great since it links a very relevant model to provide common interfaces and to increase the usability of otherwise unused models.
- The PI needs to provide some perspective on model validation, because the model's accuracy is unclear.
- It's great that the project is offering flexibility where users can either use built-in assumptions or define their own.
- The PI needs to hold a training workshop and create documentation for industry stakeholders and the analysis community to make it a marketplace tool.

- The project's macro-system model provides a central transfer station to guarantee consistency in simulations that involve multiple models.
- The project's GUI (graphical user interface) allows users with minimal understanding of the models to use them.
- Apparently, validation is included, but there does not yet seem to have been rigorous validation testing. It would be good to see some explicit testing and a report on that.
- The PI has adopted an approach in which they developed a basic model framework in past years and have incrementally added additional functionality during subsequent development. This is a good approach, as it allows the PI to respond to the community's evolving needs and incorporate stakeholder feedback on an ongoing basis.
- Going forward, the PI should be mindful of the trade-off between maintaining usability while adding functionality such that the PI does not sacrifice the former for the benefit of the latter. (It's not clear that this has been the case to date, but it could become an issue.)
- They've done excellent work in setting the friendly GUI interface and allowing the user to download their own input files and results.
- The approach seems appropriate for the intent. There is always a question as to whether a mega-model such as this will be so unwieldy as to be almost unusable. It would also seem that incorporating updates could require a continuing effort.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.3** based on accomplishments.

- The PI presented good progress on the GUI front to store the default values and multi-parameter sensitivity.
- The project's pathways report is a good comprehensive accomplishment for the last year and has very good, detailed description.
- HyDRA integration is a vast improvement for local calculations and identifying local constraints.
- HyPRO integration is also great to calculate optimized rollout scenarios. It's not clear whether HyPRO and HyDRA work together with MSM.
- The project increased GUI functionality.
- The PI used MSM to produce a pathways report contrasting seven hydrogen production and delivery pathways.
- HyDRA and HyPRO were incorporated into the MSM.
- Rigorous validation testing is needed to give a high degree of confidence.
- The project has added several additional pieces of functionality, including integration with HyDRA (which is potentially very useful) additional GUI functionality; and links to HyPRO. It also produced a fuel pathways report that was used to identify gaps in the current analysis, identify fuel production low-cost pathways, etc.
- Good progress was made toward meeting the 2009 and 2010 objectives, and most objectives have been met. The vehicle cycle component of the analysis is still in progress.
- It's difficult to ascertain, with this type of tool, the extent to which the additional functionality is actually used by the analysis community and fills gaps in overall understanding. It's hard to determine whether the additional tool is actually being used, and if it clearly advances the overall goals of the Fuel Cell Technologies Program.
- The project pathways report is very useful for those working on production and delivery areas. Improving GUI functionality and linking MSM to HyDRA and HyPRO added more functionality to the MSM and made it more useful to larger groups of end-users.
- The project has notable accomplishments, such as making GUI more user friendly and apparent progress on the mega-code. However, the project has been underway for many years at considerable cost.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.7** for technology transfer and collaboration.

- The PI needs to bring in industry stakeholders and future users as collaborators. There are plenty of models out there, and this could be the platform of choice for industry as well.
- The project included a very good mix of collaborators from national labs and energy companies.

- The project could benefit from more academic and automotive collaborators.
- The project has very good collaboration.
- The project includes collaboration with a number of stakeholders, including other analysts, technology developers, and energy companies. This is one of the strongest points of the MSM. This collaboration does a good job of ensuring that assumptions are vetted and the model is well integrated with other tools.
- The extensive list of collaborators is excellent.
- The project involved many groups in a collaborative effort.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.2** for proposed future work.

- The PI presents a good list of models remaining to be integrated.
- The project's proposed future work should include a defined plan on dissemination of the model and one on increasing the model usage in the technical and business community.
- Maintenance of MSM is an important task to keep the utility of the model.
- Evaluation of failure modes is important.
- The continued analysis of all production and delivery pathways and modes is important.
- The PI should include validation testing as a distinct objective and task.
- The future work is focused on linking to other tools, performing scenario analysis and pathway comparisons, and adding additional details to the MSM calculations. These are all useful, but all fall under the category of being either additional functionality or an internally driven analysis.
- It would be good if project work could include some future focus on usability. That would include identifying options to increase the speed of execution and stakeholder training. It was also suggested by one reviewer during the question and answer session to identify through stakeholder interaction how the tool is used.
- The project is linking many models, which could introduce more complexity, and it should be kept simple when in the revision process. The PI could consider focusing on continually updating the MSM model with validation data and updates from the other linked models.
- The future work seems to be mostly a continuation of present and past efforts. However, some of the future work should add important capabilities.

Strengths and weaknesses

Strengths
- The project team possesses excellent technical strength and has made a lot of progress in a very limited time.
- The project's combination of all models into one GUI is very powerful.
- The project's use of their model for continuous evaluation of hydrogen pathways and scenarios is a very strong aspect.
- MSM facilities' connectedness, integration, and consistency in hydrogen analysis efforts make for an excellent collaboration.
- The project could be an excellent planning tool. There are excellent personnel members and facilities.

Weaknesses
- The PI needs to include beta testing with the industry and analysis community.
- The PI needs to define a set of industry users and get them involved.
- The project needs more funding so that hydrogen scenarios can be continually analyzed as the energy economy evolves.
- The project validation is too weak. The PI should work on model credibility.
- The PI needs to ensure that additional functionality is continuing to add significant value. Anything to speed execution would be helpful.
- Even when the project is completed, it is likely to be used by relatively few groups. It's doubtful that the project will actually be completed.

