2012 — Systems Analysis
Summary of Annual Merit Review of the Systems Analysis Sub-Program

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

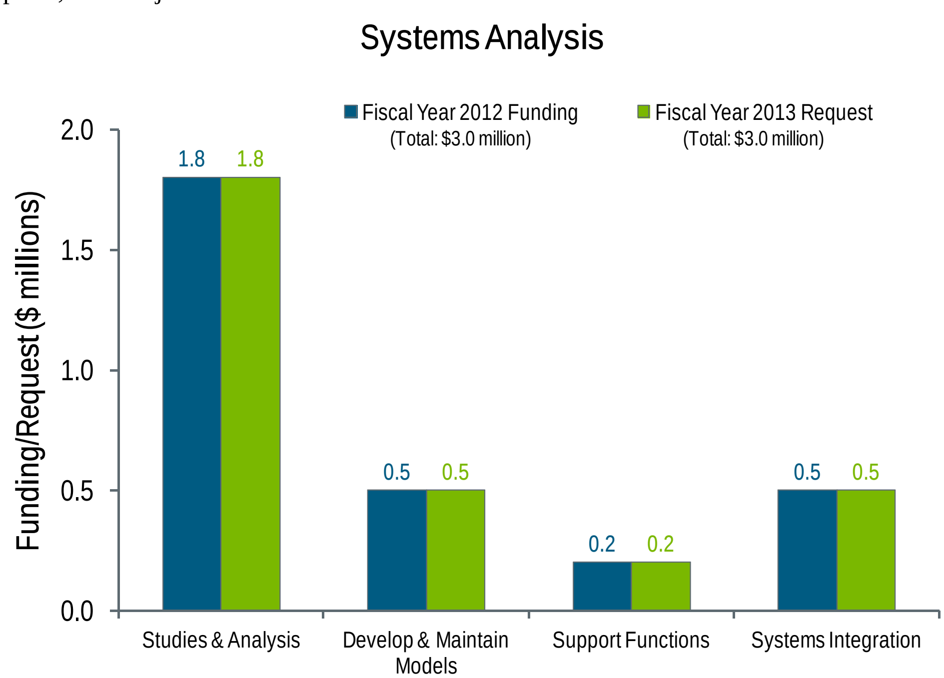
The reviewers considered the Systems Analysis sub-program to be an essential component of the U.S. Department of Energy (DOE) Hydrogen and Fuel Cells Program's (the Program's) mission. The projects were considered to be appropriately diverse and focused on addressing technical barriers and meeting targets. In general, the reviewers noted that the Systems Analysis sub-program is well managed and demonstrated the ability to address immediate analytical needs such as analyzing the impacts of the substantive drop in natural gas prices and the greenhouse gas emissions of new natural gas production ("hydro-fracturing") processes.

Some reviewers commented that the sub-program is effective in providing analytical support and key insights for the Program's research and development (R&D) efforts and that it is helpful in appropriately directing R&D efforts to address key barriers. Reviewers also commented that the analysis and model portfolio was making good progress toward understanding the issues, challenges, and opportunities to achieve the Program's technical targets. Some reviewers commented that the sub-program's focus was good, considering the limited resources.

Key recommendations for this sub-program included the following: (1) conduct a dynamic analysis of intermittent renewable electricity (primarily wind and solar) compared to the dynamic electricity load in a given region to quantify benefits of hydrogen storage, (2) develop modeling pathways for hydrogen infrastructure cost to achieve the $2–$4/gge hydrogen threshold cost, and (3) analyze high temperature polymer electrolyte membrane (PEM) fuel cells.

Systems Analysis Funding:

The FY 2012 appropriation for the Systems Analysis sub-program was $3 million. Funding for the sub-program continues to focus on conducting analysis using the models developed by the sub-program. In particular, analysis projects are concentrated on infrastructure development for early market fuel cell introduction, the use of hydrogen and fuel cells for energy storage, employment impacts of manufacturing and installation of fuel cells, and the petroleum and greenhouse gas emission reduction benefits of the Program's technology portfolio. The FY 2013 request-level of $3 million, subject to congressional appropriation, provides greater emphasis on analysis of hydrogen for energy storage and transmission, early market adoption of fuel cells, biogas resources, and other impacts, such as job creation.



Majority of Reviewer Comments and Recommendations:

The maximum, minimum, and average scores for the Systems Analysis projects were 3.8, 2.7, and 3.1, respectively.

Infrastructure: The analysis projects reviewed in this topic area were rated favorably for assessing the costs of hydrogen infrastructure development and understanding the hydrogen infrastructure costs compared to other alternative vehicle infrastructure. Reviewers acknowledged the insights gained from a wide array of stakeholders. Suggested next steps included the following: document the results and key findings, calibrate the findings with key stakeholders and other studies, and expand the analysis projects to a more comprehensive and integrated study of vehicle/infrastructure rollout.

Model Development and Systems Integration: One project involving model development for assessment of jobs impact was reviewed and received a score of 3.6. This project received very favorable reviews and was regarded as well aligned with the current program goals and objectives. Reviewers commented that the model provides valuable economic and job creation information for project funding justification. Reviewers recommended that the model be expanded to include assessment of job impacts for infrastructure construction and the model continue to be validated with original equipment manufacturers (OEMs) and industry to improve the model's credibility.

Programmatic Benefits Analysis: The reviewers commented that the analysis project to assess the Program's benefits (in terms of reducing greenhouse gas emissions and petroleum use) is relevant to the Program's objectives and provides valuable projections of the impact of fuel cell electric vehicles (FCEVs) and hydrogen in the U.S. transportation mix.

Resource Analysis: This project received a favorable review for assessing resources for hydrogen production. Reviewers specifically appreciated the insights the analysis provides about the impact renewable hydrogen production would have on the renewable resources, and they commented that the presentation of the geographic data is very powerful and makes the model results very useful. Suggested next steps included: expand the analysis beyond the light duty vehicle fleet, include regional variations, and expand the analysis collaboration to industry stakeholders.

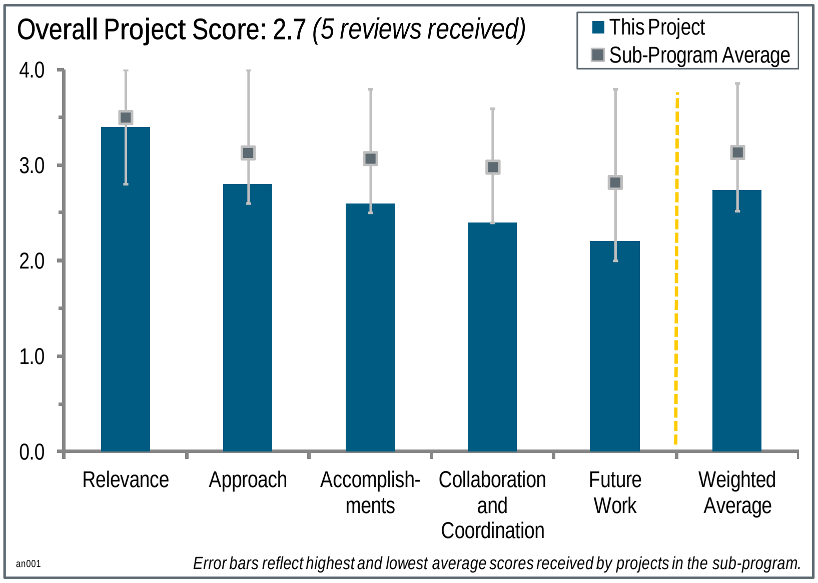
Scenario Analysis: These analysis projects examine the potential market penetration of FCEVs compared with other alternative vehicles and include sensitivity to key program variables such as the costs of fuel cells, hydrogen production, and hydrogen storage. Also, the impact of infrastructure availability and consumer choice was examined. The reviewers felt that the projects successfully showed the benefits of subsidies and compared FCEVs to other technologies. Reviewers suggested future studies recognize the compliance to U.S. regulatory standards such as CAFE and include input from automobile OEMs.

Studies and Analysis: Ten analysis projects were reviewed, with an average score of 3.1. In general, the reviewers felt that the projects supported Program goals, but they also agreed that the analysis projects need to perform the following activities: (1) involve more collaboration with industry to calibrate information with actual operation and experience for some of the projects, (2) be peer reviewed prior to issue and publication, (3) be more inclusive, and (4) use a consistent set of inputs and assumptions.

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

Brian Bush; National Renewable Energy Laboratory

Brief Summary of Project:



The objectives of this project are to use Scenario Evaluation, Regionalization, and Analysis (SERA)—a suite of tools for studying the cost implications of regional build-outs of renewable energy infrastructures—to: (1) generate self-consistent vehicle adoption and hydrogen demand scenarios relevant to the early market transition of fuel cell electric vehicles (FCEVs); (2) determine optimal regional infrastructure development patterns for H_2, given resource availability and technology cost; (3) geospatially and temporally resolve the expansion of production, transmission, and distribution infrastructure components; and (4) identify niches and synergies related to refueling station placement and early FCEV adoption areas.

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

This project was rated **3.4** for its relevance to DOE objectives.

- Conceptually, this is outstanding, but there are too many limitations associated with the many assumptions and the lack of inclusion of carbon capture and sequestration (CCS).
- This project will generate a cost model for infrastructure costs. A model of this type is needed to help DOE direct development. However, the fidelity of the model is only as good as the assumptions. The end use of the tool should be a key component in its development.
- Having the SERA model investigate approaches and issues related to the regional development of H_2 infrastructure is valuable to the DOE Hydrogen and Fuel Cells Program. Focus on this approach should continue.
- This project is an attempt to assess the regional build-out of H_2 fueling stations using data from various sources of projected FCEV introductions. Another objective of the project is to examine which H_2 production and delivery pathways would provide fuel at the lowest cost for a given demand level.

Question 2: Approach to performing the work

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

- This project has too many questionable assumptions.
- It is good that the SERA model integrates assumptions and data from multiple sources and related modeling efforts. However, with so many components and related assumptions involved, ensuring consistency, accuracy, and other factors becomes harder to control and of more importance.
- The approach is well designed to date, but it lacks regional and political reality. For example, truck transport within the major eastern cities may not be as attractive as the presentation shows due to the availability of distributed natural gas for distributed generation, congestion of the electrical grids and the desire of the electric utilities to increase non-peak base loads, and transportation restrictions for hazardous materials through heavily populated areas.

- The researchers need to coordinate with others such as the Strategic Analysis, Inc. (SA, formerly Directed Technologies, Inc.) work that showed that on-site steam methane reformers would dominate the choice of fueling option for many years if one chose the least costly option. The dominance of pipeline H_2 in slide 14 is striking, although the principal investigator said that that slide should have been labeled 2050; showing an earlier year might be instructive. The researchers also need to fold in the projected costs of H_2 from Air Products; they estimated costs of $4.50/kg–$5/kg for pipeline H_2 (see TV-007). Air Products also estimated costs between $3/kg and $5/kg for renewable H_2 from a wastewater treatment plant (see TV-006), compared to the results here of costs never dipping below $6/kg despite the preponderance of pipeline H_2.
- While the cost components of the project are consistent with the Hydrogen Analysis (H2A) models and other sources, such as the U.S. Energy Information Administration Annual Energy Outlook's energy price forecasts, the fueling station build-out is based on fuel cell vehicle rollout scenarios from the National Academy of Sciences (NAS) analysis. The level of confidence in those scenarios is relatively low, as admitted by the project itself through the downward adjustment of the rollout by 50% for the early years (but matching the high penetration of the NAS study in later years). Even the 50% reduction is not substantiated by any data, except to say that it is based on the California short-term estimates. In the absence of stated plans by original equipment manufacturers (OEMs) to introduce FCEVs in the United States by 2015, the new FCEV introductions shown on slide 19 appear to be overly optimistic. Because the demand for H_2 is directly related to the numbers of FCEVs introduced into the automotive fleet, the results of the fueling station build-out will have a low confidence level. The project also uses the geographical distributions of hybrid electric vehicles (HEVs) by postal zip code to project FCEV distribution. The growth of HEVs in the United States has slowed, if not stopped, suggesting that FCEVs are not likely to find customers in similar numbers. With the shift in focus by the OEMs for the U.S. market toward plug-in hybrid electric vehicles, at least for the near- to mid-term, the projected numbers of FCEVs are not likely to be realized over the analyzed time period.

