REPORT OF THE EXTERNAL EXPERT PEER REVIEW PANEL

DOE BENEFITS FORECASTS

December 20, 2006

**U.S. DEPARTMENT OF ENERGY, 1000 Independence Avenue, S.W.
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Introduction

With direction from Under Secretary Garman, the Science and Technology Working Group (STWG), an arm of the R&D Council's Integration Working Group (IWG), has formulated a methodology to begin integrating benefits analyses to improve the value of this information for DOE decision-making.   Participating DOE program offices include:

- Electricity Delivery and Energy Reliability (OE)
- Energy Efficiency and Renewable Energy (EE)
- Fossil Energy (FE)
- Nuclear Energy (NE)
- Science (SC)

The integration of DOE benefits analyses is being done to assist DOE senior management in budgeting and planning; in response to reviews undertaken by the National Academy of Sciences/National Research Council; and in response to requests from the Office of Management and Budget.

The primary value of DOE Benefits Forecasts is to improve portfolio management, budget decisions, and the overall effectiveness of DOE R&D investments. The objective is to ultimately develop a fully integrated DOE benefits analysis process that can serve as a useful tool for decision makers evaluating the entire DOE research portfolio. Annual DOE benefits projections are also performed to enable program offices to maintain compliance with the Government Performance and Results Act (GPRA) of 1993 and the President's Management Agenda (PMA). GPRA requires Federal Government agencies to develop and report on output and outcome measures for each program. The analysis thus produced helps meet GPRA requirements by identifying potential outcomes and benefits of realizing DOE program goals (outputs). Moreover, the forecasts that emerge from the GPRA analyses are useful for decision support, as they provide a means to compare across programs. However, the current benefits estimates do not reflect the technical risks or probabilities of realizing these goals in a consistent manner across programs, and thus their use for decision support is limited. Those concerns are addressed separately.

Rather, the reported benefits reflect only the net annual improvement from a beginning year to a future end-point of program activities included in the Budget Request of a given year. They do not, generally, reflect benefits from past work. Additionally, the benefits estimates assume continued funding for program activities consistent with multiyear program plans. The linking of estimated benefits to budget levels enables the analysis to address the performance-budget integration goal of the PMA.

While the estimation of benefits is complex and thus amenable to various levels of review, the specific purpose of the current review is to validate and improve the methodology, assumptions, and approach used to forecast benefits in a consistent manner across all DOE energy technology research, development, demonstration, and deployment programs.

Peer Review Process

The peer review was held at the L'Enfant Plaza Hotel in Washington, D.C. on December 20, 2006.

The external expert peer review panel consisted of the following:

- Hillard G. Huntington, Stanford University (Peer Review Panel Chair)
- Leon Clarke, PNNL Joint Global Change Research Institute
- Joseph DeCarolis, Environmental Protection Agency
- Alexander E. Farrell, University of California-Berkeley
- Andy S. Kydes, Energy Information Administration
- Dan Loughlin, Environmental Protection Agency
- Frederic Murphy, Temple University
- William A. Pizer, Resources for the Future

The peer review focused on the following charge questions provided to the panel.

> Does the documentation clearly describe the basis for benefits forecasts so that all assumptions and calculations are understood?
>
> Are the assumptions associated with the benefits forecast plausible or believable? (For example: Are assumptions data driven? Are sources cited? Is there clear linkage between R&D budgets and assumptions?)
>
> Was the methodological guidance for benefits forecasts followed?
>
> Is the baseline used an appropriate representation of the future without federal funding?
>
> Are the DOE program goals used in the benefits forecast appropriately represented in NEMS, MARKAL, and any additional calculation tools used?
>
> Are the scenarios used adequate to test the robustness of the DOE portfolio?
>
> Do the metrics used sufficiently capture the spectrum of benefits attributable to the DOE portfolio?
>
> Does the benefits methodology produce results that could be useful to decision makers?
>
> What are the most important changes to the methodology to improve the credibility and usefulness of DOE benefit forecasts?

The peer review panel's comments fall mainly upon the clarity of the individual reports in explaining their assumptions and results and whether the general guidelines developed by DOE were applied uniformly across all offices. The panel was not asked to address whether DOE's general guidelines were the only principles for conducting the benefits analyses. Similarly, there was no request to compare or evaluate DOE's general analytical approach with another modeling system. As a result, comments by peer review members cannot be interpreted as endorsements of DOE's approach over other reasonable alternatives that have been or could be applied to evaluation of research and development activities.

Panel members were also explicit in their discussion that the preliminary nature of DOE's analysis requires a special caveat on using these results. It is inappropriate to compare program benefits to support one program's activities over another. Despite an impressive effort to standardize the approach across programs, there remain significant differences in assumptions, parameters and techniques that it would be very dangerous to compare benefits estimates from the different programs. Instead, the effort should be considered as a useful first step in moving DOE's program offices closer to the department's goal of understanding the potential gains from its research and development programs.

The review began with an overview presentation describing methodology common to the approach taken by all of the program offices and the results of benefits forecasts for the entire DOE research portfolio. Assumptions used by each program office and individual office results were also presented.

Reviewers were asked to rate and comment on each of the five presentations. The following qualitative rating scale was used to evaluate each of the criteria:

- Excellent (E);
- Very Good (VG);
- Good (G);
- Fair (F); and
- Weak (W).

Based on the reviewer's ratings of the overall credibility and soundness of the approach an average overall score was derived for each of the topics presented.

External Expert Peer Review Results

A summary of the ratings provided by the review panel and average overall ratings are given in Table 1. A record of review panel comments, points of discussion, and the DOE response is then provided for each of the topics presented.

Table 1. Summary of Ratings

	Clarke	DeCarolis	Farrell	Huntington	Kydes	Loughlin	Murphy	Pizer	Average
Overview	VG	G	G	G	VG	NR	E	G	**G-VG**
EE	VG	VG	F	G	G	NR	VG	G	**G**
NE	VG	G	G	G	F-G	NR	VG	G	**G**
FE	VG	G	G	VG	VG	NR	E	VG	**VG**
OE	VG	G	W-F	F	F	NR	NR	G	**F**

Note: NR signifies no rating given by a panel member.

Title: Overview—Benefits of the DOE Portfolio
Presenter: Darrell Beschen and Charles Drummond
Overall Rating: Good – Very Good

A. Review Panel Comments

Leon Clarke	**Rating: Very Good**

This is a very credible and useful approach to the assessment of benefits of DOE R&D, as far as it goes. It constitutes a meaningful effort to synthesize these programs within a common framework. It uses state-of-the-art modeling efforts, including the main U.S. energy model, NEMS. This is the obvious way to approach this issue as a first cut. The use of multiple scenarios is an excellent addition.

I felt that the underlying work was good, but the analysis lacked substantially in interpretation. I am not clear what a decision-maker would do with this enormous quantity of information absent some sort of clean, clear synthesis and interpretation. This sort of analysis is never intended to be exactly correct – it is intended to provide key insights for planning. A range of metrics was developed to help with understanding the information. This is a useful step, but substantially more needs to be done. Metrics must be accompanied by discussion of the key dynamics and insights that emerge from the analysis, along with the implications of important model limitations and assumptions. Diving deeply into particularly important issues could develop stories. This is one of my major comments and recommendations for enhancing this process.

Any sort of modeling effort such as this will always fall short along a number of dimensions, because of uncertainty in understanding how the future might evolve, linking R&D to technological advance, and limitations and nuances of the underlying models. This particular effort is no exception. Many of my comments below on areas for improvement are endemic to this sort of effort more generally. I'll put them forward as something of a laundry list, but the expectation should not be that this sort of effort can get it completely "right."

R&D Issues:

- The linkage between R&D funding and achievement of program goals is not well documented or developed. Similarly, the counterfactual situation absent R&D funding is not well developed. At the same time, I suggest that a detailed analysis of R&D effects is not on the top of the list, and efforts should focus in the near-term on better understanding the benefits of advances and not the process of technological change. The process of change is extraordinarily complex, and no research approach has yet provided fully satisfactory assessments. This process isn't going to effectively incorporate this extraordinarily complex process. This work constitutes a value-of-technology analysis, which is a valuable contribution irrespective of weaknesses in links to the processes of technological change.
- Nonetheless, there are some first-order activities that could be undertaken. Certainly a simple accounting of expenditures at a government level in Europe and Japan, potentially at sub-regions such as California, and the private sector would be valuable. This information is not necessarily that difficult to obtain, so it would probably be a good first-order set of information to inform what would happen in the absence of DOE's programs.
    - Also, some analysis of DOE's relative advantage in comparison to other R&D efforts would allow DOE to think more clearly about where DOE might have the biggest bang for the buck.

Modeling Issues

- Every model has both strengths and weaknesses. The two models in this study are no exception. I would suggest that, along with continued enhancements to the models, which are probably not the charge of this exercise, several efforts should be taken to make the information more interpretable:
    - The discussions of results should include more substantial discussion and interpretation of the resulting changes in the energy system. What exists now is simply reporting of numbers that, without context, are very difficult to understand. I am not sure how a decision-maker would use this information. This sort of work is only half about analysis, and about half about interpretation. This analysis is lacking in interpretation.
    - Since both MARKAL and NEMS were run through 2030, I would suggest that results be provided for both models up through 2030, to the extent that this is feasible, and then MARKAL results

beyond. Multi-model analyses are exceptionally useful.
  - In many places the AEO is referenced as the starting point for the analysis, but there is no description of this reference case (population, GDP, energy system) to get decision-makers on board with their starting point. Similar comments could be made about the two other scenarios that were considered here. Some sort of synthesis document would be valuable.

Metrics

- I very much appreciate the analysts' efforts to develop a range of useful metrics. My impression is that the range that is currently in use is an evolving set that will be improved as part of this process. Several comments;
  - I would strongly suggest aggressive efforts, perhaps through an independent research project, to gain a better foothold on welfare metrics such as consumer and producer surplus that could be developed within the constraints of this work (e.g., using NEMS and MARKAL) – even if such efforts include off-line analysis. I understand the difficulty of developing these metrics, however, they are fundamentally important, and the economic metrics that emerge from this analysis are less about benefits and more about changes to the energy system. These are two different matters. Some of the metrics already available, such as consumer energy expenditures, might be roughly extended using some sort of simple rules of thumb to develop welfare metrics.
  - The analysis of security benefits could be improved. For example, oil imports are probably not the most appropriate metric. Oil prices or oil demand might be better. Another example is proliferation risk associated with nuclear power. R&D that reduces this risk should be given a benefit.
  - Some technologies have substantial benefits that are not clearly captured in the main metrics. Examples include the infrastructure security for the OE work and efforts to improve safety, minimize waste, and reduce security risks with nuclear power. Somehow, the process should better bring forward these benefits.
  - Rather than ask the analysts to develop the metrics themselves, it might be valuable to convene a research project by outside experts that have knowledge of the underlying modeling tools and key energy issues to develop a set of meaningful metrics. I make this one of my major recommendations.
- There is some question about the use of a 3% discount rate. Something a little higher might be more appropriate.

I have little concern over whether these numbers are "right". They cannot be, and that is not the purpose of this study. What's most important is that the analysis is transparent. I found the approach to be credible, consistent, and transparent. However, I found the interpretation to be lacking, meaning that it is exceptionally difficult to know what to make of the resulting information. This manifests itself in two ways. First, the metrics could be better and a smaller set might be valuable. On the economic side, there are too many metrics, they are confusing, and they don't clearly get to the main issues that one is concerned with. Similar improvements could be made in terms of security and environmental benefits. Second, substantially more effort needs to be put into explaining and interpreting results and pulling out key insights that will be useful for decision makers. People tend to lose focus with so much information absent some set of stories or context to put it in. These are my main recommendations for this process. Somehow the process needs to be adjusted to allow for some sort of substantial post-modeling analysis and for better representation of more complex benefits. Expanding this beyond an annual process and making it a two-year or three-year process would be valuable; but perhaps this is not viable within the confines of this process.

Joseph DeCarolis	**Rating: Good**

Looking across programs, it is clear that the use of NEMS and MARKAL needs to be standardized. According to the reports the following office used the following models:

- EERE: NEMS to 2030, MARKAL 2030-2050.
- NE: MARKAL to 2050
- FE/OE: NEMS to 2030

NEMS and MARKAL are fundamentally different models. It is not credible to directly compare the benefits analyses from different offices that chose to use different models. My recommendation is for ALL offices to run NEMs from the present to 2030, and MARKAL from the present to 2050 – this will ensure "apples-to-apples" comparisons.

There was significant confusion about which Office R&D was included in the “Program” cases. Two sets of “program” cases were run: (1) all DOE R&D included and (2) specific Office R&D only included. The latter has little relevance because it assumes that all other DOE programs other than the one under question do not meet their objectives. It is would be worth looking at other combinations of DOE R&D other than “all programs succeed” or “only one program succeeds”.

It would be useful to incorporate historical analysis of benefits from each office. Without historical perspective on the past benefits of DOE R&D, it id difficult to judge the credibility of the current projections.
Energy security metrics should be expanded beyond oil imports. In reading the OE report, it became clear the oil import metrics have little relevance to the important work that OE does. For example, improving the robustness and reliability of the electric power transmission and distribution system is a critical energy security need.

Also, reductions in natural gas consumption should be included in the security metrics. Natural gas has important geopolitical concerns in future, particularly as the U.S. relies increasingly on imports.

Not all Offices projected all of the metrics laid out in the methodological guidance. If metrics are not applicable to a particular Office’s benefits analysis, it should be clearly stated in the report.

Benefits analyses should make greater reference to industry, both domestically and internationally, and the ability of industry to undertake R&D in the absence of DOE programs. It would also be very useful to identify high-risk areas of R&D undertaken by DOE that are unlikely to be addressed by industry.

Alexander Farrell	**Rating: Good**

Use of models NEMS and MARKAL is helpful and a reasonable effort is made to make the analyses comparable. However, there are many important benefits that cannot be evaluated in a model-centric approach, and perhaps cannot be quantified at all.

A good example is oil security. Oil imports is a poor metric for this. In fact modeling may not lead to useful metrics. See the LODI project of NCEP. It seems to me that efforts and technologies that tend to reduce OPEC market power (ala non-OPEC production increases in the 1980s), but these will not be readily quantified.

Therefore, I think it is imperative that the approach to estimating the benefits of DOE R&D be expanded beyond this sort of model-centric approach. This requires gaining a much better understanding of the processes of innovation and technical change. There are scholars of and publications on this topic, DOE should seek this information out and incorporate it into future efforts.

The deterministic approach – Baseline, portfolio case plus two sensitivities is a start, but is NOT ADEQUATE. Things like responses to shocks need to be evaluated. Similarly, the assumption that program goals are met is simple and unsupported – I think the appropriate way to think about this is that the LIKELIHOOD of achievement of the level of performance represented by the program goals is what should be focused on. What evidence is there that DOE projects in the past have had what sort of impacts on energy technologies, costs, etc.?

Many environmental issues are lacking. Not all the important issues are in air – one of the largest is land use, both in production/collection and the transformation/distribution. So production of oil in currently sensitive land areas is not accounted for, the need for added transmissions for delivery of wind energy to urban areas is not included. Conversely, R&D to reduce the land impacts cannot be adequately credited.

Welfare measures are not provided. Some of the measures in terms of reductions in cost or in emissions are in the right direction, but don’t go far enough.

The deterministic quantitative benefit estimates shown in the first presentation (pp. 19-21 of the handout) are illustrative only. They are NOT credible as forecasts and should not be used as such. The ability to generate information in this area is much more limited than these figures imply. Similar, the figure on GHG emissions on p.

13 of the handout does NOT seem credible at all. These values are all very uncertain and contingent, and simplistic, deterministic representations do not convey this.

Page 13, bottom – this is not clear.

The benefits of Congressional earmarks should be studied as a separate category. These are controversial and deserve study.

Avoid presenting simple, deterministic quantitative estimates of the benefits of DOE R&D. All of the values that can be produced are highly uncertain and contingent, and this sense must be conveyed when the results are discussed. Quantitative discussions may not be suitable to this.

Hillard Huntington	**Rating: Good**

The various offices have done a credible job in identifying the benefits of DOE's energy research and development programs. They took their charge seriously and provided a reasonably objective evaluation of programs under their management. They prepared documentation of their approach that for the most part was clear and complete.

Although this effort has achieved some success, I do have some recommendations for their approach and qualifications about their results. DOE could learn much about evaluating R&D programs from useful interactions with other groups who routinely work in this area, often on topics other than energy. In the last section of this report, I have made a specific recommendation that might engage the DOE staff with these other groups.

I also remain worried that their approach may overestimate the benefits of their programs. The source of this problem lies more in the general approach than in specific assumptions used for describing individual technologies. These problems are hard challenges because experts and past research on this topic have not clearly articulated what the best model or technique should be for this issue. Perhaps the best DOE strategy at this point would be to understand and state clearly that the benefits may be overstated due to a set of conditions that the analysis could not control.

First, benefits are set equal to the program's goals, which are specified in terms of technical performance criteria such as a targeted level of or percent increase in energy efficiency. R&D expenditures will produce net societal benefits if "market failures" prevent private companies operating with open market competition to reach these technical targets. If instead, companies can overcome these barriers and reach some of these targets with their own R&D expenditures, the DOE estimates will overstate the benefits of the government's programs. It is the extent and nature of these market failures (such as energy security, environment, and R&D spillovers), rather than the technical criteria, that create the R&D benefits.