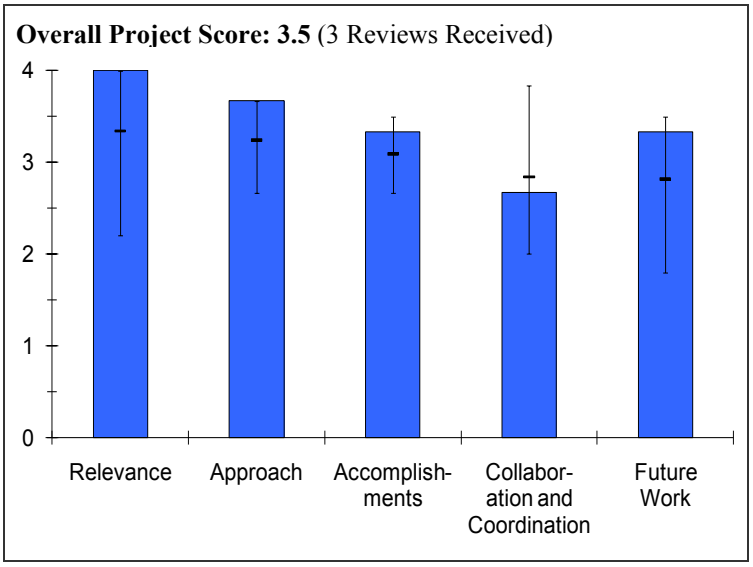
SYSTEMS ANALYSIS

Specific recommendations and additions or deletions to the work scope

- The PI should define a plan for model deployment and dissemination in the technical community.
- The PI should include a training plan within the work scope.
- The project should include more analysis of hydrogen scenarios, such as considering more out-of-the-box ideas.
- See comments under “future work”.
- The PI should determine who are the likely users of the end product and plan accordingly.

Project # AN-12: Life-Cycle Analysis of Criteria Pollutant Emissions from Stationary Fuel-Cell Systems
Michael Wang; Argonne National Laboratory

Brief Summary of Project
The objectives of the project are to: 1) Expand and update the GREET model for hydrogen production pathways and for applications of fuel cell vehicles (FCVs) and other early market fuel cell systems; 2) conduct well-to-wheels analysis of hydrogen FCVs with various hydrogen production pathways; 3) conduct fuel-cycle analysis of early market fuel cell systems to help development of hydrogen production and fuel cell technologies; 4) provide fuel cycle results for DOE OFCT activities such as the Posture Plan and the Multi-Year Program Plan; and 5) engage in discussions and dissemination of energy and environmental benefits of fuel cell systems and applications.



Question 1: Relevance to overall DOE objectives

This project earned a score of **4.0** for its relevance to DOE objectives.

- Note - This review is based on the written presentation alone: This project continues the success that Argonne National Laboratory (ANL) has enjoyed in developing and utilizing the Greenhouse Gases Regulated Emissions and Energy Use in Transportation (GREET) Model. This model is used to estimate the environmental impact, on a "well to wheels" basis, of different potential transportation fuels and the different methods of producing them. The systemization of this information is highly relevant to DOE RD&D objectives.
- Fuel cell vehicle (FCV) and hydrogen are very friendly to the environment. This focus is very important for fuel cell (FC) commercialization.
- The use of GREET is very important to better understand potential reduction of GHG and petroleum, due to both mobile and stationary fuel cell systems (FCS). Any potential improvements to GREET must be considered very relevant.

Question 2: Approach to performing the research and development

This project was rated **3.7** on its approach.

- Based on written presentation only: The approach of the PI is natural and straightforward. They obtain emissions data on both fuel production pathways and the operation of vehicles (and systems) using that fuel. The data was gathered by various means such as open literature, industry contacts, and other models, such as Hydrogen Analysis (H2A). Then, they incorporate these data into GREET, which is used to simulate scenarios of interest. The presentation noted that the PI "analyze and present" their results, but did not discuss validation to provide feedback to further improve the model.
- It's not clear if the PIs are considering using the U.S. Environmental Protection Agency (EPA) California Air Resources Board (CARB), or South Coast Air Quality Management District (AQMD) data for emissions—such as emissions from steam methane reforming (SMR).
- The relative value of co-products is very important since some sites may not have any value of heat.
- The approach seems to be both appropriate and likely very effective.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.3** based on accomplishments.

- Based on written presentation only: This year's major effort was to analyze criteria pollutant emissions of combined heat and power (CHP) and combined heat, hydrogen and power (CHHP) systems, with an eye toward analysis of CHHP as a means of distributed hydrogen generation for transportation. The direction of the analysis (slides 7-11) and the quantitative results (slides 12-16) indicate that excellent progress was achieved.
- Emission of sulfur oxides (SOx), and nitrogen oxide (NOx) for fuel cells seem to be higher than anticipated- (sub-parts per million (ppm) level and orders of magnitude lower than the engines).
- The emissions for electric and hydrogen alone (no heat) should be considered for credit calculation to show the true value proposition of fuel cells.
- The project results are impressive, but it is not clear that they are compatible with time and funding expended. Just in the last two years, over $1.6M has been expended.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.7** for technology transfer and collaboration.