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

This project was rated **2.6** for its accomplishments and progress.

- Progress toward DOE goals is questionable at best because the long-term cost of H_2 is above $6/kg, which is double DOE's targets.
- The accomplishments and process are as expected. A review of the assumptions to reflect a more complicated reality may be in order. The fuel targets, if accurate, would indicate H_2 is not a viable fuel. However, current non-taxed H_2 is often less than the $8/kg price quoted.
- Adjustments made to the nationwide scenarios based on the California plans are a good start, but California tends to be unique compared to other national approaches and initiatives. It would also be good to compare to other regional plans. In the future, as these regional plans are implemented, it would be good to validate model findings with real-world results. The researchers should be better able to determine which consumers and areas should be considered for refueling station placement as the modeling utilizes consumer preference research more (as was indicated in plans for future work). Sensitivity analyses for availability and the prices of different feedstocks should be considered. The graph presented showing the optimal choice of production technology displayed the influence of low natural gas costs. Natural gas costs are at historical lows today, but they may not be in the future years analyzed by this model. Also, central coal gasification is shown as preferred due to economies of scale, but changes in the regulatory scene for coal plants might completely alter the picture.
- Subject to the uncertainties in the underlying NAS FCEV introduction scenario, the demand for H_2 has been modeled for the 600 largest urban areas. The garaged HEV distribution is not likely to be a good predictor of future FCEV distribution. Results for the delivered cost of H_2 show a leveling out at about $6/kg, which would require more than a decade to achieve a break-even cumulative cash flow. The significance of the study results is undermined by the low level of confidence in the underlying assumptions of FCEV introduction.

Question 4: Collaborations and coordination with other institutions

This project was rated **2.4** for its collaboration and coordination.

- The researchers should coordinate with SA and Air Products' projections.

- It is good to see that collaboration has expanded. However, it could be expanded more (as the project progresses) to other stakeholders, such as industry and/or people involved in developing other regional H_2 infrastructure development initiatives.
- The project has collaborators from national laboratories, universities, and a not-for-profit partnership. It would be very helpful to involve FCEV OEMs and the industrial gas companies. Although such industry collaborators are not likely to share privileged information or data, they can still serve to identify potential errors in assumptions and they may be able to offer guidance in business-related aspects of infrastructure build-out.
- There is room for improvement in the collaboration to increase the fidelity of the model. Potential collaborators include the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration, The New York/ New Jersey Port Authority, and the Massachusetts Highway Department.

Question 5: Proposed future work

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

- The proposed future work is thin; additional examples of opportunities would help.
- Comparing FCEVs and battery electric vehicle (BEV) market penetration would be valuable.
- The proposed tasks are good, but the researchers need to make sure consistency checks, sensitivity analyses, and validating results are part of the efforts. It would be good to think outside the box a bit and not look at typical/expected deployment patterns. Instead, researchers should use this tool to investigate the "what ifs" of things such as unexpected, extreme developments and constraints; competition from other advanced technologies; and potential synergies.
- The proposed future work is to continue to update SERA, apply SERA to more complex deployment scenarios (in regional detail), and use SERA for multi-fuel (e.g., FCEVs versus BEVs) analyses. Because the results of the study are heavily influenced by the FCEV rollout scenario used in the analyses, it would be useful to examine a range of such scenarios, from the highly optimistic to highly pessimistic. It may also be useful to see what can be learned from the FCEV introduction programs and projections in other parts of the world (e.g., Germany, Japan, and Korea).

Project strengths:

- This project has good modeling skills.
- There are outstanding resources available.
- The strengths of this project are the knowledge and dedication of the project members.
- The model is customizable to meet a variety of user and analysis needs and can be used to investigate the regional issues and approaches to H_2 infrastructure development.
- The SERA model maintains rigorous self-consistency between scenario parameters, such as FCEV vehicle introduction, stock turnover, and vehicle-miles traveled to project H_2 demand. The SERA model is consistent with H2A assumptions, parameters, and results.

Project weaknesses:

- This project needs to incorporate more sensitivity analyses.
- There is a lack of collaboration or coordination with other modelers (or explanation of large differences).
- This project has too many questionable assumptions and a lack of accounting for CCS.
- The weaknesses appear to be the lack of real-world input.
- The major weakness is the uncertainty in the FCEV rollout scenario, which forms the basis for all of the results of the analysis. The U.S. automotive market is highly dynamic, and the OEM's plans for advanced technology vehicles are not included in these analyses. The results presented here and from the proposed future work do not suggest a high level of confidence.

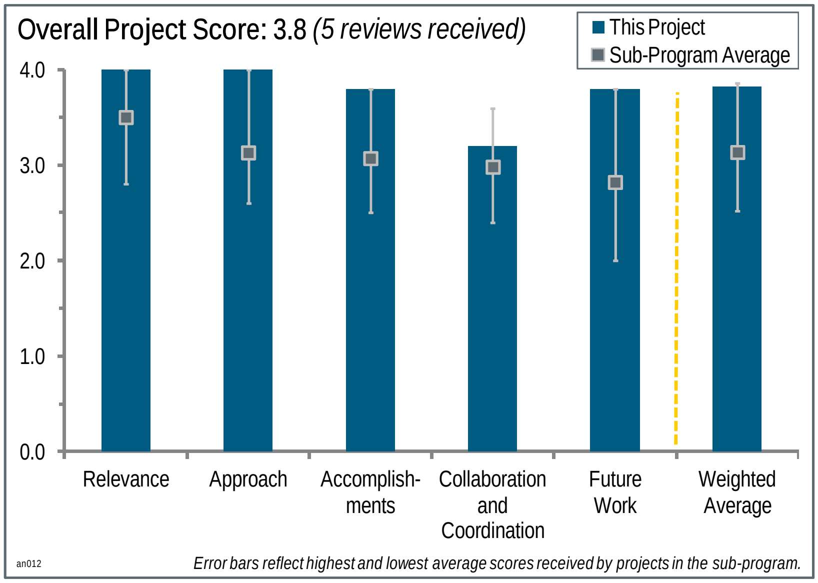
Recommendations for additions/deletions to project scope:

- Industry input, if it can be arranged, would be very helpful in strengthening the results of the study.
- This project should have more real-world technical and political input into the modeling.

- CCS should be included as an option. Parametric studies, which are valid regardless of assumptions, should be done.
- This project could be more closely coordinated with AN-020 (Melania), Hydrogen Refueling Infrastructure Cost Analysis. Findings and approaches of both these projects can help both teams. The researchers should also incorporate consumer preferences as well as behavior and sensitivity analyses.
- It would be valuable to explore the preponderance of H_2 pipelines in slide 14 by analyzing under what circumstances H_2 pipelines would be economically viable compared to trucked-in H_2 or on-site production. Presumably there would have to be large quantities of FCEVs to justify adding pipelines, but this would likely occur in large cities where the cost of installing a pipeline distribution network might be excessive. This reviewer asked how to get from on-site production and trucked-in liquid or gaseous H_2 to the situation shown in slide 14 with a preponderance of H_2 pipelines.

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

Michael Wang; Argonne National Laboratory



Brief Summary of Project:

The objective of this project is to develop and update the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model to assess the energy and emission benefits of hydrogen (H_2) fuel cell electric vehicles (FCEVs) and other fuel cell systems. Development of GREET allows for: (1) fuel-cycle analysis of H_2 FCEVs with various H_2 production pathways; (2) vehicle-cycle analysis of manufacturing H_2 FCEVs; and (3) life-cycle analysis of H_2 and petroleum infrastructure build up. Studies using GREET can now provide life-cycle analysis results for the U.S. Department of Energy's (DOE's) Fuel Cell Technologies Program activities and reports, such as the Multi-Year Program Plan. Additionally, the updated GREET model can be used to support and interact with stakeholders to address the energy and environmental benefits of H_2 and fuel cell systems.

Question 1: Relevance to overall DOE objectives

This project was rated **4.0** for its relevance to DOE objectives.

- The determination of life-cycle costs for various fuel generation technologies is relevant to the DOE objective.
- GREET is the most recognized program to authoritatively estimate well-to-wheels (WTW) greenhouse gas emissions (GHGs).
- This model has served over the years as the key tool for investigating the life-cycle emissions and energy use of various pathways and scenarios that the DOE Hydrogen and Fuel Cells Program (the Program) has considered in developing and validating various technologies.
- GREET modeling has continually provided excellent data on the emissions and GHG performance of the various fuel cell technologies and product applications.
- GREET compares alternatives in an objective manner and is useful, necessary, and the only way to separate hype from reality in most cases (e.g., the effects of shale gas production and comparison of H_2 production from shale and natural gas).

Question 2: Approach to performing the work

This project was rated **4.0** for its approach.

- Adding shale gas and biogas to the model is very relevant and timely.
- Every year the project has done a great job of adding new analyses and features, greatly expanding the capabilities of the model and providing value on the subjects of importance to the analysis community and industry, while also uncovering important factors.
- GREET continues to be responsive and provide important data, giving dimension to the environmental benefits of fuel cells versus alternative energy technologies.

- The approach was always appropriate, but it has been honed over the years to be more realistic. Potential industry changes are addressed proactively.
- The apparent approach taken, generating computer model modules using an existing program, appears to be cost effective. Expanding the models to address emerging energy supplies and updating the modules for the updated data would be wise.

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

This project was rated **3.8** for its accomplishments and progress.

- Shale and manure models were added and the overall model was cleaned up. The impact of platinum (Pt) loading and plant construction was determined. GREET.net is a step forward and will open up usage.
- The addition of fuel-cycle analysis of renewable sources for H_2 pathways, specifically conventional and shale gas supply, to the model is helpful. The addition of vehicle-based, life-cycle analysis for FCEVs, battery electric vehicles, and baseline vehicles is interesting but the values may be challenged.
- The new set of analyses performed through the model this year has uncovered important details (such as the impact of Pt loading reduction, plant construction costs, methane leakage, etc.) that typically may be missed but are revealed through comprehensive analyses such as this. These new bits of information obtained will help focus the Program's technology research and development activities.

Question 4: Collaborations and coordination with other institutions

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

- More detail on information sources would add greater credibility, as industry stakeholders is too vague a term.
- It is unclear as to who collaborated on this activity. "Industry stakeholders" is a nebulous term that often translates to consultants. It is unclear what specific industry stakeholders were involved in the collaboration and what the sources of the information were from which these conclusions were drawn.
- There is good collaboration with both analyses of other models and with industry stakeholders to ensure comprehensive data input. Going forward, more collaboration with specific user groups of the model would be suggested to make sure it is meeting stakeholders' needs and to receive important feedback on what other capabilities and components need to be added. The new GREET.net platform should enable this more.

Question 5: Proposed future work

This project was rated **3.8** for its proposed future work.

- The proposed future work appears rational.
- The list is growing shorter and includes more second-order efforts.
- The future work outlined holds promise to both make the model more user-friendly and allow for more detailed, granular analyses.

Project strengths:

- A strength is the comprehensiveness of the model.
- A strength of this project is the objective analysis of alternatives in a comprehensive manner.
- The principal investigator is very experienced with a long history of detailed WTW GHG calculations and models.
- The ability to present credible, objective, and unbiased data is of tremendous value to understanding the potential benefits of fuel cell technologies.
- The model includes a diverse array of technology options, and it has been enhanced each year to be able to perform more detailed analyses and to address emerging issues of concern. The model is well established, widely known and used, and is usually accepted as the go-to standard model for emissions/energy-use analyses. The recent development of the GREET.net platform will enable the use and understanding of the model by a wider range of stakeholders and in a more focused way.

