Systems Analysis
Summary of Annual Merit Review Systems Analysis Subprogram

Summary of Reviewer Comments on Systems Analysis Subprogram:

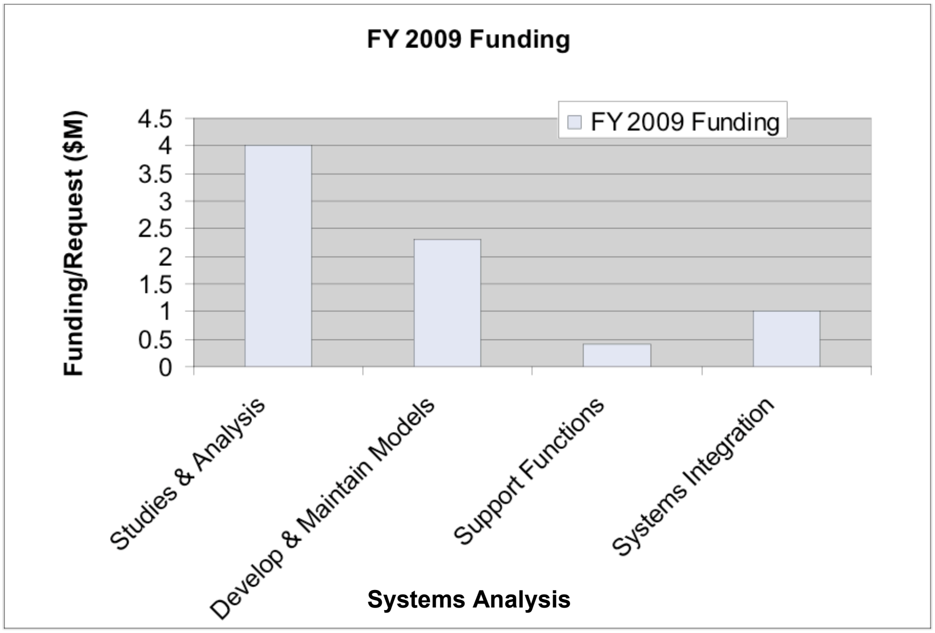
In general, the reviewers commented that useful new insights were gained, and they considered the Systems Analysis subprogram a significant activity of DOE. Reviewers stated that this subprogram is well focused and managed, while playing a critical role in placing hydrogen and fuel cell R&D into perspective. The project portfolio is considered sufficiently diverse, and the suites of models developed are deemed as useful tools for industry and academia.

It was also noted that the Systems Analysis subprogram comprises a very broad range of issues. While this presents a challenge in keeping information up to date, reviewers observed that significant progress was presented and that the evolution of analytical tools has followed a logical path with no significant gaps identified.

The main recommendations identified by the reviewers for Systems Analysis were: 1) the case of a more limited deployment of hydrogen vehicles should also be considered; 2) existing markets for hydrogen (i.e., refinery and agriculture) should be tapped into for central hydrogen generation cases to make use of this vast potential; 3) efforts to more appropriately incorporate hydrogen technologies into national energy models should be considered; 4) interactions between the variety of models should be clarified; 5) early market use of stationary fuel cells should be assessed against competing technologies; and 6) priorities of the subprogram need to be clarified and illustrated, thus allowing the information gleaned from analysis to present clear options for policy decisions. The Systems Analysis subprogram will take these reviewer recommendations into consideration in improving existing efforts and developing appropriate R&D plans.

Systems Analysis Funding:

The funding for Systems Analysis primarily includes emphasis on sustaining a suite of diverse models and conducting in-depth analysis to answer critical cross-cutting questions in meeting the Hydrogen Program's goals. The FY 2010 request-level funding profile, subject to Congressional appropriation, will focus on early market analysis, synergies of transportation and stationary applications, and resolving barriers to hydrogen infrastructure development.



Majority of Reviewer Comments and Recommendations:

In general, the maximum, minimum, and average scores of the reviewers gave for Systems Analysis projects were 3.3, 1.8 and 3.0, respectively. Reviewers commented that a consistent set of analytical tools was developed and various impacts were analyzed utilizing these tools. The main recommendations for the Systems Analysis projects are summarized below. The Systems Analysis subprogram plans to address these recommendations.

Model Development: Projects involved in developing, enhancing, and sustaining models received very favorable reviews, with the highest score given to one of these projects. The majority of the projects were regarded as comprehensive, relevant, and functional tools, developed through appreciable collaboration with a variety of stakeholders. A suggestion emphasized repeatedly by reviewers was that the models be peer reviewed and validated with industry and other stakeholders. It was also pointed out that as these models have become more complex over the years, accumulation of combined errors presents a critical issue that needs addressing. For further expansion of the models, reviewers suggested that factors such as renewable pathways, carbon capture and sequestration, criteria pollutants, and potential new vehicle fuel economy/emissions standards legislation be taken into consideration to enhance analysis results derived from these models.

Program Analysis: Most of the analysis projects reviewed this year are being completed in FY 2009. In general, the reviewers concurred that the analysis projects need to be peer reviewed and validated prior to issue and publication. The reviewers felt that the Argonne National Laboratory hydrogen quality project is an important effort that has shown good progress and suggested the inclusion of renewable fuel sources (e.g., biogas) and consideration of costs associated with analytical requirements (to track if purity is being maintained). The Sandia National Laboratory project on analyzing energy infrastructures was deemed by reviewers as addressing critical questions. Suggestions were made for its scope to be expanded to explore all-electric vehicles and renewable fuels, while recommendations were made to collaborate more closely with stakeholders and employ an iterative approach for supply and demand considerations.

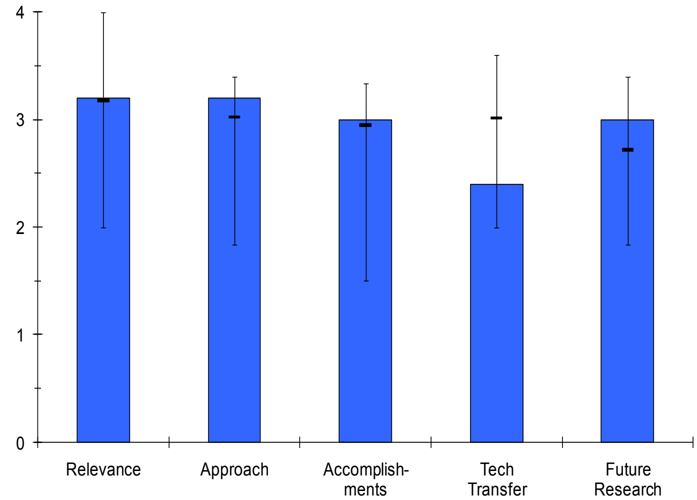
Other Studies: Other studies included in the project portfolio included a "lessons learned" study related to stationary applications by the Missouri University of Science and Technology and an assessment of the commercialization successes of related technologies and studies supported by the Program, conducted by the Pacific Northwest National Laboratory (PNNL). The "lessons learned" study is being completed in FY 2009 and has explored opportunities and strategies for the use of hydrogen in portable and stationary applications based on various national and international strategies of existing applications that were investigated. The commercialization study by PNNL is an ongoing effort that was believed by some reviewers to serve as a good feedback mechanism and a valuable data set, while others raised caution that the project may be premature at this point in time. Reviewers suggested continued updates of findings, development of a user-friendly Web-based access to the information, consideration of market needs/trends, and analysis of the information garnered.

Project # AN-01: HyDRA: Hydrogen Demand and Resource Analysis Tool
Johanna Levene; National Renewable Energy Laboratory

Brief Summary of Project

The objective of this project is to develop a Web-based geographic information system (GIS) tool to allow analysts, decision makers, and general users to view, download, and analyze hydrogen demand, resource, and infrastructure data spatially and dynamically. HyDRA is designed to display and aggregate the results of spatial analyses. It is a repository for spatial data inputs and spatial data results. To access HyDRA, go to http://rpm.nrel.gov and request a login.

Overall Project Score: 3.0 (5 Reviews Received)



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.2** for its relevance to DOE objectives.

- It's an interesting program, but it's not clear who is supposed to use it or if it would actually be used by them.
- Very relevant in assessing geographical markets and resource constraints. The Web-based tool allows further development and easy deployment.
- This activity supports Task 2, barriers A, B, C, D, and E to develop and maintain models and tools.
- This project appears to be useful for those involved in hydrogen to evaluate hydrogen demand and resource in a given geographical location.
- It is particularly useful to continually update the model with the latest cost of feedstock (e.g., natural gas, electricity) to have a more realistic picture.
- Conceptually, the relevance is excellent. Practically, gas prices and electrical energy prices are not static but vary tremendously with time as well as location. The same is likely true for real estate, construction costs, capital costs, etc. By the time a composite map is generated, it is likely outdated and might give misleading results.

Question 2: Approach to performing the research and development

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

- There is concern that the model is "static" and does not address a dynamic environment of ever changing costs. For example, as the usage of one energy input rises, would the cost remain the same relative to other options? Although a given cost might be “X” today does not mean it will stay that way if there are limits to its production.
- Focus on cross-coordination with other tools and addressing the barriers in maintaining an open structure. Database development is key to the efforts because they will allow data export/import to and from other tools.
- The idea of interactively combining GIS data sets is outstanding. The visual nature of the data will make the information much more accessible to a wider audience and will be particularly useful to government officials who need data at the county resolution.
- While it is useful to know where hydrogen demand and methane wastewater resource co-exist, it is also useful to determine if the methane resource available is enough to satisfy the potential hydrogen demand for the numbers of forecourt commercial hydrogen stations.

- Regarding the Missouri case study, need to specify the scale/capacity factor of the industrial steam methane reformer (SMR) (How much larger is the industrial SMR compared to the commercial SMR?). An "industrial" SMR hydrogen plant at a refinery can produce as much as 50 million standard cubic feet daily of hydrogen and its hydrogen cost is much lower than the industrial SMR (in the Missouri case).
- The approach is a combination of overkill and simplicity.

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

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

- Various new analyses done between last year and the current year. Again, acquiring data is the key to these efforts. Didn't quite understand why re-architecture was required; it should have been planned/done from the start.
- Changing architecture is never trivial. Impressive that team redesigned architecture and added more databases.
- The model user interface appears to be friendly and easy to navigate through.
- Analysis and spatial datasets on hydrogen demand appear to be a bit lacking.
- After over three years of effort, the accomplishments can only be considered fair.

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

This project was rated **2.4** for technology transfer and collaboration.

- Very little comment on collaboration with other organizations, other than integration with other DOE-funded models.
- Interaction with industrial partners would be helpful to validate assumptions and to see if it's really useful in rolling out infrastructure.
- Not too many (industry) partners in this work.
- At this point it would be useful to bring in collaborators from industry and governmental planning.
- It is critical that this model works in conjunction with other models to look at the whole picture (i.e., public acceptance of hydrogen fuel cell vehicles [HFCV], competing technologies, external market forces, right-of-way issues).
- There is the intent to interact with other models and simulations from other organizations, but relatively few interactions to date.

Question 5: Approach to and relevance of proposed future research

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

- Need to have a plan for dynamic transitions (in time/year).
- Expanding the model past hydrogen will be very useful. Adding a dynamically linked database to keep the model relevant is definitely needed.
- The proposed future work could also take a look at the feasibility of doing carbon capture and storage spatially, specifically the non-renewable and central cases. Given the increasing push to minimize green house gases (GHG), this might be a useful factor to consider for infrastructure installation.
- Future plans would improve the product, especially the dynamic layering and proposed interactions with other software.

Strengths and weaknesses

Strengths

- A useful input into the Macro-System Model (MSM) overall, big picture.
- Strength is its application and relevance to overall hydrogen infrastructure analysis and the creation of the database.
- Interactive GIS is a very powerful tool with wide applicability.
- This is a good concept.

Weaknesses

- It is not clear how the information will get updated over time. For example, natural gas and electricity rates are expected to be volatile. Will the model automatically update pricing or is that manual?
- Decisions on production must assume economics over a 15-20 year period prior to an investment decision, so a look forward on those costs is just as important as today's costs.
- Need to start deploying the tool for transition scenarios; make it dynamic so existing infrastructure need not be ripped up when making transitions.
- Limited to inexpensive databases. There is some more expensive data out there that the DOE should consider purchasing so that the tool can be made as useful as possible.
- A lot of time and effort has been expended for a tool that appears to be only marginally useful as it stands.

Specific recommendations and additions or deletions to the work scope

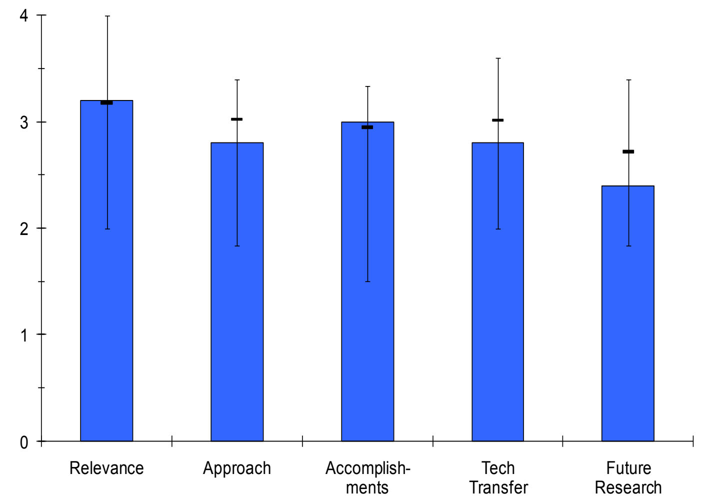
- Develop means to address impact of variable pricing due to time-of-day issues.
- Develop a means to address impact of future cost changes as demand from hydrogen production uses more of the given energy input.
- Automate the update of pricing information if this has not already been done.
- Incorporate dynamic behavior to enable playing out a transition.
- More actual studies, at some point the model will contain enough data that it should be validated extensively, especially for the conventional scenarios that exist now.
- Continue as planned.

Project # AN-02: Water's Impacts on Hydrogen
A.J. Simon; Lawrence Livermore National Laboratory

Brief Summary of Project

The objective of this project is to quantify the impact of water on a future hydrogen economy, including the economic impact of water prices on hydrogen production and the regional impact of hydrogen production on regional water resources. The project shows 1) how the energy-water nexus affects all future fuels (not just hydrogen), 2) how water impact analysis is fundamentally regional, and 3) how water permitting is likely to be a bigger impediment to hydrogen adoption than water price.

Overall Project Score: 2.9 (5 Reviews Received)



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.2** for its relevance to DOE objectives.

- To the extent that this is a problem, it's useful. To the extent that it's not, then it isn't. This ought to be a fairly quick, high-level assessment as a first step. It is likely to only have an impact in certain areas, so only focus on worst case. There is no need to even think about large portions of the country.
- Water is a critical resource and so the role it plays in any future energy infrastructure deployment is an important aspect to look at for intended and unintended consequences.
- Relevant under Tasks 1, Perform Studies and Analysis, and Task 2, Develop and Maintain Models and Tools, in addressing barriers A and B.
- Not certain if this is one of the critical issues for the commercialization of hydrogen fuel cell technologies. Wastewater from reformers and electrolyzes can be captured, treated, and recycled so the net amount of water added to the system is minimized. The total amount of water usage is relatively small.
- Regarding regional impact, it will likely be similar to current gasoline formulation requirements in places like California and the Midwest. These places typically have higher gasoline prices; places with water resource constraint or any other resource constraints will likely have higher hydrogen costs.
- Water availability is already a problem in many areas and is generally expected to become more of a problem. This could certainly be a factor in hydrogen production.