- Based on written presentation only: By its nature, this work is highly collaborative. The PI reports seeking out information from labs such as National Renewable Energy Laboratory (NREL) and industry stakeholders.
- The GREET model is publicly available on the project website, which encourages its wide adoption and use.
- The PI should consider fuel cell manufacturers' data and the statistical average of emission data.
- There seems to be relatively little actual collaboration.

Question 5: Approach to and relevance of proposed future research

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

- Based on written presentation only: The future work suggested by the PIs (slide 18) seems reasonable and appropriate.
- The emission database from California should be analyzed for greater confidence.
- Future research appears reasonable and would continue to expand the capabilities of GREET.

Strengths and weaknesses

Strengths
- Based on written presentation only, the systemization of environmental impact data in a single model is important when making comparisons between different technologies and policy options.
- Looking at criteria pollutants is an excellent need for externality benefits.
- The project involves making improvements in one of the most useful models yet formulated. The personnel and facilities involved are excellent.

Weaknesses
- Based on written presentation only, the PI should add emphasis to validating, not merely reporting, model results for target scenarios. The lack of uncertainty and a sensitivity analysis makes it impossible to distinguish the precision of the predictions. It's not clear if it's accurate within a percent or two, or simply a coarse estimate.
- Inclusion of heat in overall efficiency confuses the outcome when you look at the emissions.
- It is not clear whether there is a reasonable return for funding and time allocated.

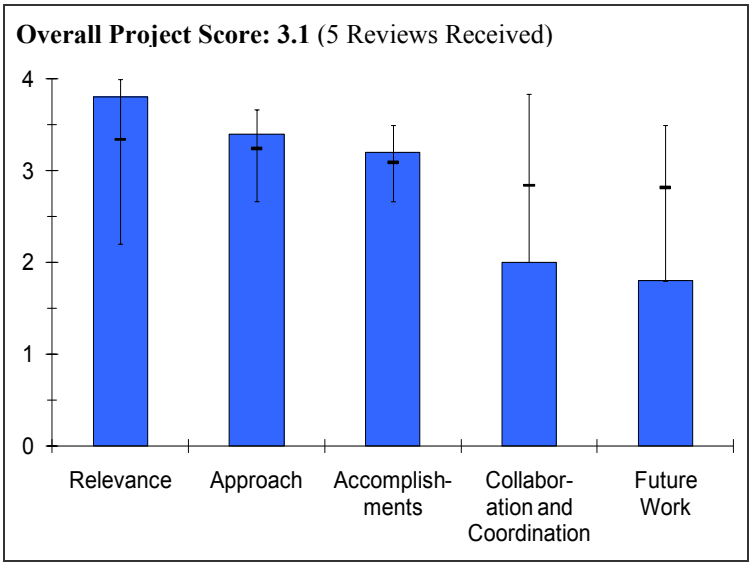
Specific recommendations and additions or deletions to the work scope

- None

- The PI should consider looking at how to maximize the value proposition using emission data and reviewing the data with CARB or AQMD or EPA.
- It would be helpful if the PI would do some site specific analysis of emissions.
- Perhaps increase expectations relative to funding.

Project # AN-13: CO2 Reduction Benefits Analysis for Fuel Cell Applications
Paul Friley; Brookhaven National Laboratory

Brief Summary of Project



The objective of this project is to perform an analysis of topics of interest to the Fuel Cell Technologies Program (FCTP) related to projected carbon dioxide (CO_2) benefits of fuel cell (FC) applications. The primary tool is the 10 Region U.S. MARKAL model developed by Brookhaven National Laboratory (BNL), which is calibrated annually to the Energy Information Administration Annual Energy Outlook and covers all energy consuming sectors of the United States from resource extraction to end-use. Analyses for fiscal year 2009 and fiscal year 2010 include: 1) sensitivity analysis of fuel cell vehicle (FCV) market penetration to changes in production, distribution, vehicle costs and CO_2 prices; 2) the impact of biomass-to-hydrogen in deep CO_2 emission reduction scenarios, and 3) additional analytical support to respond to departmental data requests and DOE program analysis needs.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.8** for its relevance to DOE objectives.

- The project addresses the impact of the potential CO_2 tax scenarios on the projected production, distribution, and cost of hydrogen-powered vehicles.
- The project studies the possible role of fuel cells in the future energy market where there will be strict controls imposed on CO_2 emissions. This should lead to important insights informing the policy debates on both fuel cells and CO_2.
- The project is important since it supports DOE's understanding of any future benefit based on carbon sequestration.
- The project is very relevant since there is so much concern nationally about CO_2. Hopefully, the many required assumptions will prove to be reasonably valid and not diminish the relevance. Also, it is not clear what the intended use of the output is, and whether it is for political purposes or technical planning.
- The project is supporting the understanding of how fuel cells can impact greenhouse gas (GHG) emissions, and that is critical.

Question 2: Approach to performing the research and development

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

- The project uses state-of-the-art market tools (MARKAL) to model the impact under a wide range of scenarios for the United States. The tool is based on future regulations that to date have not been approved by Congress.
- The project uses scenario-based analyses and BNL's 10 Region U.S. MARKEL model (which was developed in house) that is calibrated to the Annual Energy Outlook to investigate topics of interest to the Fuel Cell Technologies Program. The key feature of the analyses is the prediction of consumer behavior given various differences in cost – capital costs ($/kW), fuel cost ($/kg), and carbon cost ($/tonne). The PI should be commended for analyzing scenarios where DOE target costs are not met, as this makes the analyses potentially more relevant.