Project weaknesses:

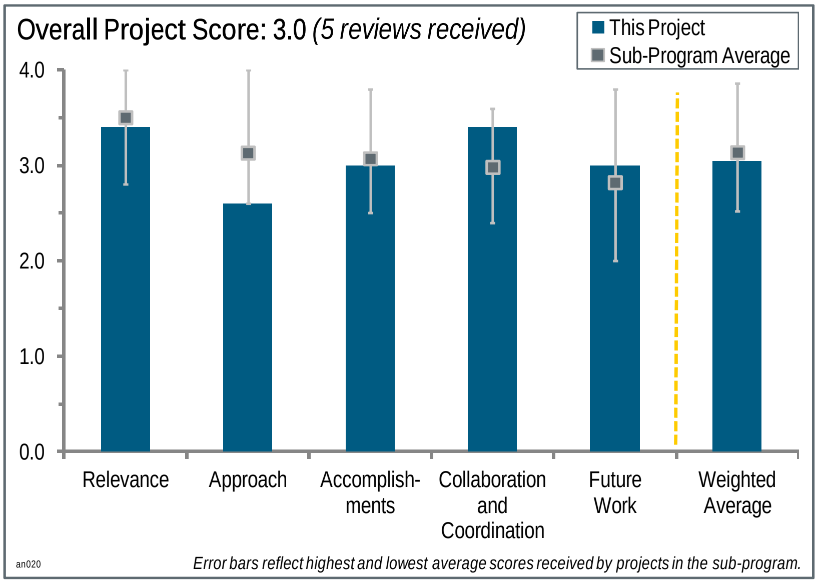
- This project has no weaknesses.
- The substantiation of assumptions is weak and needs more detailed industry input.
- As the data keeps adding more components, it might become more difficult to ensure consistency, accuracy, and validation; more care should be given to this as the project advances.
- The primary weakness is the apparent lack of visibility of the underlying data and assumptions. This leads to questions on the fidelity of the conclusions drawn from the model.

Recommendations for additions/deletions to project scope:

- The researchers should add industry peer reviews of assumptions and verifications of results.
- The research should clarify who the collaborators are and the sources of the data.
- This project should continue to provide data to support new commercial fuel cell products, such as fuel-cell-powered mobile light stands and generators.
- This project should coordinate more with the SERA model to enable more detailed energy/emissions analyses related to potential regional H_2 infrastructure development scenarios, to facilitate a more detailed, enhanced understanding of what these developments might mean and where efforts should be focused.

Project # AN-020: Hydrogen Refueling Infrastructure Cost Analysis

Marc Melaina; National Renewable Energy Laboratory



Brief Summary of Project:

This project identifies cost metrics for near-term markets for hydrogen (H_2) fueling station for commercial and private vehicles. Specifically, the objectives are to: (1) identify the capacity (kg/day) and capital costs associated with early commercial H_2 stations and (2) identify cost metrics for greater quantities of H_2 fueling stations across the United States as well as for larger capacity fueling stations.

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

This project was rated **3.4** for its relevance to DOE objectives.

- A credible estimate of H_2 station costs is essential to move the H_2 and fuel cell electric vehicle (FCEV) market forward.
- This project is extremely relevant because a refueling infrastructure is critical to FCEVs.
- This activity is relevant to the DOE objectives; the limited responses to the survey are unfortunate but expected. As fuel cell technology is maturing toward deployment, the costs of putting the fueling infrastructure in place are becoming a key factor in the overall commercialization process for the technology.
- At a time when research and development is improving technology, niche markets are developing, and automakers are coming out with strong statements regarding commercialization in a couple years, it is important to understand what the costs and required level of effort might be for early market infrastructure development. This project addresses those questions both by gathering stakeholder input and by attempting to quantify stakeholder feedback.

Question 2: Approach to performing the work

This project was rated **2.6** for its approach.

- The approach lumps all types of H_2 production and delivery together. This makes the approach and results questionable at best.
- The approach is adequate, but the execution may have areas where it can be improved. For example, multiple short surveys may be more conducive to getting the necessary responses instead of a large, single survey, which may intimidate potential responders.
- It is nice to see the four station types compared side by side. The calculator gives respondents flexibility while also maintaining a structure consistent with the Hydrogen Analysis (H2A) model. While the stakeholders providing input to the cost calculator represent diversity, a big portion (50%) is from universities and the government. It would have been better and closer to reality if a larger percentage of respondents was drawn from industry.
- Using estimates from companies involved in building early stations is valuable. The downside is that mobile refuelers, trucked-in gaseous or liquid H_2, and on-site steam methane reformers or on-site electrolyzers cannot be distinguished. In addition, it is not possible to add variable costs, because it is not known which fuel is used. The capital cost estimates can only be used to bracket the cost of H_2 stations going forward.

- In this project, qualitative input from a handful (11) of respondents, not all of whom have provided complete input, is being converted to quantitative results (from the Hydrogen Station Cost Calculator model [HSCC]). The researchers at the National Renewable Energy Laboratory (NREL) did not have direct interaction with the respondents, so they could only have access to aggregated data. The approach is further weakened by the fact that only half of the respondents were from or related to industry, the other half being from universities and the government.

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

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

- The results allow good initial estimates of what early market costs might be and how infrastructure development and cost reduction may be accomplished.
- The results on capital costs for a generic H_2 fueling station are valuable. Using a third party to shield the suppliers is a good solution to protecting proprietary cost estimates.
- Considering the level of funding, this was a good effort. However, even with a good effort the results have limited value.
- The progress to date is as expected. The identification of compression costs as an issue is obvious. However, the lack of discussion on the insufficient flow measurement issues shows that there are areas for potential improvement. The limiting of polling to a single U.S. DRIVE Partnership technical team limits the input and potential value of the survey. The fuel cell and codes and standards teams (small in situ reforming, component, and instrument development) may be additional relevant information sources.
- Although there were 10 slides of accomplishments and progress in the presentation, it is difficult to assess the usefulness of some of the results shown. For example, slide 14 shows costs for station sizes and projected time frames, but there does not seem to be any connection with the development of the corresponding demand for H_2 (i.e., plans for the manufacture or sale of large enough numbers of FCEVs in the same time frames). There was nothing shown on the potential validation of the cost equation (slide 18) with the fueling installations for fuel cell forklift warehouses, for example.

Question 4: Collaborations and coordination with other institutions

This project was rated **3.4** for its collaboration and coordination.

- It is good to see interaction with groups such as the California Fuel Cell Partnership and U.S. DRIVE.
- NREL cannot reveal the companies involved and must trust that the third-party vendor chose an appropriate mix of equipment vendors.
- Publishing the results would help with collaboration efforts.
- With the exception of the comment on the U.S. DRIVE teams, the collaboration and coordination with other entities appears to be appropriate.
- Given the constraints of proprietary restrictions on hard data, this project is attempting to work with, and obtain information from, as broad a group of stakeholders as possible. Thus, the project has good collaboration, even if it is through International Data Corporation Energy Insights, rather than directly.

Question 5: Proposed future work

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

- It is not clear what will be done with this information.
- It is good to see that this analysis related to infrastructure is going to be tied to vehicle rollout and that other models such as the Scenario Evaluation, Regionalization, and Analysis (SERA) model will be utilized.
- The proposed future work appears slim. Further examination into the station cost drivers to help direct DOE was expected.
- It would probably be better to have one or two comprehensive projects rather than many “small” projects. The principal investigator presented three of these small projects in one session.

- The project is scheduled to end by September 30, 2012; not much was said about plans for future work. The two slides on the proposed future work (slides 20 and 21) contained only generic statements on what is needed, but no specific future activities were given.

Project strengths:

- The project quantifies qualitative feedback from stakeholders.
- The project features a good team of investigators with years of experience in this space.
- This research team has very competent personnel and resources.
- The strength is the importance of collecting and analyzing the field data.
- A quantitative tool—the HSCC —has been developed that can be used to assess the effects of varying station parameters on station costs. The concept of four types of stations (one current, three future) is useful in assessing how fueling stations might be implemented to support the introduction and deployment of FCEVs.

Project weaknesses:

- A more diverse set of respondents (fewer from government and academia and more from industry) could have been used.
- There is too little value in the results of any of the small projects.
- All of the project's outcomes depend on the input received from a relatively small number of respondents. Further, only half of them were from industry, and most of them provided only partial responses. Thus, the degree of confidence in the results is not very high.
- The weaknesses are the lack of guidance to DOE on specific weaknesses and areas of needed development to support the DOE programs. A computer model, if not used to address specific issues, is of questionable value.
- This approach does not allow a desegregation of costs for different fueling stations. Hence, it is not known if the results are skewed to the low side by including mobile refuelers, for example, or skewed to the high side by including more expensive electrolyzers. This approach also excludes variable operating costs, because it is not known whether the stations use natural gas, electricity, or trucked-in H_2 as the source.

Recommendations for additions/deletions to project scope:

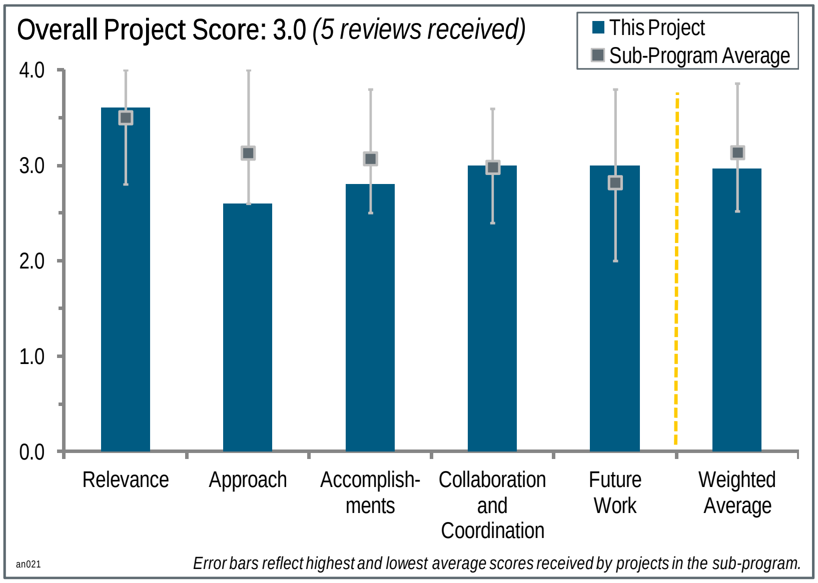
- Stop funding projects that have so many assumptions that they have little value.
- The project will come to an end soon. There is nothing specific to suggest for the remainder of the project term.
- Researchers should generate results and feedback to DOE for specific areas of future focus.
- Ideally, similar data should be obtained for each type of H_2 station, but this may be difficult given that so few stations of each type have been built.
- It would be nice to conduct a follow-on study in a couple of years, during the 2014–2016 "early commercial" time frame identified, to see if calculations and projections match with real-world deployments and developments to help understand the path forward more clearly.

Project # AN-021: Comparing Infrastructure Costs for Hydrogen and Electricity

Marc Melaina; National Renewable Energy Laboratory

Brief Summary of Project:

The objective of this project is to compare retail infrastructure costs on a common transportation energy service basis, namely, per vehicle mile traveled. The project compares capital costs between advanced vehicle types, assuming market adoption challenges of vehicle types have been met.



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

This project was rated **3.6** for its relevance to DOE objectives.

- This effort is relevant to the DOE objectives in that, if done correctly, it will result in guidance on where to focus research.
- This project is very relevant because these are two major means of reducing petroleum usage.
- This project aims to compare the cost of the fuel supply infrastructure for fuel cell electric vehicles (FCEVs) and electricity (for battery electric vehicles [BEVs] and plug-in hybrid electric vehicles [PHEVs]), but not including generation and transmission for the latter. It may be commonly assumed that the electric infrastructure has little additional cost, but this study is addressing this issue in a systematic manner.
- Vehicles are more ready in the deployment scheme, but they are now waiting for the infrastructure to develop. In addition, FCEVs and PHEVs have their challenges, but proponents and opponents of each side tend to pull the arguments relating to feasibility and deployment timelines in various directions. An analysis such as this helps lay the groundwork for clarifying and outlining issues in a more objective way and also helps guide research and development investments.

Question 2: Approach to performing the work

This project was rated **2.6** for its approach.