Question 2: Approach to performing the research and development

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

- Some of the assumptions are not clear for the use of water. Is it actual process water, and if so, is it electrolysis or reforming? Or, is the larger use as cooling water, in which case there are several options?
- Good overview chart of water source, use and disposal to provide context. Geographical information used to identify water stress areas. The approach overall is based on mass balance at a higher level and is adequate for the current purpose.
- Considering that water supply and demand is critical to hydrogen production from electrolysis, combing energy and water balances again is critical.
- It will be likely that the system developers will have multiple models of hydrogen generators designed to run at certain geographical locations. For water constraint locations, the wastewater recovery and cooling systems would have to be different compared to systems installed at places with less water constraint.

- Data from process modeling and regional analysis will be useful to tailor a system to run at specific locations to maximize efficiency and minimize water usage. Therefore, the model should tell the system developers how to design their systems, not the other way around.
- Generally good, but could be better. Approach neglects possible synergy with existing or possible industrial water users, which seems to be a likely outcome in many instances. It also seems to neglect the effect that hydrogen production, with its water usage, would have on costs.

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

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

- It is not clear this is really a barrier to a hydrogen economy. It would be good to show an overall picture of water use compared to a fuel infrastructure. For example, for a worst case (e.g., a desert climate like Los Angeles), what percent of existing water use would be needed to produce hydrogen to supply the existing vehicle fleet? If insignificant, then it's not an issue. Also, some of the existing water use might be available for dual use (e.g., use of water from thermal electricity plants as cooling water and then as process water).
- Unclear in terms of progress made in identifying water resource constraints and high-level implication on hydrogen infrastructure. Accomplishments include model development to date. Focus seems to be resource costs rather than constraints.
- Two different analyses were presented. This approach needs to be much more widely applied.
- Cooling towers most likely fit central SMR and electrolysis cases. They are not typically used at forecourt cases. The cost of treatment could be significant depending on the water purity levels required.
- Not yet complete and relatively few results available to date. Much emphasis on permitting, which seems to be a separate issue.

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

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

- Some industrial partners would be helpful, as well as support from localities in areas with limited water supply. They would be in the best position to comment on availability of permitting for water supplies, as well as ease (or not) of permitting new applications. Comments on permitting being an issue do not appear founded on actual information.
- No industry partners have vested interest in the development.
- Collaborators are mostly other national labs. This needs industrial input, especially from large utilities that may want to store large amounts of hydrogen via water electrolysis.
- Integration with the DOE Hydrogen Analysis Model (H2A) and Macro-System Model (MSM) is critical to produce any meaningful data.
- Collaborations seem appropriate for the project.

Question 5: Approach to and relevance of proposed future research

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

- Future work should focus on whether this is even an issue, prior to full integration with MSM. Given the overall uncertainty in hydrogen cost, it appears that water cost really is within the rounding error and not meaningful. There are also numerous technologies around cooling, and it is not clear if the assumptions would be accurate.
- Only a high level description is given; there are no clear milestones.
- Budget is currently zeroed. This is a shame. The project is critical to the DOE mission and should be continued.
- The project should mainly focus on water availability issues and let the system developers design their systems to best "get around" these issues based on the data.
- It might be useful to look at technologies that are/will be competing for the same water resources (especially the significant users).
- Planned work seems very appropriate to make the tool more useful.

Strengths and weaknesses

Strengths
- It is an interesting issue, and one that might not be widely recognized. Good to analyze to see if it truly is an issue.
- Nothing seems to stand out as a strength.
- Interplay of water and energy.
- Fills a need that is not otherwise met.

Weaknesses
- Need to compare to other fuel pathways for comparison. Are they a draw on water resources as well, and/or does water become available as fuel use changes?
- No information was provided (except some vague references during the presentation) on the actual costs of the water and water treatment. Based on the verbal discussions, it appears as if water cost has a minimal impact on overall hydrogen cost. This should be included in the presentation to show overall impact.
- The issue appears to be concerning the "cost" of water more than its actual availability. If so, then other technologies can overcome actual availability issues.
- Focus should be on water resource constraints and not economics.
- Not enough real world analyses have yet been accomplished.

Specific recommendations and additions or deletions to the work scope

- Develop some conclusions prior to moving any further. This does not appear to be a critical path issue on developing a hydrogen economy. If so, document and move on, with some basic input on costs to H2A.
- Add comparisons of water use/constraints via various energy pathways (e.g., conventional, hydrogen, plug-in hybrid electric vehicles, biofuels) to project scope.
- Continue project.
- Project should be continued with proposed work.

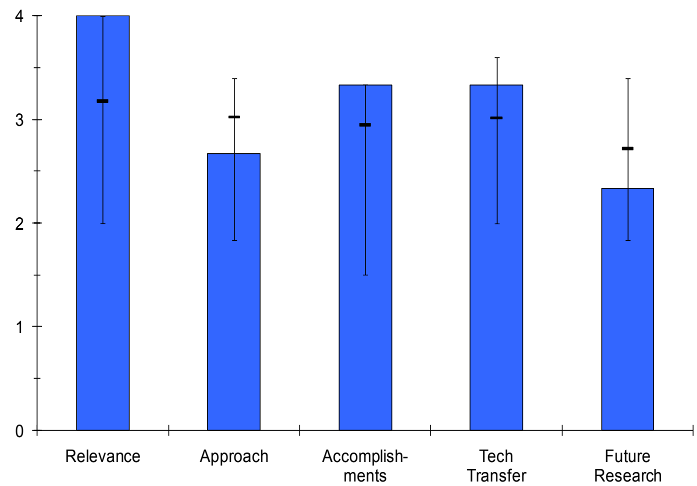
Project # AN-03: Cost Implications of Hydrogen Quality Requirements

S. Ahmed, D. Papadias, and R. Kumar; Argonne National Laboratory

Brief Summary of Project

The objective of this project is to correlate impurity concentrations (in hydrogen) to the cost of hydrogen, as functions of 1) process parameters (e.g., temperature, pressure, and steam to carbon ratio [S/C]) and 2) performance measures (i.e., hydrogen recovery, efficiency). A rigorous model of the pressure swing adsorption (PSA) system has been set up as part of a flexible systems model, and the system model results have been correlated with the cost of hydrogen. The project has concluded that the cost of hydrogen is only slightly affected by the impurity specification guideline in the natural gas-steam reformate PSA system studied.

Overall Project Score: 3.2 (3 Reviews Received)



Question 1: Relevance to overall DOE objectives

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

- Hydrogen purity is a very important topic for the hydrogen economy. This is a continuing debate and needs to be resolved.
- Hydrogen quality represents a key interface between original equipment manufacturers (OEM) and fuel providers, and it is a critical topic of contention/optimization.
- This project supports DOE RD&D objectives under Task 1, Perform Studies and Analysis and Task 2, Develop and Maintain Models and Tools, by addressing barriers A and B.

Question 2: Approach to performing the research and development

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

- The approach for this particular pathway is good, but there are several issues. One large issue (other than those mentioned below) is the potential for differences between different manufacturers' equipment.
- Approach is good looking at life cycle analysis and economic impact to determine the optimal purity levels. A reference to SAE J2719 (with current levels) would be good for the audience to look at the context.
- The approach is to analyze the effect of impurities on the cost of hydrogen using reformate from natural gas purified by pressure swing adsorption.

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

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

- This is good progress to date, but there is a lot more to do (to broaden to make the program more effective).
- Similar results as the previous year, but including more system types (autothermal reforming [ATR], gasification) and process details. Still no impact of impurity on fuel cell stack included. No progress on canary species establishment/agreement.
- This appears to be a very realistic model that can track realistic impurities. The input seems to be real natural gas and the process appears very relevant.

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

This project was rated **3.3** for technology transfer and collaboration.

- Several good partners, but should likely add some analytical companies.
- No other working/industry collaborator.
- Good mix of collaboration with other national labs and industry.

Question 5: Approach to and relevance of proposed future research

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

- The work completed to date covers only a subset of hydrogen production and there are many more to go.
- In addition, it is very important to consider not only actual hydrogen purity, but also the analytical requirements associated with those purities. Cost of production might be small compared to cost of keeping it at that purity, as well as the analysis required.
- Future work does not include identifying fuel cell impacts and costs associated.
- Too much emphasis on fossil fuel inputs.

Strengths and weaknesses

Strengths
- This is an important effort.
- Good industry collaborations.
- Well thought out engineering study.

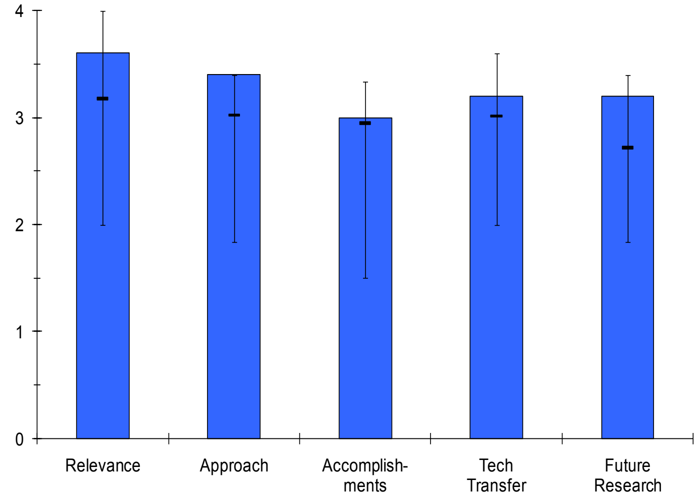
Weaknesses
- The project team comments on efficiency and recovery, but does not comment on analytical capability and costs. These are very important.
- Does not refer to SAE J2719 and the "full slate" of impurities, especially particulates.
- Looks at "full scale" production, but not impact on lower volumes with initial rollouts.
- Limited data from industry.
- Not enough emphasis on renewable hydrogen. Biomass gasification, methane from fermentation, and a comparison with hydrogen from electrolysis should be included.

Specific recommendations and additions or deletions to the work scope

- Continue with other production pathways.
- Add cost for system design (to keep gas at high purity level).
- Add cost for expected analytical requirements.
- Consider a program to analyze if impurity levels do not have to be as low as currently specified.
- Calculate the optimal levels for each impurity species based on fuel cell impacts and purification costs.
- Add more renewable fuel sources.

Project # AN-04: Macro-System Model
Victor Diakov and Mark Ruth; National Renewable Energy Laboratory
Mike Goldsby and Tim Sa; Sandia National Laboratories

Overall Project Score: 3.2 (5 Reviews Received)



Brief Summary of Project

The overall objective of this project is to develop a macro-system model (MSM) aimed at 1) performing rapid, cross-cutting analysis by utilizing and linking other models and improving consistency of technology representation (i.e., consistency between models), 2) supporting decisions regarding programmatic investments through analyses and sensitivity runs, and 3) supporting estimates of program outputs and outcomes. Objectives for 2008/2009 are to 1) improve structure of the MSM and expand graphical user interface capabilities, 2) update versions of component models, 3) expand stochastic analysis capability, and 4) build interaction between the MSM and spatial and temporal models.

Question 1: Relevance to overall DOE objectives

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

- Arguably, this is the apex of the DOE modeling and therefore must be important by definition, assuming that modeling is important to DOE goals.
- The idea is to develop an open architecture tool to connect with other tools and build the interaction with those tools. It is quite relevant to deployment and use of other tools being developed as a part of this program.
- This project fully supports the DOE objectives through Task 2, Develop and Maintain Models and Tools, addressing barriers B, C, and D.
- With so many models looking at various areas, having this tool to link the models together to produce meaningful results is important.
- Very relevant since it can tie together several important simulations.

Question 2: Approach to performing the research and development

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

- A major barrier to the success of MSM is validation.
- Approach appears to be planned out and has a step-by-step development.
- The approach is to integrate a number of individual models in to an MSM and allow access through a graphical user interface (GUI).
- Appears to be a useful tool for providing critical pieces of information for the assessment of hydrogen technology potential.
- Excellent approach and excellent presentation detailing the approach.

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

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

- From an information technology point of view, there appears to be good progress at integrating the models.
- Statements such as the one slide on greenhouse gas (GHG) tax analysis can be very deceiving if shown without the appropriate assumptions. Given the number of assumptions, this can be potentially confusing as well as deceiving. For example, one of the backup slides shows GHG emissions being cut roughly in half with hydrogen, so how can a CO_2 tax have no effect?
- Added risk analysis tool based on expert opinions, which seems like a good addition but I'm not sure how reliable the expert input is (being myself a polled expert).
- Progress towards integrating the component models seems to be on track. It is of concern that the MSM may be beginning to run too slowly. Perhaps more attention should be paid to optimizing code in the integration of the models so that the whole thing doesn't grind to a halt. It would be nice to see more examples of actual analyses run with the model.
- Not able to see much progress based on this year and last year presentations. It appears that most of the activities concentrated on improving the model's user interface. Model needs to be tested and validated by industry for a "sanity check."
- Excellent accomplishments.

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

This project was rated **3.2** for technology transfer and collaboration.

- Appears to be a number of collaborators. Could use some representatives from hydrogen producers.
- Good long list of collaborators. Need to see industry start using this tool for routine analysis.
- Nice collaborations with national laboratories. Needs collaboration with university computer scientists and government and industrial end users.
- Obviously very good collaboration with other models as they provide critical pieces of information to this tool.
- Combination of national laboratories, industry, and a university is excellent.

Question 5: Approach to and relevance of proposed future research

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

- There is a need to address the overall "error band" of the results. Each of the input models has an inherent inaccuracy. As these get built up to the MSM, do these potential errors compound to the point where the model results are questionable?
- There is a flowchart showing progress and future work, but we need to see progress in terms of analysis results.
- Adding additional models and improving the GUI are good ideas. MSM needs to allow more comparison with competing non-renewable technologies.
- It is critical that the model is continually updated with the linked updates from other models.
- Proposed future work will make an excellent project even better.

Strengths and weaknesses

Strengths

- MSM provides a means to tie all models together, which otherwise would be very difficult to do independently.
- The project is critical to expanding the use and capability of existing/other tools being developed as part of the systems analysis program.
- Integration of a large number of powerful individual models is a strength.

Weaknesses

- Need to provide a means to validate the model to make sure it provides results that are realistic. For example, if one model was somehow inputting incorrectly, how would it be noticed?
- It seems like much of the effort is spent on programming languages as opposed to real analysis.
- Need to validate the overall results with industry.

- It may be too cumbersome to deliver analysis tools in real time.
- By combining the other tools, it seems likely that there could be an accumulation of combined errors. It might be prudent to use some type of combined error bands and track possible accumulated error.

Specific recommendations and additions or deletions to the work scope

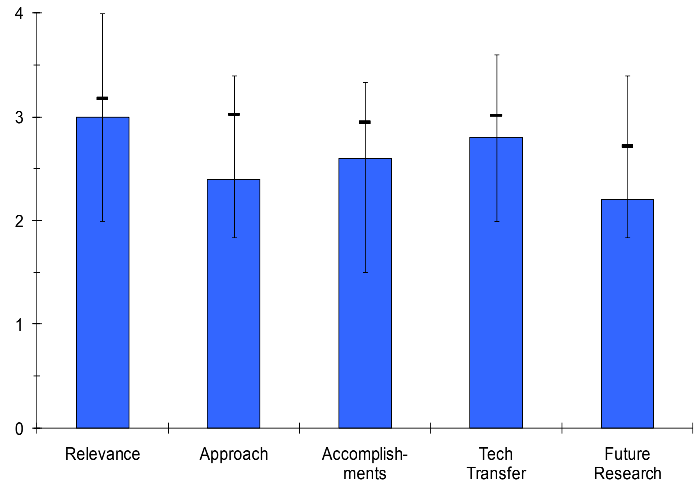
- Provide a verification step to demonstrate that the model outputs are realistic.
- Consider performing an industry validation program.
- Add more transparency in what is being calculated. Add more diversity in processes that can be analyzed.
- Continue with proposed work.