- The project approach is good, but it needs to be better integrated into other cost-analysis approaches in the program.
- The approach is very comprehensive and enough sensitivity analysis is performed to allow for many alternatives. However, there is a good chance that the range of sensitivity variables might be too optimistic, especially for the range of hydrogen prices and the range of prices for onboard hydrogen storage.
- The project approach of starting with the CO_2 Cap and Trade policy and the MARKAL model is good.
- The project is evaluating impacts on a national scale that may not be providing the detailed insights that would result if you looked at each region individually.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.2** based on accomplishments.

- The project examined a wide range of conditions and assumptions concerning the impact of hydrogen technologies on the projected cost of CO_2 emissions. Important conclusions were on the use of biomass-to-hydrogen, coupled with carbon capture and sequestration (CCS), to reduce the cost of meeting proposed CO_2 emission reductions.
- During the year, the PI modeled a number of relevant scenarios, including those involving carbon caps and carbon offsets and various ways of producing hydrogen fuel (e.g., from biomass and with carbon capture and storage). The results demonstrated that not only would carbon policy make fuel cell technology more widely used, but also that this substitution effect would help reduce the CO_2 market price (under cap and trade).
- The project sensitivity analysis was good, although many of the costs involved have not yet been attained.
- The PI needs to see the effect of wind-electrolysis and other carbon-zero approaches on the analysis.
- The project biomass analysis needs to account for non-fuel drivers to market.
- The PI should perform a CCS sensitivity analysis that includes efficiency variability and leakage variability from reservoir (often quoted as 1% per year).
- There are good results, but the project is open-ended and has been in progress since 2007.
- They produced a very complete evaluation of a large number of scenarios with varying carbon tax.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.0** for technology transfer and collaboration.

- The PI presented limited data on collaborations.
- The PI reports interactions with DOE staff and other analysts from national laboratories. Since the project is primarily an econometric model, the minimal interaction with the technical (engineering) community is not a problem. However, the results could perhaps be better vetted by increased interaction with the academic community.
- The project included very little collaboration and needs input from other cost analysis projects, industry, and especially government stakeholders.
- There seems to be little collaboration with anyone outside BNL and DOE.
- This project has virtually no collaboration. It might benefit from a partnership with the stakeholders that will be paying the carbon tax.

Question 5: Approach to and relevance of proposed future research

This project was rated **1.8** for proposed future work.

- The PI provided limited discussion on future activities.
- Proposed future work was not explicitly laid out in the presentation. It is presumed that the PI will continue to analyze scenarios as proposed by the DOE.
- Future work was not delineated, but it should be expanded from biomass.
- There were few specifics. The plan seems to be for the project to continue open-ended with periodic updates.
- The project has no future plan currently.

Strengths and weaknesses

Strengths
- It's an important project used to understand the role of hydrogen-based technologies and their potential impact on proposed CO_2 reduction legislation.
- The project provides useful insights into the possible outcomes and effects of aggressive GHG (CO_2) policies.
- The reduction programs, as shown in the conclusion (slides 11-18), were very beneficial.
- Their sensitivity analysis to CO_2 reduction based on costs was a strong aspect of the project.
- There are excellent personnel involved and good execution by them.
- The project presents a very good analysis of the impact of CO_2 tax on hydrogen price.

Weaknesses
- The projections are based on large uncertainties.
- As with all modeling and simulation efforts, the results are somewhat speculative and subject to overly precise interpretation. The results could be best interpreted by seeing what variation in results might arise were the research to engage independent academic economists as well.
- There are too many assumptions on biomass CCS technologies, and the project needs to be expanded to other methods of hydrogen production and also needs stakeholder input. They should consider multiple government CCS legislative approaches.
- There is no clear project end or intent for utilization. There seems to be an expectation for the project to continue open-ended.
- It's not clear who would use the results of this research. If it is the producers of hydrogen, then they should be involved in the project.

Specific recommendations and additions or deletions to the work scope

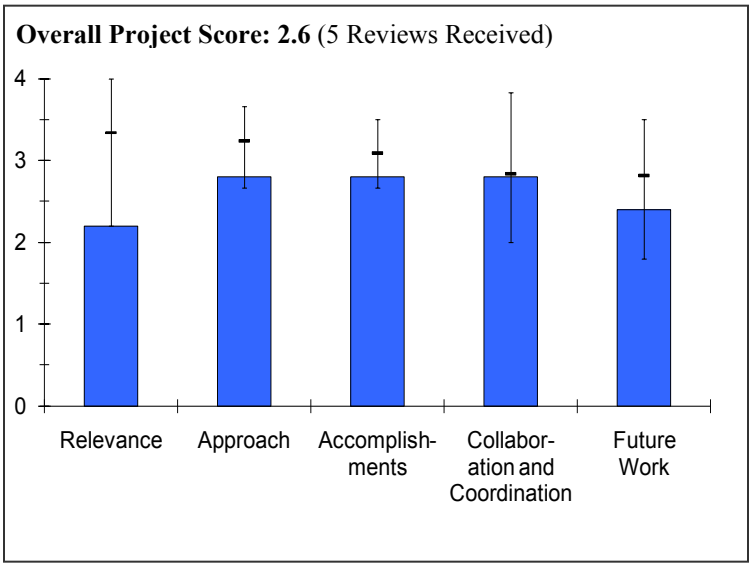
- None.
- Add other hydrogen production technologies. Consider other CO_2 reduction approaches than CCS, such as sustainable biomass production and carbon-zero approaches to hydrogen production.
- Determine by whom and for what purposes the project results are intended. Also, the range of sensitivity variables should be increased.
- Identify who the user of this work will be, and then get them involved and answer their questions.