- The approach had too many major assumptions and too little actual data.
- Some assumptions are somewhat optimistic. The industry is new and there is a lack of data, so it is harder to perform these analyses. This approach at least sets a framework for further refinement as more reliable data becomes available. Conducting some sensitivity analyses or investigating a couple different cases/assumptions could help the project.
- The approach is valid, but some of the assumptions made may invalidate the conclusions. The concept that a PHEV has a fuel mileage of 141 miles/gge, while an FCEV only has a fuel mileage of 59 mi/gge, is questionable. The current FCEV mileage of fielded units without regenerative braking has been demonstrated to meet or exceed this value. To make an FCEV with energy storage and regenerative braking, as is done currently on transit buses, will increase the mileage. Analysts should remember that an FCEV is an electric vehicle.
- This analysis assumes an established light-duty vehicle (LDV) market size of 10% in a city of 1.5 million people and 1.2 LDVs. Then, the 120,000 electric vehicles are either all FCEVs or all PHEVs (20%–30% BEVs and 70%–80% PHEVs). Using an assumed 10% interest rate and a 12-year lifetime, the results for either case are expressed as capital costs as dollars/mile and city service costs as dollars/city. Similarly, different sizes of H_2 fueling stations and different electric charging equipment configurations are being analyzed.

- The method of comparing FCEV and BEV infrastructure costs may be misleading. Other sources have shown that installing electrical infrastructure for BEVs and PHEVs could cost many times more per vehicle than H_2 infrastructure. For example, the McKinsey & Company report for the European Union (EU) estimated that electrical infrastructure would cost five times as much as H_2 infrastructure for the entire EU, while slide 13 shows an electrical infrastructure cost being less than the H_2 infrastructure cost. The electric vehicle supply equipment (EVSE) estimates also seem low. One of the most credible estimates is from Kreider & Associates, which obtained three competitive bids for Type II EVSE systems to retrofit an existing 300-car parking garage in Boulder, Colorado. The average of the three bids was \$3.72 million, or \$12,400 per PHEV, compared to slide 12, which shows a spread with a maximum of only \$6,751 per PHEV. In addition, slide 11 indicates that 43 PHEVs will recharge at work, implying that each PHEV could charge for only 11.2 minutes in an 8-hour day, which the principal investigator (PI) said would require a switching system. However, this would add significant cost to the EVSE because a switching network to switch 43 plugs at 240 volts would be expensive.

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

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

- Results give some initial insights but are based on a variety of generalized assumptions and would need to be further refined.
- The results to date are interesting but highly dependent upon the assumptions. Applying tolerances to the assumptions for a sensitivity analysis may help with the fidelity of the results. Additionally, the researchers should add some reality to some of the assumptions, such as peak time energy costs, grid saturation (brownouts), and not-in-my-backyard (NIMBY) issues with new transmission and distribution power lines. The Electric Power Research Institute (EPRI) may be able to help here.
- Subject to the assumptions used in the study, it was determined that:
  - City-wide annualized capital costs are 3.1, 3.0, and 3.2 cents/mile for FCEVs and PHEV-home and PHEV-robust scenarios, respectively (i.e., these costs are essentially the same for all three scenarios).
  - Overall costs can be reduced by implementing a combination of fast-charging public systems and slow-charging home systems.
  - Sensitivity analyses indicated a capital-cost variability of 2–3 cents/mile for all systems.
  - Fuel costs for PHEVs are 15%–20% lower than for FCEVs, but they have slightly greater uncertainty.
  - Overall, FCEV and BEV costs per mile are comparable, while the cost per mile for PHEVs is about 10% lower.

Question 4: Collaborations and coordination with other institutions

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

- This project has excellent collaboration.
- This project could expand its collaboration to also include some industry feedback.
- Collaboration with multiple entities has consisted mostly of reviews of the study results by the collaborators, rather than active collaboration and input during the course of the study.
- The collaboration within the National Renewable Energy Laboratory (NREL) staff, the U.S. DRIVE Partnership Fuel Production and Integration Technical Team, DOE staff in the Vehicle Technologies Program, and academic consultants is a start. Input from other related venues will probably offer additional insights. Researchers should leverage the other tech teams to avoid the appearance of a nepotistic viewpoint. Researchers should also leverage other organizations, such as EPRI, the Gas Research Institute, the American Gas Association, DOE Federal Energy Regulatory Commission, and the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration.
- The PI showed a graph from the McKinsey & Company EU report; part of collaboration implies a blending of opinions or results from other groups, which this report does not seem to accomplish. Another example, slide 17 implies that a BEV costs only slightly more than an FCEV, but Kromer and Heywood at the Massachusetts Institute of Technology estimated that, in mass production, an FCEV would cost \$3,600 more than an internal combustion engine vehicle, while a BEV would cost \$10,200 more. Similarly, the McKinsey & Company report estimated that, by 2030, the total cost of ownership of an FCEV would be less than the cost of either a BEV or a

PHEV. Slide 17 shows the PHEV costing less than the FCEV. The McKinsey result has particular credibility, because 10 major original equipment manufacturers shared their proprietary vehicle cost data with McKinsey in a clean room.

Question 5: Proposed future work

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

- The future work planned looks very good, but it is not likely to be relevant, with current funding levels.
- Looking into factors such as consumer preferences and regional/geographic diversity, as is proposed, will be key to clarifying and providing more realistic results from this research.
- The proposed future work is appropriate. Focusing on the fidelity of the assumptions based on external input and real-world limitations (e.g., grid saturation and NIMBY) would improve the usefulness of the conclusions.
- In future work, the study will examine different cities/regions and the geographic variability in the availability and cost of low-carbon energy sources. The researchers will also examine factors affecting consumer/investor behavior. With the high level of uncertainty in the assumptions (a major one being the number of PHEVs as a fraction of all LDVs in a city), going to this level of detail does not seem to be very useful.
- Geographic variation is important. There is one caveat from the future work slide: the PI claims that EVSE would be used more efficiently in higher-density cities. This may be true for H_2 stations, where more FCEVs per station are needed, but that does not address the main issue with EVSE: only one car can be charged at a time, so more PHEVs wanting to use a station has no impact if each car has to charge for 30 minutes to an hour or more.

Project strengths:

- This project has good resources and a good PI.
- The strengths are the knowledge and dedication of the project members.
- This project has a good approach and analysis. The researchers have done a considerable amount of work, given the limited resources for the project.
- This is a good team that has extensive experience in the H_2 and alternative vehicle fields, and access to NREL's large stable of vehicle models.
- It is useful to have a framework and effort that attempts to compare the different infrastructures involved with H_2 and PHEVs.

Project weaknesses:

- There are a variety of general assumptions and not enough data at this point.
- There is a high degree of uncertainty in the basic assumptions used in this analysis.
- This project's weaknesses are the lack of tolerance or sensitivity analysis on the assumptions, external input, and real-world constraints.
- The apparent failure in this project is calibrating results with other major studies in this area (or at least explaining the large differences).

Recommendations for additions/deletions to project scope:

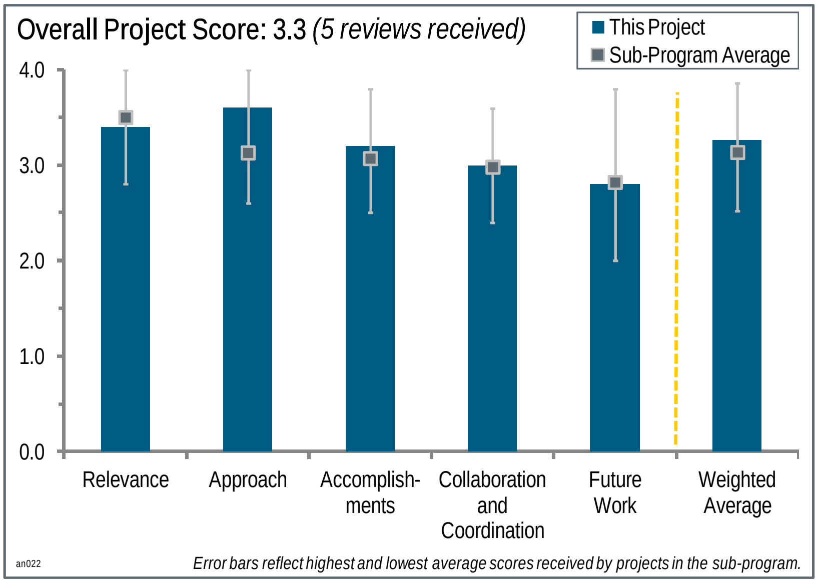
- If the researchers amend the approach slightly to address the perceived weaknesses, this project would be a home run.
- Rather than being a stand-alone analysis, it would be better if this effort was integrated into other modeling and analysis efforts such as the Scenario Evaluation, Regionalization, and Analysis (SERA) model, which already has more established assumptions and structures.
- This reviewer has no recommendations for this project.

Project # AN-022: Infrastructure Costs Associated with Central Hydrogen Production from Biomass and Coal

Darlene Steward; National Renewable Energy Laboratory

Brief Summary of Project:

This study seeks to elucidate the location-dependent variability of infrastructure costs for hydrogen (H_2) production and delivery, and the trade-offs inherent in plant location choices. By combining geographic information system (GIS) data with established cost models, the project maps resources, existing infrastructure, and centers of demand to construct cost correlations based on distance, terrain, and land use to determine the cost efficiency for hypothetical plants at any locale.



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

This project was rated **3.4** for its relevance to DOE objectives.

- This project is useful to the DOE Hydrogen and Fuel Cells Program (the Program) because it looks at details such as the location dependence of infrastructure.
- This project is extremely relevant because coal is an abundant resource and biomass is nearly carbon neutral.
- This project fully supports the goals of the Program and will enable H_2 production from biomass or coal. This project addresses barriers B, D, and E.
- This project's studies are very relevant and seem obvious on the surface, but the studies clearly must be done at some time and this seems to be an appropriate time. The choice of the two technologies is somewhat limiting, and a comparison with other methods of energy delivery is missing. The researchers should find out how these costs stack up to electricity distribution for charging or the present gasoline distribution system.
- This project is assessing the infrastructure costs of central H_2 production (and delivery) from biomass or coal with carbon sequestration. Such an infrastructure would be implemented only after the fuel cell electric vehicle markets are mature and the long-term demand for H_2 is established. The uncertainties associated with the requisite time period (considerably into the future) would lead to low confidence in the results.

Question 2: Approach to performing the work

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

- This project's approach is as good as possible, considering the size of the project.
- The use of geographic data with cost analysis is powerful and important, specifically the mapping of availability of resources and correlating this with pipeline/railroad cost limit areas where practicality can be achieved.
- This is very nice work that demonstrates the advantages of these kinds of studies. As noted above, comparison with other modes of energy distribution would have been a major plus to these studies (unless of course the results show that H_2 is hopelessly expensive).
- For the H_2 from biomass study, the project is using GIS data and existing cost models to determine the infrastructure costs (production and delivery) across the United States. For the H_2 from coal study, coal delivery, H_2 pipeline, and CO_2 pipeline (to sequestration site) are included.

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

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

- Progress on the two modes is satisfactory and valuable results are clearly obtained. The methodology may be a little simple, but it does lead to conclusions that are immediately useful to DOE.
- Some useful insights were gained from this detailed analysis because it considers various constraints in developing infrastructure that have not been considered in analyses before.
- This project gives a better of understanding of CO_2 reservoirs. However, of the three types of CO_2 reservoirs identified—saline, unmineable coal, and oil and gas reservoirs—only saline reservoirs will allow for net negative CO_2 sequestration. Cost advantages should be achieved with unmineable coal and natural gas fields where the CO_2 will displace natural gas and depleted oil fields of sufficient depth where enhanced oil recovery will occur. However, in all of the latter cases, this is not necessarily a net negative CO_2 repository. This project identified distinct geographic regions where coal or biomass would be feasible.
- Biomass delivery for 100-mile maximum transport distance would add \$0.11–\$0.26/kg of H_2. H_2 pipeline costs add \$0.21–\$2.70/kg of H_2, with terrain and protected lands affecting the costs. For coal-to-H_2 plants, the project has developed maps of carbon sequestration potential and new rail costs. Total infrastructure costs for biomass-to-H_2 and for coal-to-H_2 were assessed for several U.S. metropolitan areas.

Question 4: Collaborations and coordination with other institutions

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

- It would be useful to also collaborate with other modeling efforts.
- The project collaborators include researchers from several other research teams.
- This project has excellent collaboration between industry partners and other national laboratories. The project integrates well with the Hydrogen Analysis sub-program. This project probably needs more collaboration with organizations outside of the National Renewable Energy Laboratory (NREL). The database is limited.
- The combination of NREL, DOE, and the Pacific Northwest National Laboratory is not a very strong collaboration.