Project # AN-05: Discrete Choice Analysis of Consumer Preferences for Refueling Availability
Marc W. Melaina; National Renewable Energy Laboratory

Brief Summary of Project

The objective of this project is to 1) quantify consumer reluctance to purchase an alternative fuel vehicle due to a lack of refueling availability, 2) compare survey results to comparable results derived from analytic models, and 3) develop a general discrete choice model for major urban areas. The project has developed an improved quantitative representation of the cost penalty for limited refueling availability using discrete choice survey and modeling methodology. Penalties have been estimated for limited coverage at three geographic scales (i.e., metropolitan, regional and national) and for four distinct metropolitan areas (i.e., Los Angeles, Seattle, Atlanta, Minneapolis-St. Paul).

Overall Project Score: 2.6 (5 Reviews Received)



Question 1: Relevance to overall DOE objectives

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

- Very relevant. Understanding the degree of infrastructure needed to enable a reasonably sized hydrogen car fleet determines whether the goals of the overall DOE program are achievable.
- Not critical to the program, but of good relevance to transition scenarios and various possible outcomes (including unintended ones).
- This project supports the DOE objectives under Task 1, Perform Studies and Analysis, addressing barriers A and B.
- It is unclear if this work would be necessary. The interdependency between vehicle and infrastructure availability will largely dependent on both the original equipment manufacturers (OEM) and energy companies and their recognition as to when it is economically viable to enter the "hydrogen economy". There must be a business case for both sides. It is also dependent on government actions. In the end, the single most important factor for the consumer is cost.
- The relevance is good since the types of issues addressed are very important.

Question 2: Approach to performing the research and development

This project was rated **2.4** on its approach.

- Approach defined the difference between alternatively and conventionally fueled vehicles in a mostly neutral manner. However, calling the car an "alternative fuel vehicle" and touting its green benefits may not be the most conservative way to go about it. It is much easier to check a box that says "I would spend another $2,000 for this" than to actually spend that money.
- It would be interesting to calibrate the survey. To get an idea of the difference in response if people had to put real money on it. The researchers could use the same methodology to attempt to predict consumer preference for the hybrid Honda Civic over the less expensive baseline model to see if reality matches the prediction.
- Not clear how many surveys were completed; with so many variables, a large sample may be required to be able to draw a statistically valid conclusion.
- Discrete choice is a good approach to look at qualitative possibilities, not quantitative. Requires quite a lot of behavioral data, which makes this model all the more inaccurate.

- The approach is to use market survey data in order to predict the essence level of market introduction to achieve a vehicular-based hydrogen economy.
- This study is only looking at one side of the picture. While it is true that the consumers will be reluctant to purchase a hydrogen fuel cell vehicle (HFCV) because of the lack of fueling station availability, the level of reluctance is equally as much for the energy providers since building hydrogen stations represent significant capital investment, especially in the early stage. The old saying "if you build it, they will come" does not necessarily hold true in this case.
- It is useful to eliminate other factors and only include social and environment benefits and limited fuel range factors. This will provide more meaningful survey results based on these limited considerations.
- These types of surveys almost always give unreliable results.

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

This project was rated **2.6** based on accomplishments.

- The approach delivers the right outputs to guide decisions on infrastructure. Per this reviewer's other comments, it needs validation and market input to ensure that the outputs are correct.
- Very well designed survey for consumer acceptance based on refueling availability. The data should be quite useful to fuel providers and OEMs.
- Not convinced that we really learned anything new from extending the study to the new cities studied this year.
- Again, as indicated, the cost barrier for infrastructure is significant and should not be overlooked.
- Better user interface for the survey is a plus.
- Might need to verify for the regional cases whether the number of stations shown is practical from a resource availability standpoint.
- With respect to the charts showing the highest number or percentage of hydrogen station available where there are zero cost penalties, are the hydrogen stations displacing the gas stations or are they in addition to the gas stations? Would a gas station be bulldozed and a hydrogen station built on the same lot?
- The project is complete so the planned work has been accomplished; however, I'm not sure of the value.

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

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

- Team should consider bringing an automaker on board or another contractor with significant auto marketing experience. Such a partner could provide a lot of insight on how consumers choose which vehicle to buy.
- Quite a few collaborators. Need to get industry validation/approval of this approach.
- Needs collaborations with auto industry and energy companies.
- Good collaborations with various institutions. Consider rolling out the survey to a broader range of the public.
- Some collaboration, but not impressive.

Question 5: Approach to and relevance of proposed future research

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

- The approach needs to be validated before going forward, for example, by checking the method against a currently available market choice (e.g., regular or hybrid Honda Civic). People want to say they would buy an alternative fuel vehicle if given the choice, but would they really do it?
- Proposed future can include a high level validation of the results from the model.
- The proposed trade-study (scale vs. numbers) is a good one to look at and will be useful for the industry.
- This project appears to have run its course.
- Additional trade-off studies between station capacity and numbers of station will be useful. It is not necessary to have all stations initially be at 1,500-kg/day capacity. This will ease the infrastructure cost penalty pain.
- Proposed additional work seems to be of marginal value.

Strengths and weaknesses

Strengths
- Good methodology and important topic. Examines different strategies and acknowledges the importance of the market driving hydrogen acceptance.
- The project is based on a good theoretical approach.
- Consumer driven surveys allowed real analysis of the market.

Weaknesses
- This project needs validation and specific auto market insight.
- The project team needs to get a thorough validation of the conclusions.
- Not really integrated into other DOE analysis models.
- Too much dependence on an approach that is known to be unreliable.

Specific recommendations and additions or deletions to the work scope

- Add validation tasks.
- Model validation should be a good addition to the project scope.
- The project should end until market conditions change.
- Expansion of scope is not recommended.

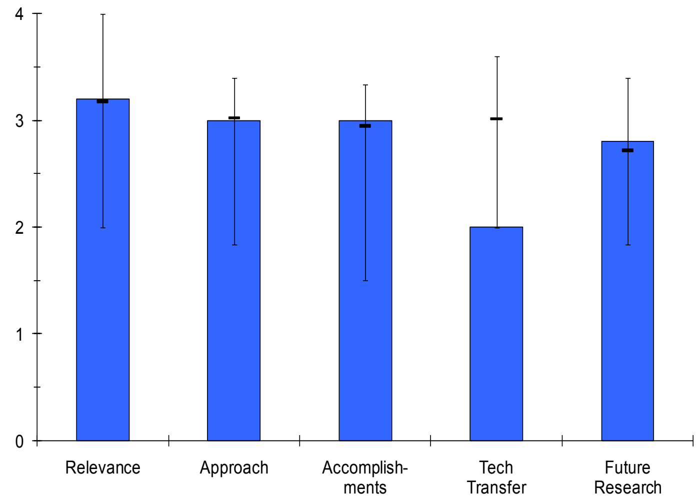
Project # AN-06: Analysis of Energy Infrastructures and Potential Impacts from an Emergent Hydrogen Fueling Infrastructure

Andy Lutz and Dave Reichmuth; Sandia National Laboratories

Brief Summary of Project

The objectives of this project are to 1) use dynamic models of interdependent infrastructure systems to analyze the impacts of widespread deployment of a hydrogen fueling infrastructure and 2) identify potential system-wide deficiencies that would otherwise hinder infrastructure evolution, as well as mitigation strategies to avoid collateral effects on supporting systems. Transition to hydrogen fueling is expected to rely on distributed steam-methane reforming; we must understand the impact of hydrogen vehicles on the infrastructure.

Overall Project Score: 2.9 (5 Reviews Received)



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.2** for its relevance to DOE objectives.

- It is good that this project considers plug-in hybrid electric vehicles (PHEV) and conventional vehicles as competitors to hydrogen vehicles. This is a critical point for the DOE program to understand. The project answers important questions about feedstock supply limits.
- Good relevance to look at the transition in light of other competing vehicles.
- The project is critical to the Hydrogen Program and supports DOE RD&D through Task 1, Perform Studies and Analysis, addressing barriers A, B, and E.
- Not certain how useful this work is since it only looks at one part of the picture (forecourt steam methane reforming [SMR]) regarding infrastructure and only two vehicle technologies [PHEVs and hydrogen fuel cell vehicles [HFCV]).
- Not certain of relevance of looking at plug-in hybrids and other vehicles. They are competing technologies; however, the projected timelines to commercialization are different.
- This project addresses a major issue.

Question 2: Approach to performing the research and development

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

- The approach presupposes market share between gasoline, PHEVs, and HFCVs. The prior work that determined the market share does not consider the possibility presented in this project − that the increase in natural gas price makes HFCVs expensive to operate and therefore lowers their market share.
- The Energy Information Administration (EIA) projections for gasoline price do not take into account the model's prediction that there will be no gasoline cars on the road.
- An iterative approach should be used to take into account how supply problems affect demand. In the present work, the demand is presupposed and its effect on supply is studied.
- A system dynamics model is a good way to look at the various possible scenarios and the design vs. unintended implications. This is similar to work being done by Massachusetts Institute of Technology (MIT), Shell, and Ford. The teams need to collaborate.

- This project addresses critical questions. In particular, at what HFCV penetration does the demand for natural-gas-derived hydrogen negatively impact natural gas distribution? Also, what conditions affect the competition between HFCVs and PHEVs?
- Night-time-only charging for PHEVs might not be realistic.
- While it is useful to look at competing vehicle technologies (PHEVs and HFCVs), it might also be useful to look at smaller, high efficiency internal combustion engine vehicles and diesel vehicles that can get 30+ mpg.
- It is recognized that the SMR is only an interim technology for hydrogen fueling applications, so looking at SMR out to 2020 and beyond might not be very realistic. Instead, the project should look at renewable hydrogen production technology cases for the long term.
- The approach requires many assumptions, some of which are questionable. Limiting current modeling to California was a good move.

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

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

- Work makes a clear case that penetration of hydrogen vehicles will be severely limited by availability of natural gas. This is the most important outcome of the work.
- This is a fair projection of the issues presented. Scope could be much wider in terms of looking at other parameter impacts, policy, geography, regulations, etc.
- This study looks at a very real limitation of the adoption of fuel cell and plug-in hybrid electric vehicles on the existing infrastructure with some very sobering conclusions.
- It is doubtful that oil will be at $140/barrel if the forecast of PHEV and HFCV rollouts holds true.
- While it is useful to learn about the natural gas supply capacity in the future in anticipation of alternative vehicles, it is also important to understand whether the current natural gas pipeline networks can support the spike in demand in the future.
- It is too early in the program to have significant overall accomplishments, but the California results looked quite promising.

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

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

- Need to collaborate with industry and other academic entities doing similar work.
- This project needs industrial and governmental collaborators.
- The project could work more with other institutions to review and validate model.
- No collaborations were mentioned except using some results from MIT and ORNL.

Question 5: Approach to and relevance of proposed future research

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

- The additional work is in the right direction but the primary barrier to overcome is understanding the interaction between supply limit pressures and consumer demand.
- Good description of the proposed future work and milestones.
- Model will be expanded to the production of hydrogen from electrolysis. More renewable inputs should be examined.
- Perhaps the project can look at cost penalties from the infrastructure side for the energy providers (numbers of station and capacities).
- Consider closer look at GHG and other renewable hydrogen production technologies.
- Planned continuation seems appropriate and includes additional collaborations.

Strengths and weaknesses

Strengths
- The project establishes supply limitations on vehicle penetration.
- It is the right approach to look at a very complicated transition scenario.
- This is realistic modeling that looks at limitation of existing infrastructure.

Weaknesses
- The model presupposes market share, which in fact will be affected by the supply limitations predicted by this model.
- Need to validate some of the results.
- There are not enough renewable inputs or scoping for renewable inputs.

Specific recommendations and additions or deletions to the work scope

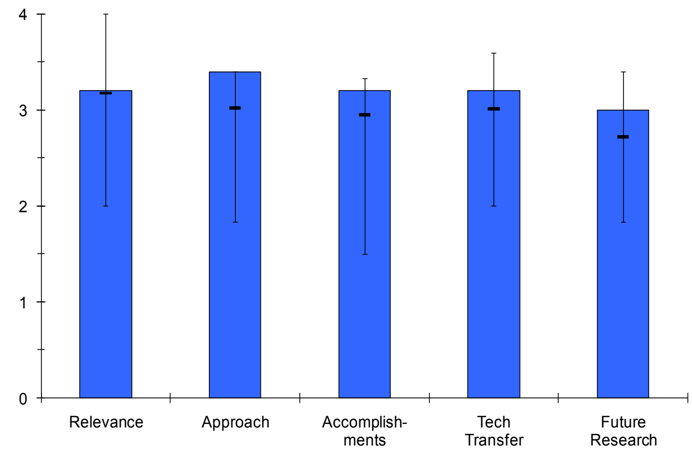
- Consider all-electric vehicles as another competitor.
- Must use iterative approach for supply and demand.
- Propose incorporating biofuels impact as another competitive choice.
- Add more renewable inputs and the effect of additional natural gas pipelines or liquid natural gas terminals in California.
- Continue as planned.

Project # AN-07: Hydrogen Deployment System Modeling Environment (HyDS-ME)
Brian W. Bush; National Renewable Energy Laboratory

Brief Summary of Project

The objectives of this project are to 1) evaluate and update the Hydrogen Deployment System Modeling Environment (HyDS-ME) to assess the state of its tools and to propose and implement enhancements, 2) perform scenario analysis and exercise the enhanced tool on a national case study, 3) expand the interoperability of HyDS-ME with tools such as the Hydrogen Demand and Resource Analysis (HyDRA) Tool, and 4) perform scenario analyses to understand how coal gasification with carbon capture and storage systems might be introduced to serve western markets.

Overall Project Score: 3.2 (5 Reviews Received)



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.2** for its relevance to DOE objectives.

- The project is very well aligned with the analysis barriers, but it is not clear how it is aligned with technical barriers. Does it enable a better or more easily deployable infrastructure? Researchers should consider how to measure their progress against the bottom line.
- Good tool to look at optimized hydrogen infrastructure rollout possibilities. It is quite critical that reliable manufacturing, supply, and retail data are used for doing the analysis.
- This project is critical to the DOE objectives under Task 1, Perform Studies and Analysis, and Task 2, Develop and Maintain Models and Tools, addressing barriers, B, D, and E.
- Relevant to assist energy providers in deciding the best location to install hydrogen fueling stations at a regional level.
- It is more relevant for the model to integrate well with other models in order to provide valuable data on resource availability, hydrogen demand, costs, etc.
- Generally very relevant, but does not (and probably could not) include many intangible factors that will influence production sites.

Question 2: Approach to performing the research and development

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

- Project used the DOE Hydrogen Analysis Model (H2A) to build empirical correlations for infrastructure deployment. It is demand-driven and takes most important market forces into account.
- Good approach to use existing/other tools and not recreate something. Tool integration planned to be seamless and scalable. Flowchart displayed showing various interactions.
- The model integrates production, transmission, demand, and feedstock costs to predict the delivered cost of hydrogen. The model is transparent, flexible, scalable, and maintainable.
- Model optimization approach is useful to decide on production and transmission technologies based on demand and feedstock price forecasts (temporal and spatial).
- Model appears to have some flexibility for continual updates to reflect the latest changes.
- Given the fact that the model incorporates inputs/information from various models, it is critical to closely examine key assumptions of the models to avoid overlap and conflict information (too many assumptions could lead to erroneous output).
- Generally good, but requires many assumptions which limit the value of any specific numbers.