Second, the reports assume that there is a 100% chance of meeting these goals. There is no risk of not attaining the goals. Many companies undergoing R&D activities assign considerable risk to their not meeting their intended goals. These companies also assign risk to any product that is a technical success but that does not become an economic success. This market bias may not be as serious as the technical bias in the DOE analysis, because the NEMS model should be competing each technology with other technologies to determine which one wins the economic competition.

Third, the federal government is viewed as being the only entity that is investing in R&D options. It is possible that federal R&D enhances other R&D spending. Removing federal spending could threaten the benefits from this additional research as well as the benefits of its own program, making the total benefit estimates too small. However, the reverse situation may be the more important issue. Particularly with today's high energy prices, corporations are investing heavily in technologies that will expand supply or energy efficiency. This spending is a substitute for federal expenditures. The fixed energy efficiency targets used frequently to define benefits in the DOE program may be achieved by private rather than public spending.

Fourth, the analysis does not incorporate the general market setting that relates one economic sector to another. For example, consider a program that reduces electricity expenditures by $30 million by introducing energy efficiency lighting. As households and firms reduce their expenditures, more money becomes available for spending on vacation trips, computer games, and a range of commodities and services. These additional expenditures will be allocated to other sectors and activities, which will require more energy, perhaps increase energy imports and produce more pollution. When the NEMS system is applied to an evaluation of specific technologies, it counts the reduction in energy due to the energy-efficiency program but it does not offset some of this reduction with an increase in energy use as resources are shifted to other sectors. The reallocated expenditures are lost because NEMS does a good job of measuring energy markets but does not measure shifts in economic activity.

Fifth, the analysis measures economic costs primarily with consumer energy expenditures. When a program reduces energy use and prices, direct consumers of energy will gain because they spend less for energy. Some of this improvement is derived from having better opportunities when energy prices are lower, but much may come at the expense of the government tax revenues or energy supplier profits. Since citizens look to the government to provide a number of public goods and services and since corporations pay dividends to retired citizens and other residents, these transfers should not be discounted because they are important to consumers when they are not directly using energy.

It is difficult to estimate improvement in general economic welfare directly from changes in consumer energy expenditures. For technology improvements, general economic welfare effects involve adjustments that are almost entirely excluded from the change in consumer expenditures. This point is shown in the figure below. The original

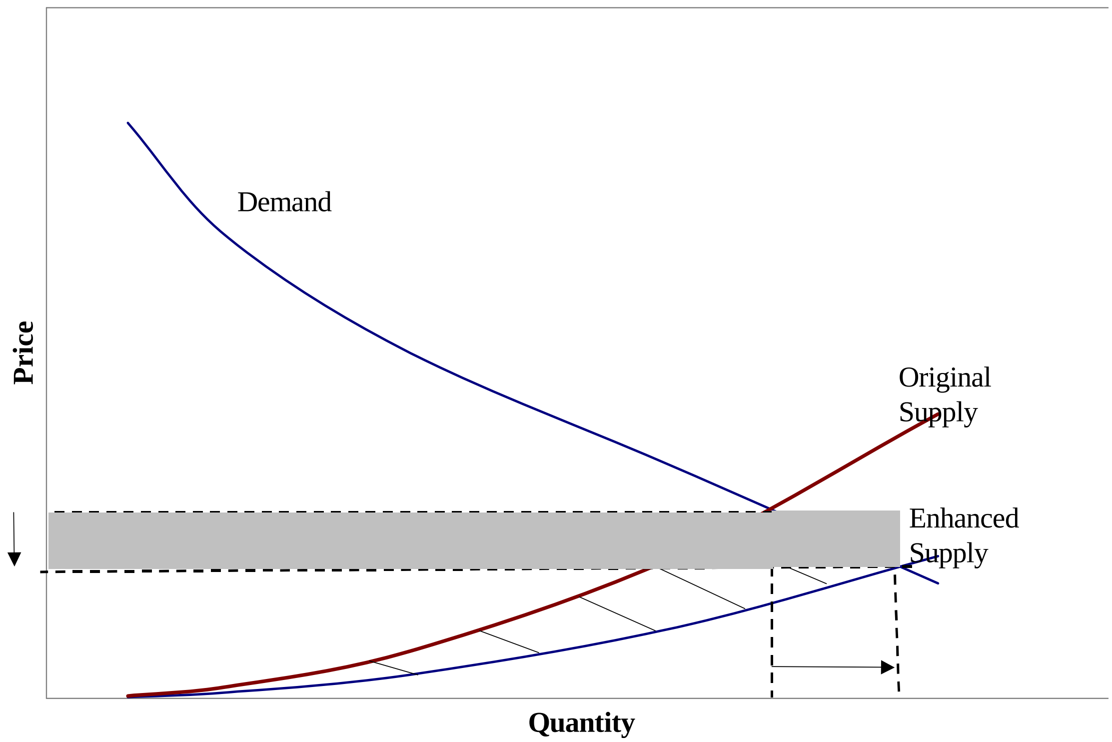


Figure: R&D's Effect on Enhancing Energy Supply or Efficiency
Gray area represents consumer surplus gains.
Diagonal dashed-line area represents total economy gains.

energy supply and demand curves intersect to determine the original energy price (vertical axis) and original energy quantity used (vertical axis). If R&D expenditures on windpower, solar cells or natural gas production successfully reduce the costs of supplying electric power, the new enhanced supply curve shifts to the right. Consumer surplus increases by the shaded area; better technology opportunities increase by the diagonal, dashed-line area. The overlap between the two areas is very small, and it is impossible to determine which area is larger. (Technologies that augment end-use energy efficiency can be represented with a similar diagram, except that it must be interpreted somewhat differently. In this case, the original supply curve represents the BTUs of energy being supplied both with and without the R&D expenditures. The enhanced supply curve now represents energy in terms of the more efficient units - not its original heat or BTU value. Energy in BTUs now falls, as prices decrease along the original supply curve.)

I do not believe that DOE has an easy solution for reconciling these problems. It is not simply picking a better modeling framework "off the rack" and running with a different framework. For example, the DOE could overcome my fourth and fifth concern by adopting a very different modeling structure. Economists often use a computable general equilibrium (CGE) framework to measure how some sectors lose inputs to other sectors, as the economy adjusts to meet new directions placed by policymakers. These frameworks also allow a direct measure of the economic gains or losses for the whole economy. Although these are attractive features, the framework is not particularly well suited for representing technical performance criteria in sufficient detail for DOE's purposes.

Additionally, there are several other comments:

Use of 2 models is OK. But MARKAL needs to be run "less aggressively" to avoid the spike in many charts at 2030 (e.g., oil imports security benefit).

Security measures should be oil consumption primarily, because even domestic production costs more during a disruption. Imports are not so critical.

Model response (elasticity) should be reported as part of documentation.

Should consider Decision Analysis (Risk Analysis) that estimates the expected NPV (risk-adjusted) of the different programs.

If you need to compute household expenditure impacts, suggest that you measure the change in household expenditures divided by household income (% of income).

Andy Kydes	**Rating: Very Good**

Generally clear but some of the assumptions are questionable or unclear. The scenarios approach is appropriate. Some assumptions by programs are in question. Offline analysis concerns me for technology portions.

I am also somewhat concerned about whether the same level of optimism was used across programs to develop the "technological successes." This is the issue of a level playing field across program. It would be nice to develop a process for developing the program success. This may be impossible but should be thought about.

The EERE goals and metrics are sometimes inconsistent with or not directly related to the U.S. DOE Goals as stated in Box 1.1 and Tables 1.1 -1.3.

- The DOE goal 1.1 of "affordable" relates generally to cost effectively improving economic efficiency as discussed in Goal 1.4. The EERE metrics (1-8 page 1-6) of Table 1.1 focus on changes in natural gas prices or expenditures by various market segments. Some discussion of why these metrics (1-8) improve economic efficiency should be made, otherwise there is no adequate link between the EERE metrics and the DOE Goal 1.4.
  - Item 1. A reduction in the average natural gas price may or may not improve U.S. economic efficiency, depending on how it is accomplished.
  - Items 2. Energy Systems costs is only one part of the U.S. energy-economy and MARKAL does not represent the U.S. economy so economic efficiency is not assured unless the energy and non-energy parts are relatively unrelated.
- Table 1.2. The only measure for environmental pollutants is focused on central station air emissions. What happened to other energy-related by-products that influence water quality or other contaminations (e.g., nuclear waste), particularly from refineries or the industrial sector or even the agricultural sector. Neither of the models used are necessarily adequate at this time to address these issues (which may require additional model enhancements in the future) but these issues are also important. Mobile emissions from vehicles are another important area that should also be mentioned.

  The equation described for measuring benefits of metrics 3, "Reduced Cost of Criteria Pollutant Control," seems to either underestimate or overestimate the savings, depending on the formulation. That is, the discussion in the GPRA08 Benefits Metrics suggests that the computation is the following for each year:

$$GPRA08Savings_t = [Q_{NOX} - Q^p_{NOX}]*Pr^p_{NOX} + [Q_{SO2} - Q^pS_{O2}]*Pr^p_{SO2} + [Q_{HG} - Q^p_{HG}]*Pr^p_{HG}$$

Note that the programs could, in principle, impact both the trading price and the quantity. However, the most likely change could well be the reduction in the trading price because the programs could make it easier to meet the existing policy constraints. If the programs reduce the criteria pollutant below the required emissions target, the trading price could go to zero. The two savings formulas are not the same and the second formula overstates the pollution control savings by the following amount

$$\text{Difference Savings Estimate} = Q_{NOX}(Pr_{NOX} - Pr^p_{NOX}) + Q_{SO2}(Pr_{SO2} - Pr^p_{SO2}) + Q_{HG}(Pr_{HG} - Pr^p_{HG})$$

Because $(Pr_{NOX} - Pr^p_{NOX}) >= 0$ (same for the other terms).

If the second equation uses the original trading prices (e.g., Pr_{NOX} instead of Pr^p_{NOX}), that the savings will be underestimated since the difference equation between the two becomes

$$\text{Difference Savings Estimate} = -Q^p_{NOX}(Pr_{NOX} - Pr^p_{NOX}) - Q^p_{SO2}(Pr_{SO2} - Pr^p_{SO2}) - Q^p_{HG}(Pr_{HG} - Pr^p_{HG})$$

I could not tell from the description which equation was being used.

If I am correct, the estimate for the savings has been overestimated by the following amount:

$$Q_{NOX}(Pr_{NOX} - Pr^p_{NOX}) + Q_{SO2}(Pr_{SO2} - Pr^p_{SO2}) + Q_{HG}(Pr_{HG} - Pr^p_{HG})$$

because $(Pr_{NOX} - Pr^p_{NOX}) >= 0$ (same for the other terms).

I believe that the savings formula for each year should have been computed as:

$$Saving_t = Q_{NOX}*Pr_{NOX} + Q_{SO2}*Pr_{SO2} + Q_{HG}*Pr_{HG} - Q^p_{NOX}*Pr^p_{NOX} - Q^pS_{O2}*Pr^p_{SO2} - Q^p_{HG}*Pr^p_{HG}$$

- Table 1.3, page 1-7, is the most disconnected from the DOE goal 1.3. The DOE goal focuses on reducing dependence on unstable foreign fuel supplies and improving reliability of supply. The EERE metrics, except for the metric 4, measures reductions in total imports. The DOE goal, the goal focuses on achieving diversity in our import sources as a way of reducing U.S. vulnerability to disruptions and increasing the flexibility of the market to meet U.S. energy needs. The EERE goal does not measure diversity or vulnerability.
  - Table 1.3, metrics 1 and 2: These metrics fails because they would count greater ethanol imports from Brazil or greater petroleum imports from Canada, Mexico, or other OECD producers as being just as bad as petroleum imports from the Persian Gulf. An alternative metric might be the percent of U.S. liquid imports from the Persian Gulf. While this may not be politically correct, it would more directly aligned to the DOE goal.
  - Metric 3 is just an efficiency measure. If this metric identified total LDV miles traveled divided by the relevant liquids imported for use in LDV's, then you would have a more directly aligned measure though it might be redundant.
  - Metric 4 should be generalized to include all liquids consuming sectors of the U.S. economy, not just the transportation sector. It appears to be a good metric otherwise and directly relates to the DOE goal 1.1.

Also need much better calibration between MARKAL and NEMS to get the similar consumer behavior patterns.

The documentation is of mixed quality and usefulness, depends on the area. Graphics and descriptions need better labels. See following set of comments.
Better calibration of using two models (NEMS and MARKAL) when going to 2050. This is important because of 3% discount rate.

Better information that supports R&D investments and what impacts they have had – historically.

Better documentation of causality for stark changes in technology changes, particularly for fuel cells, solar PV, and ethanol.

Please include short summaries (no more than 3 pages) of the assumptions in the appendices for each program area. While there is a natural tension and desire to be complete, the amount of time allocated to the reviewers requires that short summaries be included in the benefits analysis document.

Dan Loughlin	**Rating: No Rating Given**

The environmental metrics do not capture many of the *real* environmental impacts. For example, there are water quality, air quality, and land impacts related to the realization of the energy system. An example is with the adoption of plug-in hybrids. These vehicles would likely reduce pollutant emissions on roadways (close to people) in exchange for pollutant emissions from electricity production. These may be centralized (large coal-fired EGUs) or distributed (small natural gas turbines, renewables). It may be useful to determine health impact metrics and include these.

Should there be a differentiation between natural resources and environmental impacts? I'm not sure what the answer is. I tend to think of water use and land use as resource impacts, while air quality and water quality impacts are environmental. The difference may be semantics, however. In general, the addition of both more detailed environmental and resource metrics may be beneficial.

For energy system modeling, there is a continuum from the goals of modeling "what will happen" (simulation) to modeling "what should I do?" (optimization). MARKAL and NEMS act in different parts of this continuum. NEMS is detailed and provides a hybrid simulation/optimization approach. MARKAL (in its regular/base configuration) e.g., it tells us how to achieve goals, not what might happen (except with strong caveats about how actors tend to act in least cost, but not 'perfectly'). They differ in other ways as well… MARKAL is less detailed but has a longer time horizon, is faster, and perfect foresight… MARKAL is fast, and thus is useful in sensitivity and uncertainty analysis applications. MARKAL also has a stochastic option that may be useful in evaluating robust portfolio strategies. **The methodology should take into account the strengths of these models and what each can add to a portfolio evaluation process.**

There is an intrinsic benefit to using multiple models to investigate an issue. **From this context, I think that it may be of more use to use NEMS and MARKAL in parallel (both applied independently) than in series (MARKAL results considered only for 2030 to 2050 period).**

Benefits of individual programs were evaluated relative to the baseline scenario. **I believe that it might also be interesting to evaluate the benefits of programs relative to the portfolio scenario. For example, if we take "out" a program, what are the benefits that would not be realized.** The results would take into account where other programs might fill in the gap. Together, these two approaches may provide a more full picture of individual program benefits.

How are program decision-makers expected to make use of the benefits information to make decisions? If this is known, then it may help drive the development of the methodology. Is it, in fact, an ultimate goal to rank the programs with respect to the different metrics, or is that left up to another analyst or decision-maker in the chain. If one did want to rank programs, how might one do it? It is clearly a multi-objective problem. **One easy step would be to determine when a program is dominated by one or more others in "all" dimensions. Such a program may be of a lesser priority. If not dominated by all others, then tradeoffs must be considered in ranking.**

Where MARKAL and NEMS results appeared to have discontinuities in their linkage, it would be helpful to have some description of how the assumptions/methodologies for each that may have resulted in the discontinuity.

Frederic Murphy	Rating: Excellent

This is a hard problem. My comments focus on what is needed. This is not a denigration of the major effort that has been undertaken by people who are taking this task very seriously.

Need to use the literature on science and patent networks to evaluate the contribution of DoE funding to the actual technology development.

Need to do retrospective analysis of the success of programs and apply the success rate to future outcomes rather than assume the programs will be successful.

Transportation fuel diversity index should reflect the avoidance of oil-based transportation. Diversity in crude oil is a chimera as this is a world market. The diversity has to be measured in non-crude-oil contribution.

Natural gas price reduction is not an appropriate goal. It smacks of mercantilism. Rather focus on increased supply or energy efficiency.

The model documentation of Markal needs to be improved. PC's now can be used to solve very large models. Markal should be rebuilt in a way that an expert in LP can run it relatively easily and the version used should be freely available on the web.

Be clear about what funding is related to what benefits.

Publish summary tables of assumptions that cut across all of the programs so that it is easy to see if the assumptions are consistent.

Making the story lines clear and readily available is a good idea.

Energy security at a macro level is best measured by GDP loss. It should also be measured at the micro level as the impact on the budgets of model households.

The portfolio benefits of funding diverse technologies are lost in using such deterministic representations.

The DoE R&D expenditures should be put in context of other R&D expenditures, nationally and internationally.

There are multiple equilibria given learning because of the non-convex cost structure. These multiple equilibria may be interesting as alternative futures based on the potential of the different winners in the portfolio.

Think through the next questions you will be asked if you succeed in this enterprise. One way to deal with being used in the budget process to cut programs is to focus on the portfolio risks of picking winners as well as the best estimate of the total benefits.

Reporting needs to be standardized across areas. A generic outline needs to be negotiated among the areas so that a reader can compare the assumptions, implementations, and results across areas. At the same time differences have to be respected. For example, EERE has many diverse programs while NE is focused on a few large areas.

When evaluating the program benefits, the total benefits are not equal to the sum of the individual benefits. The Shapley value can be used to generate individual program benefits that sum to the combined benefits. The policy question is the marginal contribution of the individual programs for budgeting purposes.