Question 5: Proposed future work

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

- The future work proposed will add value to the study.
- This project needs a comparison with present energy distribution systems.
- The proposed future work is primarily to examine sensitivities to various parameters and assumptions. Perhaps analyses to such detail are not very meaningful.
- The planned work looks good, but it may not be possible considering funding levels. Also, a pipeline for CO_2 should be included.
- If rail delivery of biomass is to be considered, the cost of drying it must also be included, as there may be significant disadvantages to transporting partially wet biomass. Possible cost advantages to certain CO_2 reservoirs should be considered, especially as the oil and gas industry is changing so fast, not just in terms of enhanced oil field recovery, but also the use of CO_2 for clathrate methane production.

Project strengths:

- A great deal of work has been done with very limited resources. The analyses seem to be very comprehensive.
- This project has extremely good integration of geographic data with cost analysis.
- This project uses simple methodologies with well established methods to get results quickly. Given the funding levels, this is a wise strategy.
- This project's strength is its NREL resources.
- Constraints that were not considered in previous analyses give new insights.

Project weaknesses:

- This project needs a much better understanding of the fossil fuel industry in general. It is totally based on cost, which is fair, but at some point CO_2 emission increases/decreases will have to be evaluated.
- This project's weaknesses arise from low funding levels. Better collaboration is needed and comparisons with present inefficient gasoline delivery systems would be most useful.
- These analyses really apply to situations rather far into the future. This time frame adds to the uncertainty in the assumptions and gives results that offer low levels of confidence.

Recommendations for additions/deletions to project scope:

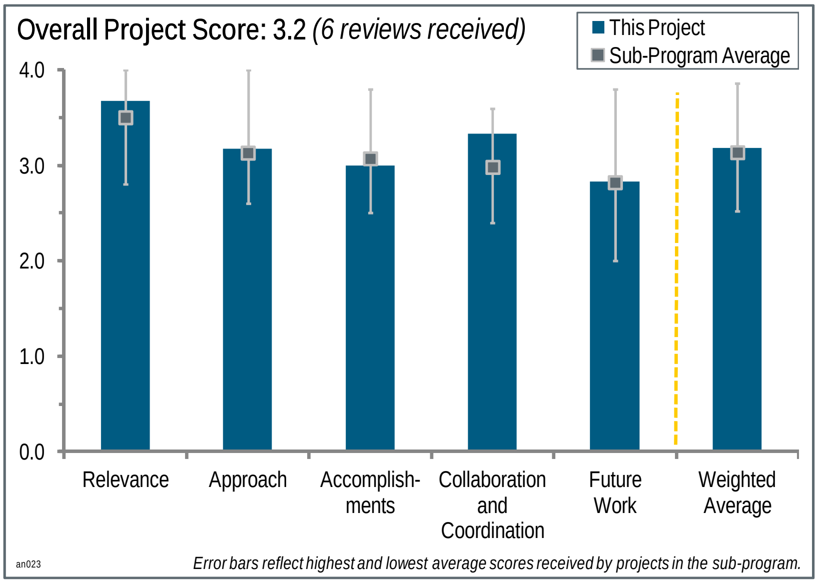
- This project should add comparisons with present systems.
- This project should include CO_2 pipelines for coal.
- This project should integrate findings with the Scenario Evaluation, Regionalization, and Analysis (SERA) model and the Hydrogen Demand and Resource Analysis Tool (HyDRA). It could also look into other types of biomass resources and factor in coal plants that potentially might go offline in the future due to regulations to see what other limitations might occur.
- This reviewer had no recommendations.

Project # AN-023: H2-Vehicles Market Prospect, Cost, and Social Benefit

David Greene; Oak Ridge National Laboratory

Brief Summary of Project:

The overall objective of this project is to understand market prospects, costs, and benefits of light-duty vehicle (LDV) hydrogen (H_2) fuel cells, and their sensitivity to fuel cell and battery improvement and other factors. Specific goals of this project are to: (1) conduct a market analysis by integrating output of various U.S. Department of Energy (DOE)-sponsored and other federal projects, (2) project market penetrations of H_2 vehicles under varied scenario assumptions, (3) estimate social benefits and public costs under different penetration scenarios, and (4) compare the cost-effectiveness among scenarios.



Question 1: Relevance to overall DOE objectives

This project was rated **3.7** for its relevance to DOE objectives.

- This project is very relevant.
- This project will be of great importance now that the focus is shifting back to fuel cell electric vehicles (FCEVs) and H_2 fueling infrastructure.
- Understanding the relevance is of value for all stakeholders. It provides additional perspective for the original equipment manufacturers (OEMs).
- The project helps to identify the most probable pathway toward the utilization of H_2 in vehicles.
- This modeling work is crucial to projecting potential FCEV market penetration and to identify options to increase that penetration.
- This is important work to help define what the customers will prefer and helps guide where DOE should put its scarce resources. It is not quite clear how the customer preferences are measured or defined and the validity has not been adequately demonstrated, judging by this presentation.

Question 2: Approach to performing the work

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

- This project uses a great model.
- This project makes many questionable assumptions, especially “cheap” batteries.
- The approach is OK, although there is confusion as to how the consumer preferences are measured. The presentation did not provide a description of the validation of the models.
- The approach is appropriate because it is taking data and input from a number of sources. How the results are factored into the conclusions when the technology is changing so quickly and the fact that there are so many uncertainties will ultimately determine the feasibility of the approach taken in this assessment.
- The model is used to analyze several factors likely to influence the competitiveness of FCEVs and the price sensitivity analyzed. The consumer preference part is always a little subjective. Perhaps only the hard parts of the study, such as fuel availability and range of vehicle, should be considered.
- Speaking from personal experience in the auto industry, automakers assign high importance to compliance with the corporate average fuel economy (CAFE) requirements, federal mobile source emissions regulations, and the

California Clean Car Program and zero-emissions vehicle mandate because they must comply with these regulations or face onerous penalties. Any study involving LDVs has to recognize the impact of compliance to the U.S. regulatory standards. Also important to any study of LDVs is recognizing the various vehicle market segments, such as B-class, C-class, and C/D segments. The buyer profiles of each of these segments are substantially different, and they are limiting factors in terms of vehicle choice. There are technology limitations that need to be recognized. As an example, it will be difficult for the automakers to sell battery electric vehicles (BEVs) in segments above B-class because the size and weight of the battery compromises the overall vehicle package. In terms of addressing the cost of ownership, while the purchase price premium for FCEVs is a recognized barrier, the study should also recognize the uncertainty of residual value as a cost premium. Other nuances are lease financing (probably about 25% of new car retail sales) and the commercial fleet segment (about 2–3 million vehicles annually).

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

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

- The study is off to a good start and this reviewer is impressed with the team that will be doing the project.
- The work pulled together a wealth of information from various sources and formed a framework from which to assess the opportunities. The scenarios covered were appropriate, yet it was impossible to assess the significance of the key pathways without knowing the key assumptions and the impact thereon.
- The project did a nice study of the effect of oil prices and concluded that FCEVs will be successful if the technological goals are achieved. The study successfully showed the beneficial effect of subsidies and compared fuel-cell-only vehicles to other technologies.
- The progress to date covers less than 50% of the project, so one will expect to see more useful results as the momentum increases in the second half of the project. Validation is necessary.
- This project's accomplishments are in question due to questionable assumptions.

Question 4: Collaborations and coordination with other institutions

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

- This project has good collaboration between national laboratories, a university, and OEMs.
- Industry, national laboratories, and universities make for outstanding collaboration.
- The collaborative partners are appropriate, yet the only U.S. OEM fully engaged was not a collaborative partner (General Motors).
- The major collaborations appear to be with other national laboratories. The information that the laboratories have is hopefully sufficiently accurate and broad-based. The details about collaborations with the car companies and the fuel suppliers are not adequate.
- The team of people who will be doing this study is very well respected. However, this team should seek out the input of the automakers that will be challenged with selling these vehicles.

Question 5: Proposed future work

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

- This project does not state much about its future work.
- The future work appears to be appropriate given the time remaining in the project.
- The cost estimates for electricity infrastructure subsidies should be added to compare with the H_2 infrastructure subsidy estimates.
- Completion of this project will be very important for directing future research and policy toward H_2 vehicles. The consumer preference part of this work must be critically evaluated before implementation, so as to not erroneously push the results toward a metric that is purely subjective.

Project strengths:

- The people assigned to the task are a strength of this project.
- This project has an outstanding principal investigator (PI) and good resources available.
- This project's strengths are the experience of the PI and the team's modeling skills.
- The team clearly was proficient as evidenced from the available data and models utilized in the assessment.
- This project completed a comprehensive sensitivity analysis toward implementation of H_2 for vehicular applications.

Project weaknesses:

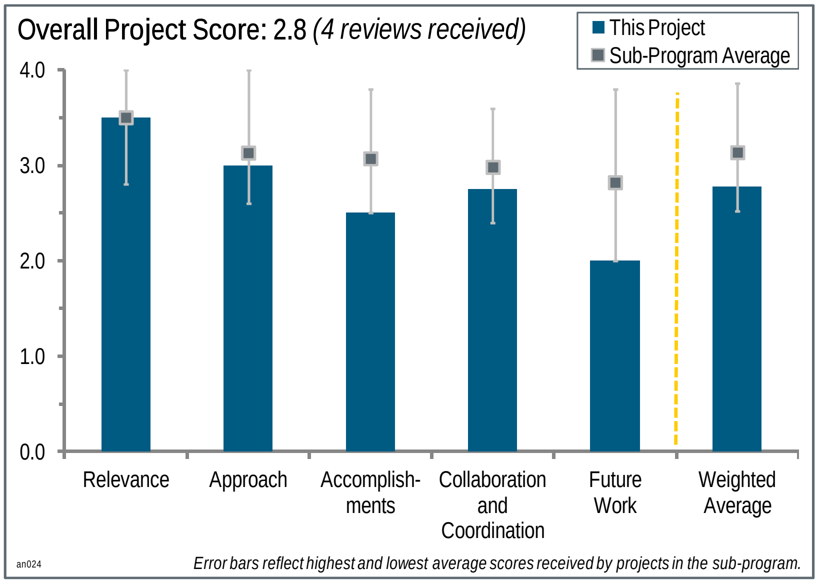
- More emphasis should be placed on interactions with the auto industry.
- Trying to predict customer preferences is a losing battle.
- The researchers should use greater care in the consumer preference part of this project.
- This project does not have any specific weaknesses yet as it is only a one-year program. The field is immature and continuously evolving at this point in time. The output of this program should be able to adjust to such factors as they emerge.

Recommendations for additions/deletions to project scope:

- The researchers should conduct parametric studies when investigating customer preference impacts.
- The researchers should add estimates of the electricity infrastructure subsidies needed for BEVs and PHEVs.
- The conclusions at the end of this program should, if they are appropriate, become a baseline from which to gauge the key issues and progress of vehicle penetration over the next few decades.
- It may be worthwhile to address the commercial fleet market separately. The automakers can approach this market differently and like to do so in marketing alternate fuel vehicles.

Project # AN-024: Issues Affecting Hydrogen Pathway Succession

Mark Ruth; National Renewable Energy Laboratory



Brief Summary of Project:
The objective of this project is to improve the understanding of options and trade-offs in the evolution of hydrogen (H_2) production and delivery infrastructure for transportation. Existing data is examined using various analysis models and tools, including the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model (GREET), the HyPro model, and the Macro-System Model (MSM). The anticipated result will be an improved understanding of how policy changes, market issues, and technology status may affect technology selection and emissions.

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

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

- This is a very important study.
- It is important to model H_2 pathways because this is critical to the commercialization of fuel cell products.
- This project analyzes the likely succession of technologies that will occur during the ramp-up of use of H_2 as a fuel and thus overcome multiple barriers, especially future market behavior.
- This project is very relevant to DOE's goals. The development of scenarios of how H_2 will be produced and the implementation of the technology is critical. However, the relevance is somewhat reduced because of the uncertainties of the technologies available and possible competition from other fuel sources, such as breakthroughs in battery technology, etc.