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

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

- Nice, iterative approach that simulates the market-driven deployment of hydrogen infrastructure. Will be very useful in making decisions on future infrastructure programs.
- Clear presentation of milestones and status; it is quite useful to look at progress in that format.
- Simulation results presented only at a very high level; need to look at them in further detail.
- Need to look at the existing infrastructure and possibility of adding on to or taking out from the base state.
- Accomplishments included optimizing 20,000 lines of code and completion of several studies. It would have been nice to see these published in the peer-reviewed literature.
- Appears to have generated quite a bit of data. Need to focus more effort on carbon capture and sequestration and scenarios for places outside of California. Need to also consider the logistics, geopolitical aspect, and feasibility of installing hydrogen pipeline within a regional area. Perhaps this area is being looked at by other models.
- Apparently, a great deal has been accomplished relative to the original planned work.

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

This project was rated **3.2** for technology transfer and collaboration.

- This project unifies several analysis efforts.
- There are a good number of collaborators. Need to involve other industry partners.
- Several national laboratories and an engineering company, but the project needs more industrial collaborators.
- Good collaborations with H2A and Macro-System Model. Perhaps the model needs to be looked at and validated by industry experts in the area.
- Several good collaborations noted.

Question 5: Approach to and relevance of proposed future research

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

- It is the right idea to look harder at feedstock availability effects.
- The proposed future work should include the timeline for when it will be completed. Also, need to validate the assumptions from an infrastructure industry player.
- Model will be applied to more elaborate scenario analysis.
- Consider expanding model study to outside of California. Looking at additional key constraints will be useful.
- Proposed work seems appropriate based on material presented.

Strengths and weaknesses

Strengths
- The model is market-driven, iterative, and connects a suite of predictive analysis tools.
- The approach of geographic infrastructure optimization is nice and can be useful.
- Optimized code for powerful transparent analysis is a strength.

Weaknesses
- Unclear connection to technical and market barriers.
- Need to involve an industry collaborator for validation and feedback.
- Need more comparison with renewable resources.
- There are so many assumptions that isolated results could be questionable. Best use is probably for trends and first comparisons.

Specific recommendations and additions or deletions to the work scope

- Include a model validation step.
- None.
- Not clear that program should be expanded after current planned work is completed.

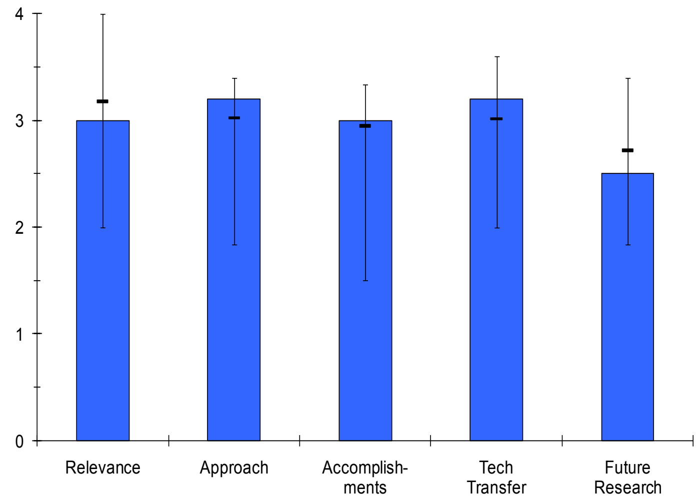
Project # AN-08: Analysis of Hydrogen Production and Delivery Infrastructure as a Complex Adaptive System

George S. Tolley; RCF Economic and Financial Consulting, Inc.

Brief Summary of Project

The purpose of this project is to use agent-based modeling to address the "chicken or egg" problem between the supply of hydrogen fuel and the purchase of hydrogen vehicles. The overall aim is to answer two questions: 1) Will the private sector invest in hydrogen infrastructure, and 2) What, if any, policy assistance is needed? Objectives for 2008-2009 are to 1) add finishing touches to the model, 2) carry out parameter sensitivity analysis, 3) conduct policy analyses, 4) do model validation, and 5) write the final report.

Overall Project Score: 3.0 (5 Reviews Received)



Question 1: Relevance to overall DOE objectives

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

- The analysis on issues of hydrogen-fueled vehicles competing with/replacing gasoline vehicles is in the interest of the DOE program. A would-be investor can use this report as a decision making tool and understand market behavior.
- The Hydrogen Production and Delivery scenario reports financial indicators as the individual investor's risk and decision analysis tools. The model appears to assume that there is no issue with hydrogen availability at cost and convenience similar to gasoline (failures are stated in the Policy scenario analysis). It is assumed in the final report that issues with hydrogen availability scenarios at costs competitive with gasoline will be discussed. Hydrogen availability at costs and convenience competitive with gasoline along with the financial predictors will make the analysis more complete.
- Evaluating market is critical for infrastructure deployment strategy. However, while the project predicts the choices, different "agents" might make it is unclear exactly what is to be done with this information. The project should lead to one or more strategic recommendations.
- Good premise. This is a very real issue. This is needed to best understand what incentives might be needed to spur development.
- The project is critical to the DOE RD&D objectives under Task 1, Perform Studies and Analysis, addressing barriers A, B, and C.
- Understanding of the parameters affecting market development is certainly important. The model addresses most questions.

Question 2: Approach to performing the research and development

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

- The work focuses on predictive financial models, competition from other investors, and parametric sensitivity; it also provides information for potential investors to make go/no-go decision.
- There are three drivers: legislation, market forces, and technical barriers. Hydrogen production technology cost, on-board storage, pumping stations, feedstock (renewable or fossil), and many other safety, emission, and environmental issues remain for commercial maturity of hydrogen production technology at quantities needed for the successful introduction of hydrogen vehicles. The study isolates these issues, although the issues are not mutually exclusive, and therefore the usefulness of the predictive models cannot be objectively ascertained.

- This is an intriguing approach. This project addresses motivations and is an important complement to other projects that take a purely mathematical approach to predicting market choices. Not clear how this approach addresses the barrier "lack of consistent data, assumptions and guidelines"; it seems to be more about performing a better analysis on the assumptions that exist.
- A comment was made that it does not consider alternative pathways to infrastructure, such as home fueling.
- The uncertainty is broad, and it's not clear that there are specific recommendations at this point.
- Project analyzes complex interplay of consumers, investors, geography and companies and assesses whether or not policy intervention is needed.
- Agent-based modeling is a good approach for studying this problem.
- This project has mostly been geared toward developing a model. But what about the continued use of the model, with the associated upgrading and stewardship of it? If the project is not continued in some fashion, the model will be relegated to past work.
- Unfortunately, this project was hard-wired for hydrogen, and therefore cannot easily be used to study other energy systems. This limits the way that the model can be used to evaluate hydrogen within the context of other energy options, or if hydrogen is not the only answer.
- Early transition is important, and solves the “chicken or egg” problem, but what about full commercial deployment or half-hearted adoption of hydrogen? Won't agents behave very differently at a mid- or end-point?

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

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

- The question is how an individual investor can and needs to be educated. The study results are based on 140 parameters (from the DOE Hydrogen Analysis Model [H2A]) and a variety of sensitivity analyses. The terms and analysis methodology may not readily comprehensible to an investor.
- The near-to-mid term negative discounted cash flow rates of return as reported in the financial indicator analysis results study does not suggest how best to interpret the information and may simply be a deterrent to a potential investor. The analysis reports the barriers, but could have discussed alternative assumptions and scenarios to overcome the barriers.
- The project takes into account sensitivities to many important factors, and concludes that "if parameters are right," there will be investment in hydrogen. It is not clear what those parameters need to be in order to overcome barriers.
- As presented, the graphs are somewhat confusing and not easy to understand. Presumably, they are truly reflective of reality. It is not clear what inputs were used for assumptions for the graphs shown, such as hydrogen storage pressure (350 or 700 bar), cost of hydrogen, which source (i.e., reformer, liquid, gas), etc. Making the assumption that H2A is accurate enough to eliminate the need for a sensitivity analysis might not be a good assumption.
- A sensitivity analysis for various factors has been completed, and it appears to be useful.
- It is hard to tell what was accomplished this last year. However, this is an excellent set of results and a very useful model.
- It seems unreasonable to assume that all stations will grow in capacity utilization at the same rate.
- Very interesting use of comparative technology adoption scenarios. What would happen if the decision to adopt a technology were based on a real or perceived need (e.g., gasoline not available or way too expensive), rather than just an item to own (e.g., color television)?
- Why does a higher familiarity premium result in slower adoption?
- This is an excellent set of sensitivity analyses. What are the boundaries of the analysis, i.e., best case of all parameters tested and worst case of all parameters tested?

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

This project was rated **3.2** for technology transfer and collaboration.

- A national laboratory, auto manufacturing company, and oil producer are team members in addition to other hydrogen technology industries and industry advisors.
- Not clear how this fits in with other analysis projects in the program.

- Good list of partners from pertinent functions, provided that they were involved heavily. This was not clear.
- Excellent collaboration with a national laboratory and energy and automotive companies.
- Good team, but would like to know who the industry advisors were and what advice they provided.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.5** for proposed future work.

- The project is fully funded and ends in June 2009.
- Future work is aimed at providing a specific set of scenarios that would enable hydrogen investment. It is not clear that a comprehensive and actionable picture will follow from the work presented here.
- Project is effectively complete except for the report, so this future work proposed is not applicable. It was stated that there would be more recommendations in the report; if so, then that would be key to its effectiveness? It is difficult to comment without the report.
- Project is ending.
- Yes, the project is ending, but a slide should have been provided just in case additional funding is available for analysis activities. Or, if someone else (e.g., DOD) has money to continue this model, what would be your suggestions? How will the model live on, even if its development is not continued?

Strengths and weaknesses

Strengths
- Includes important sensitivity factors and an agent-based approach.
- Provides some realistic expectations for market penetration to start discussions.
- It will be a strength if specific recommendations are in the report that can further the rollout.
- Great model with lots of capability.

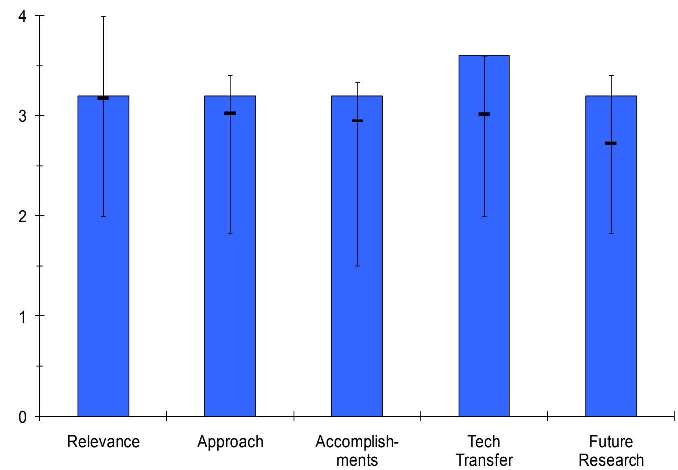
Weaknesses
- The project needs a more specific path to conclusions.
- This has been an expensive analysis compared to other programs.
- The conclusions and answers to previous questions are very broad and generic − they are somewhat obvious and not surprising.
- The model is only relevant to hydrogen. No plans for continued use of model.

Specific recommendations and additions or deletions to the work scope

- The potential fuel economy and emission regulation of gasoline vehicles may change hydrogen energy economy scenario. It is suggested that this scenario be included in the final report.
- The project is complete except for the final report.

Project # AN-09: Adapting the H2A Hydrogen Production Cost Analysis Model to Stationary Applications
Michael Penev; National Renewable Energy Laboratory

Overall Project Score: 3.2 (5 Reviews Received)



Brief Summary of Project

The DOE Hydrogen Analysis (H2A) Power Model allows for transparent and consistent analysis of new transition strategies. The H2A model's discounted cash flow model has been modified to perform distributed generation analysis. Hydrogen infrastructure costs for an early transition phase are large, and are relatively high risk due to the uncertainty of demand. Combining hydrogen production with combined heat and power (CHP) capability may reduce upfront costs and reduce investment risks. Hydrogen can be generated by electrolysis and fuel cell co-generation.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.2** for its relevance to DOE objectives.

- The predictive model reports cost information related to phased transition to hydrogen energy and, therefore, relevant to DOE Hydrogen Program objectives.
- One purpose of systems analysis is research guidance. In the hydrogen community, it appears the two groups are not communicating with each other and not using each other's results for advancing hydrogen energy technology overall. The audience pretty much gets to hear the same story each year at the Annual Merit Review, from either side, mutually exclusive.
- CHP is not going to make or break hydrogen infrastructure. This project considers the idea that CHP would make facility owners want to invest in tri-generation. There are still very significant compression and storage capital costs: the classic barriers to infrastructure adoption still exist, but they are lessened.
- This type of analysis showing an integrated infrastructure is very useful to maximize efficiency. Need to prove value (or not), which is the purpose of the model.
- Project has good alignment with the goals and objectives of the Hydrogen Analysis Subprogram as evidenced by its focus on evaluating transition strategies needed to introduce co-production of hydrogen for transportation applications at stationary fuel cell sites.
- Excellent description of how the project relates to meet DOE objectives.

Question 2: Approach to performing the research and development

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

- The models predicting transition to hydrogen energy economy are based on highly idealized assumptions and have not changed in the past few years to more realistic scenarios based on emerging new experimental, market, technology, or legislative information.
- The approach involves approximately $3,000/kWe capital and suggests that without Federal incentive, market diffusion of the technology is not an option. This is somewhat understood, and a detailed modeling effort may be redundant.
- The highly competent team does not address the assumption that a CHP plant capital of $3,000/kWe is not cost-competitive; it is ~3 times more than today's proven, rapidly environmentally progressing coal-fired plants.
- The system analyses results are informative but do not seem to help to really move the hydrogen energy technology potential forward along the program's defined technology development road map.

- There are a lot of factors in the model: electrolysis, CHP, etc. The question to answer is simple: does CHP enable a hydrogen infrastructure?
- Seems to have addressed major variables.
- Good approach to the "chicken or egg" issue for introducing hydrogen sites and hydrogen vehicles in a timely, well-coordinated time frame. Co-production of hydrogen coupled with CHP would accelerate the introduction of hydrogen stations with minimal risk.
- All aspects of co-production of hydrogen and power are included.
- The modeling assumptions are consistent and practical.
- Connecting with industry for input and review is very productive.

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

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

- The analysis is very well done and well presented. Hydrogen co-production is claimed to be practical and economical, but compared to utility industry economics, is not clear. If CO_2 capture and sequestration cost is added, even though lower CO_2 emission is predicted under ideal production cases, the reported options become cost-intensive.
- The model accomplishments predicting greenhouse gas (GHG) emissions, etc. do not address the adoption barriers. The work should focus on the factors that influence deployment of fuel cell CHP systems and the case for CHP system owners making the additional capital investment required to co-produce hydrogen.
- The analysis seems complete and was well presented. It is in a clearly understood format.
- Tri-generation of hydrogen by utilizing waste heat from high temperature fuel cell systems is an interesting approach to not only generate electricity, but also process heat and hydrogen. Good analysis of the need to optimize mix of applications at different times of the day. Good example model output for the U. S. Postal Service (USPS) site in San Francisco.
- Excellent results.
- Very good parametric analysis.
- Good application to real life applications such as the post office.
- Good recommendations on how to apply their work and results.

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

This project was rated **3.6** for technology transfer and collaboration.

- NREL, appropriate DOE offices, and Directed Technologies, Inc., are team members. Fuel Cell Energy, UTC Power, Plug Power, ANL, and SNL are also partners/reviewers.
- Works with existing fuel cell companies and includes relevant case studies.
- A good cross-section of partners was included.
- Good list of collaborators, but little detail on collaborations except for USPS.
- Excellent coordination with industry and other laboratories.