William Pizer	Rating: Good

Benefit metrics: I would suggest the environmental metrics include relevant measures of non-air pollution, including water, nuclear, and (if relevant) solid. Otherwise, the characterization of some programs (i.e. nuclear) will not reflect adverse environmental consequences. On the security side, considerable work has gone into developing security metrics (suggest talking to Vito Stagliano at the National Commission on Energy Policy, 202 637 0400, who has been leading an exercise on this). Personally, I think overall oil consumption, oil intensity of consumption, diversity of global supply, and some measure of flexibility (how well use can substitute away from oil consumption) would be most useful, along with imports.

Broadly, measures should have as close as possible of a connection to the public good externality as possible, and should have a description of how they relate. Aside from the security examples above, the economy example should somehow summarize increased productivity, which must underlie the various measures in the list. Ideally, the economic category should capture the improved welfare holding security and environment constant.

I am somewhat concerned about the need to forecast effects far into the future to identify the largest benefits. Our ability to discern effects on these horizons is (in my opinion) weak. While this effort is probably necessary given the long horizons associated with research, it could be supplemented with more empirical efforts to tie DOE funding to nearer term intellectual progress (the patent idea mentioned in the discussion was particularly interesting). This may be a more convincing bit of evidence than 50-year forecasts.

Future efforts to consider not just attainment of DOE program goals, but the likelihood of attainment, will be extremely useful.

The documentation appeared to be rather complete, but there needs to be a way that key assumptions are distilled to a more manageable volume. I would suggest some kind of summary sensitivity analysis that provides a focus on the key assumptions. More comments forthcoming on individual programs.

It would be good to have a clean summary up front (in the presentation) of the baseline v. AEO reference.

While impacts are necessarily measured over long horizons, it may be important to emphasize nearer term impacts where confidence is higher (or intermediate impacts). I would suggest that benefit discounting more closely match hurdle rates being used on the cost side.

B. Discussion

NEMS and MARKAL – Different offices used the models differently to cover different timeframes. This approach made it difficult to judge the benefits and to compare them across office programs.

Before 2030, estimated benefits from NEMS seem conservative; post-2030 benefits from MARKAL seem much more aggressive. There is a need for benchmarking discount rates so models are more similar in behavior. The rapid growth in benefits over the post-2030 period probably reflects the lower, 3% discount rate used in MARKAL.

The DOE goal related to vulnerability implies diversity of sources, away from unstable regimes. If you measure that goal with total imports, you imply incorrectly that Canadian oil and natural gas imports are more vulnerable to interruptions than domestic supplies.

Environmental metrics all dealt with air, none for water. If current models can't incorporate these issues, DOE may need an external source.

NEMS is a highly documented model from a quasi-independent agency that seeks to produce an unbiased forecast. MARKAL is a difficult model to understand and to generate a reasonable matrix when it is solved. Has MARKAL improved to where the documentation standards and public availability of the model are useful?

Are there any structural failures in either or both models that make the analysis wrong? Identifying those is important. There was not much documentation on why the results might be limited due to this potential problem.

The national configuration framework for MARKAL could be used more to conduct sensitivity analyses. There should be more effort to explore the inner workings of that system.

Part of the documentation of these models should be alternative simulations around the base cases that provide various elasticities of supply and demand to make sure they are reasonable. The big problem with these models is hidden bounds. With elasticity calculations, you can see where analysts are constraining the model in ways that significantly determine the model's solution.

One of the big issues is the contribution of DOE expenditures to technology development. From some of the reports, it is unclear if the expenditure led to the generation of new technology. One reconciliation would be to review the social networks literature on the science contribution and trace the path of articles about who is central to new developments in various scientific disciplines through referencing patterns, etc., in the scientific literature. It may be possible with new search technologies to link the disparate data sources for DOE funding to the articles; it also can be done with patent databases. (See Fred Murphy's comments in the final section.) One can then see if the particular expenditures are contributing to, or establishing, the central flow of ideas.

There is also a considerable patent literature that categorizes patent awards in different fields and that might be suitably applied to the DOE programs.

The evaluation should incorporate the technical risk involved in achieving the program goals.

The National Commission for Energy Policy (NCEP) has constructed metrics for oil dependence and oil security. DOE should contact this group for further details. Oil imports may not be the correct metric. Instead, the benefits might depend upon how flexible the system is to shocks. Environmental benefits and solid and hazardous waste are also important.

Environmental metrics for water and air quality are important additions. Since location matters quite a bit for these concepts, DOE might consider population-weighted impacts. Tradeoffs between mobile sources of emissions and stationary sources (e.g., electric systems) can be quite different.

Given the joint nature of R&D activities, natural gas prices are an inappropriate measure for the benefits of increased supply through new technologies or efficiencies. One suggestion is to use the Shapley value, which is a concept in game theory that describes an approach for sharing gains achieved through cooperation among several actors.

C. DOE Response and Action

METRICS:

Issue 1. The list of environmental metrics is insufficient.

Response: We agree with the reviewer, and are undertaking efforts to expand our list of environmental benefits. For GPRA '09, we will include the change in market price of other capped pollutants (Hg, PM) in addition to SO_2. This year we will also investigate the possibility of reporting changes in the non-capped pollutants from vehicle emissions, but this requires updating many of the emissions coefficients in NEMS. Finally, we are undertaking a deeper effort to measure environmental benefits in other media, such as water use or land use. One of the difficulties is that the scale of our analysis is national R&D, while the environmental and ecological damages associated with energy production and use are very localized and heterogeneous.

Also, other environmental and nuclear specific metrics will be considered for nuclear energy, such as waste reduction, proliferation risk reduction, and improved plant safety and security. To the extent objective measures can be made (e.g., lower spent fuel production by volume or radiotoxicity), they will be incorporated into MARKAL. Proliferation risk reduction is not considered a major metric for a national model; it may be reasonable to cover it in global modeling.

Issue 2. The metrics are not related to the DOE goals.

Response. We believe we've taken great pains to make the metrics align well with the DOE strategic goals of providing "reliable, affordable and clean" energy. We will change the order of our metrics to align more exactly with the DOE strategic goals.

We also do not believe that "diversity" in the DOE goal relates to geographic diversity of import source or exporting country, though we understand the reviewer's point that this is an important policy consideration. As of now, we have no way of forecasting the sources of future imports, and believe it to be beyond our scope to attempt to do so. We interpret diversity to mean diversity of fuels used. We are still examining the energy security metrics in general, and will begin to employ some of the recent work by David Greene of ORNL on this matter.

In addition, it is clear that, while some of the current DOE benefits metrics are useful, an improved set of metrics would provide greater value. An assessment of current metrics will be conducted and additional metrics will be evaluated.

Summary of actions to be taken to improve DOE benefits metrics:

- Ensure metrics are directly related to DOE Strategic Goals.
- Assess welfare metrics such as consumer and producer surplus and general economic welfare. Possible economic welfare metrics to consider:
    - change in household expenditures
- Evaluate approaches to expand energy security metrics beyond oil imports, while maintaining a focus on oil consumption (especially, non-crude-oil contribution to transportation energy sources). Possible energy security metrics to consider:
    - GDP loss
    - overall oil consumption
    - oil intensity of consumption
    - diversity of global supply
- Appraise ways to expand metrics related to environmental and natural resource impacts to include water quality, air quality, and land use impacts.
- Consider whether natural gas price reduction (as currently applied) is an appropriate metric.

Issue 3. The economic metrics are insufficient and should include changes in producer and consumer surplus and/or other welfare measures.

Response: We agree that it would be preferable to have a welfare measure, and investigated calculating an approximation of surplus in NEMS. We presented EIA with two alternative methods, and their consensus recommendation was that we avoid either method. EIA suggested that the methods would either rely on incomplete data, or would force analysts to make too many assumptions, thus we should not attempt to calculate surplus. Further, we considered using another model as a post-processor in order to arrive at a welfare measure. We agree with the reviewer that models that capture welfare, such as CGEs, are not well suited for representing technical performance criteria in detail. Thus, our conclusion was that the benefit of adding another model to our analysis simply to arrive at one more measure was outweighed by the costs of using another model and the analytical costs of interpreting results dependent on translation from one model to another. Moreover, because we have multiple economic metrics, we believe that decision makers are already offered a large amount of information. We believe that consumer energy expenditure savings is a metric that is intuitive to non-economists, but in the future we will be more careful to note that the overall gain for the economy is lower.

Issue 4. The metric on lowered cost of pollution abatement is not calculated correctly and misrepresents the true benefits.

Response: DOE's definition for pollution control costs is in fact the one that Andy Kydes recommended:

QNOX*PrNOX + QSO2*PrSO2 + QHG*PrHG - QpNOX*PrpNOX - QpSO2*PrpSO2 - QpHG*PrpHG

We will clarify the documentation regarding this definition. In future analyses, we will modify the metric reported as simply change in the allowance price for these pollutants.

MODELS:

Issue 5. NEMS and MARKAL should be used in parallel (both applied independently) rather than in series (MARKAL results considered only for 2030 to 2050 period). More insight about the results can be gained by showing the full set of results.

Response: For GPRA '09 we intend to show the results from MARKAL for the entire forecast period. One of the reviewers suggested that MARKAL be more closely calibrated to match the NEMS forecasts, while other reviewers suggested that we let MARKAL act as a fully separate model. Our inclination is more towards the latter suggestion, however we do calibrate MARKAL for the baseline, so that both models' answers are based on a common starting point. Moreover, many of the technical parameters in MARKAL are derived from NEMS and the AEO.

A more consistent approach to the application of both NEMS and MARKAL will be used. All DOE offices will run NEMS from the present to 2030 and MARKAL from the present to 2050 when forecasting benefits. It is agreed that there is an intrinsic benefit to using multiple models to investigate benefits forecasts. Both models will be run in parallel and applied independently to gain a deeper understanding of the issues.

Means to better characterize, understand, and describe how model response is constrained or bounded (including elasticities of supply and demand) will be evaluated in an attempt to improve transparency in the use of the models.

Issue 6. "Before 2030, estimated benefits from NEMS seem conservative; post-2030 benefits from MARKAL seem much more aggressive. There is a need for benchmarking discount rates so models are more similar in behavior. The rapid growth in benefits over the post-2030 period probably reflects the lower, 3% discount rate used in MARKAL."

Response: MARKAL-GPRA08 did not use a 3% discount rate. MARKAL-GPRA08 end-use sector discount rates range for 10 to 46% (in real terms). The 3% discount rate was used by both NEMS-GPRA08 and MARKAL-GPRA08 for post processing model results and determining discounted economic cost savings.

Issue 7. MARKAL is a difficult model to understand and to generate a reasonable matrix when it is solved. MARKAL documentation needs to be improved.

Response: The MARKAL modeling code is widely available and used by over 100 modeling teams around the world. The model code is maintained by the Energy Technology Systems Analysis Programme (ETSAP) which is an implementing agreement of the International Energy Agency (IEA). Individual databases differ and tend to change often, which is an impediment to providing documentation of individual MARKAL databases. MARKAL-GPRA08 relied primarily on the NEMS technology assumptions used by EIA to produce the 2006 AEO.

ASSESSMENT AND INTERPRETATION OF RESULTS:

Issue 8. Is there evidence of the impacts of past DOE R&D?

Response: The National Academy of Sciences undertook a major retrospective analysis on the benefits of DOE R&D in 2001. Their findings are available at http://www.nap.edu/books/0309074487/html/ . The panel found significant benefits to past R&D; however those benefits are now part of our baseline case.

Issue 9. Benefits of individual programs were evaluated relative to the baseline scenario. It might also be interesting to evaluate the benefits of programs relative to the portfolio scenario. For example, if we take "out" a program, what are the benefits that would not be realized? The results would take into account where other programs might fill in the gap. Together, these two approaches may provide a fuller picture of individual program benefits.

Response: We agree that "taking out" a program from the portfolio case, in addition to showing the programs relative to a baseline without any DOE R&D would be instructive. In fact, we have experimented with this approach and have done some internal analyses that have yielded insights. Unfortunately, we are too time-constrained to do this analyses for all technologies and programs during the budget decision season, but we will consider doing this analysis for a small subset of technologies.

Issue 10. More analysis of model results should be undertaken and more of a "story" should be told to provide intuition to the metrics.

Response: It is agreed that DOE benefits analyses would benefit from more substantial interpretation of results to provide key insights for planning. An effort will be made to develop the ability to interpret results and articulate the key dynamics and insights that emerge from the analysis, along with the implications of important model limitations and assumptions.

Approaches to be evaluated include:

- Sensitivity runs to explore other combinations of DOE R&D other than "all programs succeed" or "only one program succeeds."
- Probability distributions for program performance risk.
- Comparisons of nearer-term impacts where confidence is higher with longer-term impacts.

ASSUMPTIONS:

Issue 11. The baseline case is not clear.

Response: The baseline case and baseline assumptions for each technology are all documented in the individual appendices to the main report.

Issue 12. Using a 3% discount rate is inappropriate, and is not reflective of the private sector rate of return.

Response: NEMS and MARKAL do not use 3% for the internal calculations; instead they use interest rates that are more specific to the decision maker or sector in question. 3% is used in post-processing for NPV calculations. 3% was suggested by the NAS/NRC panel, and is also OMB guidance for calculations for periods of 30 years or more. The appropriate discount rate (3% or 7%) for this type of analysis will be assessed.

DOCUMENTATION:

Issue 13. Documentation needs to be improved.

Response: Approaches to ensure clear, comprehensive documentation will be assessed. The following improvements to documentation will be considered:

- Preparation of a synthesis document for the DOE portfolio.
- Descriptions of all scenarios (population, GDP, energy system, emissions) to provide readers with a starting point for understanding the benefits forecasts.
- Documentation of reasons for stark changes in technology penetration in the models.
- Explanation of uncertainty of results.
- Summary tables that allow the reader to compare assumptions made by all of the DOE programs.
- Comparison of the no federal R&D baseline v. AEO reference case.
- Exposition of differences between MARKAL and NEMS results.

Title: Energy Efficiency and Renewable Energy
Presenter: Scott Hassell
Overall Rating: Good

A. Review Panel Comments

Leon Clarke	**Rating: Very Good**

I found the approach and assumptions to be credible and transparent.

Excellent. I found the documentation to be very good and very clear. It allowed meaningful discussion of the underlying assumptions.

I thought this was an excellent analysis, but substantially more effort needs to be made on interpretation to improve the value of the analysis. This is my primary recommendation for each program and for the program as a whole.

Joseph DeCarolis	**Rating: Very Good**

EERE did the best job of applying the GPRA metrics. Other Offices did not estimate all metrics.

Results from NEMS and MARKAL should not be spliced together. In many of the figures, there is a kink in the results in the year 2030, when the analysis transitions from NEMS to MARKAL.

Offshore wind capital cost reductions as a direct result of EERE RD3 seems implausible. The net result is roughly 100 GW of offshore wind in the Program relative to no offshore wind in the baseline case. According to the Appendix E, this will be achieved with minimal EERE RD3 work.

The offshore wind input assumptions to the integrated models must be revisited.

Present results from NEMS and MARKAL separately.

Alexander Farrell	**Rating: Fair**

Many elements are unjustified assumptions, or at least appear to be unjustified. For instance, the efficiency of FCVs vs. conventional vehicles. Also the choices of *n* in *n*-year analyses tend to be unexplained.

GRPA08 – biomass analysis is far too narrow. You should explore possibilities of success of gasification plus F/T diesel, MSW-to-ethanol, and the possibilities of non-DOE technologies becoming successful. This will tend to be a disappointing outcome to some degree, but such an effort could help inform what R&D strategies are robust in this way.

There are many, many environmental issues associated with biomass energy, including land use conversion, fertilizer runoff, soil erosion, water use, and more. These are often dependent on agricultural practices, which are not modeled in NEMS or MARKAL (and should not be). Therefore, quantification is not feasible but these environmental effects SHOULD be considered and discussed qualitatively.

These analyses are all about budgets proposed by the President, while what really happens is the result of the Congressional appropriations effort, which changes budgets in total and also create earmarks. It would be very instructive and helpful to analyze the benefits of the actual, Congressionally- approved budgets to see how these decisions change the benefits.

California light duty vehicle GHG standards (AB1493) are improperly ignored. How consistent is this analysis with the analysis that supported the CA rules? Lacking evidence to the country, I would trust the CA studies more than the DOE estimates.

Long-term wind costs for onshore and offshore converge to the same value. This seems impossible, the offshore costs will be significantly higher, I think.

Deterministic estimates of benefits are not credible.

From what I can tell, the FCVT benefits analysis assumes that more energy efficient technologies result in more fuel-efficient vehicles without public policy to create this effect. This seems quite wrong. It is very clear that most vehicle makers are constrained by CAFE requirements, and that technological advances in energy efficiency have been used to design larger, faster vehicles that meet these requirements. There are differences between vehicle manufacturers, of course, and Toyota's hybrids help that company surpass their requirements. However, simply assuming this will occur across the board without fuel or emission policy is a major error. Just consider the lawsuits against California's auto CO2 emissions bill (AB1493 Pavley)

As I understand, MARKAL is extremely inflexible in AEO2006 due to constraints that permit the model to create reasonable replications of current (near) year results. This means, among other things, that CO2-constrained cases very expensive. Therefore, this could make the *savings* of EERE programs in such cases appear larger than they really are. In general for the DOE benefits estimate, the development of scenarios and cases, and the accompanying model specification and other analyses, need to be improved.