Question 2: Approach to performing the work

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

- This project has too many major assumptions and much of the work was done last year.
- The use of the MSM enables the use of many of the models developed for H_2 production, delivery, and utilization. Parameters in models can be varied in sensitivity runs to allow for future scenarios.
- A lot of the projections involve capital costs, and the source of the capital costs is not clear. No mention is made of collaboration with equipment manufacturers or construction firms that would have these numbers. Further, the carbon capture and sequestration (CCS) technology is not proven at the moment, so the projections may not be realistic. Similarly, the potential impact of breakthroughs in battery technology, liquid fuels, etc. is not included.

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

This project was rated **2.5** for its accomplishments and progress.

- The work from this project has been generally very good. Especially useful is the incorporation of GREET emissions data.

- Progress is good for the goals that have been focused upon. The next phase should look at the effects of "left field" technology developments that are almost certain to occur in the time frame dealt with.
- The researchers made an excellent choice of comparison technologies, showing that steam methane reforming is still the most feasible near-term method for producing H_2. CCS is still not a proven technology and so the analysis of this is still a little hard to believe.

Question 4: Collaborations and coordination with other institutions

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

- It does not seem that there was much collaboration; industry input is needed.
- This project has good collaboration with national laboratories and industry partners. The project would be strengthened with more industry and government input.
- This project's collaborations are with the same group of national laboratories and contractors. No mention is made of collaborations with equipment suppliers or construction firms, and the review by the technical team does not constitute collaboration.

Question 5: Proposed future work

This project was rated **2.0** for its proposed future work.

- No specific comments are offered on future work because the project is finished.
- The researchers should look at other pathways or better define or re-define the studied pathways.
- The project is complete; the proposed improvements are OK, but they hardly give a good reason to fund more of this.
- The use of learning curves would be highly valuable and, together with unforeseen randomness, could make the model more realistic.

Project strengths:

- This project has focused and robust predictions.
- This project's strengths' are its use of multiple models and contrasting H_2 production methods.

Project weaknesses:

- This project has ended.
- There is clearly not enough collaboration with industry players.
- There are too many major assumptions required.

Recommendations for additions/deletions to project scope:

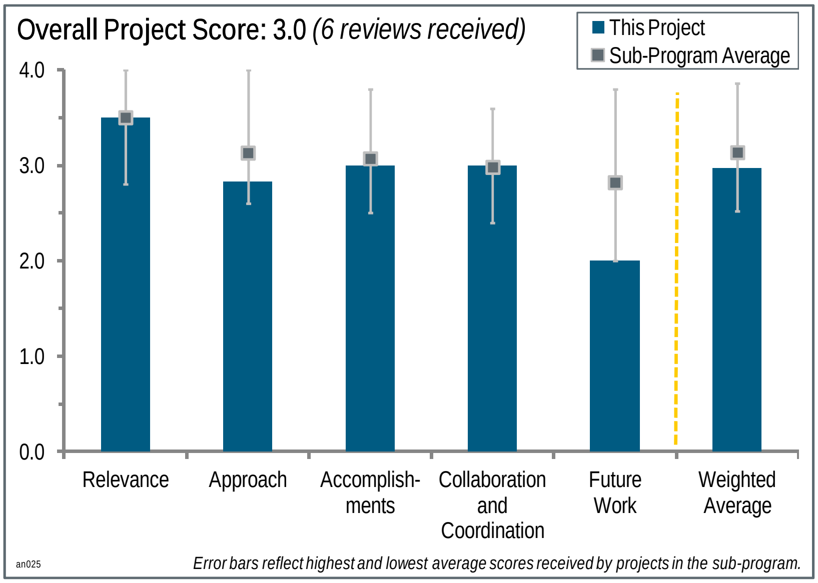
- The researchers should continue with the proposed new project.
- Future projects should bring in industry players as full partners.

Project # AN-025: Impact of Program Targets on Vehicle Penetration and Benefits

Zhenhong Lin; Oak Ridge National Laboratory

Brief Summary of Project:

The overall objective of the project is to estimate the impact of the U.S. Department of Energy (DOE) program goals on the market prospect, costs, and social benefits of hydrogen (H_2)-powered light-duty vehicles (LDVs). Specific goals of this project are to: (1) conduct market analysis by integrating the outputs of various DOE-sponsored and other federal projects; (2) project market penetrations of H_2 vehicles under varied assumptions of program goals for fuel cells, H_2 storage, batteries, motors, and H_2 supply; (3) estimate social benefits and public costs under different program goal scenarios; and (4) compare cost-effectiveness among scenarios.



Question 1: Relevance to overall DOE objectives

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

- This project is very relevant to the DOE activities.
- This study could be a major contributor now that more focus is shifting toward fuel cell electric LDVs and H_2 infrastructure.
- The Market Acceptance of Advanced Automotive Technologies (MA3T) model development/utilization could assist DOE in setting goals to achieve emission and fuel consumption reductions. Exogenous model development is critical to this objective.
- This project directly addresses the consequences of meeting the DOE Hydrogen and Fuel Cells Program goals, and it will be a very useful tool as these need future modification.
- This project has good relevance because it examines the consequences of missing technology implementation goals. This allows DOE to be aware of where the important bottlenecks are and the necessity to provide adequate resources to the critical activities.

Question 2: Approach to performing the work

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

- This project explores various scenarios for fuel cell electric vehicles (FCEVs), battery electric vehicles (BEVs), and hybrid vehicles using multiple models and projections.
- The approach seems fair, but perhaps the source of data is too limited. There does appear to be adequate accounting for BEV development.
- The approach appears sound but the delivery is confusing. Unless the reader is familiar with the details of the analysis, the presentation curves have no relevance. More explanation of the assumptions made and maximum error bands may make the presentation more user friendly. In addition, listing the assumptions that are truly critical path (i.e., have more than a 25% effect on the total prediction) would be helpful for DOE.
- This project has a low budget to model a very complex situation with a huge number of variables and alternative scenarios. It is a laudable goal, but many would consider this to be pure speculation where the choice of the assumptions determines the outcome.

- Speaking from personal experience in the auto industry, automakers assign high importance to compliance with the corporate average fuel economy (CAFE) requirements, federal mobile source emissions regulations, and the California Clean Car Program and zero-emissions vehicle mandate because they must comply with these regulations or face onerous penalties. Any study involving LDVs has to recognize the impact of compliance to the U.S. regulatory standards. Also important to any study of LDVs is recognizing the various vehicle market segments, such as B-class, C-class, and C/D segments. The buyer profiles of each of these segments are substantially different, and are limiting factors in terms of vehicle choice. There are technology limitations that need to be recognized. As an example, it will be difficult for the automakers to sell BEVs in segments above B-class because the size and weight of the battery compromises the overall vehicle package. In terms of addressing the cost of ownership, while the purchase price premium for FCEVs is a recognized barrier, the study should also recognize the uncertainty of residual value as a cost premium. Other nuances are lease financing (probably about 25% of new car retail sales) and the commercial fleet segment (about 2–3 million vehicles annually).

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

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

- Progress is good and as expected at this stage of a one-year project.
- The progress on the models is noted and appreciated. The fidelity of the results (effect of tolerances) is a start. In the future, a technology that shows where the assumptions and key parameters are should be selected so that the researchers can explain how they arrived at their predictions. It can then be assumed that a similar methodology was used for the other technologies. This would give the reader more confidence in the usefulness of the analysis.
- The team performing the analysis is doing a great job mathematically and analytically, but there is no way to verify this model, so its usefulness is uncertain. The assumptions dominate everything else in the model. The assumption that American Recovery and Reinvestment Act or similar funding will continue is very unlikely, and yet it dominates the model. The most capable leaders cannot predict what will happen next year and certainly not 5, 10, or 40 years from now. The model does show that DOE’s goal accomplishment will influence the outcome, but the other factors and assumptions will dominate.
- The sensitivity analysis of one or more goals being met on time or delayed by 10 years has important implications for the synergy between goals and will allow for better planning of program goals. The results show that meeting all goals would reduce petroleum use by 80% and greenhouse gas emissions by 50%, as well as produce cost and market penetration benefits.
- This project is off to a good start, but it is strongly encouraged that the study team recognize the need for automaker compliance with emissions, CAFE, and other regulatory standards in terms of the modeling. Quite simply, the automakers are not free to sell any vehicle they want. Their fleets must comply with standards, or else they will face onerous penalties. The likely societal impact in the absence of FCEVs could be a sharply reduced number of vehicle choices for consumers. As an example, Ford terminated the Crown Victoria in part because they could no longer offset the CAFE penalty. As a result, people who wanted to purchase this class of vehicle no longer had that option.

Question 4: Collaborations and coordination with other institutions

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

- The collaboration efforts appear to be appropriate for this task.
- The team is encouraged to seek out the input of the automotive industry in terms of modeling.
- A wider group of collaborators would be preferable, but it is hard to see how much more can be done in a one-year project.
- This project’s collaboration with knowledgeable technical parties is extensive. There is not enough input from social scientists and psychologists.
- This project features good collaborations with national laboratories and universities. Industrial data are available, but this would be a better project if more industrial input was sought.

Question 5: Proposed future work

This project was rated **2.0** for its proposed future work.

- This project makes no mention of future work.
- Future work for this project was not addressed in the presentation other than to say the researchers would complete the last 50% of the work.
- This project will continue and is clearly of value, but future work is not clearly delineated.
- There does not appear to be any proposed future work; this is unfortunate. Suggestions, even if not funded, would support the justifications for the work. The researchers need to say what they want to do with the tool.
- The project's future work is limited and would benefit from making stronger efforts to collaborate with more stakeholders, particularly battery and fuel cell manufacturers, as well as the fuel providers.

Project strengths:

- This project has a good model.
- The project gives recognition to the fact that studies such as this need to be done.
- Looking at the impact of the actual program goals is a strength of this project.
- This project is focused on important "what if" scenarios that DOE must know about.
- The strengths are the knowledge and dedication of the project members.
- This project's strength is a competent and knowledgeable team that is building a usable mathematical model, which yields quantitative results for assumed input.

Project weaknesses:

- The model results depend on assumptions for modeling that are ungrounded.
- More industrial feedback is needed for this project.
- This project is too short-term and needs wider participation by stakeholders.
- The weaknesses appear to be the lack of a clear presentation on the assumptions associated with the model and the use of this program.
- The researchers need to recognize the unique body of regulatory compliance that the automakers must address in their business and product planning.

Recommendations for additions/deletions to project scope:

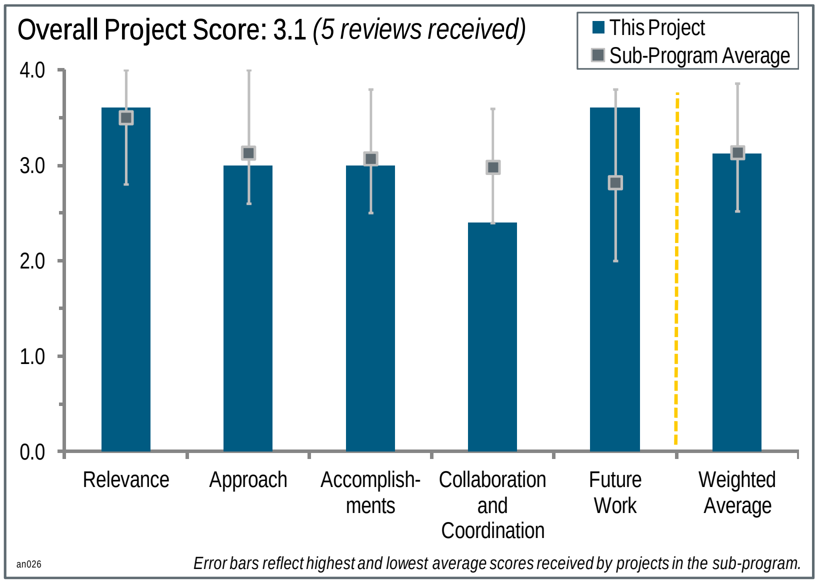
- The researchers should complete the model.