Project # AN-14: Pathways to Commercial Success: Technologies and Products Supported by the HFCIT Program

Steve Weakley; Pacific Northwest National Laboratory

Brief Summary of Project

The objective of this project is to assess Fuel Cell Technologies (FCT) Program benefits by tracking the commercial success of technologies developed by FCT and FCT predecessor programs and by estimating their impacts and benefits. The milestones for 2010 are to: 1) update the FCT technology tracking database containing information on commercial and emerging technologies, and 2) update the FCT report on the status of commercialized and emerging technologies and patents.



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.2** for its relevance to DOE objectives.

- The project objective is to document and compile a list of patents that were supported wholly or in part by the DOE. It is hard to understand how the act of compiling a list of patents addresses goals of the DOE R&D plan.
- The project is relevant to assess the technology and commercial benefits of the work funded by the DOE over the years. However, this work should not be subcontracted. It should instead become a routine part of DOE's own work where they can monitor the progress of funded technologies.
- The DOE should have internal assessment platforms and criteria that are quarterly reviewed to see how progress has been made in terms of commercial deployment of funded technologies over the years. Perhaps this project is trying to tackle that, but it's not a research activity for a merit review.
- The project is good for information sharing not for merit reviews.
- This is a "back end" project to research and quantify, retrospectively, the impact that federal funding had in spurring energy innovation. The metrics used are patents and commercialized products. This is essential information in the research cycle, as it both informs appropriators of the merit and the effect of federally funded research and informs program managers as to what characteristics of proposals ultimately might lead to worthwhile (desired) outcomes.
- While it is often useful to have composite information on commercialization, the big issues that remain to be solved include many technology problems associated with the fuel cells, on-board storage, and also production and delivery.
- Understanding the benefits and being able to show commercial products flowing from the program can become critical for continued program funding.

Question 2: Approach to performing the research and development

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

- The PI performed a fair job on compiling a list and following through on patents that were actually used commercially.
- The project consumed a large budget for this assessment activity. This should be a routine tracking activity within the DOE. The budget should be significantly reduced.
- There is nothing new, different, or extraordinary about the project approach. It is very similar to the routine competitive assessment done in the industry (at much lower budgets).

- The PI surveys the patent literature and interviews the DOE headquarters staff and patent holders to develop a database of commercial and emerging technologies. This database is actively maintained and updated annually.
- Slide 3 is a bit controversial, because it's not that patents are an alternative to "Further Development by Industry," as drawn. Rather, it is preceding patent protection that encourages "Further Development by Industry," by allowing a firm to capture the benefits from what resources they put into the "further development."
- The project approach is generally okay, but it was almost doomed to failure from the beginning due to no apparent incentive by participants to cooperate or to be accurate.
- Conducting a patent search and then going to the organizations that own those patents to follow through is the right way to go.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.8** based on accomplishments.

- The PI identified more than 100 patents that were funded by the DOE. The presentation was followed by a lively discussion indicating interest in the topic.
- The project cannot be differentiated from a routine competitive analysis-type work that industry does at a lot lower budget. The project progress relative to the budget is poor.
- The project is not a technology activity but more of a programmatic assessment activity, and it should be out-of-scope for merit reviews.
- The major accomplishments of this project are its data mining, data aggregation, and results reporting.
- It is particularly noteworthy that the project reports in multiple formats: a polished, peer-reviewed printed as a PDF report, posted for public use (e.g., on the web), and in database form for in-house DOE use. These products are updated annually.
- Even though there are top-notch people working on the project, the accomplishments are modest, especially considering the time and funding dedicated to it.
- The search and documentation of the results are on par with the funding expended.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.8** for technology transfer and collaboration.

- The level of collaboration was limited to discussions with patent holders and follow-through on commercialization. There was no collaboration on accelerating or assisting patent holders on commercializing technology.
- The project entails fair collaboration with DOE staff and industry proof of concepts (POC).
- By its nature, this work is highly collaborative. The PI seems to be doing an excellent job of seeking out information from former grant recipients and convincing them to voluntarily contribute to his research (approximately 81 sources reported).
- There is little collaboration other than contacting and trying to question previous contractors.
- Virtually all hydrogen and fuel cell researchers funded by the program are given collaborators.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.4** for proposed future work.

- The project's future research should be more of the same.
- The project is routine programmatic work with nothing new or different, which should be done continuously within DOE and not outside of it as a separate project.
- The future direction of this work arises naturally. Continue to search the patent database for newly issued patents, and continue to actively monitor (query the companies about) the business activity of former grant recipients.
- The future work seems to involve doing more of the same things that they have been doing.
- The project output needs to be updated on an annual basis.

Strengths and weaknesses

Strengths
- The project identifies success stories as measured by patents. It provides one metric to demonstrate success of fuel cell projects to DOE management and Congress.
- None. It is just an essential activity that DOE should be doing to track the progress.
- This project provides essential and highly desired information to policy makers about the impact of federal R&D spending.
- There are excellent personnel members involved.
- The project provides a communication tool to show that, although we have not moved to a hydrogen economy, the nation and economy are benefiting from the program's research.

Weaknesses
- The project focuses solely on patents and does not address invention disclosures, industrial collaborations, publications, etc., as metrics for progress.
- The project is not relevant to any specific technology developments or new research. This is mostly a programmatic activity that should not be merit reviewed.
- It's recommended to make the starting point of the survey the list of former grant recipients rather than the patent record. This might provide a greater volume of information concerning commercial products protected by trade secrets rather than patents and about commercial products with pending patents.
- This project is not, in and of itself, advancing hydrogen and fuel cell technologies.