Question 5: Approach to and relevance of proposed future research

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

- Future work is a legitimate extension of current work.
- The future work as presented makes sense. Building in CO_2 reduction with the Macro-System Model will be a key with future regulation.
- Would like to see more discussion on the USPS project. Aside from the analysis, is the USPS moving forward on this project and will they be privy to data to validate their model?
- The proposed plans are very useful and will produce helpful results for DOE and industry.

Strengths and weaknesses

Strengths
- Good collaboration and an interesting deployment model.
- This might have good applicability as a tool for customers to assess their suitability for fuel cell systems. It will be very useful to prove the value to people who otherwise would struggle with the complexity.
- Modeling co-production of hydrogen for transportation – this is an important approach to overcome the "chicken or egg" issue for HFCVs.
- This is a comprehensive model.
- Engaging all stakeholders is great.
- Good return on DOE funds with 85% work done at <50% funds spent.

Weaknesses
- The model does not focus on what this reviewer believes to be the primary barriers to hydrogen adoption.
- The output needs to be validated compared to a real-life installation.
- None.

Specific recommendations and additions or deletions to the work scope

- The future work should also consider the impact of potential fuel economy and emission standard legislation of gasoline-powered cars.
- A model for renewable supply would be very useful.
- Can you include effects of NO_x, SO_x, CO_2, and VOC emissions and monetize them?
- Include universities and national laboratories as possible demonstration sites.

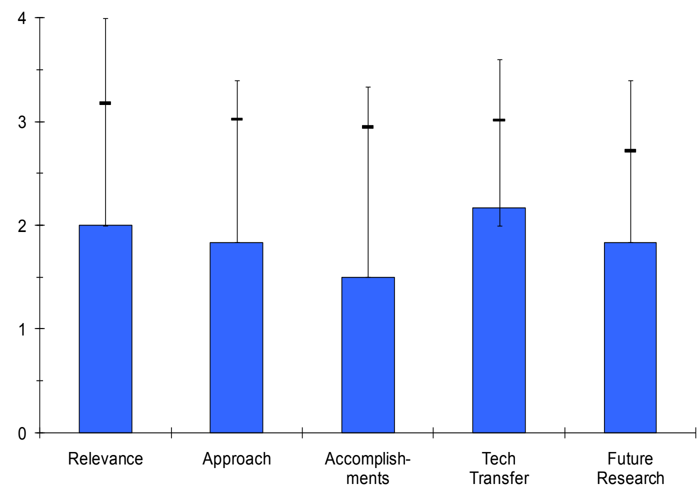
Project # AN-10: Hydrogen and Fuel Cell Analysis: Lessons Learned from Stationary Power Generation

S.E. Grasman; Missouri University of Science and Technology

Brief Summary of Project

The objective of this project is to collect and articulate lessons learned from past experiences that can improve future decisions related to hydrogen fueling infrastructure development. Project objectives are to 1) to consider opportunities for hydrogen in stationary and portable applications in order to make recommendations related to research, development, and demonstration strategies and 2) analyze the different national and international strategies utilized in existing systems and identify the different challenges and opportunities for producing and using hydrogen as an energy carrier.

Overall Project Score: 1.8 (6 Reviews Received)



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.0** for its relevance to DOE objectives.

- The project objectives are relevant to DOE Hydrogen Program goals. The approach-milestone checklist is quite informative.
- A stated objective is R&D guidance based on system analysis results; however, no such recommendation can be gleaned from the presentation.
- The presentation is mostly a checklist of activities, ongoing or past. A member of the audience new to this presentation cannot have many "take home" messages.
- The project is a survey of existing fuel cell users and manufacturers. The researcher states that this will give important market knowledge and lessons learned.
- The objectives are too broad for the amount of analysis. The intent is good, but it is difficult to grasp how this study, for example, can "model and analyze the hydrogen supply network" among several other equally broad objectives.
- Project is reported to be a “lessons learned project” to assess the issues that stationary fuel cell developers are experiencing, which if properly carried out, could have an impact to identify critical issues that need to be rectified. However, no substantive details were provided on critical issues.
- Lessons learned from stationary fuel cell experience are of good relevance, in principle, to apply to other programs.
- This is a typical market research type study approach, but it is unclear exactly know how it fits within the prescribed R&D scope of DOE.
- Some description of relevance in the presentation.
- Not quite clear how it meets DOE goals or which barriers it overcomes.

Question 2: Approach to performing the research and development

This project was rated **1.8** on its approach.

- Well-defined approach, consistent with achieving intended results. Approach is relevant to diffusion of early market entrance of hydrogen technologies.
- The survey, as presented, appears simplistic. It is not clear about how it will contribute to overcoming the stated barriers of technology validation and predicting future market behavior.

- This appears to be a qualitative "survey" as opposed to a quantitative, scientific process. It also appears to be subject to "self-selection," both in selecting the sample population as well as getting the responses. Too many variables for the amount of data. The results are not likely to be meaningful or conclusive, and there is risk that false conclusions cold be drawn.
- Approach appears to involve development of a Web-based survey, literature reviews, and site visits. No discussion of the types of questions and level/details of responses was presented.
- Data collection is based on survey rather than a more methodical approach of collecting inputs from industry. General survey does not necessarily reveal key lessons learned. Milestones are activity-based rather than meeting some key targets.
- The approach portion of the presentation is inadequate.

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

This project was rated **1.5** based on accomplishments.

- Technical objectives and barriers were not addressed in a manner comprehensible to the reader. The value and applications of the technical accomplishments are not clear; it is difficult to interpret the information. What problem needs to solved for early market penetration of hydrogen energy is not understood, nor does the study identify what challenges and opportunities exist in order to produce and use hydrogen as an energy carrier in a market-competitive scenario.
- The results presented are unspecific and not really actionable. The insights gained from the work, as presented, do not seem to tell us anything we do not already know about fuel cells.
- The survey is likely to be somewhat subjective. There were also comments from previous years about manufacturer input, but that perspective on the applicability of various markets and technologies (e.g., PEM vs. SOFC vs. MCFC) can skew this survey. It is also not clear how survey results could be affected by one particular manufacturer's good (or bad) equipment.
- Progress presented appears to be a list of the number of respondents, sites visited, and reports analyzed. Details on typical responses are lacking.
- So far, the project team has created a Web-based survey with 100 respondents. Don't know how/why this is called a "technical accomplishment"?
- The presentation included only general learnings, nothing new or surprising.
- Relevance of survey results not adequately presented.

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

This project was rated **2.2** for technology transfer and collaboration.

- Missouri University of Science and Technology is the lead. Other team members, if any, are not listed.
- Collaboration consisted of site visits and meetings with manufacturers.
- This activity does not seem to interact well with the other DOE analysis programs. Not sure how it would tie in. Some contacts with manufacturers, but report could have made this participation more clear.
- The fact that they had numerous responses and site visits shows a good degree of collaboration, but the collaboration appears to be one-sided. No indication of how the responses and analysis are being used as feedback to collaborators to share experiences and solutions.
- No collaborators to assess.
- Not clear how this was achieved.

Question 5: Approach to and relevance of proposed future research

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

- Future work is listed.
- Scope of future work is not specified.
- This is not really applicable since the program is finalizing its report at this stage.
- No follow-on work proposed.

- Proposed future work mostly includes sharing learning.
- No clear path related to DOE goals.

Strengths and weaknesses

Strengths
- None.
- The idea is very good.

Weaknesses
- The two slides on Technical Accomplishments & Progress are not comprehensible. What an investor should interpret from the information presented is not clear.
- This project does not appear to lead to a useful conclusion.
- The span of types of fuel cells, applications, and time (e.g., widely varying usage history) makes the data too sparse in any one area and not easily comparable.
- This project appears to be a literature search of limited value to fuel cell industry. It is unclear how results/findings are of sufficient detail to be useful.
- Survey-type project that is non-technical; not clear why DOE is funding this.
- The data analysis appears to be inadequate.

Specific recommendations and additions or deletions to the work scope

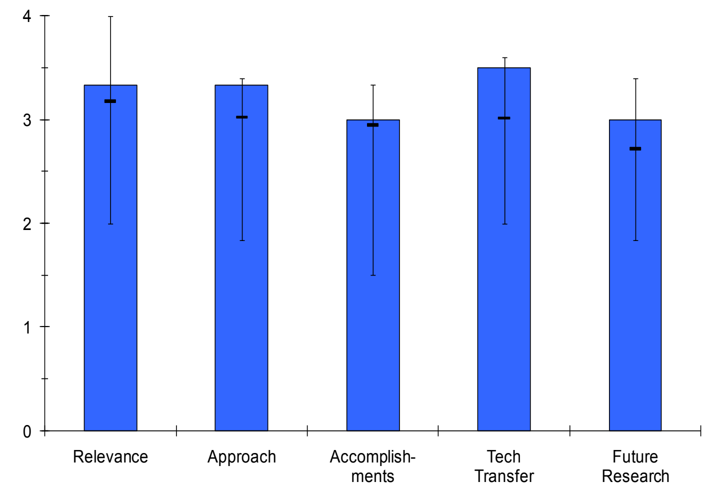
- A statement like, "The role and use of hydrogen fuel cells in stationary and portable applications can be significant," is difficult to interpret. Market is not yet ready to quite accept this inference, although similar statements have been made during the last several years.
- The presenter needs to interpret the model results for the reader and audience. The PI needs to use more realistic assumptions in system analysis studies.
- Project cost seems very high given the scope as presented.
- Too late at this point, but if meaningful input is desired, then narrow the scope to a specific type of fuel cell and applications.
- It is not likely worth gathering any additional data (unless a more precise methodology is established and a there is a greater sample to draw from) or pursuing any further activity past the project conclusion.
- Terminate project.
- This project should not be within the DOE Systems Analysis scope.
- Better presentation of data by customer-choice parameters would help better interpret the data.

Project # AN-11: Modeling the Transition to Hydrogen

Paul N. Leiby, David L. Greene, Zhenhong Lin, David Bowman, and Sujit Das; Oak Ridge National Laboratory

Brief Summary of Project

Overall Project Score: 3.2 (6 Reviews Received)



This project addresses the need for transformational and long run analysis of hydrogen and fuel cell vehicle market potential, using valid and consistent data from the program. The project supports benefits analysis and greenhouse gas/energy security impacts analysis. By updating and improving the HyTrans (hydrogen transition) integrated market model, the approach is to develop a dynamic market simulation model integrating fuel production and delivery pathways, vehicle technologies and production costs, and consumer choice. In FY 2009, ORNL will 1) complete analysis of storage technology cases, 2) develop model-capability and scenarios to integrate early hydrogen transportation and stationary power in early market, and 3) incorporate global trends and explicit representation of uncertainty.

Question 1: Relevance to overall DOE objectives

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

- The work aims to determine the true potential and possibility of hydrogen vehicles using credible transition scenario analysis, and it is highly relevant to program objectives.
- This work provides an important insight on quantifying the effect of performance to target parameters on the market penetration of hydrogen vehicles.
- The intent is excellent, provided that it is done correctly.
- The project is well aligned to meet DOE goals and to develop an analytical tool to model the transition to a hydrogen-based transportation economy and the impact of achieving critical DOE technical goals on the timing of the transition.
- Good relevance to determine the scenarios for transition to the hydrogen economy.
- Analysis emphasizes estimation of different scenarios, including if partial goals of DOE Storage Technology are met.
- Exploring synergy between stationary and transportation applications is quite useful.

Question 2: Approach to performing the research and development

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

- The intended results are bulleted and comprehensible to the reader.
- The attempt to develop an integrated model of all major components of hydrogen fleet addressing market and technical issues fully supports the DOE Hydrogen Program goals.
- The project team realizes what information the analysis should provide to the appropriate stakeholders, and attempts to accordingly fill the knowledge and information gaps.
- An integrated approach is so much more comprehensible; discreet approaches seem to contradict one result with another.
- One of the few projects in this field that includes all the relevant vehicle choices in the model.

- As discussed even in the report, input assumptions are key to the validity of the model. It will be difficult to look at all the potential combinations and permutations, although that is the effectiveness of the model. It is also subject to being manipulated to show the "desired" outcome. For example, the inputs shown in the presentation for battery and fuel cell costs seem very aggressive.
- Good analysis in that it includes competing technologies (i.e., advanced gasoline, gasoline hybrids, and hydrogen fuel cells). There does not appear to be any evidence that hydrogen internal combustion engine vehicles are modeled.
- Good approach to make use of existing models/data and project the transition. It is quite critical to have the right policy inputs/scenario and use the correct data from industry regarding current status of vehicles and infrastructure.
- The market simulation and coordination with Europeans is very useful.
- Focusing the tool on the "chicken or egg" problem to help transition to hydrogen economy is very relevant and productive.

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

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

- Results are insightful. However, there is now a third driver, and the project team needs to consider that. The driver is the potential legislation of fuel economy and emission standards of gasoline-powered vehicles. This new factor is highly inclusive for studies on market acceptability and technical barrier issues for hydrogen vehicles that need to be overcome. Crude prices may fluctuate some, but perhaps will not impact fuel-cell-powered car production to any significant extent, and there is competition from all electric cars. The growth projection for the hydrogen fuel cell vehicles (HFCV) from 2015 (only 6 years from now) may not apply. The scenario analysis presents impact for not meeting DOE high-tech goals for storage costs, and the information tends to indicate that HFCV is more of a "no-go." The work presents more "what if" analysis results. Decision makers cannot rely on speculative information as decision tools.
- This project synthesized a large number of existing models, provided a lot of unique functions, and demonstrated relevant outputs.
- Barriers are vague and somewhat general. This year it seems most effort is on software-related issues and not "real analysis."
- A lot of cautionary interpretations/incomplete results are reported suggesting the progress is slow.
- Would like to have a more structured view of the technical accomplishments. What were the proposed milestones and how/when were they accomplished?
- The transition analysis published in FY 2008 is clearly a major accomplishment. Not sure if the shared results today represent new learnings beyond that publication.
- The three-dimensional plots of delivery costs presented were not very clear. Two-dimensional plots may be better.
- The addition of PHEV types is a good improvement to the existing model.
- Results shown compare the cost of hydrogen storage (current vs. goal) and the impact. This is quite useful.
- The result presentations showed that PHEVs and HFCVs are very comparable. Does this mean HFCVs may face a serious challenge in successful commercialization?

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

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

- Coordinated collaboration with relevant stakeholders including U.S. auto manufacturers, other national laboratories, university, and fuel cell manufacturer and marketer will generate credible information acceptable to decision makers.
- Incorporates existing models and provides a good framework.
- There appear to be a number of partners and collaborators across a wide range of specialties, including government, industry, and academia. Assuming that they are actively involved, this is encouraging.
- Excellent coordination and collaboration with other modeling efforts at sister laboratories as evidenced by future incorporation of results from the Powertrain Systems Analysis Toolkit; DOE Hydrogen Analysis Model;

and Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model into the Hydrogen Transition Model.
- Why were there no collaborations with the energy industry?
- Very good coordination with NREL, ANL, and University of California-Davis.
- Getting input from auto and fuel cell suppliers is very productive.

Question 5: Approach to and relevance of proposed future research

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

- Legitimate future work proposed by extending scope, including sensitivity analysis and benefits assessment.
- In addition to storage cases, the project should also consider feedstock supply scenarios as potential limiting factors to deployment.
- Given the task at hand, the approach forward seems logical.
- Effort will include co-production of hydrogen at stationary fuel cell sites.
- No mention of transition scenarios with PHEVs, biofuels, etc. in the proposed future work. Otherwise, seems like a good list.
- Shared fueling structure concept offers a fresh option to help transition to hydrogen economy.
- Hydrogen CHP system evaluation is timely and useful.