For FEMP, why is NEMS necessary? This is such a straightforward issue that a much simpler approach of energy and cost savings should be sufficient. WIP is appropriately done offline.

Slide on bottom of page 20 of handout (Energy Intensity) is very helpful and should be required for all benefits estimates.

Figures that show reductions of GHG emissions growing over time are misleading because GHG emissions will actually grow over this time, just a bit more slowly. This sort of information is contained in the energy intensity figures. These sorts of figures may tend to make it hard to observe that GHG emissions are growing in the absence of a GHG mitigation policy and give the incorrect impression that voluntary approaches are likely to reduce GHG emissions.

Hillard Huntington	**Rating: Good**

Differentiate between market barriers and market failures (reasons why private sector will not invest).
Private sector investment will increase with energy prices. This will cut into DOE's portfolio.
Care required in adjusting NEMS. Should not use early adopters (Californians using solar panel) to represent the entire market population.

Explain whether offline models use optimization or empirics to estimate penetration, etc.

Can N-rule be cast in terms of technology cost terms? E.g., compute the decline in today's cost that would result in a 20% increase in NPV. Then, calculate the number of years of escalation that would result in the same 20% jump in NPV.

Tables explaining how NEMS was adjusted for baseline and for portfolio are very helpful. You need more of the tables that were provided in the presentation to appear at the front of your prepared report.

Andy Kydes	**Rating: Good**

Mixed credibility based on documentation. Some goals/targets seem implausible based on historical information on how technological progress has occurred.

Comments on Chapter 1

General Comment

The EERE goals and metrics are sometimes inconsistent with or not directly related to the U.S. DOE Goals as stated in Box 1.1 and Tables 1.1 -1.3.

- The DOE goal 1.1 of "affordable" relates generally to cost effectively improving economic efficiency as discussed in Goal 1.4. The EERE metrics (1-8 page 1-6) of Table 1.1 focus on changes in natural gas prices or expenditures by various market segments. Some discussion of why these metrics (1-8) improve economic efficiency should be made, otherwise there is no adequate link between the EERE metrics and the DOE Goal 1.4.
    - Item 1. A reduction in the average natural gas price may or may not improve U.S. economic efficiency, depending on how it is accomplished.
    - Items 2. Energy Systems costs is only one part of the U.S. energy-economy and MARKAL does not represent the U.S. economy so economic efficiency is not assured unless the energy and non-energy parts are relatively unrelated.

- Table 1.2. The only measure for environmental pollutants is focused on central station air emissions. What happened to other energy-related by-products that influence water quality or other contaminations, particularly from refineries or the industrial sector or even the agricultural sector? Neither of the models used are necessarily adequate at this time to address these issues (which may require additional model enhancements in the future) but these issues are also important. Mobile emissions from vehicles is another important area that should also be mentioned.

  The equation described for measuring benefits of metrics 3, "Reduced Cost of Criteria Pollutant Control," seems to either underestimate or overestimate the savings, depending on the formulation. That is,

  The discussion in the GPRA08 Benefits Metrics suggests that the computation is the following for each year:

  $$GPRA08Savings_t = [Q_{NOX} - Q^p_{NOX}]^* Pr^p_{NOX} + [Q_{SO2} - Q^pS_{O2}]^*Pr^p_{SO2} + [Q_{HG} - Q^p_{HG}]^*Pr^p_{HG}$$

  If I am correct, the estimate for the savings has been overestimated by the following amount:

  $$Q_{NOX} (Pr_{NOX} - Pr^p_{NOX}) + Q_{SO2}(Pr_{SO2} - Pr^p_{SO2}) + Q_{HG}(Pr_{HG} - Pr^p_{HG})$$

  because $(Pr_{NOX} - Pr^p_{NOX}) >= 0$ (same for the other terms).

  I believe that the savings formula for each year should have been computed as:

  $$Saving_t = Q_{NOX}{*}Pr_{NOX} + Q_{SO2}{*}Pr_{SO2} + Q_{HG}{*}Pr_{HG} - Q^p_{NOX}{*}Pr^p_{NOX} - Q^pS_{O2}{*}Pr^p_{SO2} - Q^p_{HG}{*}Pr^p_{HG}$$

- Table 1.3, page 1-7, is the most disconnected from the DOE goal 1.3. The DOE goal focuses on reducing dependence on unstable foreign fuel supplies and improving reliability of supply. The EERE metrics, except for the metric 4, measures reductions in total imports. The DOE goal, the goal focuses on achieving diversity in our import sources as a way of reducing U.S. vulnerability to disruptions and increasing the flexibility of the market to meet U.S. energy needs. The EERE goal does not measure diversity or vulnerability.
    - Table 1.3, metrics 1 and 2: These metrics fails because they would count greater ethanol imports from Brazil or greater petroleum imports from Canada, Mexico, or other OECD producers as being just as bad as petroleum imports from the Persian Gulf. An alternative metric might be the percent of U.S. liquid imports from the Persian Gulf. While this may not be politically correct, it would more directly aligned to the DOE goal.
    - Metric 3 is just an efficiency measure. If this metric identified total LDV miles traveled divided by the relevant liquids imported for use in LDV's, then you would have a more directly aligned measure though it might be redundant.
    - Metric 4 should be generalized to include all liquids consuming sectors of the U.S. economy, not

just the transportation sector. It appears to be a good metric otherwise and directly relates to the DOE goal 1.1.

Comments on Chapter 2

General Comments

How was the EERE BAU case formed? That is, how was the *AEO2006* reference case changed to reflect the absence of EERE programs? It is not clear from the write-up. It may be clear in the appendices.

It is unclear why a 3 % discount rate was used to measure the benefits and costs. Was this prescribed by the NRC *for both costs and benefits* or just benefits? If the investments are entirely Federal government investments, then the 3% might be OK. If any investments are required by the private sector, then the 3% rate in the market diffusion calculation might be questionable.

- It is unclear how the 3% discount rate was used to levelize the capital investments and why that is appropriate when actual investment discount rates might be much higher for private sector investments. Clarification is required here.

There appears to be a problem in the way the mid-term benefits derived from NEMS-GPRA08 were merged with the longer-term benefits from MARKAL-GPRA08. The discontinuity of benefit rate changes is apparent in virtually all of the graphics and Table 2.1. While these differences are explained as the use of two different models, the results might result in biased conclusions.

- Table 2, annual consumer savings through 2030 is increasing at a declining rate while the savings from the MARKAL model jumps in 2035 and has a different, more aggressive pattern. This pattern is evident in the most of the remaining categories of savings also.

- The figures following on pages 2-3 through 2-11 illustrate in most cases the discontinuity of behavior pre-2030 and post 2030 by the energy market participants represented in the two models in this analysis. The MARKAL-GPRA08 model is obviously much more optimistic about the rate of increase in adoption of EERE technologies and the consequent savings implied. If consistency with the NEMS-GPRA08 is required, this analysis has not accomplished that and more care must be taken to align the two model behaviors/results and explain differences in slopes/patterns. The patterns of savings, even within the longer term are not intuitively obvious, e.g., annual electric power industry savings, the double peak for natural gas price savings, the annual avoided carbon emissions, the year-to-year avoided oil imports show plateaus in the last 5-10 years.

The energy savings discussions and graphics do not always appear to be made with respect to the correct baseline to measure EERE benefits, but this may be a product of my confusion in reading the discussion of the cases. For example, if the EERE portfolio was run with a carbon-constrained case, the correct comparison would be relative to the carbon constrained case without the EERE portfolio; similarly for the high price case with and without the EERE portfolio. The only difference between cases should be the inclusion of the EERE portfolio. Other comparisons made confuse the issue (e.g., page 2-15, last paragraph). In general, the comparison should never be made between the BAU case and the CC case with the EERE portfolio. The write-up is somewhat confusing in this regard. Perhaps better labels on the graphics on pages 2-13 through 2-25 would help solve (part or all of) my problem. For example, on page 2-21, the shaded area is labeled BAU and then Annual Avoided Carbon Emissions in the darkest area while the second line is labeled High Oil. Since there are no avoided emissions in the BAU, what case is being used to generate these savings? Is this the BAU with carbon constraints or the BAU with the EERE portfolio or both? Is the carbon savings in the High Oil line just the High Price case or does the high price case have anything else associated with it? The text implies more might be included.

Bottom of page 2-21 is a good example of an incorrect (not valid) comparison which compares the emissions of a High Price case with the EERE portfolio with the BAU case. Does this mean that EERE is taking credit for the high prices as well as the EERE portfolio? I don't think so. The correct comparison of the savings should be between the High Price case without the EERE portfolio and the High Price case with the EERE portfolio.

- The statement (page 2-13, second full paragraph) that the benefit of the EERE portfolio cannot be calculated in an emissions constrained case is not obvious. While it is clear that the calculations might be approximate and the value may not entirely accrue to sectors cleanly, some national estimate could probably be made using the following idea for any particular year (or do an integration between the two curves of prices versus prices).

$$Saving_t = Q_{NOX}*Pr_{NOX} + Q_{SO2}*Pr_{SO2} + Q_{HG}*Pr_{HG} + Q_{CO2}*Pr_{CO2} - Q^p{}_{NOX}*Pr^p{}_{NOX} \quad Q^pS_{O2}*Pr^p{}_{SO2} - Q^p{}_{HG}*Pr^p{}_{HG} - Q^p{}_{CO2}*Pr^p{}_{CO2}$$

Where

Original Case Control Cost = $Q_{NOX}*Pr_{NOX} + Q_{SO2}*Pr_{SO2} + Q_{HG}*Pr_{HG} + Q_{CO2}*Pr_{CO2}$

Programs Case Control Cost = $Q^p{}_{NOX}*Pr^p{}_{NOX} + Q^pS_{O2}*Pr^p{}_{SO2} + Q^p{}_{HG}*Pr^p{}_{HG} + Q^p{}_{CO2}*Pr^p{}_{CO2}$

Comments on Chapter 3 – Individual Programs

- Fix all graphs in chapter 3 so that the vertical bar is on 2030 to separate NEMS-GPRA08 versus MARKAL-GPRA08 results.

- **Question.** Were all of the programs run fully integrated in separate NEMS runs or were just the sectoral models (e.g., residential, commercial, industrial, transportation, electricity generation) run individually? If run individually, the savings may have been overestimated to varying degrees.

- The discussion of savings and what contributed the most is confusing.

- Page 3-11, table 3.1. How do the goals identified in this table compare with the EPACT2005 goal of 5 commercial-scale operating cellulosic ethanol plants, 50 million gallons per year, by 2012? Does this say that EERE expects the first commercial cellulosic plant to be built around 2017? I can't tell.

- If NEMS was used to derive the Benefits of Biomass Benefits Estimates, the entries for many of the benefits should have been identified as "not significant" or "ns."
    - "ns" should be defined as "not significant relative to model level of detail and convergence tolerance." This is NOT an issue of "error" but of convergence tolerance so please correct the footnotes that refer to "ns' throughout the text. Was the biomass case run in an integrated framework?
    - The row entitled "reduction of fraction of household income spent on energy" should have "ns" in its entirety (both the NEMS-GPRA08 and MARKAL-GPRA08 entries) since they are insignificant for either model.
    - Under "Environmental Benefits", the row entitled "Avoided Greenhouse Gas Emissions, Annual" should have "ns" for 2020 and 2025, and 2030, given the convergence tolerance.
        - The change between the NEMS-GPRA08 and MARKAL-GPRA08 solutions in 2030 to 2035 for Cumulative GHG Emissions are too large to simply say that they are different models. A much more careful calibration needs to be done for these models or the authors should explain their results if they believe them. The issue is important because of the 3% discount rate used in the benefits analysis.
    - When does the EERE ethanol program believe that the posited programs will make cellulosic ethanol commercially available and what is the assumed first of a kind cost? It is not clear from the table or discussion. I would guess sometime between 2015 and 2017 but I am not sure. If true, this suggests that the EPACT2005 incentive for cellulosic ethanol will have no impact.
    - The cellulosic ethanol assumptions incorporate a credit for co-generated electricity. The price in the appendix appears to be the wholesale price of electricity. Is that correct?
    - Appendix C, page C-6, quotes Tony Radich as saying the EIA assumed cellulosic ethanol will enter the market in 2010, ramp up to 250 million gallons per year by 2012 (correct so far), and will not grow further (a misquote). EIA made no such assumptions regarding the penetration of cellulosic ethanol. The penetration of cellulosic ethanol is endogenously determined by the NEMS-GPRA08 model on an economic basis.
    - The significant disparity between the cellulosic capital cost assumed by the EERE program office and that used by EIA in AEO2006 is striking and very hard to rationalize.
        - EIA assumed the capital costs for a 50 million gallons per day plant provided by IOGEN,

scaled up to include project contingency which all plants must have, and an "optimism factors" which is typically 10-15% above the pre-construction cost estimate of the first plant. No such costs were provided for the EERE cellulosic plant. However, the Aden publication reference appears to show the capital cost at $217 million dollars (page 64, converted to 2004$). Annualizing this number with NEMS assumptions plant size and a 15% capital recovery factor yields a per gallon cost of approximately $0.65 for the capital component. This is almost 50 percent higher than the capital cost component identified in the appendix, page C-18, of $0.45/gallon in 2015. The EERE hypothetical plant may be assuming a higher annual output like 68 million gallons per year.

- The EERE estimate for the cellulosic ethanol capital cost references the report by Aden, et.al. of NREL in 2002.
  - Aden's costs are $217 million in 2004 dollars and a relatively *mature* technology (nth-of-a-kind, not the first-of-a-kind) commercial plant costs. Since virtually no full-scale commercial plants are built before 2015, it must be the implicit assumption of EERE program that virtually the entire cost reduction to the $217 million is due to government R&D before 2015. Is that correct?
  - EERE then assumes that the capital costs will decline another 40 percent by 2030 to about $117 million dollars (40% of the unadjusted IOGEN number). The EERE costs are assumed to decline further to 102 million dollars by 2050.
  - At the costs assumed for cellulosic ethanol provided in the Aden paper, cellulosic ethanol would probably have won the ethanol market easily after it had entered the market, even without further cost reductions.

The cellulosic ethanol capital cost assumption path, if I have understood the assumptions correctly, does not appear to be credible. I wonder if the O&M assumptions have a similar problem of assuming the starting plant is already mature. I suggest that at the very least, *EERE start with the IOGEN number* which is currently the best informed for the first of a kind plant, and then reduce that cost to whatever percentage your program can justify.

- The Buildings program does not summarize the assumptions in the budget document and why many of the savings have been estimated using an external analysis to NEMS. A brief summary of what was done would have been useful.

- The differences in the historical fuel cell costs by sector between EERE programs and the AEO2006 are startling and raises the question of whether EERE has discussed these differences with EIA experts. Since changes to AEO assumptions must be documented using citable and credible sources according to the OMB and DOE directions, why does such a difference exist for something as basic as cost and performance historical data? The same criteria for adopting technology cost and performance data apply to EIA. Such cost disparities for the cost and performance for an historical year should not exist between EIA and the program offices.

- Why was MARKAL used for the transportation analysis rather than NEMS-GPRA-08 through 2030 and MARKAL thereafter? Given the optimism shown by MARKAL in other sectors, the use of MARKAL pre-2030 is questionable.

- Is the EERE program assuming a breakthrough technology through R&D? The potential to achieve the goal of SAI for grid-connected PV systems (Table 3.9), to be cost competitive with grid connected systems by 2015, from normal technological progress is questionable. Using standard learning theory and empirical data, assuming that 10 GW of cumulative PV solar capacity has already been added in the past 20 years, the "technological progress rate" or "learning rate" implied by the EERE goals for PV between 2005 and 2015 implies an over 65 percent cost reduction for every doubling of capacity in the commercial sector -- historically unprecedented for ***any*** significant energy technology, especially at the levels of market penetration projected in these cases by 2015. Even if we assume that the U.S has only 50% of the total world growth and assuming perfect spillover affects, the learning rate implied is over 45% (a less than 55% progress ratio). See the table below.

No Spillover Affects

SOLAR PV	PV Commercial System Costs: Cumulative Installed Capacity	PV Commercial System Costs: Capital Cost-$/KW	PV Residential System Costs: Cumulative Installed Capacity	PV Residential System Costs: Capital Cost-$/KW
Q0 = cumulative Capacity to date-KW	10000000	6300	10000000	8500
QT = Cumulative Program Target Capacity by 2015	20000000	2200	20000000	3300
Calculated Value of b	1.517848305		1.364996817	
calculated value of a	2.65631E+14		3.05068E+13	
Implied Progress Ratio (2^-b)	0.3492		0.3882	
Implied Learning rate	0.6508		0.6118	

Perfect Spillover Affects in World

SOLAR PV	PV Commercial System Costs: Cumulative Installed Capacity	PV Commercial System Costs: Capital Cost-$/KW	PV Residential System Costs: Cumulative Installed Capacity	PV Residential System Costs: Capital Cost-$/KW
Q0 = cumulative Capacity to date-KW	10000000	6300	10000000	8500
QT = Cumulative Program Target Capacity by 2015	30000000	2200	30000000	3300
Calculated Value of b	0.957655657		0.861217105	
calculated value of a	3.184E+10		9076923231	
Implied Progress Ratio (2^-b)	0.51		0.55	
Implied Learning rate	0.49		0.45	

- The highest learning rate recorded learning rate in the literature appears to be about 45 percent (See Dutton and Sutton (1984)). Is there a basis for EERE's optimism? The issue of solar accessibility is based on an IEA study published in 2001. Surely we have more recent data that is specific to the U.S.