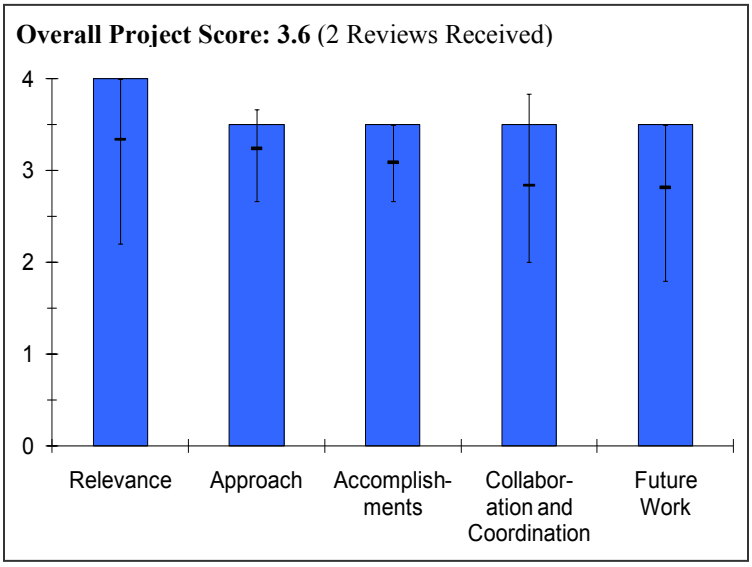
Specific recommendations and additions or deletions to the work scope

- This project should not be considered a research project.
- The project should be deleted from the merit review, as it is not relevant for technical assessment. It's a DOE programmatic activity and one hopes that funding is not taken out of research dollars.
- Since many grant recipients were universities and labs operated by universities, it might be interesting to study the effect of Bayh-Dole on the energy innovation process.
- They should use national labs for help resolving the many technical issues remaining and pass this type of project to a different type of organization.
- It would be helpful to identify how the commercialization successes of this program compare to other programs.

Project # AN-15: Fuel Cell Power Model: Evaluation of CHP and CHHP Applications
Darlene Steward; National Renewable Energy Laboratory

Brief Summary of Project

The objectives of the project are to: 1) accurately model performance for stationary fuel cells (FC) in combined heat and power (CHP) and combined heat, hydrogen and power (CHHP) applications and 2) combine detailed performance information with a comprehensive discounted cash flow methodology to evaluate lifecycle costs.



Question 1: Relevance to overall DOE objectives

This project earned a score of **4.0** for its relevance to DOE objectives.

- The purpose of this project is to model the economics of CHP and CHHP systems to see, among other things, whether CHHP systems might be a practical source of distributed hydrogen production. The question to be answered is whether CHHP systems, which are stationary fuel cells servicing large buildings, might be able to also produce hydrogen fuel for transportation applications. Since this is a transition strategy of interest, the project fully supports DOE objectives.
- The project could become a valuable tool for potential early adopters of CHHP to evaluate the economics of the system.

Question 2: Approach to performing the research and development

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

- The project approach is to first model the technical performance of stationary fuel cells suitable for CHP and CHHP operation; and second, to overlay this with the best available cost data to determine discounted cash flow lifecycle costs. Among other things, the PI developed a simplified system model for molten carbonate fuel cells (MCFC) in order to execute this approach. It is inherently difficult to validate both the technical performance and the cost data in such early-stage technology and to predict how costs might trend down over time. Nonetheless, the PI has made a reasonable effort through numerous interactions with staff at DOE labs, universities, fuel cell companies, and organizations where CHP and CHHP systems have been installed.
- The project should primarily support those looking at adopting the CHHP option, based on their location and available infrastructure, resource, utility costs, incentives, etc. The project should help determine how much and when one should be producing heat, hydrogen and power to maximize return on capital investment.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.5** based on accomplishments.

- The PI developed the model to provide the analysis results sought. Slides 13 and 14 compare the cost of hydrogen production from CHHP systems and small-scale steam methane reforming (SMR) systems, an alternate technology choice. The poster also demonstrated other results of the model. An example is the economics of using a CHP system to derive value from dairy farm waste.
- The model appears to assume a relatively low capital cost for the system and an unrealistically low internal rate of return (IRR). Different end-users have different business models, evaluation tools, and drivers for adopting

new, unproven technologies. The model should allow as much flexibility for users to input these numbers as possible.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.5** for technology transfer and collaboration.

- This project was highly collaborative with long lists of reviewers and partners on slides 2 and 12.
- Good collaborations with the National Renewable Energy Laboratory (NREL) hydrogen analysis team and other entities. The PI should consider continually validating the model with feedback from industry and available data from real-world testing and operations.

Question 5: Approach to and relevance of proposed future research

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

- The PI describes a number of fruitful activities as proposed in slide19. Most importantly, the PI intends to continue to "modify and enhance" the model as further real-world experience is gained. Further, the PI intends to study solid oxide fuel cells (SOFC) and residential-sized systems and also better integrate his model with a Macro-System Model (MSM) and Scenario Evaluation and Regionalization Analysis (SERA).
- The PI should consider other renewable sources outside of wind and solar.