Strengths and weaknesses

Strengths
- This is a very comprehensive market model. It unifies other good analysis work.
- If done correctly, the tool can be very useful to understand sensitivity of various inputs. A "roll-up" of the models is really needed to understand the bigger picture.
- Prediction of market share of competing technologies into the future is a strength.
- Good skill set of people involved in the project.
- ORNL experience in model development is a plus.

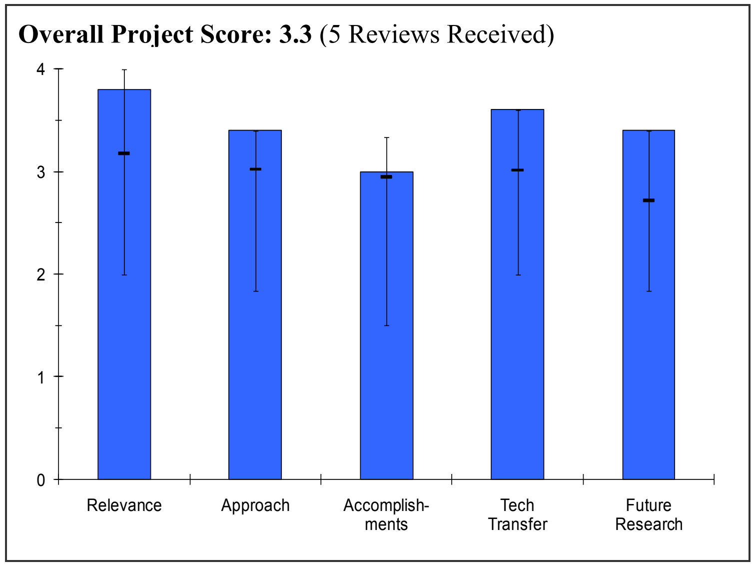
Weaknesses
- This is the integration of multiple models, each of which having their own potential errors or inaccuracies. These may be compounded as the individual models are connected.
- Lack of buy-in from energy industry and the government.

Specific recommendations and additions or deletions to the work scope

- Future work should consider three drivers: market, technology, and regulation.
- Consider effect of supply pressures on feedstock cost in vehicle choice model as studied by Lutz (Project Number AN-06).
- A method to validate that the results are "accurate" will be important to trust the results.

Project # AN-12: Fuel-Cycle Analysis of Fuel-Cell Vehicles and Fuel-Cell Systems with the GREET Model
Michael Wang, Amgad Elgowainy, and Jeongwoo Han; Argonne National Laboratory

Brief Summary of Project



The objectives of this project are to 1) expand and update the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model (GREET) model for hydrogen production pathways and for applications of fuel cell vehicles (FCVs) and other fuel cell systems, 2) conduct well-to-wheels (WTW) analysis of hydrogen FCVs with various hydrogen production pathways, 3) conduct life-cycle analysis of hydrogen-powered fuel cell systems, 4) provide WTW results for Hydrogen efforts on the Hydrogen Posture Plan and the Multi-Year Program Plan, and 5) engage in discussions and dissemination of energy and environmental benefits of hydrogen FCVs and other fuel cell systems. Data were obtained for hydrogen production pathways (from open literature, DOE Hydrogen Analysis Model (H2A) simulation results, process engineering simulations) as well as hydrogen FCVs and other systems (from open literature, Powertrain Systems Analysis Toolkit simulations, data from industry).

Question 1: Relevance to overall DOE objectives

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

- The project objectives, especially the WTW analysis of hydrogen FCVs with various hydrogen production pathways, are consistent with DOE Hydrogen Program objectives.
- Development of this model is critical to understanding production pathways.
- The GREET model has been extremely relevant and useful in doing WTW analysis of various pathways. It is a critical enabler for the hydrogen economy.
- This project seeks to expand and update the GREET model, which enables WTW analysis of unwanted atmospheric emissions under different scenarios.
- Environmental modeling tools of this sort provide confidence in the ability of the fuel cell program to deliver intended environmental benefits.
- This work is essential for the quantification and comparison of energy use and emission reduction benefits for alternative technologies.

Question 2: Approach to performing the research and development

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

- The approach is fairly general, obtaining data from known, available, and public-domain sources. The project team uses the tools to analyze, validate models, and present WTW results. A variety of scenarios on vehicle types, fuel options, power generation mixes, and hydrogen production pathways were considered, and the presented results are insightful.
- Recommend a consistent figure of merit to compare different pathways. This could be minimization of kilowatt -hours of fossil fuels or minimization of kilowatt-hours of imported energy, for example.
- Detailed analysis of various pathways with good background knowledge serves the project well and offers good credibility to this program.

- The investigators obtained the necessary data from appropriate sources, programmed it into the GREET workbook (Microsoft Excel), and demonstrated its application.
- Data collection, which is from multiple sources, is an important aspect of the ongoing effort to validate data sets and to verify results.

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

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

- The predictive models present results that appear consistent with conventional wisdom. PHEVs based on steam-methane reforming (SMR) or electrolytic hydrogen will reduce petroleum use. What is missing is cost-competitive and environmentally acceptable hydrogen availability and hydrogen infrastructure. It is not clear if such parameters are considered in the model assumptions.
- Conventional hydrogen production technologies are CO_2-intensive. Advancements are not yet mature in the areas of hydrogen production technologies, feed stock availabilities, product recovery, storage, use, and distribution in a cost-effective, environmentally acceptable manner. How these factors affect the study results and conclusions are not clear.
- Carbon dioxide management approaches in a distributed power generation scenario are not discussed and could be cost intensive. Results do not indicate if this factor was considered in analysis.
- Cannot evaluate progress since the project is "ongoing" and does not appear to have performance milestones at specific times.
- Plug-in hybrid electric vehicles (PHEV) are now included in the GREET model, which is a good and relevant addition.
- Combined heat, hydrogen and power (CHHP) is also useful addition and a positive technical accomplishment.
- Need to look a structured progress update (progress vs. proposed milestones).
- A new version of GREET (v. 1.8c) was released.
- Fuel-cycle studies of forklifts and distributed power generation (prime early-adopter markets) were published just last week. (These data were in last year's review.)
- Preliminary results for a hypothetical CHP system address another prime early-adopter market.
- The principal results on slides 9 and 10 demonstrate the use of the GREET model to compare petroleum use and greenhouse gas emissions under different (mostly PHEV) scenarios. However, the data of the last three bullets would be a lot more meaningful if some form of uncertainty analysis was provided in each case. Its absence over multiple studies indicates a systemic weakness that can be improved.
- The incorporation of the evaluation of forklifts and distributed power generation are important additions to the public version.
- The ongoing PHEV and CHHP work will also be important additions to the public version.

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

This project was rated **3.6** for technology transfer and collaboration.

- A team of several national laboratories and industry partners are involved. The contribution(s) of each team member is not described.
- Very good coordination with academia and industry. The model is widely accepted and used as the benchmark tool for WTW analysis.
- There is a high level of collaboration in the acquisition of the data to build the GREET model.
- The GREET model is publicly available on the project website, which encourages its wide adoption and use.
- Excellent collaboration with industry to obtain data.

Question 5: Approach to and relevance of proposed future research

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

- Landfill gas is not carbon neutral or negative. Many analyses over years have worked on "early market applications," but a market transformative technology scenario has not evolved yet.

- Consideration of PHEV and electric grid is very important.
- Biogas/landfill gas would be a good addition to GREET; so would an expansion on PHEV and CHHP capabilities.
- The proposed future work evidences a commitment to keep the GREET model relevant, broad-based, and user friendly.
- I encourage future work to quantify the uncertainty of the model parameters within GREET and to facilitate the propagation of those uncertainties through calculations.
- Good plan that builds on past success and future modeling needs, particularly related to improving ease of use.

Strengths and weaknesses

Strengths
- Technical expertise and background knowledge of people involved is a strength.
- Compilation of modeling data in publicly and easily accessible format is a strength.
- The model provides credibility for environmental benefit claims of the Fuel Cell Program.
- Continued relevance to evolving interests of the fuel cell program, e.g., early market opportunities such as forklifts, premium power, and CHHP systems.
- A strong team contributes to the continued success of this work.
- The addition of new technologies or new configurations in a timely manner is strength.

Weaknesses
- Need to increase collaboration with the energy industry.
- The lack of uncertainty/sensitivity analysis makes it impossible to distinguish precision of predictions, e.g., accurate to within a percent or two or simply a coarse estimate.

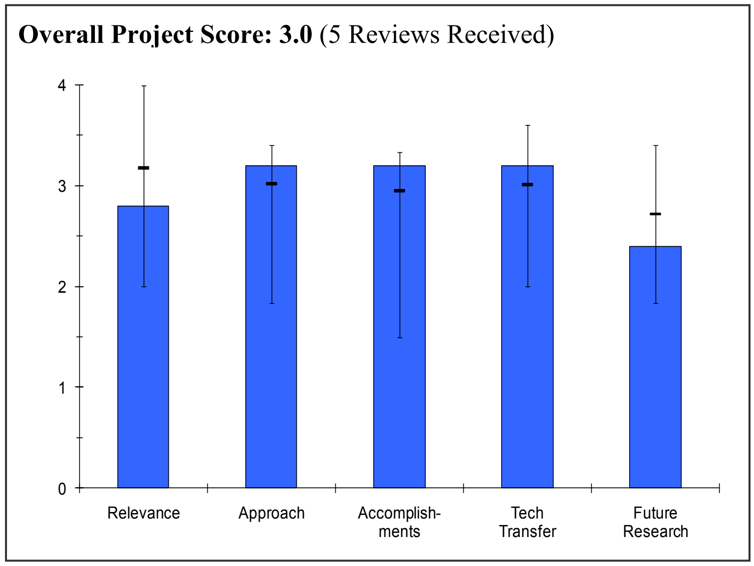
Specific recommendations and additions or deletions to the work scope

- New potential fuel economy and emission standard regulations need to be considered in future studies.
- All possible pathways for hydrogen production should be included.

Project # AN-13: Evaluation of the Potential Environmental Impacts from Large-Scale Use and Production of Hydrogen in Energy and Transportation Applications

Don Wuebbles; University of Illinois at Urbana-Champaign

Brief Summary of Project



The purpose of this project is to systematically identify and examine possible ecological and environmental effects from the production and use of hydrogen from various energy sources based on the DOE production strategy and use of that hydrogen in transportation and power applications. This project uses state-of-the-art numerical models of the environment and energy system emissions in combination with relevant new and prior measurements and other analyses to assess the understanding of the potential ecological and environmental impacts from hydrogen market penetration. In the process, DOE will be provided with a capability for further assessing current understanding and remaining uncertainties for addressing the potential environmental impacts from hydrogen technologies.

Question 1: Relevance to overall DOE objectives

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

- This is an important study of potential impacts of large-scale hydrogen production.
- This project is an amalgam of modeling projects to assess environmental benefits and consequences of large-scale adoption of production and use of hydrogen fuel.
- Environmental impact studies of this sort provide confidence in the ability of the fuel cell program to deliver intended environmental benefits.
- The objective of this project is to assess the potential ecological and environmental effect of large-scale production and use of hydrogen in transportation and stationary applications out to the year 2050.
- With the hydrogen technologies of interest to this program still being in their formative stages, such a study appears to be premature at this time.
- Ground-level changes in air quality pollutants are important to study, but focus should be on show-stopping concerns regarding stratospheric ozone.

Question 2: Approach to performing the research and development

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

- In part, the project uses standard models such as Community Atmosphere Climate Model with Chemistry (CAMChem) and Community Multiscale Air Quality Model (CMAQ) to compute the effects on the atmosphere from emissions under various scenarios.
- Other aspects of this project have tailored approaches that were not described in detail.
- The project uses a combination of measurements, modeling, and analyses. They use global effects models for air quality, ozone, climate effects, etc., and they are trying to assess sensitivity to hydrogen leaks and embrittlement effects on materials. These are important questions, but focus on troposphere seems to miss the point. From basic chemistry, you would expect regional air quality to improve with increased hydrogen availability. Need to move more quickly to stratospheric impacts. Ozone reduction in the stratosphere could be catastrophic to hydrogen future. And what about indirect greenhouse gas (GHG) formation? Why has team

spent so much time on troposphere? Should have started at the top of the atmosphere. Seems like you answered the obvious questions first.
- Are the right climate/atmospheric models being used?

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

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

- The project is very comprehensive. Estimate changes in concentration of all atmospheric species are likely to be affected.
- Project reports progress in several areas: a conclusion that atmospheric hydrogen is not a threat to metal structures; a conclusion that oxygen discharge from hydrogen production is probably not a problem; a model of hydrogen uptake by soil; and atmospheric impact analysis of emissions under certain scenarios for 2050. However, the results in all these areas would be a lot more meaningful if some form of uncertainty analysis was provided in each case. Its absence over multiple studies indicates a systemic weakness that can be improved.
- LANL partner is unfunded in FY 2009. They were at an impasse in gathering actual data of hydrogen emissions from typical industrial plants. There were also unspecified "setbacks in laboratory studies at LANL relating to equipment suitability."
- The project determined that hydrogen embrittlement and oxygen plumes from centralized hydrogen production by electrolysis would not be of concern.
- Hydrogen uptake by soils was difficult to understand from the way it was presented and discussed.
- Only the extreme case of all transportation conversion to hydrogen was considered for assessment of emissions changes for hydrogen, CO, NO_x, etc. The resulting ambient concentrations of O_3, CO, NO_x, etc. showed only minor changes; even the 25% to 40% increase in the ambient hydrogen concentration still led to less than 1 ppm hydrogen or so.
- It was not clear whether the analysis considered a static global fleet of vehicles or if it assumed the global vehicle fleet to grow at a certain rate.
- The global pollutant concentration maps shown were interesting, but the significance of the indicated changes was not clear. Also, the speaker could not explain certain features, such as why the summertime CO concentrations showed a decrease by two-thirds over the New York City area.
- The rate of progress on this project appears to be slow. The soil hydrogen uptake study interesting, but not worthy of focus. The oxygen plume study is also interesting. The leak measurement study very useful and important; it is good to spend future work on understanding leaks from other systems. Graph on slide 16 has way too much information to digest in a presentation. Suggest a breakout, different format, or interpretation at the bottom of the slide.

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

This project was rated **3.2** for technology transfer and collaboration.

- This is a joint project of University of Illinois at Urbana-Champaign, LANL, PNNL, University of Calgary, and Stanford University. While this is a nice, diverse set of institutions, the synergies are not clear. The institution reported the results, not the team as a whole.
- Even within UIUC, the two departments reported separately.
- The project collaborates with three other universities and two national laboratories, although at least one of those collaborations (with LANL) has not yet been successful due to external considerations.
- Lots of good partners; not clear what role each played. Not sure that coordination is tight because presenter actually said, "Someone else made this slide on our team, and I'm not quite sure what it's saying; I haven't talked to him directly."

Question 5: Approach to and relevance of proposed future research

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

- Complete switchover to hydrogen would result in less than 1 ppm of hydrogen in the atmosphere. Any future work should begin with an estimate of the effect on stratospheric ozone in the most extreme case. If this is not a cause for concern, then no additional work to refine the case is required.
- The future work is largely connected with studying hydrogen uptake by soil.
- Future work should be more clearly linked to specific issues that need resolving, relevant questions that need answers, or technology decisions that need be made.
- They propose to complete the ongoing analyses, incorporate new soil uptake measurements, and refine regional air quality models.
- Based on the overall very minor effects observed so far for even the extreme case of all transportation switching to hydrogen, such refinements are not likely to provide any additional meaningful insights.
- Consider the project done when it comes to the troposphere. It is time to move to the stratosphere. Soil uptake study is complete. Oxygen plume study is complete.