I find the wind programs insufficiently documented to be plausible. I find the PV assumptions on the technology progress from the program implausible for the same reason.

Documentation is mixed in quality. Graphics need better labels. Need short assumptions in benefits discussion.

Graphic on the Freedom Car and Vehicle Input shows the characteristics between NEMS and MARKAL. It turns out that the where NEMS and NEMS agree are the least important factors for consumers in NEMS – that is why NEMS and MARKAL disagree so much. To optimize in MARKAL, everyone should be buying GEO METRO's. However, that doesn't capture preferences for horsepower and internal space for people and luggage. This is why MARKAL overestimates oil import reductions.

Basis for development of savings discussion needs to be carefully laid out.

Generally need to explain how radical improvements occur in a short amount of time., i.e., what causes them, especially if it is contrary to historical trends. The path of improvement needs to be better supported.

Dan Loughlin	**Rating: No Rating Given**

In the EERE baseline, more flexibility was allowed in the model choosing vehicle types. It is not clear what this really means. From a strictly cost perspective, an optimization model might elect to put all travelers on motorcycles or mini-compacts. So, how this relaxation is implemented is important.

I am concerned regarding the use of the Consumer Spending metric in the context of the carbon limited and high fuel price scenarios. For example, consider high fuel prices. These would, in turn, lead to decreases in energy demands, and hence expenditures, because of demand elasticities in NEMS and energy efficiency improvements (Can the amount contributed to each be easily characterized?). One might argue that households might be worse off with respect to their overall economic well-being, however, and this isn't captured solely in an energy expenditures metric (example… fewer VMT affects ability to travel and get to work, and high fuel prices would have some impact most areas of household expenditure… so fraction of household expenditures to energy might also be a misleading metric if household expenditures are not adjusted to match the given scenario). **A recommendation going forward is that it may be use turning demand elasticities on/off to determine their impact. Also, it may be useful to look to additional metrics (maybe outputs of an economic post-processing) to examine more tangible metrics that describe household/consumer financial outcomes, as well as overall GDP impacts (possibly as output from a CGE model).**

Frederic Murphy	**Rating: Very Good**

People in the program offices have to be optimistic. How do you deal with this natural bias in developing program benefit-estimates?

Document how one estimates the benefits of leveraged programs like weatherization.

Bounds drive results. Document clearly how they are developed. Consider putting in price responsiveness because of the high-price scenarios.

The n-year rule should be price responsive and calibrated to the scale of the companies. For example, the aluminum program makes no sense if the funding goes to Alcoa, as it is a small part of their R&D program.

The role of the venture capital industry needs to be investigated in altering the scale requirements for a technology to be developed.

Uncertainty is important. Models that mechanically require probabilities will not work. Look at the finance literature.

William Pizer	**Rating: Good**

DOE is to be commended for a monumental effort. There are a number of fundamental questions I wonder about.

1. How well can DOE evaluate translate its goals into reasonable outcomes and model inputs. The discussion on wind and biomass suggested an optimism appropriate for leaders in an agency, but perhaps not a hard, objective evaluation.
2. How much can assumptions be ground-truthed. Application of the n-year rule and other assumptions about cost declines and technology penetration – how much can they be compared to previous results.
3. Are there dominant assumptions. Are the overall results a composite of many little things, or are there some bigger results that we should focus on. I would like to have some summary that ranked the assumptions in

order of importance to facilitate review.

4. Assumptions and results should be presented in context. Part of this reflects #2 – putting assumptions in terms of historical experience. But also results should be provided with some kind of scale – costs versus GDP, emission reductions versus overall levels, etc.
5. In addition to assumptions being ranked by overall effect, it would be useful to highlight assumptions that are relatively controversial, as judged by variance among experts in the field.
6. Costs with emission caps in place. There seemed to be some counting of reduced transfers as savings. When consumer prices reflect taxes or the cost of emission allowances, reducing household consumption cannot be valued at household prices.

Despite my appreciation of the level of effort, my gut reaction was that key assumptions were more optimistic than might be warranted. I am unclear about whether those key assumptions surround program goals – which are not really being questioned at this point – or the translation of program goals into program outputs and model inputs.

Elaborating from above:

The documentation and presentations would benefit from (a) a prioritization of issues / assumptions and (b) putting assumptions and results into a more natural context (historical experience or overall values). The presentations tended to highlight where the programs were coming from, with lots of institutional detail, and not so much where we are going with the analysis. If this is an analysis of benefits, and in particular a discussion of methodology, I would START by highlighting (1) what are the inputs we need to focus on (e.g., costs, availability, efficiency, etc.), where the programs focus, (2) how the programs are targeting those inputs. So, you start with slide 13 (on ethanol) showing a key input (cost) and the assumed estimate of the program. Then explain what the program goal actually is, and what the activities are to achieve the effect. It would be a lot easier to evaluate the credibility this way (along with some context of historic experience, already noted).

If assumptions are flowing directly from program goals, this should be clearly stated.

A huge improvement will be some assessment of the relative likelihood of achieving programmatic goals, and a link to the actual funding activities. Evaluating whether assumptions are reasonable is difficult without some tie to the funding level. For example, the discussion of offshore wind assumptions would be less relevant if we deemed the current funding level inadequate to achieve the goal.

As a non-expert in the specific technologies, increased peer-review of key assumptions would be extremely helpful.

B. Discussion

Benefits estimates are based on achieving goal – base case N-year rule not possible because of established program inputs.

N-year is used only if there is no better way.

N-year rule should be price-dependent. High oil prices led to a lot of movement.

Carbon policy – effect on households is a better measure than reduction in energy expenditures.

Some skepticism on the cost reductions in offshore wind power for 100 GW units by 2050. Large cost reductions are achieved with small expenditure.

How does DOE differentiate R&D effects from learning by doing (LBD)? If LBD, baseline should be more gradual. Portfolio case shows incredible amounts of reduction in cost.

By 2025 onshore and offshore have same cost – not credible. How much area? Environmental implications?

Models are based upon deterministic, portfolio theory. Need some way to cope with uncertainty.

Biofuels view is narrow with its focus on sugar-based fuels only and not syngas. Different scenario might be useful to elucidate the effect of accelerating the transformation from using starch to cellulose.

Perhaps conduct analysis of earmarked programs. Look at effectiveness of programs that are not DOE.

Solar Panels – California is an early adopter with different building structures. There is some danger in this type of analysis.

Why do the benefits escalate in the high-price case? When prices are high, private companies will invest more in energy R&D. Baseline projections for energy use in the reference case will move closer to the program's targets, resulting in smaller benefits as measured by the difference between reference and targeted levels.

Although there was an enormous amount of research and information provided by DOE, it was not easy to come away with a lot of insight. Lessons for policymakers need to be stated very simply and upfront. Using models for communication rather than quantification takes much practice, but it can be extremely effective.

C. DOE Response and Action

METRICS:

Issue 1. Goals and metrics are sometimes inconsistent with or not directly related to the U.S. DOE Goals.

Response: An assessment of current metrics will be conducted focused on the comments listed below.

- Energy Intensity metric (Thousand Btus per $ GDP) is very helpful and should be required for all benefits estimates.
- Mobile emissions from vehicles should also be considered.
- Some discussion of why the economic metrics improve economic efficiency is needed; otherwise there is no adequate link between the metrics and the DOE Goal of "affordable" energy.
- Energy security metrics need to measure diversity or vulnerability of energy supply to be consistent with DOE Strategic Goals.

MODELS:

Issue 2. FEMP and WIP should not be modeled in NEMS and MARKAL, but should be done exogenously.

Response: To some extent, FEMP, WIP, the Industrial Technologies Program and the Building Technologies Program are modeled through a combination of off-line analyses and use of the integrating models. Although we agree that the scale of some programs suggests that it is inappropriate to use a large integrating model to capture the benefits, part our charge to "integrate" GPRA analyses is to make all the benefits claims comparable. One clear way to make benefits claims comparable is to utilize the same set of tools. To the extent possible, we ensure that the offline analyses are consistent with NEMS forecasts, and integrate offline analyses into NEMS and MARKAL.

WIP and FEMP are primarily budget driven programs with historical track records. Their benefits are primarily estimated offline based on that record. NEMS is used in addition to that offline analysis in order to provide the appropriate mix of energy and carbon savings from reduced site electricity consumption and so that these programs are included in the EERE and ESE Portfolios.

Issue 3. Uncertainty is important. Models that mechanically require probabilities will not work. Look at the finance literature.

Response: DOE is building two models that will treat uncertainty explicitly. One is an extension of MARKAL, called Monte-Carlo MARKAL (MC-MARKAL). The other is the Stochastic Energy Deployment Systems Model (SEDS). We have studied the finance literature, and have been considering the use of real options and other valuation techniques, but their application in a government R&D portfolio is not straightforward, and further, may have to wait until completion of the probabilistic models.

Issue 4. How does the DOE distinguish between R&D and Learning by Doing?

Response: In the base case treatment, R&D and LBD are conflated. This is in part due to the treatment of technologies in NEMS in which an endogenous learning parameter (via a progress ratio formulation) accounts for both R&D and LBD effects. In the program case, we disable NEMS' endogenous learning so as not to "double count" program R&D effects with those generated endogenously. Up to the completion of the goal years, all advances are strictly R&D advances. Beyond the goal years, the advances are again a combination of R&D and LBD, and are based on the expert judgment of program analysts and modelers. In the future, we will attempt to be more specific in teasing out the effects of the two causes of advance.

Issue 5. Were all of the programs run fully integrated in separate NEMS runs or were just the sectoral models (e.g., residential, commercial, industrial, transportation, electricity generation) run individually? If run individually, the savings may have been overestimated to varying degrees.

Response: All of the individual EERE programs were modeled individually in the fully integrated NEMS, and then also as a portfolio of programs combined. The integrated NEMS provides electricity sector response for the energy efficiency programs and demand side response for the renewable programs.

Issue 6. The notation "ns" should be defined as "not significant relative to model level of detail and convergence tolerance." This is NOT an issue of "error" but of convergence tolerance so please correct the footnotes that refer to "ns' throughout the text.

Response: We will define "ns" as per the reviewer's suggestion in the future.

ASSESSMENT AND INTERPRETATION OF RESULTS:

Issue 7. Private sector investment will increase with energy prices. This will cut into DOE's portfolio.

Response: Private sector investment does indeed increase with increasing energy prices. This is most clear in the High Fuels Price scenario. Many benefits are smaller in the high fuels price case. Nevertheless, there are some technologies, such as hydrogen, for which we believe only government action will spur significant R&D and ensuing technological change.

Issue 8. People in the program offices have to be optimistic and some of the goals seem quite aggressive. How do you deal with this natural bias in developing program benefit-estimates?

Response: The current GPRA exercise is structured around the question: “What are the benefits that would accrue if a program’s goals are achieved?”, and thus optimism is part and parcel of the analysis. In the documentation, programs are asked to include a data-driven and intuitive storyline for their inputs, goals and milestones. Quite often, goals and milestones are based on program multi year plans, which are in turn carefully developed through processes that involve analysis and outreach to industry. Finally, in GPRA ’09, we will begin to experiment with a treatment of technological risk. As the GPRA analysis continues to evolve, our treatment of risk will become more explicit and more widespread. Eventually, the GPRA exercise will likely be structured around the new question: “What are the benefits that accrue given that the R&D increases the probabilities of success?”

Issue 9. More sensitivity analysis should be conducted to see which assumptions dominate.

Response: We agree that more sensitivity analysis is needed. We hope to be able to do more of this in the future.

Issue 10. More consideration should be given to how the future goals relate to historical trends and performance.

Response: We agree with this recommendation, and will attempt to present more analyses of this kind, in particular graphical depictions, in the future.

Issue 11. Why do the benefits escalate in the high-price case? When prices are high, private companies will invest more in energy R&D. Baseline projections for energy use in the reference case will move closer to the program’s targets, resulting in smaller benefits as measured by the difference between reference and targeted levels.

Response: The amount of energy savings due to the program is smaller in the HFP case, but each barrel of oil or Kwh avoided is worth more in that case than in the reference case. But because energy demand is largely inelastic and because advanced technologies which reduce costs are not as easily available in the base case (no R&D case), the effect of the programs R&D in the program case is evidenced in cost savings.

ASSUMPTIONS:

Issue 12. The n-year rule should be price responsive and calibrated to the scale of the companies. For example, the aluminum program makes no sense if the funding goes to Alcoa, as it is a small part of their R&D program.

Response: We are largely moving away from the n-year rule for GPRA ’09.

Issue 13. The role of the venture capital industry needs to be investigated in altering the scale requirements for a technology to be developed.

Response: In many cases, the role of the venture capital industry is considered, albeit implicitly as part of the role of “private industry” generally. However, for some of our technologies, their role is more explicit and determines the pace at which we project that innovations move from lab scale to demonstration scale to commercialization.

DOCUMENTATION:

Issue 14. The offline analyses should be better documented.

Response: We will attempt more complete documentation of offline analyses in future GPRA reports. Further, we are taking steps over a few years to: a) have offline analyses peer reviewed, and b) integrate offline analyses as much as possible into NEMS and MARKAL, and c)minimize the need for offline analyses.

Issue 15. Document how one estimates the benefits of leveraged programs like weatherization.

Response: The assumptions behind our analysis of the Weatherization program and other "leveraged" programs are documented in the appendices to the main report.

Issue 16. Bounds drive results. Document clearly how they are developed. Consider putting in price responsiveness because of the high-price scenarios.

Response: We assume that this comment refers to the MARKAL modeling. The assumptions for any bounds used are contained in the appendices to the main report. For GPRA '09, we intend to minimize the use of hard bounds in MARKAL, and replace them with "soft bounds," that assign an increased cost as installations increase quickly and cumulatively. Moreover, for GPRA '09 we intend to implement elastic demands in MARKAL.

PROGRAM SPECIFIC ISSUES:

Responses to Comments on Wind R&D:

Issue 17. The projected cost reduction for offshore wind technology does not seem reasonable based on the proposed budget.

Response: At this time a go/no go decision is planned in FY09 which will determine whether the program will invest significantly in offshore wind technology development. Much of this development program will rely on cost-shared partnerships with industry; the budget projection in the report does not account for the cost-shared amount that would be contributed by industry partners.

Issue 18.The convergence of offshore wind technology cost with land-based wind technology cost in the future does not seem plausible.

Response: The Wind Program is currently undergoing concept studies to model and evaluate the technology improvement opportunities that may be realized for offshore wind technology. These studies are not complete at this time. Although it is not completely implausible that the offshore and land-based wind technology costs could be similar, the program will modify the cost projections for the next version of the DOE benefit analysis. The primary difference between land-based and offshore wind technology is the foundation. One concept under consideration is the development of a method of floating the foundation to the site and sinking it in place. It is conceivable that this process could be similar in cost to the construction of a foundation for land-based technology. Because the technology evaluation has not been fully completed, the program is revising the cost projections to be more conservative. A delta between offshore and land-based wind technology will be determined.

Responses to Comments on Solar R&D:

Issue 19. Care is required in adjusting NEMS. EERE should not use early adopters (i.e., Californians using solar panels) to represent the entire market population.

Response: The system sizes used in the analysis were based on a technical assessment of roof space availability for average building sizes. This is where the 4kW for residential and 100kW commercial system sizes came from. The fact that the early California systems have been in this range lends credibility to the estimates, but is not the driving reason for the assumption. Systems/inverters in the U.S. (in multiple states), as well as in Germany and Japan, are all moving to similar sizes for residential systems (4-5 kW) and commercial systems (100-500kW). For example, on the commercial side Sharp's commercial inverter is 100kW, SMA makes a wide range of commercial inverters from 60-1000kW (half dozen in the 100-200kW range), and Xantrex makes commercial inverters of 105kW and 515kW. Economies of scale (installation, wiring, etc) encourage systems to be as big as possible for a given location, and moving to standard designs (inverters, module sizes, mounting, etc) makes sense to reduce system costs. So it is reasonable to expect system designers to move towards common building blocks based on typical building roof spaces. Source: Inverter sizes from Photon International, April 2006, Annual PV Inverter Survey.

Issue 20. The progress ratio (and learning curve) implied by the Solar Program's goals is unreasonable and inconsistent with history.