Project # AN-026: Resource Analysis for Hydrogen Production

Marc Melaina; National Renewable Energy Laboratory

Brief Summary of Project:

The objectives of this project are to: (1) understand the hydrogen (H_2) production requirements for a future demand scenario, (2) estimate the low-carbon energy resources required to meet the future scenario demand, (3) compare resource requirements to current consumption and projected future consumption, (4) determine resource availability geographically and on a per kg of H_2 basis, and (5) estimate fuel cell electric vehicle (FCEV) miles traveled per unit of resource.



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

This project was rated **3.6** for its relevance to DOE objectives.

- Anything that helps understand H_2 production is very relevant.
- The analysis supports basic calculations and estimates the DOE Hydrogen and Fuel Cells Program (the Program) needs in gaining a general understanding of future resource needs and related impacts.
- This project is critical to DOE's objectives because it will help to determine where the energy for 100 million FCEVs will come from.
- This project attempts to estimate the energy resources required to support the production of H_2 for a projected 100 million FCEVs in 2040. The project attempts to determine if sufficient energy resources will be available, and if not, how much more will be required. The project looks at three renewable energy sources (biomass, wind, and solar) and three traditional sources (natural gas, coal with carbon capture and sequestration, and nuclear). The project estimates the hypothetical need to supply 50% (10 million tons of H_2 annually) of the assumed 2040 demand. Such information is required to determine the viability of an FCEV transportation system. If the fuel is not available, significant resources will be required to develop the production infrastructure, which would hinder acceptance of H_2 FCEVs as a viable option.
- Although it may be a little premature to be looking at H_2 supply scenarios 30 years out, the study's design parameters were clearly spelled out: in the 2040 time frame, assume 20 million tons of H_2 per year will be needed to satisfy the demand from 100 million FCEVs. Given this set of conditions, the study will analyze different low-carbon sources needed to individually meet half of this demand (i.e., 10 million tons of H_2 per year from natural gas, coal, nuclear, biomass, wind, and solar). This would then be compared to the current consumption of that resource to put the fuel resource situation in perspective.

Question 2: Approach to performing the work

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

- Considering the funding limitations of this project, the approach is excellent.
- The approach of using simple energy balance calculations for plant-gate H_2 production is appropriate for the scope of this project. It is hoped that this analysis will feed into a complete well-to-wheels analysis as well.
- Based on assumed energy conversion efficiencies (e.g., 46 kWh per 1 gge of H_2 [roughly 1 kg of H_2]), the model uses current and predicted future capacities to model the number of FCEVs that could be supported by the

different energy options. The approach was very limited in detail (in part due to the limited funding: $15,000 in fiscal year [FY] 2011 and $25,000 in FY 2012) and was somewhat confusing in the presentations.
- Simple energy balance and conversion (reforming, gasification, and electrolysis) efficiencies (with most values taken from Hydrogen Analysis [H2A] case studies) are used to determine the volume of the resource required to meet the 10 million tons of H_2 production value. Analysis covers production up to the plant gate only and does not include delivery or storage. This level of analysis would provide a good first-cut at resource needs.
- The approach is OK for getting a rough idea of how far a resource would need to be stretched, and if it would be enough to meet future demands. This is useful for trying to envision if there are any major limitations. However, a more useful analysis would be looking at cases where each resource has competing demands from other uses.

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

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

- This project has made good progress given the level of support.
- This project's accomplishments are understandably limited.
- These updated estimates are valuable and these results are a good starting point, but the analysis needs to be taken a step further to employ a more granular approach.
- The somewhat sobering analysis—that in order to utilize renewable H_2, renewable capacity will have to be ramped up dramatically—is critical. Using geographic data is very powerful and makes the model results much more useful. It is a little hard to see how H_2 competes with other energy carriers in these results.
- The results were presented in an easy-to-understand and useful format. One such format was to determine the factor increase in the use of a given resource to fulfill the target H_2 demand compared to the current use of that resource. Thus, for non-renewable resources, consumption of natural gas, coal, and nuclear would need to increase by factors of 1.05, 1.10, and 1.44, respectively. The corresponding factors for biomass, wind, and solar would be 1.33, 2.53, and 6.75, respectively. For the renewable resources (biomass, wind, and photovoltaic solar), the geographic distribution of the resource was shown on county-level maps for the United States. This representation of the resource serves to visually show where the resource is versus where H_2 is needed (i.e., raises the question of how best to transmit energy over long distances, as electricity or as H_2 for wind and solar). The results are based on an updated and consistent calculation of the technical potential of the individual resource.

Question 4: Collaborations and coordination with other institutions

This project was rated **2.4** for its collaboration and coordination.

- This project has no external collaborators. Even though this is a very small effort, it would be good to see additional national laboratory and industry input.
- In this project, there is indirect collaboration with a broad group of researchers and stakeholders through making these analyses consistent with H2A case studies, and having the results reviewed by knowledgeable researchers.
- The collaboration in this project would be better if the report had been accepted for publication.
- It would be useful for this project to collaborate with other model developers, so that values and findings from this analysis could feed into more detailed modeling and analyses conducted through other efforts (and vice versa).

Question 5: Proposed future work

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

- The proposed future work to expand beyond light duty vehicles (LDVs) and look at regional variations and constraints is very exciting.
- It is good to see that this initial analysis will be relied upon more and investigated on a more detailed basis for future scenario analyses.
- In addition to publishing the results of the analyses already conducted, future work will address regional variations, constrained scenarios, and inclusion of non-LDV transportation energy demands.

- This project uses realistic and consistent units. With the level of support and effort available, this project should not be listed as a separate, stand-alone project. It should have been a task folded into one of the other H_2 analysis projects. The researchers should either increase the support to enable a strong effort, or fold it into another project.

Project strengths:

- The project addresses resource availability, which is a key question.
- This project has a simple, straightforward, and analytical approach.
- This project's strengths are its energy balance approach and the current regional data.
- A considerable amount of work has been done with very limited resources.
- This project gives an overall framework and scope for thinking about resource issues as they relate to H_2 production.

Project weaknesses:

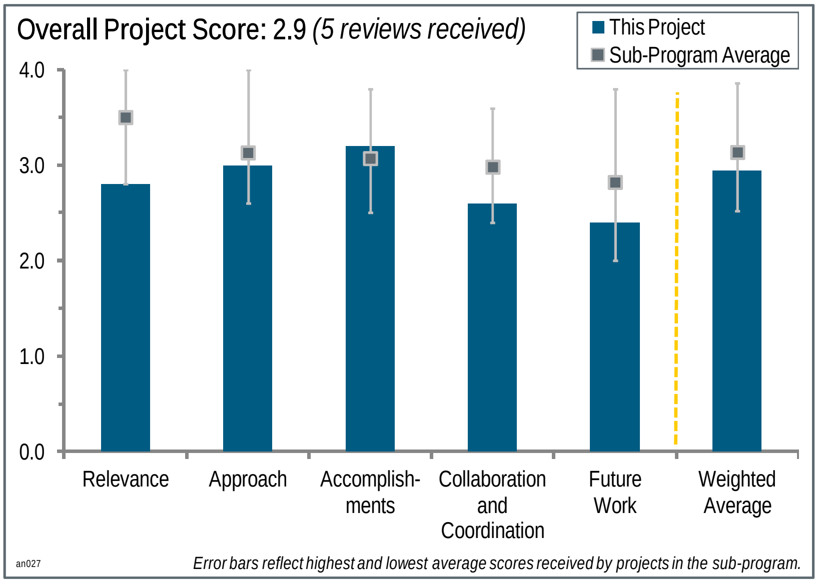
- This project needs more input and resources.
- There is not much substance in the results to date.
- This project makes a rough estimate on a national scale. Taking the research a step further by looking at regional variations, other constraints, the variety of uses for H_2, etc. will provide more value.
- The current (2012) and projected (2040) consumption data is presented in different units (trillion cubic feet for natural gas, ton of coal, GWe for nuclear, ton/year for biomass, and kWh/year for wind and solar). Future comparisons should use consistent comparisons, at least for those that directly produce electricity (nuclear, wind, and solar). The presentation quotes the increases in projected consumption that will be needed as being from 1.05 to 6.75 (slides 1 and 12), but then lists the increase as a percent increase on slide 14. The researchers need to be clear whether it is a 6.75% increase or a factor of 6.75. The comparison for wind and solar is based on installed capacity, not actual production, which is considerably lower. The authors should base their analysis on actual production.
- This reviewer sees no weaknesses.

Recommendations for additions/deletions to project scope:

- The researchers should concentrate more on comprehensive projects instead of numerous small projects.
- The researchers should continue this effort by going into more detail and using those details to inform other Program models and analyses.
- The principal investigators should attempt to use consistent units to estimate current and projected consumption especially for resources (nuclear, wind, and solar) that all produce electricity (kWh). For nuclear, it is easy to project 102 GWe to kWh/year (roughly 700 billion kWh/year, assuming 80% availability).
- This reviewer has no recommendations.

Project # AN-027: Cost, Energy Use, and Emissions of Combined Hydrogen, Heat, and Power Tri-Generation Systems

Mark Ruth; National Renewable Energy Laboratory



Brief Summary of Project:

The objectives of this project are to: (1) quantify levelized cost and greenhouse gas (GHG) emissions from tri-generation (combined heat, hydrogen, and power [CHHP]) systems for various fuel cell types, building types, and building locations, and (2) develop a methodology for Macro-System Model (MSM) users to create optimized CHHP scenarios easily.

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

This project was rated **2.8** for its relevance to DOE objectives.

- CHHP is needed to round out complete models of alternative energy generation approaches and fuels.
- This project evaluates the possibility of using tri-generation to produce heat, electricity, and hydrogen (H_2). This is a potentially exciting possibility, but is perhaps not as critical to DOE as other approaches.
- This project models the overall system cost and GHG emissions of a commercial building tri-generation fuel cell system capable of providing H_2, heat, and power from natural gas. This includes regional costs, upstream energy usage, and emissions in the fuel cell model.
- The relevance of this activity is not clear. Optimizing a product for an application that would not be cost effective to the owner is confusing. It does not make sense to operate an expensive product in a manner that would not meet the owner’s perceived needs. Evaluating the use of a product in regions where it would clearly be at a severe disadvantage does not seem useful.
- This project is an attempt to assess the cost of H_2 and GHG emissions from CHHP systems using high-temperature molten carbonate or phosphoric acid fuel cells (MCFC or PAFC). This appears to be a forced fit of using fuel cells to produce H_2 as an extra credit to reduce overall costs. As the results show, the overall costs are not likely to be reduced. With the current low prices of natural gas (as a source of H_2 by conventional steam methane reforming [SMR]/pressure swing absorption), the added complexity of CHHP systems would argue against such systems becoming commercially attractive.

Question 2: Approach to performing the work

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

- This project is a very good approach to using the MSM suite together with the fuel cell power model.
- This project is a good application of existing models in an MSM that does not require the development of individual models.
- Model construction approach using the MSM framework is good, but the choice of the sample fuel cell type and size/application is unrealistic. Many of the assumptions made are difficult to verify.
- The project approach was to add a fuel cell power model (for PAFC and MCFC) for CHHP to the MSM. An analyst could then use the MSM to assess regional (Seattle, Los Angeles, Chicago, and Baltimore) costs, upstream energy use, and emissions.
- The approach appears to be valid. However, the assumptions on how a product would be optimized invalidated the results. The customer will normally endeavor to maximize the energy savings for CHP devices in order to

reduce the overall operating costs. Exceptions are usually limited to special applications, such as isolation from the electrical grid, premium power (computer systems), electrical grid stability/reliability, high demand for low-grade or moderate-grade thermal energy (hot water and forced hot air), etc. Regional uses of CHP products (barring the exceptions) are usually predicted by the spark gap. The spark gap is the cost of electricity from the grid versus the cost of heating and electrical generation from alternative fuels (usually natural gas). Currently, this generally limits the market to the Boston to Washington corridor and California. With the advent of shale gas and coal syngas, this may grow to include the Midwest. Areas where the predominant energy source is hydro/coal are usually non-completive.