Strengths and weaknesses

Strengths
- Comprehensive study of the effects of a full-scale hydrogen economy.
- The strength of the project is the extent to which it seeks new measurements to serve modeling (e.g., soil effects and hydrogen emission studies).
- The project's major strength is the involvement of multiple disciplines in the study.
- Nice tropospheric modeling and mapping of regional air quality impacts.

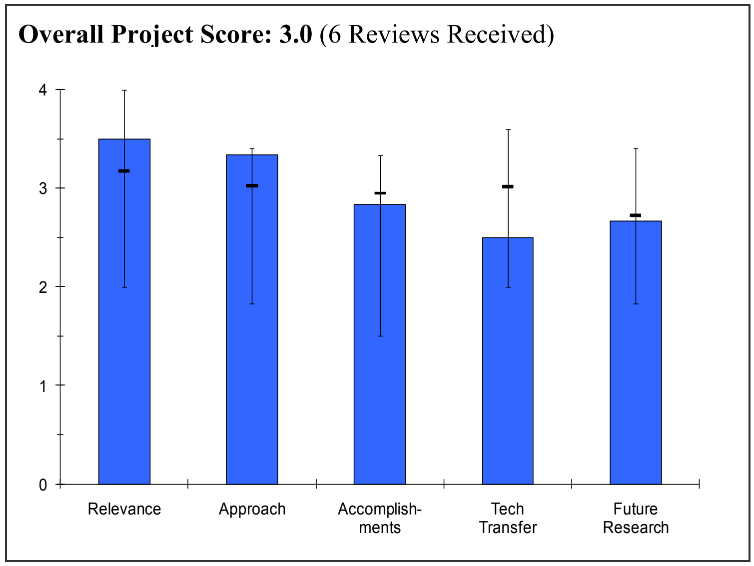
Weaknesses
- Project appears to be a disjointed collection of efforts, only loosely grouped around the common theme of assessing environmental impacts.
- Lack of uncertainty/sensitivity analysis makes it impossible to distinguish precision of predictions, e.g., accurate to within a percent or two or simply a coarse estimate.
- The major weakness is that the hydrogen technologies are still maturing, and the results of this study may be only a very preliminary first cut at the resulting assessments.
- Need to move above the troposphere.

Specific recommendations and additions or deletions to the work scope

- The project should not consider multiple scenarios: take the maximum case for hydrogen in the atmosphere and confirm that there are no ill effects.
- Reconcile overlaps with Project Number AN-14.
- The project is due to be completed in September 2009.
- It might be useful to assess the uncertainties in the different results obtained to date, rather than derive new ones, in the remaining months of the study.

Project # AN-14: Potential Environmental Impacts of Hydrogen-Based Transportation & Power Systems
Mark Z. Jacobson; Stanford University

Brief Summary of Project



The objectives of the project are to 1) compare emissions of hydrogen, the six criteria pollutants (CO, SO_x, NO_2, PM, ozone, and lead), and greenhouse gases (GHG) from near and long-term methods of generating hydrogen for vehicles and stationary power systems and 2) evaluate the effects of emissions on climate, human health, ecosystem and structures. The following will be developed: 1) market penetration scenarios for vehicles, 2) market penetration scenarios for electricity generation, 3) emission-profile databases, and 4) a soil uptake model. Changes in hydrogen and other atmospheric gases and aerosols in the troposphere and stratosphere will be predicted. Effects due to the implementation of two market penetration scenarios will be quantified.

Question 1: Relevance to overall DOE objectives

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

- The project seeks to determine the environmental benefits and consequences of hydrogen fuel production (and use) both by different methods of production and by comparison to fossil fuel production (and use).
- Environmental impact studies of this sort provide confidence in the ability of the Fuel Cell Program to deliver its intended environmental benefits.
- The project objectives could be clarified. Slide 3 gives an objective of evaluating effects of emissions on human health − something that would require an epidemiological study, which this is not. Likewise, this is not a study that directly evaluates effects of emissions on ecosystems and structures. The present study estimates atmospheric changes that result from predicted emissions as determined by atmospheric chemistry and physics. It also predicts certain climatic changes that may result.
- Assessing emissions of hydrogen and criteria pollutants for a technology that is still in its formative stages appears to be premature.
- This analysis is absolutely needed to explore showstoppers for hydrogen future.
- The study of the impacts of hydrogen concentrations in the troposphere and stratosphere address questions raised about the potential and unintended consequences of increased hydrogen use.
- The majority of the tropospheric impacts are from decreased criteria pollutants due to displacement of fossil-derived fuels.

Question 2: Approach to performing the research and development

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

- The most useful output would be to show pollution reduction benefits for a reasonable market penetration case and estimate stratospheric ozone effect of maximum hydrogen penetration.
- The investigators use the Argonne Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model (GREET) to estimate emissions under various scenarios and then use the highly detailed and computationally intensive Gas, Aerosol, Transport, Radiation – General Circulation, Mesoscale, Ocean Model (GATOR-GCMOM) model to predict the effect of these emissions on atmospheric composition and climate.

The results, detailed global maps of the characteristics of interest, are then differenced to demonstrate the difference in outcomes of the scenarios.
- They are analyzing components of the simplified hydrogen cycle (i.e., soil uptake, emissions, and concentrations of hydrogen and other gases in the atmosphere).
- They have defined the market penetration scenarios for vehicles and electricity generation.
- They are assessing quantitative effects of two different market penetration schemes.
- Excellent work in studying both the troposphere and stratosphere. Expansion of system to include status quo of fossil fuel vehicles excellent. Suggest looking at fossil-based hydrogen production transitioning to renewable hydrogen. Also, what about high-atmospheric loss of hydrogen to space? How will this change the balance of gases in the atmospheres? Need to look at secondary GHG formation and destruction. How does increasing cloud formation affect global albedo and, thus, temperature?
- Explicit modeling approach eliminates the parameterization issue, although this results in a large complex simulation that requires very long computer run times.

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

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

- The addition of a soil-uptake model to GATOR-GCMOM provides added refinement.
- The complexity of the GATOR-GCMOM model makes some results difficult to interpret. The effort the presenter took to explain slide 16, "Effects of Wind-HFCV on Global Climate and the Ozone Layer," illustrates this.
- The complexity of the GATOR-GCMOM model also makes uncertainty and sensitivity analysis difficult; nevertheless, results such as slide 16 would be a lot more meaningful if some form of such analysis was to be performed.
- There was a slight drift in study purpose from comparing effects of different methods of hydrogen production (slide 3) to comparing two 2050 scenarios, one with hydrogen (wind generated via electrolysis) and one without (slides 19-24). Again, uncertainty analysis would make these results much more meaningful and would calibrate expectations of how precise these results might be.
- They have shown reasonably good agreement between model predictions and several atmospheric parameters, concluding that the model is, thereby, validated.
- They then used this validated model to assess the hydrogen deposition flux, surface concentrations of hydrogen, and global changes in temperatures and ozone concentrations using the Intergovernmental Panel on Climate Change (IPCC) 2050 scenarios "A1B" and "A1B with hydrogen fuel cell vehicle penetration."
- Several global maps were shown as the results from 18-month-long simulations, but the significance of the relatively small changes in the various values was not made clear. Furthermore, the significance of the study so far was not readily apparent.
- Getting a better understanding on leak rates is needed. What about large accidental releases? How would sudden hydrogen plumes affect regional atmospheric chemistry?
- Good use of existing models and validating models. Good scenario setup and set of runs made in models.
- Test model predictions show excellent comparison to data.

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

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

- The level of collaboration seems appropriate to the task.
- The researchers are aligning their work to Argonne's GREET model.
- The only collaborations identified were among Tetra Tech, Inc., Stanford University, and Hudson Engineering, Inc.
- Would be interesting to collaborate with atmospheric scientists at the National Center for Atmospheric Research and the National Oceanic and Atmospheric Administration. The contributions of the partners were not clear from the presentation.

- No collaboration with another funded effort (Project Number AN-13) that is performing very similar studies.
- The difference in the results is significant and should have been discussed prior to the review meeting and on a regular basis.

Question 5: Approach to and relevance of proposed future research

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

- Recommend completing the study after the estimate of ozone in the maximum hydrogen case is complete.
- The proposed future work in modeling and effects will complete the project within scope.
- The proposed future work is necessary to compare the two 2050 scenarios to the 2000 baseline.
- The proposed future work returns to the objective of comparing impacts of different methods of hydrogen generation.
- The capability of high resolution and a fine computational grid within the GATOR-GCMOM model yields nice graphics. However, it is not clear what actual decisions would be dependent on this level of detail or the level of precision to which the results are meaningful and/or necessary.
- This project is scheduled to end by September 2009. As such, the only future work identified was to complete the ongoing model simulations and to further quantify the effects of market penetration of hydrogen vehicles.
- The study of impact of hydrogen on structures does not seem very compelling; suggest skipping this work and focusing on increased use of models in your domain. Do not dilute this modeling work and expertise with work on structures. Similarly, work on environmental effects from mining, etc., will only dilute the outstanding work you are doing on climate modeling. The name of project needs to be changed from "Environmental Effects of Hydrogen" to "Effects of Hydrogen on the Troposphere and Stratosphere." Seems like the future work is being written generally to keep the funding flowing rather than digging into the very important topic that you've started to address.
- Completion of the current plan is appropriate.

Strengths and weaknesses

Strengths
- There is a huge amount of information embedded in the GATOR-GCMOM model. Applying it to this problem has the potential for revealing outcomes that would not otherwise be obvious.
- Several simulation results of GATOR-GCMOM have been published over the past two decades, which is offered as confirmation of the validity and value of the model.
- Excellent use of climate models and study of the two first layers of the atmosphere.
- The detailed model can be used to evaluate effects at a global scale.

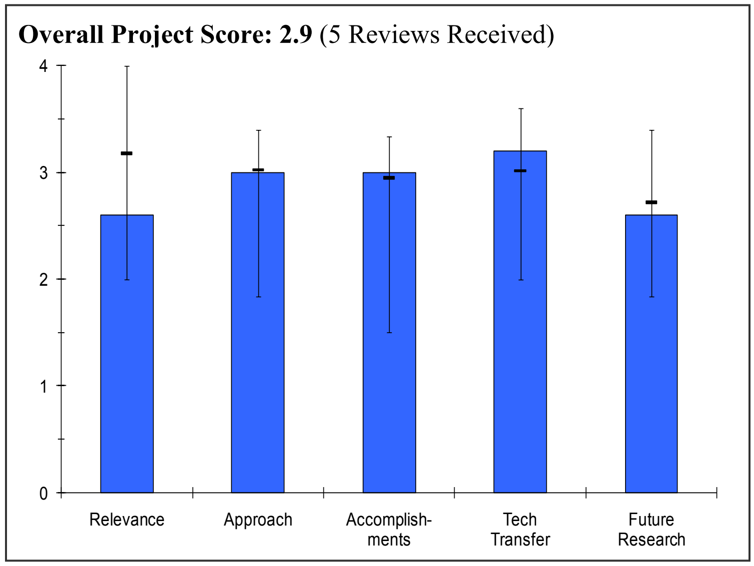
Weaknesses
- Absent an uncertainty and confidence analysis, one cannot distinguish between a precise prediction and a coarse estimate. The more detailed the figures produced, the easier it is to forget this point.
- Last year, a reviewer asked how to determine confidence levels for the model outputs, and the response was that the GATOR-GCMOM model had been widely published (45 publications) over 19 years. This answer could be made much more responsive by the investigators demonstrating how this historical information might be applied to their work to quantify its level of uncertainty.
- The results of the hydrogen effects that were shown took 18 months of model run, and the results were still listed as preliminary! This suggests that trying to examine the effects of varying any of the parameters or assumptions (for a sensitivity analysis, for example) would require a prohibitively long effort.
- There is the potential to dilute the effectiveness of work with study of other environmental effects. Recommend that researchers focus their work where their strengths lie and their reputation is strong. This work is needed and should not be diluted to all environmental effects.
- Complex model requires enormous computation resources and is not likely to be useable by many other groups.

Specific recommendations and additions or deletions to the work scope

- Reconcile overlaps with Project Number AN-13.
- I encourage future work to quantify the uncertainty of the results as derived from the uncertainties of the fundamental processes making up the model (slide 9) and the sensitivity of the results to the input conditions. This could be done, of course, at lower resolution.
- This project is scheduled to end in a few months (by the end of September 2009), so no specific recommendations are appropriate.
- For similar studies in the future, it would appear that the DOE Hydrogen Program is, perhaps, not the appropriate sponsor.

Project # ANP-01: Pathways to Commercial Success: Technologies and Products Supported by the HFCIT Program

Steve Weakley and Marylynn Placet; Pacific Northwest National Laboratory



Brief Summary of Project

The objective of this project is to provide an assessment of retrospective HFCIT Program benefits by tracking the commercial success of HFCIT-developed technologies (and technologies developed by HFCIT predecessor programs) and estimating their impacts/benefits.

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.6** for its relevance to DOE objectives.

- This survey of the HFCIT-supported technology R&D products is a good feedback mechanism to analyze the program success and its contributions to achieving the overall DOE RD&D objectives.
- The database would help future technology developers and program officials to obtain necessary background information, both knowledge and technical know-how, in order to formulate R&D plans and technical strategies to further advance and/or commercialize the technology products.
- This project attempts to provide a quantitative measure of the outcomes of DOE-sponsored projects that can promote the commercialization of the related technologies. Such a "measure" is of benefit to the DOE management.
- As hydrogen is not a commercial success yet, this project seems a little premature.
- If the purpose is to develop marketing materials to justify past and future funding (see slide 22), then the barrier being addressed is not, "Inconsistent data, assumptions, and guidelines."
- Not sure if this project adds much value. It is very likely that various companies and venture capitalists are already doing this type of monitoring/tracking work.
- The collection of "corporate" knowledge is important. Analysis of the information could be more effective.

Question 2: Approach to performing the research and development

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

- This is a rational approach to creating a database on HFCIT-sponsored technology, R&D activities, and products for systematic feedback and forward planning of R&D needs and programs.
- Starting with a patent search, and following through with the inventors and the HFCIT Program managers, is a good way to initiate this study.
- One concern that could lead to under-counting, is that the appropriate HFCIT technology development managers (TDMs) may have moved on to other positions, thereby making it difficult to resurrect the "corporate history" of the technology developments in the program over the years.
- Such a study is best done in retrospect, after a market develops and there are actually products being sold. However, the resulting success stories are quite interesting (maybe not analysis, but interesting). The database of previous research efforts could also be useful.
- Tracking product offering for sales and patent issues in hydrogen and fuel cell areas might be worthwhile; however, initial offering of a product for sales (a few units) does not necessarily make it a "commercial success."

- Patents typically get granted 3 to 5 years after they were initially filed. By this time, the idea might or might not have turned into a commercial product. The commercial product and patent timelines need to be properly tracked.
- It is not clear how the process of going from patents to licensing and commercial products is being effectively tracked.
- The information that is most needed seems to be difficult to collect from corporations and some labs.

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

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

- Examples of accomplishments regarding hydrogen storage tanks, distributed hydrogen production systems, etc. have been listed; however, what continued improvements may be necessary for industrial competitiveness is not discussed (perhaps delegated to future researchers to determine).
- It is certainly OK to accentuate success, but issues such as hydrogen leaks from the high-pressure storage tanks (and thus, issues on materials and seals) are not addressed. The success of high-pressure hydrogen tanks may solve one problem, but create another.
- The project has prepared a quantitative listing of the patents issued in the three different categories along with the current status of these patents, i.e., commercialized, part of emerging technology, being used in research, or abandoned.
- Some examples given are a bit of a stretch. For example, it would be difficult to qualify two units sold as a “commercialized technology.” The other major example given, that of Quantum compressed gas tanks, appears to predate the technology assessment period of 2002 onwards.
- In the poster presentation, there was no mention of software being trademarked and licensed, which is a significant component of the DOE Hydrogen Program. The poster presenter, Steve Weakly, assured me, however, that the software commercialization is included in the draft report that has been prepared.
- To say that, "Of the 118 patents reviewed, 48% are being used in commercial products, are part of emerging technology development, or are still being used in research," implies that these three categories are equally representative of how successful the patent-generating research is. These three categories are not equally representative.
- This study only represents R&D that resulted in patents, not all HFCIT R&D. Would like to know what percentage of HFCIT R&D money led to patents or emerging technologies.
- The cumulative number of commercial technologies (slide 12) is less than 25! Project “success stories” seems a little enthusiastic given this small number.
- Having a tracking database might be useful to the HFCIT. It is unclear how the HFCIT plans to use the data.
- Completed a draft report as required.