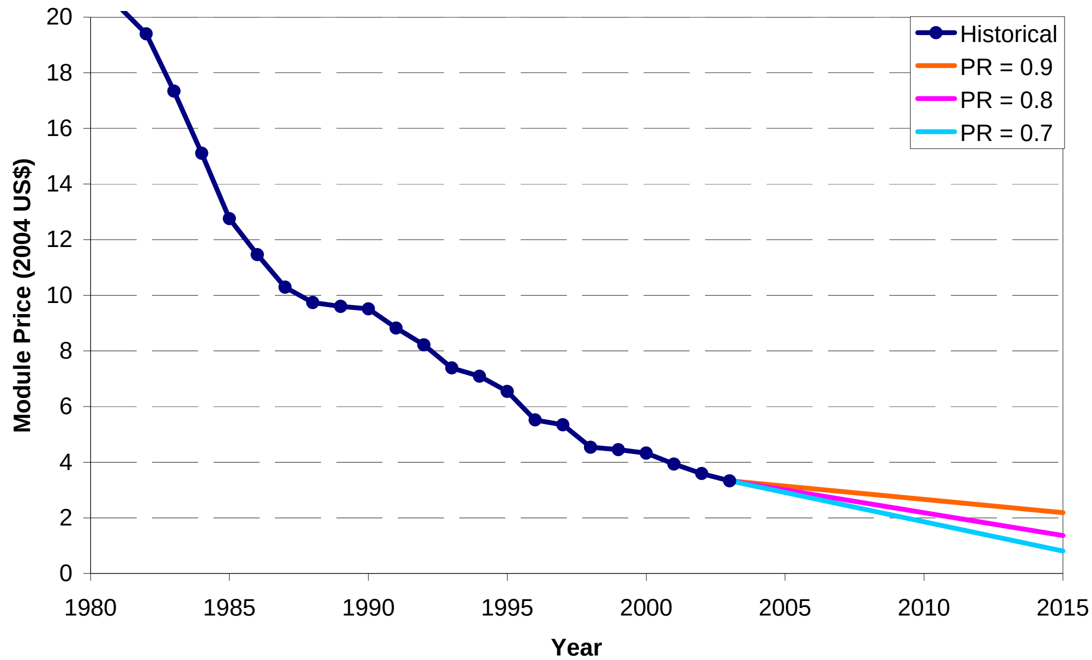
Response: The reviewer raises an important issue when thinking about the potential cost reductions for a specific technology, for example, as envisioned in the SAI targets for PV. In setting our targets for the SAI we have used a combination of detailed bottom-up analysis and learning curve theory. However, it is worth noting that in the case of PV technology, learning curve theory can only be applied at the module level due primarily to data limitations. The Solar Program would be the first to admit that we have set aggressive goals for the SAI – they are stretch targets that are meant to challenge the industry – however, they are well informed by the technical limits of reducing both component and system-wide costs.

There is a considerable body of literature reviewing historical production and prices of PV modules as well as the potential for future improvements in PV module technology. The fact that PV modules account for about 50% of the total installed system cost, have good historical data, and are manufactured as a tractable commodity makes them a reasonable component to focus on. As shown in Figure 1, the price of PV modules has declined dramatically over the past couple of decades. In fact, as shown in the figure, in real terms the price of PV modules declined by 85% between 1980 and 2004.

The module cost reductions (shown in Figure 1) were driven by cell efficiency gains (shown in Figure 2) in conjunction with increasing economies of scale of production and learning-by-doing. While it is difficult to split out the relative contributions of these factors from historical data, recent scholarship has pointed to the critical role played by R&D in the case of PV technology.[1] And it is clear that improvements in cell efficiency lead to improvements in module efficiency (with a time lag), which lead to reductions in module cost per Watt. In terms of moving forward, a critical emphasis of the SAI is on accelerating this process.

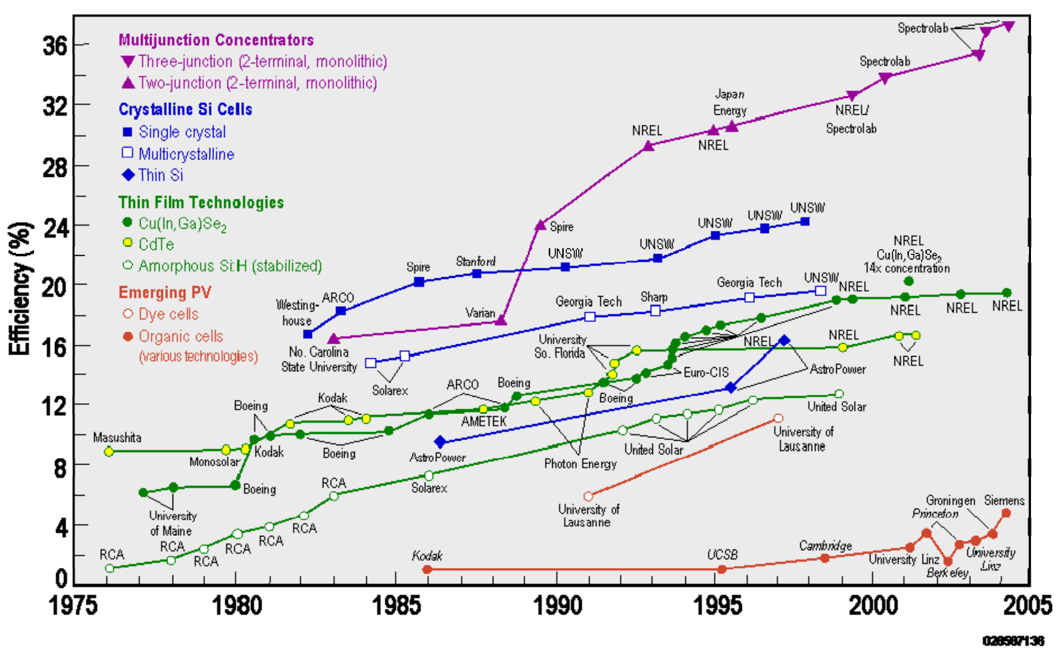
[1] Nemet, G. 2006. "Beyond the learning curve: factors influencing cost reductions in photovoltaics." *Energy Policy*.

Figure 1. Placing the Program's Module Price Targets in Historical Context



Source: Historical Data is from Strategies Unlimited (2005).

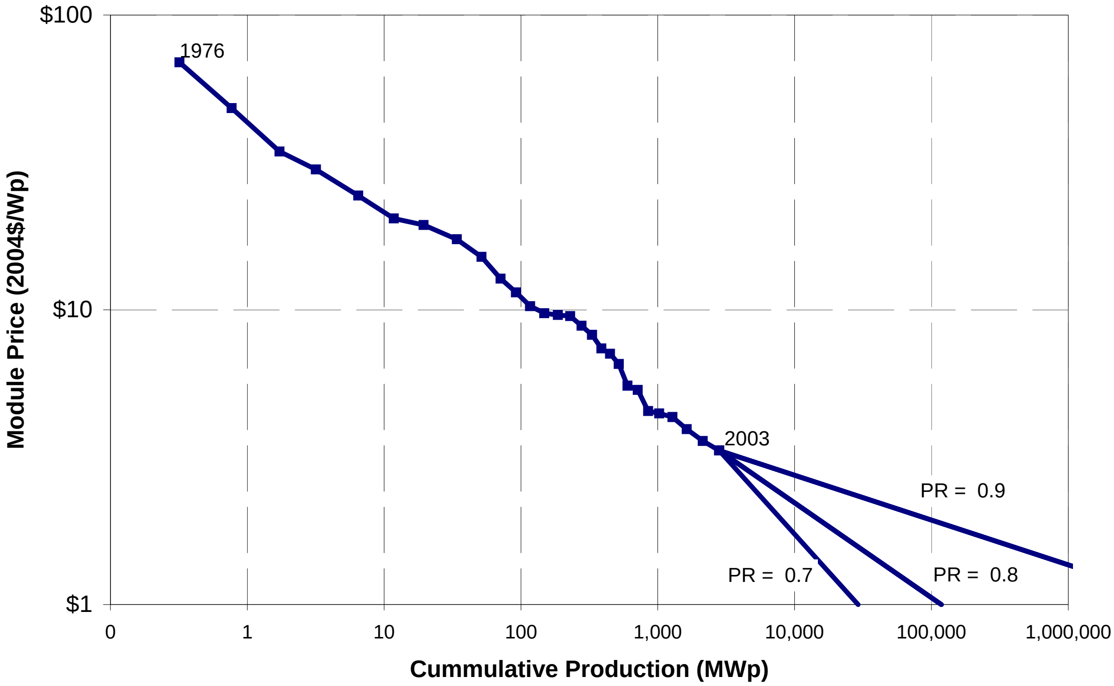
Figure 2. Best PV Cell Efficiency Evolution (1976 to Present)



Source/Notes: NREL (2005). The efficiencies shown are best small area efficiencies measured under standard laboratory test conditions.

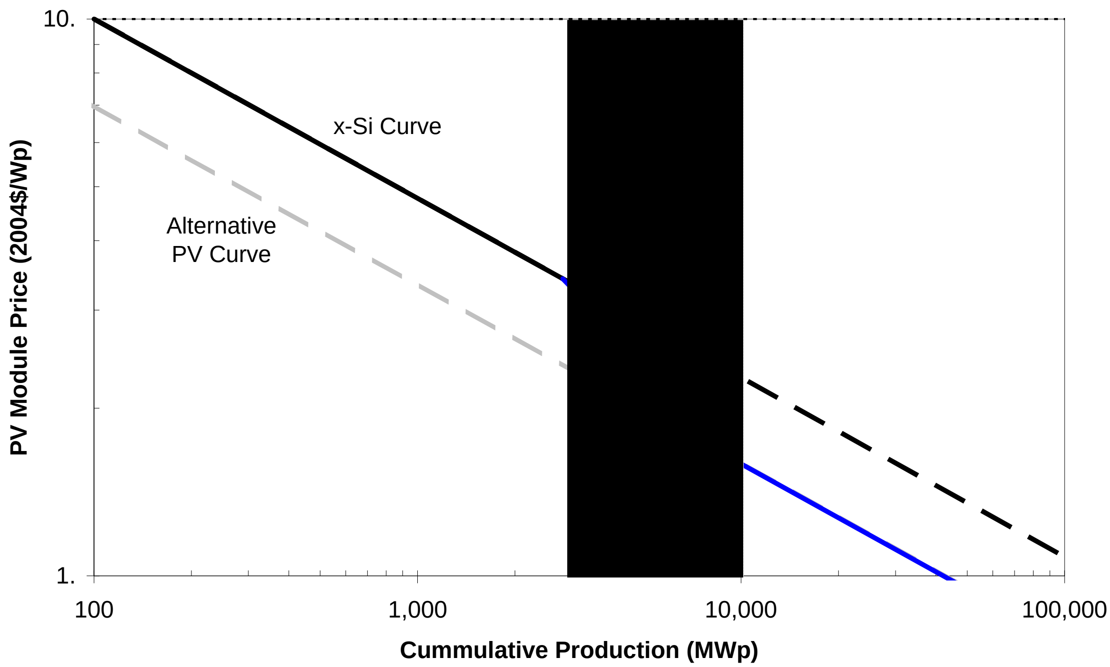
Translating the data in Figure 1 into log-log space creates a standard learning-curve diagram as shown in Figure 3. As shown in this figure, achieving the types of cost reductions envisioned in the SAI will require accelerating the historical progress ratio to somewhere between 70-80%. What is important to understand about the historical data shown in Figures 1 & 3, however, is that the data represent the experience curve primarily for crystalline silicon PV technology (which has accounted for roughly 95% of historical PV module production). Accelerating the rate of progress can thus be achieved either by increasing the rate of technological advances in crystalline technology or by transitioning to an alternative curve. For example, there are a number of alternative PV technologies (CdTe, CIS, aSi, dye cells, organic cells and some yet to be discovered) that could shift the curve as shown in Figure 4.

Figure 3. Historical and Projected Experience Curve for PV Modules



Source: Historical Data is from Strategies Unlimited (2005).

Figure 4. Illustrating a Breakthrough in PV Technology



The point of Figures 3 & 4 are to illustrate that there are multiple paths towards meeting the SAI targets, and the program is pursuing these multiple paths aggressively. The Solar Program has estimated that module prices will need to be in the $1-1.25/W range to achieve the SAI targets. As shown in Figures 3, at the historical x-Si PR of 0.8 this will require a cumulative global production of > 100 GW (unlikely by 2015), while at an accelerated PR of 0.7 this target will be met with a global production of ~ 30 GW. One of the things that make PV technology such an attractive technology for R&D is that it has multiple technological pathways that have the potential to reduce costs along these lines.

In addition there are significant opportunities to achieve system level cost reductions through “balance of system” improvements related to inverters, installation, permitting, interconnection, etc. The cost reduction opportunities at the system level are significant and went largely untapped prior to the launching of the SAI. In fact the SAI has marked a dramatic shift within the solar program towards implementing a systems driven approach to R&D. Thus the Program has increased its emphasis on achieving low-cost inverters with long-lifetimes, as well as encouraging industry to move towards building integrated and plug-and-play systems. Under the SAI the program has also increased its effort on reducing cost through the development of improved standards and codes, system certification, and streamlined permitting policies.

Responses to Comments on Building Technologies R&D:

Issue 21. "The Buildings program does not summarize the assumptions in the budget document and why many of the savings have been estimated using an external analysis to NEMS. A brief summary of what was done would have been useful."

Response: Within the FY09 GPRA documentation for the Builidng Technologies Program, a summary of assumptions, along with a brief explanation as to when and why offline analyses were used, will be provided in the front end of the technical appendix. In brief, many of the technologies worked on by the program are not represented explicitly in NEMS, and there is no logical way to model these within the current version of NEMS. Over the next few years, EERE plans to work with EIA to improve its representation of buildings technology, specifically to address some of these issues.

Responses to Comments on Vehicle Technologies R&D:

Issue 22. Many technology assumptions appear to be unjustified.

Response: The fuel economies for all light vehicles were determined by using the PSAT (Powertrain Systems Analysis Toolkit) model. The PSAT model was used to evaluate the fuel economy of all the alternative vehicle technologies on an "apples-to-apples" basis.

Information on the PSAT model is available at:

http://www.transportation.anl.gov/software/PSAT/index.html

Documentation of model results for the GPRA08 analysis is contained in the following reports:

1. *Sharer, P. and Rousseau, A. PSAT Results for GREET and GPRA – FE Adjusted 081705.xls, Argonne National Laboratory, August 17, 2005.*
2. *Rousseau, A, Number Associated with Presentation, Argonne National Laboratory, July 6, 2005.*

Issue 23. California light duty vehicle GHG standards (AB1493) are improperly ignored.

Response: Up to this point, we have run the vehicle technologies (based on PSAT, as noted above) as a single set of assumptions for the nation as a whole. We have not attempted to model differences across the Census regions represented in the NEMS model. The NEMS model is not able to deal with state differences. How we could take the California standards into account will take some thinking. EIA may have to do this as part of their next version of NEMS, which may include a more regional transportation model. If incorporated into the next version of NEMS, we will use that framework.

Issue 24. It appears that the FCVT benefits analysis assumes that more energy efficient technologies result in more fuel-efficient vehicles without public policy to create this effect. This seems quite wrong. It is very clear that most vehicle makers are constrained by CAFE requirements, and that technological advances in energy efficiency have been used to design larger, faster vehicles that meet these requirements.

Response: : The goal of the FCVT program is to drive the cost of the advanced technologies down so much that they become a "better buy" for new vehicle buyers because they save money within three years after they are purchased. No standards would be necessary because the rational buyer would choose the new technologies. We admit that assuming that new vehicle buyers are economically "rational" is not completely reasonable, but all vehicle choice models do this.

The EIA Reference Case assumes that vehicles continue to improve their 0 to 60 times and gain weight. We accept these assumptions. Moreover, the GPRA benefits analysis differs from that of many other energy projections and energy analyses: its purpose is to measure the value of a particular R&D program and the robustness of the DOE portfolio set of RD3 activities. If we were to assume any set of complementary policies that would provide further incentive to adopt our technologies – and thereby break the "*ceteris paribus*" logic -

we wouldn't be able to measure the benefits of the R&D itself.

Issue 25. MARKAL and NEMS oil forecasts disagree because MARKAL optimizes without consideration for vehicle choice factors. MARKAL "overestimates oil import reductions."

Response: Two classes of LDV's, passenger cars and light duty trucks, are represented in MARKAL-GPRA08. Within these two size classes, we compete "average" vehicles with different types fuels and drive trains. Size classes are not disaggregated or competed against each other. Therefore, the model does not compete inexpensive and highly efficient sub-compact cars with more expensive and less efficient full size sedans. Thus, MARKAL-GPRA08 will not optimize by choosing GEO METROS over full size Mercedes sedans.

MARKAL does not have many of the non-economic consumer choice parameters, such as vehicle range, acceleration or luggage space that are used in NEMS. However, the Vehicles Technologies Program and Hydrogen, Fuel Cell and Infrastructure Technologies Program assume that their R&D will result in characteristics for these non-economic parameters that are similar to traditional internal combustion engine vehicles. Thus, the vehicle assumptions are not very different between NEMS-GPRA08 and MARKAL-GPRA08.

MARKAL-GPRA08 did not include demand elasticities. This is one cause of the difference in the MARKAL-GPRA-08 and NEMS-GPRA08 benefits calculations for the transportation sector. In NEMS-GPRA08, the demand elasticities "take back" some of the energy savings as LDV VMT's increase in the Program Cases due to a lower cost of driving. We intend to include demand elasticities in future MARKAL models.

Furthermore, both hydrogen fuel cell and plug-in hybrids are introduced in 2020 and only begin to gain a significant share of the LDV vehicle stock by 2035. This is another reason why the 2035 MARKAL-GPRA08 oil savings are significantly larger than the 2030 NEMS-GPRA08 oil savings.

Responses to Comments on Hydrogen R&D:

Issue 26. "The differences in the historical fuel cell costs by sector between EERE programs and the AEO2006 are startling..."

Response: We will investigate this discrepancy and document any reasons for differences in future reports.

Issue 27. The analysis improperly ignores the effects of policies on providing incentives for uptake of technologies or in establishing infrastructure for the technologies.

Response: The GPRA benefits analysis specifically excludes policies that are not already established, because the aim of the exercise is to focus on the incremental benefit associated with R&D. If new, hypothetical policies were included, we would not be able to estimate the portion of the improvement associated with R&D.

Responses to Comments on Biomass R&D:

Issue 28. Many elements are unjustified assumptions, or at least appear to be unjustified. For instance, the efficiency of FCVs vs. conventional vehicles. Also the choices of n in n-year analyses tend to be unexplained.