Strengths and weaknesses

Strengths
- The project has important practical value, since it's providing a tool to enable potential early adopters' means to predict the costs of installation and operation of specific fuel cell systems (FCS). Similarly, it provides means to predict the costs of the proposed CHHP strategy of distributed hydrogen production for transportation applications.

Weaknesses
- None noted. However, as with all modeling efforts, one might potentially extrapolate incorrect conclusions based on the limited data.

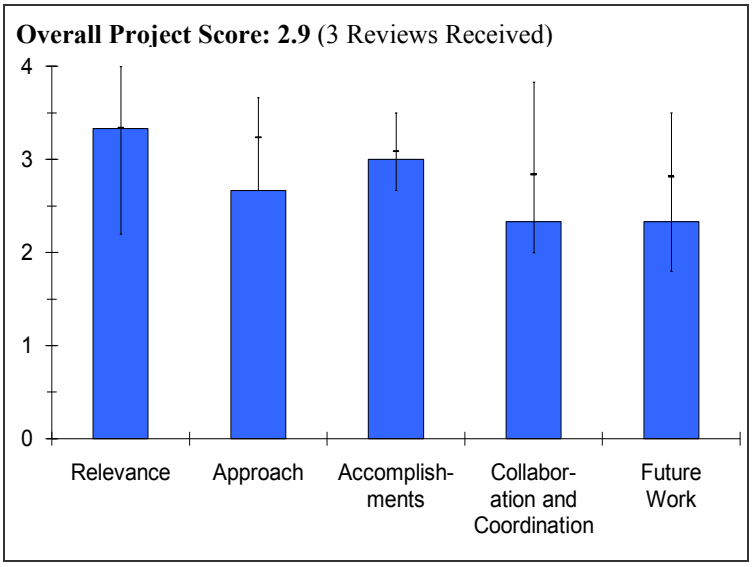
Specific recommendations and additions or deletions to the work scope

- None.

Project # AN-16: Geospatial Analysis of Hydrogen Production Pathways
Matt Kromer; TIAX, LLC

Brief Summary of Project

The objectives of the project are to: 1) develop a tool (the Hydrogen Logistics Model) to compare hydrogen production pathways and policy options; 2) compare production pathways using a single common framework to input assumptions consistent with other hydrogen analysis tools, account for geographically sensitive characteristics, and offer flexibility to test a variety of input assumptions, and 3) perform a scenario analysis to identify low-cost hydrogen production pathways at demand centers across the United States, and characterize the effect of monetizing carbon emissions, varying hydrogen demand scenarios, and economic inputs on hydrogen price, resource utilization, and carbon dioxide emissions.



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.3** for its relevance to DOE objectives.

- The project has a useful purpose and can assess the viability of hydrogen to reduce emissions. However, it's not clear that the cost input information is consistent with other models.
- The project appears to be relevant to DOE goals; however, it seems to be taking a somewhat slow stepwise approach that appears to lead to more contracts. The general picture of what the PI can really do is not clear, and the PI needs to address this rather than addressing smaller sections.
- Hydrogen resources and demand are very important parameters for fuel cell vehicle (FCV) and infrastructure development.

Question 2: Approach to performing the research and development

This project was rated **2.7** on its approach.

- The PI mentioned some of the project barriers but did not really address the way to overcome them.
- The project approach has been reasonable given the small amount of money. Validation of the tool is now a priority, and this seems to be absent.
- The project is presenting good considerations of hydrogen resources.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.0** based on accomplishments.

- Progress has been made as the model is close to completion. However, the accuracy of the model is unclear.
- The PI's comment on carbon mitigation costs seems quite optimistic at less than five percent of hydrogen cost.
- The delivery cost of over $3/gge also sounds high.
- The project progress is reasonable for the funding.
- Hydrogen delivery cost comes out to be more than 50% of hydrogen cost. This indicates that on-site production is a favored pathway.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.3** for technology transfer and collaboration.

- The project has no external partners to validate and provide input. It's not clear if companies actually make the investment needed.
- The project collaboration is definitely not good enough. They really should have more players involved.
- The project may benefit more by including additional stakeholders such as large hydrogen suppliers.

Question 5: Approach to and relevance of proposed future research

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

- The project is effectively complete. Other models seem to address some of the work that is proposed for future research, so it is not clear if it's needed.
- The project is ending and proposed future work is not overwhelming. Increasing the project funding is in doubt without a large increase in the collaborative net and pathways for validation. It's not clear how to confirm that the project is correct.
- The PI should consider a transition strategy for the project.

Strengths and weaknesses

Strengths
- If the model is used, then it could be useful.
- They have a good list of hydrogen sources.

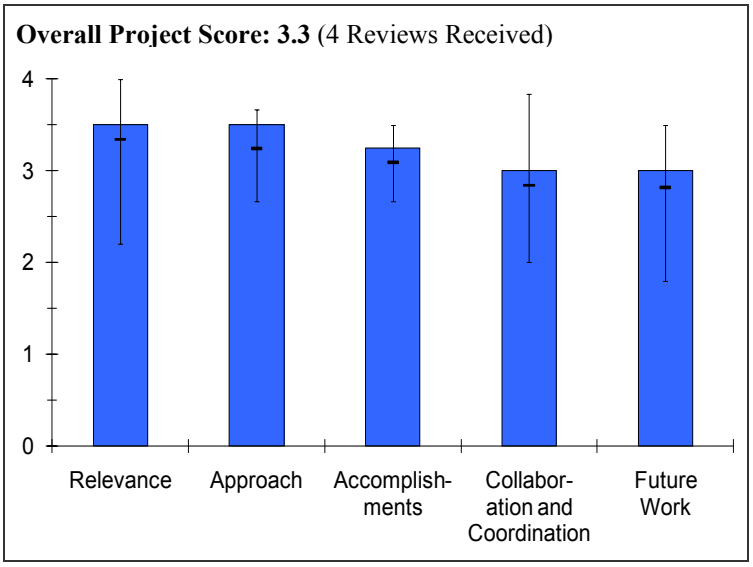
Weaknesses
- The model validation is weak.
- The carbon capture analysis methodology and impacts are not clear.