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

This project was rated **3.2** for technology transfer and collaboration.

- The team is working closely with HFCIT partners, laboratory/contractor researchers, and private sector vendors to establish the database.
- This project has involved developing contacts and relationships with the wide spectrum of researchers sponsored by HFCIT. In terms of sheer numbers, this project has most likely "worked with" more individuals and organizations than any other HFCIT-sponsored project.
- Excellent contacts with hydrogen technology developers. The list of projects and researchers is, in itself, a valuable data set.
- It is difficult to understand how the benefit of this database/report will be realized.
- Have obtained information through cooperation with a number of players, but not all.

Question 5: Approach to and relevance of proposed future research

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

- It is an ongoing project, and the project personnel will continuously update the database as new information becomes available.
- Finalizing and publishing the annual report, which is presently in draft stage, will be a useful documentation of the technologies identified in the project.
- Also useful will be providing Web-based access to the project's findings and updating these findings in an ongoing manner.
- Not sure that future work is warranted.
- Future work also needs to make the database and other information widely available to those involved in hydrogen research.
- No plans to address the difficulty in getting complete information. Important to keep this database up to date.

Strengths and weaknesses

Strengths
- A database on the current technology state-of-the-art and currently available commercial hydrogen energy technology products would benefit technology developers, vendors, and program analysts to legitimize future work.
- They have set up a comprehensive database that should prove to be a good resource of information for HFCIT and other interested organizations.
- Interesting data set.
- Good starting point for the database.

Weaknesses
- The success of the project is limited by the combined "memory" of the program office TDMs. As such, some of the older projects may not have been covered adequately.
- Seems really premature and of little value in setting up R&D priorities and "pathways to commercial success." However, in providing marketing material for the Hydrogen Program, some very interesting stories emerged.
- Very little in-depth analysis of the information. Limited utility as a tool to assess the success or failure of the program.

Specific recommendations and additions or deletions to the work scope

- The database should be widely available in the public domain. Combining this work with market needs and trends for future diffusion of hydrogen energy knowledge and technical know-how would be of much benefit.
- Once the draft report has been approved for release, the information should be made readily available.
- Any database is only as current as the date of the last entry for each item. To be meaningful, the database would need to be continually updated (even if there is new information for a particular item in it).
- Perhaps one additional piece of information to track is the change in the number of employees of these companies from year to year. If a company in the hydrogen and fuel cell areas has workforce reduction, it would most likely imply that any new commercial products or their current product(s) are not doing too well.

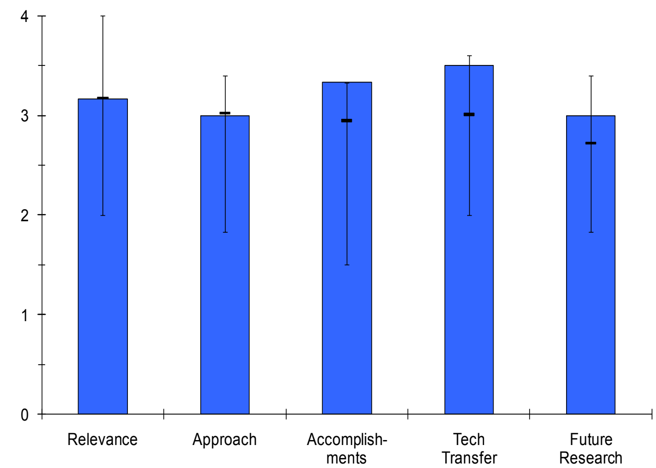
Project # ANP-03: Thermodynamic, Economic, and Environmental Modeling of Hydrogen (H_2) Co-Production Integrated with Stationary Fuel Cell Systems (FCS)

Whitney Colella, Aerel Rankin, and Amy Sun; Sandia National Laboratories
Pere Margalef and Jack Brouwer; University of California at Irvine

Brief Summary of Project

The objective of this project is to analyze the potential for hydrogen co-production within high-temperature stationary fuel cell systems (H_2-FCS) and identify novel designs with minimum CO_2 and cost. Specific objectives are to 1) develop novel H_2-FCS designs that release low greenhouse gas emissions; and 2) develop novel H_2-FCS designs with low hydrogen production cost.

Overall Project Score: 3.2 (6 Reviews Received)



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.2** for its relevance to DOE objectives.

- This project is highly relevant to the existing technical challenges of stationary fuel cells and their integration with hydrogen production and/or cogeneration.
- The project supports the DOE Hydrogen Program objectives.
- Hydrogen co-production integrated with fuel cell systems is an interesting technology idea, although its viability is uncertain. Distributed hydrogen production facility management, maintenance, safety aspects, product recovery, and CO_2 management are not expected to be cost-effective and may be operationally difficult. Without adequate analysis and information of relevant parameters, an objective evaluation of the concept is difficult.
- The project focuses on thermodynamic, economic, and environmental models to analyze recouping waste heat from high-temperature stationary fuel cell systems to enhance steam-methane reforming to co-produce hydrogen for transportation and/or industrial applications. Interesting approach to build stationary fuel cells, and then utilize waste heat to produce distributed sources of hydrogen that can be used to power mobile fuel cell applications. Project addresses key issues facing introduction of hydrogen fuel cell vehicles (HFCV) and hydrogen infrastructure: which comes first? By introducing the use of stationary fuel cells (powered by steam reforming of natural gas), one can switch over to using waste heat to produce hydrogen for transportation.
- This project has the objective of investigating options for combined hydrogen, heat, and power production using high-temperature fuel cells that have the potential to lower the overall costs and lower the CO_2 emissions (as compared to generating the three separately and independently).
- This project addresses the multiple elements of the overall Hydrogen Program to produce hydrogen (e.g., for fuel cell vehicles) and to commercialize fuel cells for distributed power production. Being able to use the fuel cell waste heat effectively is an added bonus.
- The scenario of co-producing electricity and hydrogen in a high-temperature fuel cell from natural gas would only be attractive in places where there is a wide price spread of natural gas purchased to electricity sold (back to grid). It might be more relevant to look at a forecourt case where the electricity is used for charging hybrid batteries and hydrogen for HFCV. There is a time-of-day issue that needs to be worked out.
- Hydrogen at 350-bar would not necessarily be liquid.
- The modeling approach/tool is quite useful in developing a value proposition for stationary fuel cells to produce power, heat, and hydrogen. The lower cost hydrogen will enable HFCV deployment.

Question 2: Approach to performing the research and development

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

- A good combination of a simpler model for preliminary details plus a more detailed Aspen model for improved estimates.
- The diverse team is more than qualified and capable to execute the intended tasks successfully. However, it appears that the work scope and objectives are too broad, varied, and unfocused. It is not clear what specific technical issues and barriers the research team is addressing and intends to overcome. Without a focused approach that is comprehensible to the audience other researchers, analysts, and program managers, the work and its conclusions may not be meaningful. For example, what technology R&D product is intended and what is its value and application for improving science, technology, commerce, etc.?
- A good approach that first models the thermodynamic requirements (although the models assume all waste heat is converted to hydrogen). My only hope is that subsequent versions include realistic assumptions on waste heat utilization and actual (not ideal) component efficiencies.
- This is an analytical rather than an experimental project. In the system models they are developing and analyzing, they are attempting to identify opportunities for close thermal integration.
- They have analyzed solid oxide fuel cells (SOFCs) and molten carbonate fuel cells.
- They have also investigated other options, such as a network of such systems to provide for load following and other benefits, even if some of these options may be rather difficult to implement (at least, until the technology is much more fully developed and mature).
- While the concept of using the excess heat from a SOFC for a reforming reaction to produce hydrogen is straightforward, the controls complexity of this system should not be understated, especially when additional heat is generated through capturing and burning of tail-gas stream from the pressure swing adsorption (PSA).
- The system might not be running robustly due to the degree of interdependency of the fuel cell, the internal reformer, the external reformer, the combustor, and the PSA. This concept offers operating flexibility, increased efficiency and lower greenhouse gases (GHG), but also adds complexity and capital cost (potentially).
- A high-temperature fuel cell and PSA might not be the best match. The fuel cell runs at high temperature and low pressure, whereas PSA likes low temperature and high pressure.
- Thermodynamic analysis and modeling activity is well organized for high temperature fuel cells. The hydrogen purification approach is also theoretically sound. The team is well qualified.
- Involving fuel cell manufacturers in proactive planning and review of results has led to useful work based on realistic assumptions.

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

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

- Really good value. A lot of work for very little funding.
- Significant results have been presented. However, the PI has presented an enormous amount of material with excessive narratives, thereby making it difficult for the reader to comprehend the real story. The coherence and continuity of the subject matter is soon lost. The slides are extremely busy with so much text, tables, figures, and mathematical derivations that a reader cannot understand the message of what (i.e., the issue, what problem needs to be solved), why (i.e., why and how solving the problem would advance the current status of science in support of DOE program goals), how (i.e., the technical strategy for achieving the intended results) and, finally, the so what (i.e., benefits of the study results).
- Simple statements of technical approach, results, and how the results advance the state-of-the-art generally interest a broad audience. This presentation is suitable only for a specific audience.
- Considering the project just started in January 2009, the progress has been remarkable. Three scenarios have been developed and modeled with increasing levels of complexities.
- The accomplishments were illustrated by describing a case study of networked systems that could provide variable heat-to-power and hydrogen-to-heat ratios for load following of either heat or hydrogen, respectively.
- The case study presented analyzed thirteen different system configurations, showing that different configurations would be optimum, depending on whether the manufacturer revenues, CO_2 emissions, or cost to the consumer is the major driving factor.

- Many of the results of their analyses appeared to be affected significantly by external factors, such as fuel prices. With such interconnected relationships, it is difficult to assess the usefulness of the results.
- It was difficult to understand the major outcomes or implications of the studies conducted.
- Project started recently. Appears to have done quite a bit of work and be on the right track.
- 1 MW(e) is too large for forecourt electricity while 450 kg per day of hydrogen is too small for hydrogen (1,500 kg/day for commercial station). A few hundred kW(e) for forecourt might be more practical and run the fuel cell less efficiently to produce more hydrogen as demand dictates.
- Results of tri-generation system look reasonable. Load following analysis for power, hydrogen, or heat is interesting. Value-based prioritizing of co-products will help to focus the tool better for a majority of applications.

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

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

- Great consortium of national labs, academia, and industry.
- A highly competent team of six national laboratories, University of California-Irvine (UC-I), and industry (e.g., Fuel Cell Energy, Inc.; Technology Management, Inc.) are conducting the tasks, and major industries (e.g., ExxonMobil, Shell, ConocoPhillips, and Chevron) are evaluating models. This is truly an exemplary collaborative R&D effort.
- There appears to be a large degree of collaboration. Not quite sure how detailed interaction with such a large number of collaborators can be. Would it be better to focus on fewer collaborators with a higher level of interaction with select partners?
- The project has a good breadth of collaborators from universities, national laboratories, and the high-temperature fuel cell industry. In principle, this collaboration offers the model developers good access to realistic fuel cell data.
- Very good collaborations with fuel cell industry partners and national labs.
- Suggest the team talk to reformer developer to confirm numbers and validate key assumptions.
- The PI and team come from SNL and UCI. Both have very good experience in the stationary fuel cells and hydrogen systems. Strategy to solicit input and share results is very well focused. Good coordination between team members.

Question 5: Approach to and relevance of proposed future research

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

- A good plan for future research. Hope the project can continue.
- This section is missing. However, only 12% work has been completed since the project started in January 2009. It is expected the competent team will continue the work per established technical baselines and a planned development path.
- Future efforts focus on continued model development/enhancement, which is appropriate for a project at this stage (6-9 months). The project indicates it will include more realistic assumptions for the input, which will temper the predicted advantages and hydrogen production to values below the 150 to 450 kg/day.
- They will develop more detailed Aspen models to validate the potential for hydrogen co-production with heat and power. This would offer a good comparison with their modeling results, particularly with regard to variable hydrogen, heat, and electricity production.
- Suggest the team verify key assumptions in the model.
- The future work plan is logically organized. Creating a value proposition for a potential consumer to maximize the benefits is very useful. Techno-economic-environmental analysis is good.

Strengths and weaknesses

Strengths
- Good collaborations with multiple partners.
- Good skills and expertise from the PI.

- Results are important for the future of stationary fuel cells.
- Super accomplishments within a limited time. Analysis of an innovative H_2-FCS integrated concept, which can potentially make enough hydrogen cost-effectively and can power 660 fuel cell cars per day with no additional CO_2 emissions.
- Interesting approach to introduce hydrogen production (distributed) through by recouping waste heat from stationary FC systems. Could provide a route to produce the levels of hydrogen needed for early introduction of FC vehicles.
- Defining and analyzing of innovative system and network configurations is a strength.
- Analyzing systems from different perspectives, such as whether the highest priority is electricity production or GHG emissions reduction, is a strength.
- Thermodynamic analysis is based on good electrochemical principles and chemical system analysis. Use of realistic assumptions derived from fuel cell experience is very good.

Weaknesses

- Presentation is hard to read and follow. It is understandable that they want to show the extensive work conducted, but they should reduce the number of slides and focus on the key points.
- The PI has not addressed how CO_2 emissions can be managed (i.e., captured, transported, and stored) in a distributed scenario. Also, how easy or difficult it is to pump hydrogen in vehicles, and the associated safety and hydrogen emission concerns, has not been addressed.
- The use of ideal efficiencies is unrealistic and oversells the concept. More realistic thermal and mechanical efficiencies should be used to provide more realistic predictions.
- Project should indicate how the models and codes will be used to demonstrate the co-production aspects. Are they working with an actual demonstration or is this still in the concept development stage?
- The models have a large number of parameters that have significant influence on the analysis outcomes (i.e., costs, GHG emissions, relative amounts of electricity, heat, and hydrogen). It is difficult to understand the main messages from the study.
- It is difficult to understand how to use the results from such analyses to guide future R&D or future analyses.
- Focusing on practical aspects and realistic data will help improve the benefits of the study.

Specific recommendations and additions or deletions to the work scope

- Continue detailed analysis of optimum stationary fuel cells.
- Suggest the team present each focus or barrier area, one at a time. Present an analysis of what problems need to be solved so that audience has a comprehension of what results are expected.
- Use realistic efficiencies to bracket the projected benefits.
- Should consider how we get from the present situation (conventional stand-alone systems for electricity, heat, and hydrogen) to the intermediate scenario of combined heat and power, and then to the ultimate situation envisaged in this study (combined hydrogen, heat, and power) without discarding or stranding the earlier investments i.e. how should the near-term systems be configured so that they are flexible enough to add heat recovery at a later time, with the capability of then adding hydrogen production (initially small amounts and then subsequently larger amounts) at an even later stage.
- Please include effect of financial incentives related to emission trading-NO_x, SO_x, VOC, PM-2.5, etc.
- Apply the model to university sites and national laboratory sites.
- Include renewable fuels in the analysis.
- Use of photovoltaic and wind in a smart grid may be helpful.