Response: The choice of n is somewhat arbitrary, but tries to reflect the current level of engagement of the private sector in these technologies. The private sector is currently operating dry mills and has an immediate profit motivator to be more efficient with the process (e.g., converting fiber and products). These activities will happen faster than the 7 or 12 years for the cellulosic feedstocks. As part of our analysis for GPRA09, we have moved away from an arbitrary "n-year rule" and have adopted a qualitative assessment of the industry's current attitude toward cellulosic ethanol technology in light of planned DOE cost share of demonstration scale cellulosic ethanol technology.

Issue 29. GRPA08 – biomass analysis is far too narrow. You should explore possibilities of success of gasification plus F/T diesel, MSW-to-ethanol, and the possibilities of non-DOE technologies becoming successful. This will tend to be a disappointing outcome to some degree, but such an effort could help inform what R&D strategies are robust in this way.

Response: We acknowledge that the scope of possible biofuels technologies could be broader than the biological conversion technology for ethanol production that served as the centerpiece of the GPRA08 analysis. Already this year, we have completed techno-economic analyses to better understand the cost of future thermochemical processes. Limited funding in the past has forced DOE to make much more limited choices in technology scope. As interest and funding in biofuels R&D expand, we may broaden the technology horizon of DOE's R&D program.

Issue 30. There are many, many environmental issues associated with biomass energy, including land use conversion, fertilizer runoff, soil erosion, water use, and more. These are often dependent on agricultural practices, which are not modeled in NEMS or MARKAL (and should not be). Therefore, quantification is not feasible but these environmental effects SHOULD be considered and discussed qualitatively.

Response: The Biomass program has a long history (back to 1992) of conducting life cycle assessments of the conversion of biomass to fuels. A detailed study was completed in 2002, which includes the impacts on the farm land, erosion, etc. DOE plans to continue enhancing these types of studies. A limited level of life cycle accounting in NEMS and MARKAL is included in order to be able to estimate greenhouse gas emission and fossil energy savings associated with biofuels technology. But we acknowledge that we can do more to incorporate many of the measures of sustainability that are important to biofuels. At a minimum, the kind of qualitative discussion suggested by the reviewer is appropriate.

Issue 31. These analyses are all about budgets proposed by the President, while what really happens is the result of the Congressional appropriations effort, which changes budgets in total and also create earmarks. It would be very instructive and helpful to analyze the benefits of the actual, Congressionally- approved budgets to see how these decisions change the benefits.

Response: We recognize this to be an important issue and to the extent possible, the effect of budget changes such as earmarks needs to be considered in setting program goals.

Issue 32. Can N-rule be cast in terms of technology cost terms? E.g., compute the decline in today's cost that would result in a 20% increase in NPV. Then, calculate the number of years of escalation that would result in the same 20% jump in NPV.

Response: We do not think this is feasible. Doing this would simply be replacing one n-year rule with another and would remain just as indefensible. Nevertheless, we acknowledge the importance of moving away from an arbitrary n-year rule to an approach that better captures the economic calculus of private sector investors as they consider the relative timing and payback of investing in longer term technology.

Issue 33. Page 3-11, table 3.1. How do the goals identified in this table compare with the EPACT2005 goal of 5 commercial-scale operating cellulosic ethanol plants, 50 million gallons per year, by 2012? Does this say that EERE expects the first commercial cellulosic plant to be built around 2017? I can't tell.

Response: The section 932 projects will provide 6 commercial scale plants. Their total output is not expected to meet the 250MM gallon requirement. These will be the first pioneer commercial scale plants.

Issue 34. When does the EERE ethanol program believe that the posited programs will make cellulosic ethanol commercially available and what is the assumed first of a kind cost? It is not clear from the table or discussion. I would guess sometime between 2015 and 2017 but I am not sure. If true, this suggests that the EPACT2005 incentive for cellulosic ethanol will have no impact.

Response: First pioneer commercial plants from section 932 awards will be by 2012. First commercial plants would be probably 2015. In the future, we will attempt to be more clear on distinguishing first costs and nth plant costs.

Issue 35. The cellulosic ethanol assumptions incorporate a credit for co-generated electricity. The price in the appendix appears to be the wholesale price of electricity. Is that correct?

Response: Yes

Issue 36. Appendix C, page C-6, quotes Tony Radich as saying the EIA assumed cellulosic ethanol will enter the market in 2010, ramp up to 250 million gallons per year by 2012 (correct so far), and will not grow further (a misquote). EIA made no such assumptions regarding the penetration of cellulosic ethanol. The penetration of cellulosic ethanol is endogenously determined by the NEMS-GPRA08 model on an economic basis.

The significant disparity between the cellulosic capital cost assumed by the EERE program office and that used by EIA in AEO2006 is striking and very hard to rationalize.

- EIA assumed the capital costs for a 50 million gallons per day plant provided by IOGEN, scaled up to include project contingency which all plants must have, and an "optimism factors" which is typically 10-15% above the pre-construction cost estimate of the first plant. No such costs were provided for the EERE cellulosic plant. However, the Aden publication reference appears to show the capital cost at $217 million dollars (page 64, converted to 2004$). Annualizing this number with NEMS assumptions plant size and a 15% capital recovery factor yields a per gallon cost of approximately $0.65 for the capital component. This is almost 50 percent higher than the capital cost component identified in the appendix, page C-18, of $0.45/gallon in 2015. The EERE hypothetical plant may be assuming a higher annual output like 68 million gallons per year.

Response: There is a disparity between the program assumptions and EIA's. We suspect that the root cause is that EIA assumes lower yield performance.

Our calculation is as follows: $217,000,000*.15 = $32,550,000, production 69,300,000 gal/yr ratio is 0.47 (a little higher than the value of 0.43 in the table, but not 50% higher)

Issue 37. The EERE estimate for the cellulosic ethanol capital cost references the report by Aden, et.al. of NREL in 2002.

- **Issue 37a**. Aden's costs are $217 million in 2004 dollars and a relatively mature technology (nth-of-a-kind, not the first-of-a-kind) commercial plant costs. Since virtually no full-scale commercial plants are built before 2015, it must be the implicit assumption of EERE program that virtually the entire cost reduction to the $217 million is due to government R&D before 2015. Is that correct?

Response: There will be EPAct Section 932 pioneer commercial projects in 2011 time-frame, so the facilities in 2015 would at least be the 2nd generation, but not "nth" as would have been assumed here. We acknowledge that this assumption is optimistic.

- **Issue 37b**. EERE then assumes that the capital costs will decline another 40 percent by 2030 to about $117 million dollars (40% of the unadjusted IOGEN number). The EERE costs are assumed to decline further to 102 million dollars by 2050.

Response: These capital cost reductions are due to a different technology being developed by 2030. Consolidated Bioprocessing technology eliminates several of the unit operations and hence capital.

Issue 38. The cellulosic ethanol capital cost assumption path, if I have understood the assumptions correctly, does not appear to be credible. I wonder if the O&M assumptions have a similar problem of assuming the starting plant is already mature. I suggest that at the very least, EERE start with the IOGEN number which is currently the best informed for the first of a kind plant, and then reduce that cost to whatever percentage your program can justify.

Response: The IOGEN number is more of what is assumed for the pioneer plants of 2011 timeframe.

Issue 39. The n-year rule should be price responsive and calibrated to the scale of the companies. For example, the aluminum program makes no sense if the funding goes to Alcoa, as it is a small part of their R&D program.

Response: With the n-year assumption we are assuming that it is the big companies, ADM, Cargill, Dupont that will carry the burden of developing the technology on their own. Th n-year rule, for all its acknowledged shortcomings, is a function of how big a gap exists between competitive market prices for fuel and our best understanding of the current state of cellulosic ethanol technology and the amount of effort required to bring the technology cost down to competitive levels.

Issue 40. How much can assumptions be ground-truthed. Application of the n-year rule and other assumptions about cost declines and technology penetration – how much can they be compared to previous results.

Response: We are currently working with Independent Process Analysis (http://www.ipaglobal.com

Title: Nuclear Energy
Presenter: John Stamos
Overall Rating: Good

A. Review Panel Comments

Leon Clarke	**Rating: Very Good**

I found this to be a useful and credible approach. The one major concern I have is the incorporation of difficult, not easy to model benefits associated with (1) reductions in waste, (2) proliferation of nuclear materials, and (3) safety.

Documentation is useful and clear. There should be more discussion of the assumptions about issues associated with proliferation, safety, and waste.

I found the work to be useful, credible, and transparent. My sense is that more time, as with all the programs, could be spent on interpreting the results and putting them into a form more useful for decision makers. For this program, it would also be useful to add more discussion and consideration of benefits associated with waste, proliferation, and safety.

Joseph DeCarolis	**Rating: Good**

Generally, the approach is reasonable and consistent with the other Offices.

Parametric sensitivity analysis is needed to explore how different cost realizations affect penetration levels. Two factors contribute to the uncertainty in cost projections: (1) several techs lumped together in a single technology representation and (2) capital cost estimates are paper-based without any physical demonstration.

Hard to distinguish between R&D requiring fundamental breakthroughs and R&D requiring incremental work. For example, the idea of separation and transmutation of transuranics has been around a long time; so what is required to achieve the currently projected R&D benefits?

The report emphasizes that "it is more useful to focus on the differences between the scenarios … rather than on the absolute numerical results for either scenario." This logic has its pitfalls. Because MARKAL is a linear optimization, slight changes in capital costs near a tipping point can make the difference between zero and high levels of technology penetration. This further emphasizes the need for sensitivity analysis.

Although not applicable to other Offices, it is critical that NE include safety and security metrics regarding new plant operation.

Alexander Farrell	**Rating: Good**

Much more sensitivity analyses are needed. Particularly on costs reductions. The very low capital costs for GenIV seem hard to believe.

Some parts of documentation (e.g. pp. 35-39) are particularly clear and useful.

However the overall document is a bit unclear. Material presented in slides 36-38 would have helped.

Add qualitative security issues.

Add context.

See verbal comments.

Hillard Huntington	Rating: Good

Explain what can be done by private sector and by other international countries.

Parameter sensitivity analysis would be useful.

Explain whether costs are engineering costs or also include managerial costs (covering Fred Murphy's unknown expenses).

Explain your assumptions about "maximal growth rates for capacity additions" that appear in your document.

Andy Kydes	Rating: Fair to Good

Based on the presentation:

- Credibility of DOE role to reduce first-of-a-kind from $2031/KW to $1659 by 2010 seems implausible unless DOE is prepared to buy down the difference in some form. Describe what DOE actions would cause the rapid cost reductions. (Speaker has.)
- Learning rate between 2010 and 2020 seems huge and begs the question of what learning rate was assumed in the model.
- MARKAL over-optimizes unless it is carefully controlled - makes value of results questionable. What constrains nuclear from taking over the generation market? An annual build constraint? Basis for long-term constraint of 10 GW per year?
- Assumptions seem arbitrary.

Do sensitivity analysis on costs reflecting plausible variation since none have been built yet.

Run the cases through 2030 with NEMS to make sure that the answers are comparable with MARKAL. This should provide more credibility to the benefits.

Discuss issues that are specific to nuclear programs should carefully laid out – e.g., distribution of R&D between private and public sectors and what the private sector do in the longer term if the feds cut back.; also issues of riskiness of the investment relative to other generation investment.

Dan Loughlin	Rating: No Rating Given

I cannot comment on the extent to which air quality regulations were included in the MARKAL analysis of NE impacts (or overall programmatic impacts), but I would like to stress that these regulations do have important interactions with energy system technology penetrations. For example, a large amount of additional nuclear capacity would effectively free up room under electric utility NOx limits (applied as state caps under regulations such as CAIR). A result likely would be that electric utilities would be able to use fewer controls on NOx emissions. This decreases the cost of electricity generation via coal, improving its competitiveness relative to natural gas and other technologies. Compared to these other sources, coal is relatively high in CO2 emissions, meaning that some of the potential CO2 benefits of nuclear may not be realized. Other criteria emissions, fuel use/imports impacts also may occur. **Considering the impacts of air regs thus should receive the appropriate level of attention if it isn't currently.**

Frederic Murphy	Rating: Very Good

The analysis has to deal explicitly with the effects of restructuring on the risks to the plant owners and market penetration.

One of the big problems has been construction management. The side analyses have to deal with the project management aspects of the cost of the plants.

It is impossible to assign probabilities to outcomes given the nature of the uncertainties in success. A scenario tree needs to be developed to better highlight the possible outcomes.

William Pizer	**Rating: Good**

Critical issues here are much clearer because there is a much narrower focus on (a) NP 2010, and (b) Gen IV versus, for example, the EERE program. It re-iterates the need in something like EERE to prioritize.

The critical issue seems to be (a) whether the long-term cost estimates (e.g., vendor price of $1100/kw) are accurate, (b) whether the progression of development will indeed bring estimates down to this level, and (c) the role of DOE programs in this progression (and, particularly, whether efforts by other governments might compensate).

Despite the presentation, the estimated cost decline to $1100 seems remarkable over such a short horizon.

The questions raised about regulated versus competitive electricity markets also pointed to an important point: How much do local PUC priorities and preferences influence these results. Are utilities more constrained by PUCs or by the need for federal support?

I would like to see the documentation consider more of a debate on key assumptions. For example, the $1100 cost for the 2010 program drives many results. It would be useful to hear what critics might say about those numbers – or are those really the best central estimates. Similarly, it would be useful to hear what critics would say about the rate of cost reduction. During the meeting, Kydes expressed some concern about these numbers; I am not an expert but I would have liked to have seen more of these types of issues raised in the process of measuring benefits.

Perhaps the most fundamental credibility issue is that the analyses are not being conducted independently outside of the DOE offices. As an outsider, it seems like there are numerous questions about the assumptions and it is difficult to evaluate whether the estimates are truly in the middle. Given the heroic assumptions, it seems filled with opportunity for biases to creep in – even unintentionally.

I do not think it is particularly adequate, given the volume of information, to have this kind of external review.

B. Discussion

Implications regarding safety and reliability appear to be missing.

It was suggested to conduct a parametric analysis of costs. DOE's cost estimates rely on white papers. What about nuclear cost overruns? If costs overrun by 20%, how would that affect the analysis?

What DOE activity improves the rate of learning and reduces the costs?

Analyses seem silent on electricity restructuring issues. What are the assumptions and how do changes in the scenario definition affect nuclear technology's role? Some discussion lacks definitive statements about political and technological conditions.
Draft report needs information on slides 36 through 38.

The section on translating MARKAL outputs should be reviewed for consistency by the other programs.

Could discuss how things would be different if DOE pulls out of R&D on international nuclear programs.

EERE and NE are different; standardization would be good. Special differences need to be reflected.

With technology R&D, how difficult is it to achieve benchmarks? What needs to happen? Is it incremental advances or major breakthroughs?

Need to think more about R&D investments' bang for the buck. Are funds being allocated toward projects embodying significant innovation? How do expenditures complement or substitute for energy investments in Europe and Asia? What is happening on the international scene is very important and ought to be reflected.

Where does DOE have a comparative advantage in the international energy R&D picture? What does DOE contribute that is above and beyond the efforts of other groups?

C. DOE Response and Action

METRICS:

Issue 1. It would be useful to add more discussion and consideration of benefits associated with waste, proliferation, and safety.

Response: NE is considering other environmental and nuclear specific metrics such as waste reduction, proliferation risk reduction, and improved plant safety and security. To the extent objective measures can be made (e.g., lower spent fuel production by volume or radiotoxicity), NE will request their incorporation in MARKAL. Proliferation risk reduction is not considered a metric that is calculable in a national model; NE is currently engaged in a study using a global MARAL model to examine the role of NE technologies in a global context, this approach may supply sufficient information to quantify a proliferation risk metric.

MODELS:

Issue 2. Parametric sensitivity analysis is needed to explore how different cost realizations affect penetration levels. Two factors contribute to the uncertainty in cost projections: (1) several techs lumped together in a single technology representation and (2) capital cost estimates are paper-based without any physical demonstration.

Response: Approaches to conducting parametric sensitivity analysis will be assessed to explore how different cost realizations affect penetration levels. Some of the factors that contribute to uncertainty in cost projections are:

- The way that several technologies are frequently combined in a single technology representation.
- The necessity for capital cost estimates to be paper-based without any physical demonstration.
- The use of models where slight changes in capital costs near a tipping point can make the difference between zero and high levels of technology penetration.

In cases where fuel cycle differences justify modeling by specific design, NE will do so. In the case of most Generation III+ designs, this is unnecessary. Because Generation IV technologies to be supported will be down-selected, NE will wait to see which technologies merit being competed by design.

ASSESSMENT AND INTERPRETATION OF RESULTS:

Issue 3. Parameter sensitivity analysis would be useful.

Response: NE is working on incorporation of parametric analyses to understand the performance of technologies under varying market conditions and cost reduction assumptions to better identify parameters with the greatest impact.

Issue 4. More time could be spent on interpreting the results and putting them into a form more useful for decision makers.

Response: NE will participate with the other DOE offices to improve the interpretation of model results reported in a form more useful to decision-makers.

ASSUMPTIONS:

Issue 5. Learning rate between 2010 and 2020 seems huge and begs the question of what learning rate was assumed in the model.

Response: NE will continue to refine the estimates for capital cost, learning rates, and infrastructure constraints that may limit penetration of new reactors.

DOCUMENTATION:

Issue 6. The overall document is a bit unclear. Material presented in slides 36-38 would have helped.

Response: Information from this year's peer review presentation slides that was not included in the annual report will be incorporated in next year's report.