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

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

- The project showed that capital was the number one cost driver for all fuel cells. The differences in load following ability and heat generation became apparent from the model, allowing systems choices to also be determined by application.
- The progress to date is questionable due to the assumptions. However, if the assumptions were reevaluated and revised, and the models rerun, the results would be interesting if not outright useful.
- The models were completed and exercised for two fuel cell types with reasonable results. The sizing of systems for lowest H_2 cost was not optimal. The difficulty is the balance of H_2 generation, electricity use, and heat generation. GHG reductions are minimal and not large enough to be a market driver. H_2 generation costs are lower at low rates compared to SMR.
- Progress is reported to be at 80%. The results were presented for two different size buildings/power requirements (320 kW and 1,440 kW) and two classes of fuel cells (PAFC and MCFC). The results presented focused on four different regional locations (Seattle, Los Angeles, Chicago, and Baltimore) that contain a variety of electricity costs, climates, and heat load scenarios. Comparisons were made that indicate MCFC systems are effective for load following, while PAFC systems are optimum for H_2 and power generation. Capital is the primary cost driver for these units, and variable costs (rent and labor) are secondary for the smaller MCFC units.
- The researchers have exercised the updated MSM in a variety of analyses for the two fuel cell types and several different building applications. For all of the systems, the capital costs were the major cost drivers. Minimizing the cost of H_2 resulted in significantly higher overall costs for heat and electricity for all of the scenarios analyzed. These overall costs ranged from 20% to 231% higher than the base case of using grid electricity for power and natural gas for heat and H_2. The corresponding reductions in GHG emissions range from a high of 40% to a low of -17% (i.e., the GHG emissions for that case were actually higher with the CHHP than the base case).

Question 4: Collaborations and coordination with other institutions

This project was rated **2.6** for its collaboration and coordination.

- The collaboration appears to be inadequate. It appears to have been limited to data on a product rather than expected or demonstrated customer usage.
- Collaborators included industry (Fuel Cell Energy), national laboratories (the National Renewable Energy Laboratory and Argonne National Laboratory), and the U.S. DRIVE Partnership’s Fuel Pathway Integration Technical Team.
- This project has good DOE interactions and collaborated with one industry player. The researchers should have also collaborated with UTC Power.
- The project coordinates with other national laboratories, but it desperately needs input from stack manufacturers of the various technologies to see if what is proposed is feasible now or in a short time frame.

Question 5: Proposed future work

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

- The proposed future work would justify additional funding, especially the load leveling applications.

- The project's report should be finalized and the MSM should be updated.
- The only specific future work presented for this project was finalizing the project report. In general, the researchers expect to continue to further develop and exercise the MSM for a variety of applications.
- Additional funding is not planned for fiscal year 2013. The plans are to wrap up the project, even though additional options were proposed.
- The lack of proposed future work is disappointing. Correcting the assumptions with a focus on applications where CHHP is cost effective (hospitals, nursing homes, college dormitories, sports facilities, etc.) would be interesting. The researchers should focus on applications that have the need for thermal energy and have a favorable spark gap.

Project strengths:

- The strengths are the knowledge and dedication of the project members.
- The models appear sound, but verification is left undone.
- Focusing on tri-generation was certainly an interesting scenario that needed to be looked at.
- Integrating existing sub-models to optimize the use of tri-generation concepts is valuable and is needed to guide the development of novel concepts.
- The researchers completed quite a bit of work with limited resources. The results are illustrative of the challenges in implementing CHHP systems in a manner that would be competitive with conventional technologies.

Project weaknesses:

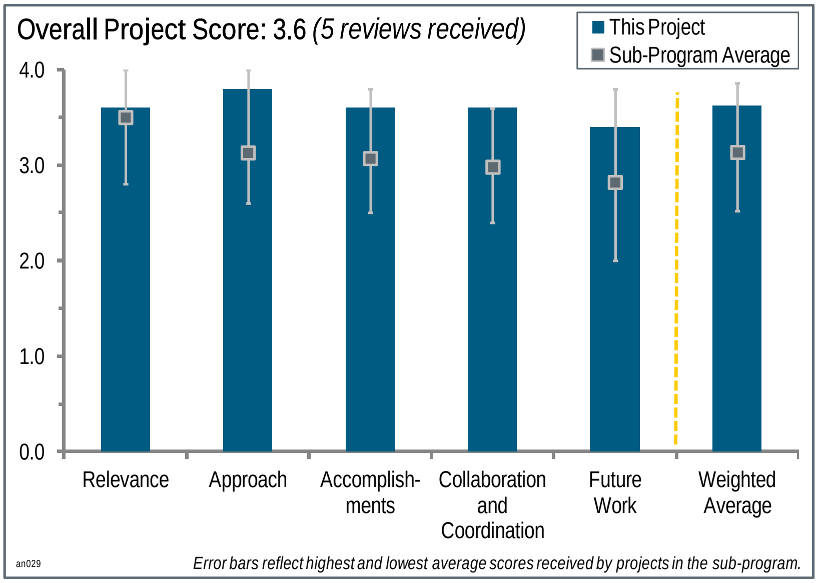
- There are weaknesses, but they can be quickly corrected.
- This project really needed some industrial input.
- The choices and assumptions made, such as the fuel cell systems, are a weakness in this project.
- While modeling is valuable, the results suggest the application of tri-generation systems only makes sense if GHG emissions are factored in. Based on the cost of H_2, power, or heat, a tri-generation unit does not appear to be cost effective. This may be a strength or weakness depending on the use of the models to assess a given pathway. Proponents of tri-generation may not see the results positively.
- This project had no weaknesses.

Recommendations for additions/deletions to project scope:

- This effort should continue to be supported.
- CHHP should remain a possibility for a system approach, but other techniques for optimizing heat, H_2, and electricity balance should be addressed.
- The project is nearing completion, so there are no recommendations for additions or deletions to the scope of the project.

Project # AN-029: Employment Impacts of Early Markets for Hydrogen and Fuel Cell Technologies

Marianne Mintz; Argonne National Laboratory



Brief Summary of Project:

The objective of this project is to produce the Jobs and Output Benefits of Stationary Fuel Cells (JOBS FC) model, which provides a means for calculating employment and other economic implications of fuel cell investments. The JOBS FC model translates investment and operations expenditures into direct, indirect, and induced jobs and economic activity.

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

This project was rated **3.6** for its relevance to DOE objectives.

- Given where things stand on a deployment phase of hydrogen (H_2) technologies, getting a handle on the impact on job creation is very relevant to the mission of the DOE Hydrogen and Fuel Cells Program and will help the community to understand the economic (jobs) impact.
- This model is definitely needed, because jobs and exports have become a focal point for legislators and administration. Helping raise the profile of the potential of fuel cells and related jobs is important for continued support as well as the implementation of actual installations and deployments.
- Employment and jobs calculations are critical criteria for project valuation and continued public funding. This value attribute is often qualified, but not often quantified. This project will provide an opportunity for uniform quantification and more accurate project valuation.
- It is crucial that industry and government continue to support modeling jobs. The PI has done a wonderful job of creating a transparent tool for stakeholders to use. It is unclear whether demonstrating economic benefits of fuel cells is part of DOE's program plan or research and development (R&D) objectives, but it should be.

Question 2: Approach to performing the work

This project was rated **3.8** for its approach.

- This project has very thorough models that seem to be taking in user and tester feedback and addressing the issues raised.
- So many of these types of tools are too hard for people to use. The principal investigator (PI) and research team made this tool accessible and easy to use.
- This is a very good application of the JOBS FC tool. The data input is quite thorough, with its high-fidelity treatment of the input supply chain. However, the modeling is somewhat limited in its ability to provide understanding of regional differentiations. Admittedly, this is driven mostly by a lack of relevant data. The PI would still be encouraged to address this issue.
- The Regional Input Output Modeling System (RIMS) model is an appropriate substitute for the Impact Analysis for Planning (IMPLAN) model for direct, indirect, and induced estimates. Targets for forklifts, fuel cell backup power, and combined heat and power (CHP) are also appropriate, but they could be expanded as needed. Online offerings of the model will provide opportunities for universal and consistent project valuation. Regional variations and the use of supply chain information is of high value.

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

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

- This project is on schedule to complete the tasks and has made impressive progress since the 2011 Annual Merit Review (AMR).
- This tool has grown in scope since the presentation at last year's AMR. It is important that scope creep does not keep the tool from being finished.
- This work (and results) is very timely as H_2 technologies increase their presence in the marketplace. Counting jobs is important to government leadership, so having a handle on this metric is important.
- Refining the project to use RIMS as a substitute for IMPLAN appeared to be challenging, but necessary. This modeling is appropriate and is now nearly ready to estimate economic and job creation impacts of the American Recovery and Reinvestment Act (Recovery Act) and other public funding of projects. Supply chain information and regional variations are complete and ready for online access.

Question 4: Collaborations and coordination with other institutions

This project was rated **3.6** for its collaboration and coordination.

- This project has a wide reach of stakeholders for peer review/testing.
- This project has an impressive list of collaborators and stakeholders.
- This project has good input from industry and is working with state and regional programs for data and validation.
- Collaboration and coordination for this project is very good, but the nature of the model will require continual updating, additional testing, and refinement of model variables with stakeholders, original equipment manufacturers (OEMs), and institutions. This work will be necessary initially to validate the model and of continual value to confirm consistency and accuracy over time.

Question 5: Proposed future work

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

- It is good to increase past Recovery-Act-funded projects.
- This project definitely needs to expand to include solid oxide fuel cells (SOFC), H_2 stations, and transportation as proposed. Anaerobic digester gas/biogas is a definite market to include as well, because that could be used not only for utilities and municipalities, but also for factory farms, wineries, and other industrial processes that are dealing with image and waste problems.
- This project needs to get into position to provide information on jobs and economic impacts of the infrastructure rollout in aggressive states such as California and New York. When asked, the PI recognized this and suggested that movement in that direction was on the table, but this reviewer would like a more concrete plan of action for doing this. This work focuses on jobs created by current deployment activities. It would also be good to make educated projections on the job market impact driven by the planned rollout of H_2 technologies. The impact on job creation by the early development of infrastructure elements and the introduction of hundreds of thousands of vehicles would be very interesting. This project should work to get a handle on the future job impacts as well as the current impacts.
- User training, data valuation, and documentation are on schedule. Comparing job-creation value with other technologies (photovoltaic, wind, and conventional, etc.) would be of value. Expanding the models for other applications, such as non-CHP electric only, SOFC, transportation, high-temperature baseload polymer electrolyte membrane fuel cells, and combined heat, hydrogen, and power is appropriate and of value. The location of the tool at other job estimation websites (i.e., Jobs and Economic Development Impact [JEDI] sites) might allow for comparative analysis for various technologies. Additional information on sensitivity analysis would have been helpful.

Project strengths:

- This project is producing clear, easy-to-use web-based tools and has good data transparency and coordination with industry and regional programs.
- This is a much-needed tool to advance industry and helps position the technology as more than environmentally friendly, which is important in the current climate.
- This is a great application of the JOBS FC tool, with solid high-fidelity data input. Including first- and second-order effects is very important to understanding the ripple-down effect on jobs from introducing this technology.
- This model provides valuable economic and job creation information to justify public funding. The work combining clean energy, economic development, and job creation is of high national value. The initial targets are appropriate and future work is consistent with DOE's goals for technology deployment.

Project weaknesses:

- The researchers need to ensure the tool gets in front of the right people: a wide audience with potential customers, lawmakers, etc. A marketing/promotion/education plan was not addressed.
- As with every good project, scope creep can make the project never ending. It also becomes easy to get too detailed. The researchers should be cautious of this.
- This task should broaden its geographical reach to include regions that are particularly aggressive in their rollout plan, such as New York and California. This project should embrace extrapolation into the future to get a handle on the job impact by the planned 2015 infrastructure and vehicle rollout.
- Validation through testing with end users and OEMs is needed for continual model refinement. A more detailed explanation of sensitivity analysis would have been helpful. More funding will be needed for model updates and refinement.

Recommendations for additions/deletions to project scope:

- This project should include H_2 stations.
- Marketing/education, expansion of fuel cell types, and applications are needed.
- Researchers should establish model sites with other job calculators/estimators (i.e., JEDI) to allow comparative analysis and track hits on the model. A white paper on comparative analysis with other technologies for job creation would be of interest. Researchers should update the model as appropriate and expand the model's scope for additional technologies including SOFC, non-CHP SOFC, transportation applications, and high-temperature PEM fuel cells. The researchers should also consider the expansion of a sub-program for financing.

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