Specific recommendations and additions or deletions to the work scope

- The project is effectively complete.
- The project should have much more collaboration with stakeholders in future stages.
- Higher delivery costs of hydrogen, as identified in the analysis, lead to on-site hydrogen production. CHHP using biogas and/or natural gas offers a promising option to investigate.

Project # AN-17: Recent Developments in the Hydrogen Demand and Resource Assessment (HyDRA) Model
Johanna Levene; 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 datasets. Estimating hydrogen demand, finding and organizing resources, and designing, building, and managing the hydrogen production and distribution infrastructure all require spatial and temporal modeling and analysis, which require and produce spatial and temporal datasets. Hydrogen Demand and Resource Analysis (HyDRA) is a repository for spatial demand and resource and infrastructure data related to hydrogen. Data are provided in maps and via model integration. The objectives for fiscal year 2010 are to: 1) implement functionality to support further interoperability between HyDRA and the Scenario Evaluation, Regionalization and Analysis (SERA) model; 2) develop a process for automatically updating SERA input data in the HyDRA application on a regular basis, and 3) implement automatic updates of data and prototyping of the exploration of temporal and multivariate datasets.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.5** for its relevance to DOE objectives.

- The project likely aligns well with the DOE's objectives to evaluate hydrogen as an alternative fuel.
- Spatial data is essential to determining localities to implement hydrogen infrastructure.
- HyDRA supports program goals related to sharing of data, developing common assumptions and platforms, and it also appears to be widely used within the community.
- Web tools are very useful for potential users of hydrogen infrastructure and fuel cell vehicles (FCV).

Question 2: Approach to performing the research and development

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

- The project seems impressive with regard to the amount of connectivity from various models.
- The project's spatial data display was integrated with over 90 databases. It addresses multiple technical barriers well.
- The project's overall approach is good. It uses a well-designed Web-based interface to enable visualization and the transfer of geospatial data and integration with other tools. The team developed an initial platform several years ago and has incrementally added functionality over time that is focused on improved usability and integration with other tools. The use of open, Web-based tools facilitates communication and collaboration.
- They employed an excellent strategy to connect the user's needs with available data.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.3** based on accomplishments.

- If the modeling data can truly be automatically updated, that is a plus for its usefulness and longevity.

- The model has a growing number of new users.
- The project has a growing integration with other models including Marco-System Model (MSM) and SERA.
- The project is working on new layers.
- Significant progress was made this year toward adding functionality to enable collaboration and integration with other analysis tools.
- The model's Web-access features are very desirable.
- Hydrogen price and greenhouse gas (GHG) emissions by county are useful in the future decision making process.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.0** for technology transfer and collaboration.

- The project challenge is to get meaningful feedback on issues that people are willing to share. The only partner shown is National Renewable Energy Laboratory (NREL), although it appears as if there is a lot of Web-based feedback. It's not clear how effective that Web-based feedback is.
- The PI needs to present better information on the project collaborators to clarify if the project is serving all communities well.
- The project collaboration is very strong. Much of the work during the last year focused on improved integration with other tools and improving the usability of the tool. It is now able to accept data from external applications and export data for use in other applications.
- The PI presented a very good list of university and industrial partners.
- The project is cross cutting among different agencies such as the U.S. Environmental Protection Agency (EPA), Federal Energy Management Program (FEMP), the DOE Fuel Cell Technologies Program, Clean Cities , Vehicle Technologies Program, Office of Biomass Programs (OBP), and Solar Technologies Program.

Question 5: Approach to and relevance of proposed future research

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

- The PI should also work to validate the model and see if businesses would use it to make decisions.
- Increasing reliability and functionality of this model can only be a good thing.
- The ability for third party users to more easily integrate with the model will be useful.
- The project is presenting a very useful model that can be used by different stakeholders.

Strengths and weaknesses

Strengths
- The project's spatial data representation with other models and a large database is a strong aspect.
- The collaborative work has focused on improving coordination and accessibility with other contributors in the analysis community.
- The visualization tools and overall design for usability are very good.
- Automatic update features will allow the model to be useful for many years in the future.
- Involving many stakeholders in the project is very good.

Weaknesses
- It's doubtful if the data would actually be used by a business with the thought of building infrastructure.
- The PI should consider more collaboration.
- It's recommended to further identify how end-users use the tool.

Specific recommendations and additions or deletions to the work scope

- It's recommended for the PI to get feedback from companies who would actually build infrastructure to see if this analysis would be used to make decisions.

SYSTEMS ANALYSIS

- The PI should include cases where the model was used to demonstrate how the tool can be or is used to manage hydrogen infrastructure development and communicate information. HyDRA is primarily a tool that enables other analysis activities, so it is difficult to ascertain exactly how it is used within the community without seeing example results from end-users.
- A joint meeting or a Webinar of stakeholders to review the model and its application will be very productive. The meeting should include industry, EPA, Office of Biomass Programs, Vehicle Technologies Program, etc