Title: Fossil Energy
Presenter: Julianne Klara
Overall Rating: Very Good

A. Review Panel Comments

Leon Clarke	**Rating: Very Good**
This work was credible and transparent. One area for improvement was the treatment of carbon capture. Under the sort of aggressive carbon constraint considered in this analysis, retrofit of existing power plants with carbon capture technology could be important. That should be considered in future work. In addition, the costs of carbon storage should probably be considered. EOR is one possible application, but the larger and longer-term application will be in saline aquifers, and there will be economic costs from such storage. The documentation was useful, credible, and transparent. The information was credibly presented and transparent. As with my general comments, I think that there is room for substantial additional effort on synthesis and assessment of the results of this analysis, within and across programs.	
Joseph DeCarolis	**Rating: Good**
It was instructive to see the comparison between program case with only FE R&D and all DOE R&D. Similar comparisons should be made for all Offices. Credibility of the order of magnitude reduction in fuel cell capital cost is questionable, despite verification by a third party. FE did the best job of clearly laying out assumptions in both the baseline and program cases in both the presentation and report. Although mentioned for future work, the benefits analysis needs to be extended to 2050. Instead of employing year-by-year cost targets in NEMS, those year-by-year estimates could be used to derive a learning curve for fossil technologies. This would allow cost reductions resulting from learning to take place after the fossil program goals are achieved. There is a need to put the FE R&D in an international context. Perhaps some fossil technologies (e.g. IGCC-CCS) may not be major players in the U.S.; they may have huge potential elsewhere that will lead to deep cuts in CO_2 emissions (e.g. China). Also, are there industrial players that would take on some of this research in the absence of FE R&D?	
Alexander Farrell	**Rating: Good**
See prior comments on NEMS and overall approach. See verbal comments. Documentation is okay.	
Hillard Huntington	**Rating: Very Good**
Excellent presentation and documents. This office seems to have had much more practice in conducting R&D benefit analysis and works with technologies that may be easier to represent in the models than is the case for some	

of the other DOE offices.

Tables that compare inputs in the R&D portfolio case with those in the reference case should become a benchmark for the other groups.

Comparing scenario input assumptions with actual experiences with different technologies could provide lots of useful information about whether the assessments are using appropriate assumptions. This part of the presentation was particularly effective.

Andy Kydes	**Rating: Very Good**

The presentation was clear.

- The linkage between the DOE goal and the FE goal has some of the same weaknesses that the EERE has in that energy security is linked to reduction in imports which is too broad a category for the DOE goal.
- On page 6-64, should refer to the inability to do sequestration/ storage for *retrofit technologies* since the sequestration and storage technologies for IGCC and NGCC are modeled in NEMS and are available to be chosen. The cost and performance of these can be tailored to the assumptions of the FE program.
- When FE usable information on gas hydrates with a satisfactory characterization and assessment is available, please be sure to provide that information to the NEMS group so that the resource can be properly modeled.
- Page 22-64, Figure 3. Figure 3 should probably be broken out into a 3a, 3b, grouping similar technologies together. The same is true for Figure 4 – too crowded. The graph is much too crowded to read. The assumption (goal) on the price drop in a single year (2011-2012) for utility fuel cells from about $4,600/KW to about $800/KW is more than a “stretch goal” and appears to be implausible in that there is no commercial technology that has experienced a 475% reduction in one year, to my knowledge. What assumptions/facts are behind this amazing expected accomplishment? Clarify what this total technology is. Can it be supported? If the technology exists and is simply evolving, then the fastest learning rate I have seen in the literature is about 45% for every doubling of capacity. If this is the impact of R&D, can you provide supporting information that supports plausibility?
- Minor note -- Cost of 90% mercury removal at ¾ cost of reference case: add “by 2010” (page 27, Table 9).
- Reduction of NOx to N2 efficiency progress. The NOx emissions rate reduction from 0.1 lb/MMBtu in 2010 to 0.01 lb/MMBtu by 2020 at the same or lower cost as the 2010 target seems very aggressive.
- Table 14, (SECA) fuel cell, says the target cost per KW is $350/KW compared to $5,500 in 2000. Re-label the table heading by adding “Stack Costs” at the end. Have we achieved the target cost goals in 2005 since the date is well past? Explain this technology better. This technology should penetrate the market like crazy if these costs are real.
- How often do the stacks have to be replaced? At what costs?
- The Target IGCC capital cost reduction of 20% from pure R&D seems aggressive. How certain are these targets?
- If the SECA technology is successful as targeted by 2012 with total all-inclusive cost at $400/KW, why are any new IGCC or supercritical plants relevant? What are the probabilities of success?
- Page 28, if the ORNL porous membrane by ORNL is the most promising, why does it remain classified? If it remains classified, what value is to the U.S. energy market?

The statement about NEMS ability to represent capture and sequestration is true only in the sense that NEMS does not have specific technologies represented to do so. The model contains marginal abatement cost curves for other GHG’s gotten from EPA and are used for scenarios when GHG emissions are being constrained as a whole.

The presentation is very clear in identifying what the assumptions are and how they were developed. It should be used as a model for the other areas. The assumptions should be transparently identified.

The documentation was largely clear. Parts of it should be used as a model for others.

The technology assumptions should be presented in a standard format by sector. The format can vary by sector.

Dan Loughlin	Rating: No Rating Given

It would have been helpful to have compared NEMS results with MARKAL results in the 2010-2030 timeframe. Also, MARKAL would have allowed explicit consideration of learning by doing, which one of the reviewers commented upon the NEMS approach lacking.

I think it is important to consider more fully cross-sector and system-wide impacts (these could be considered more fully in other program areas as well). For example, the ability to deliver cheaper electricity would likely lead to fuel switching to electricity (from natural gas and oil) in the residential, commercial, and industrial sectors. A result could be more natural gas available for vehicles and possibly ethanol production. These changes might result in very different impacts on many of the metrics being tracked.

There was some discussion about how to evaluate the potential individual and combined contributions to various metrics. **I think that there are several approaches that may be of use to address this. I would suggest that DOE explore these approaches:**

1. Monte Carlo simulation in which program benefits are varied (simultaneously) on a range from 0 to 100% of potential. The inputs and output metric values could then be analyzed (via data-mining, ANOVA, and/or correlation coefficients) to examine/characterize the relative contribution of each program (and combinations of programs) to various metrics of interest.
2. MARKAL's stochastic optimization feature could be used to evaluate explicitly incorporate alternative states of the world involving different levels of realization of program benefits (and possibly alternative future-year assumptions on carbon limits and high fuel prices). This approach could potentially then be used to evaluate robust short-term portfolio expenditures to meet goals on specific metrics in the future.

This latter approach may also be very useful in the context of risk management.

Frederic Murphy	Rating: Excellent

Good documentation of the base case. This should be a template for all areas.

Clarify the ultimate disposition of mercury. Any landfill leakages or reuses should be part of the benefit calculations.

William Pizer	Rating: Very Good

I found this forecast to be the most credible of the three so far. This was a combination of clarity with regard to assumptions but, even more importantly, the inclusion of an external 3rd party review.

The discussion of benefits for the FE program needs to address the potential value of these technologies in addressing climate change in countries like China. Many people do not see a solution to climate change unless we can provide a cheap way for China to continue to use its coal resources without (or with less) CO_2 emissions.

I was a little concerned about the PC capture estimates. I know that Alstom has been working on this and, while it is obviously in their business interest to do so, they have not given up on a cost effective PC solution.

Like NE, I felt the FE presentation / program was more focused. There did not seem to be an indeterminate number of key assumptions. That said, it would be nice to have a list up front of the key assumptions, just so we know we are not missing something.

In this case, it seems like a really important component of benefits is the potential to export this technology to address climate change. With the enormous importance of China and its coal resources, developing a technology pathway whereby China can use its coal resources with a smaller GHG footprint could be critically important.

B. Discussion

There was some discussion about the costs of fuel cells. It was suggested that the critical $400 cost estimate is now $211.

There was some discussion about how R&D expenditures were being allocated to carbon capture and pulverized coal units. Additional questions related to how retrofits of powerplants were included in R&D programs.
NEMS does not have transmission networks and thus cannot analyze issues associated with transmission lines.
International aspects are important – what is the right mix for the U.S.?

Incorporating cross-sector impacts is important. If you can generate electricity more cheaply, you will use more rather than less gas or oil. This development will have an impact on emissions, etc.
Most FE funds are going to longer-term projects.

The baseline presentation was clear and the different assumptions were clearly explained. It is a good template because one table explained all key assumptions for the reference and R&D portfolio cases. EERE's wind discussion also summarized cost inputs, but these cost estimates were more difficult to compare because they appeared in different tables.

What is the ultimate disposal of mercury – is it totally safe?

Are the FE technologies represented better in NEMS? Are they so different from the technologies being analyzed by the other offices? Or should there be a push for more standardization and similar reporting across offices? Decision makers could decide more easily the value of different technologies if there was more uniformity in assumptions and estimates.

It was acknowledged that not all outcomes can be expressed in terms of a welfare metric.

It might be more useful to compare all power technologies as a group. This approach would require cooperation between FE's evaluation of fossil-fuel-based plants and EERE's evaluation of renewable-energy-based plants.

Capture and sequestration and their effect on climate change are applicable to other countries. China's coal use or its mitigation efforts alone could dwarf the decisions made elsewhere in the world.

Are there plans for future sensitivity studies?

C. DOE Response and Action

MODELS:

Issue 1. Are there plans for future sensitivity studies?

Response: Approaches to conducting parametric sensitivity analysis will be assessed to explore how different cost realizations affect penetration levels. MARKAL's stochastic optimization feature will be one of the approaches evaluated.

Issue 2. One area for improvement is the treatment of carbon capture. Under the sort of aggressive carbon constraint considered in this analysis, retrofit of existing power plants with carbon capture technology could be important.

Response: The treatment of carbon capture will be improved in NEMS. The improvements being considered include: retrofit of existing power plants with carbon capture technology, and supply curves for carbon storage.

Issue 3. When FE usable information on gas hydrates with a satisfactory characterization and assessment is available, please be sure to provide that information to the NEMS group so that the resource can be properly modeled.

Response: When FE usable information on gas hydrates with a satisfactory characterization and assessment is available, that information will be provided to the EIA so that the resource can be properly modeled in NEMS.

ASSESSMENT AND INTERPRETATION OF RESULTS:

Issue 4. There is a need to put the FE R&D in an international context.

Response: Approaches to put the FE R&D in an international context will be explored to determine how to best address the potential value of these technologies in addressing climate change in rapidly developing economies like China.

Issue 5. It is important to consider more fully cross-sector and system-wide impacts (these could be considered more fully in other program areas as well).

Response: An assessment of ways to consider cross-sector and system-wide impacts will be conducted. For example, the ability to deliver cheaper electricity would likely lead to fuel switching to electricity (from natural gas and oil) in the residential, commercial, and industrial sectors. As a result, there could be more natural gas available for vehicles and possibly ethanol production. These changes might result in very different impacts on many of the metrics being tracked.

Issue 6. I found this forecast to be the most credible of the three so far. This was a combination of clarity with regard to assumptions but, even more importantly, the inclusion of an external 3rd party review.

Response: FE will continue to include assessments of progress toward R&D goals performed by external 3rd party review.

Issue 7. It might be more useful to compare all power technologies as a group.

Response: The value of comparing all power technologies as a group will be evaluated.

ASSUMPTIONS:

Issue 8. Provide information that supports the plausibility of R&D goals.

Response: Information that supports R&D goals will be explicitly described.

Issue 9. Have a list up front of the key assumptions, just so we know we are not missing something.

Response: A list of key assumptions will be prominently displayed in future documentation.

DOCUMENTATION:

Issue 10. It was instructive to see the comparison between program case with only FE R&D and all DOE R&D. Similar comparisons should be made for all Offices.

Response: Comparisons between program cases each of the R&D programs and the whole DOE R&D portfolio will be provided for all Offices.

Issue 11. Tables that compare inputs in the R&D portfolio case with those in the reference case should become a benchmark for the other groups.

Response: Tables that compare inputs in R&D program cases with those in the baseline case will become a benchmark for the all Offices.

Issue 12. The technology assumptions should be presented in a standard format by sector.

Response: Technology assumptions will be presented in a standard format by sector.

Title: Electricity Delivery and Energy Reliability
Presenter: Joseph Paladino
Overall Rating: Fair

A. Review Panel Comments

Leon Clarke	**Rating: Very Good**

I found the approach to be credible, transparent, and useful.

I found the documentation to be clear and useful.

There are some issues with using NEMS to do this sort of analysis. It may be valuable to do some of the load-shifting analysis outside of NEMS. There were questions about whether NEMS is really the right platform for some of this analysis. This work suffers, like others, from difficulties in really getting at some of the more challenging benefits such as infrastructure security. These are simply difficult problems; so this is not as a much a criticism as a comment on some key issues that should probably be addressed to better represent the benefits of this program.

I found the documentation to be useful, credible, and transparent. One major comment, as with all the programs, is that the process could be adjusted to allow for substantial post-modeling analysis and interpretation.

Joseph DeCarolis	**Rating: Good**

OE has an extremely important role to play, and the benefits must be analyzed in fundamentally different ways from the other offices.

NEMS is not the right tool for this analysis – other tools are required.

General DOE metrics related to energy security have a narrow focus on oil that doesn't have much relevance to OE.

Develop metrics that are specific to OE, and push DOE/OMB to include these metrics in the general guidance.

Don't try to shoehorn analysis into NEMS. Your work presents a strong case for developing new analytic tools.

Alexander Farrell	**Rating: Weak to Fair**

Use of offline analysis and expert panels is good. Use of NEMS is much less satisfactory, for reasons discussed in the report. The DG results are hard to interpret and understand.

In my view, DG is likely to be most successful with combined heat and power (CHP) including cases in which the heat is used for absorption cooling. This is because of both economics and emissions – recent research on the intake fraction of air pollution from DG units is much higher than from central stations, by orders of magnitude. In places where air pollution matters (which includes most of California and many eastern cities), mitigation steps are required; of which CHP is an attractive one. (Full disclosure: I was one of the committee members for the recent UC Berkeley Ph.D. on this topic. Also, I am co-PI on a grant for the Pacific Regional CHP Applications Center, through the California Energy Commission.)

NEMS is not suitable for this sort of analysis, in part because it varies so much over the course of the day, and from building type to building type. Further a model designed to look at reliability, such as an optimal power flow model, is not designed to do this either. The sort of analysis that LBNL does with the DER-CAM model, bottom up and site specific, is essential to understanding the energy and emission effects of DG with CHP. (Full disclosure: I am part of a proposal to the California Energy Commission to fund such analysis specific to the state.)

HTS results are informative and helpful; although I'm not sure I believe the HTS Cable assumptions. But I'm not an expert.

Documentation is moderately useful; but some things are confusing. See verbal comments.	
Hillard Huntington	**Rating: Fair**
You have defined peak load shifting problem as a technology program. The private sector might develop many of these technologies if public policy allowed electricity markets to charge real time prices to cover the full costs of meeting peak demand. Another approach would be to develop insurance programs that would provide incentives for providing system reliability. This approach might be less expensive than trying to promote certain possible technologies. Most energy models (including NEMS) do a poor job in representing the congestion issues that are central to your office's mission.	
Andy Kydes	**Rating: Fair**
The estimate of the savings from the reliability program is estimated at over 6 billion in 2020 and 11 billion in 2030. This is somewhat questionable because if it were true, we should just fund this program at say 200 million per year and eliminate the rest of the R&D. In this sense it seems to that something serious has been omitted on the cost side to achieve these savings. Documentation is not too clear. Don't use large systems model for reliability analysis. Use/develop a detailed model in the flavor of real-time power flow model to analyze issues of reliability and interface or inform, if necessary, with large energy-economy systems model, possible to develop electricity demand. The detailed model could inform the NEMS-type model by adjusting T&D efficiency and rerunning to look at impacts. You need to develop metric relative to reliability if the current ones are not appropriate. In the presentation, the comparisons of savings need to be compared relative to like cases. For example, the savings of the OEHFP carbon increase should be relative to the HFP case without the OE program. This type of problem also occurs in the EERE approach.	
Dan Loughlin	**Rating: No Rating Given**
From the environmental benefits perspective, it may be interesting to look at how areas such as high temperature superconductivity might allow electric generation utilities and even wind/solar to be sited in remote areas (e.g., small impact on humans and possibly environment), but avoiding high transmission losses. The outcome of load shifting leading to CO2 emissions increases probably also include a discussion of the combined benefit with the NE or other programs… so if electricity produced fossil free, this emissions increase may not be as high or may be negated. **This underscores the utility of investigating the combined effects (synergies with respect to benefits?) of programs.** The Monte Carlo approach discussed above potentially has an ability to provide insight with respect to synergies.	
Frederic Murphy	**Rating: No Rating Given**
Have to include contingency analysis in understanding congestion. Currently, this is done with engineering rules. Making it more economically driven will lower the costs of congestion. Talk to FERC about their modeling of congestion and outages. The person is Than Luong, also Dick O'Neill.	

A measure of congestion cost is the differences in LMP's on versus off peak.

Modeling from the outcome to the required costs is backwards from the normal logic. We termed this inverse modeling with PIES. What is needed is a further analysis of the realism of the resulting costs.

William Pizer	**Rating: Good**

As before, I would like to have seen more drilling down on the key assumptions; for example, the HTS assumptions on slide 7. Rather than just examples, focus on quantitatively the most important assumptions and defend them.

I agree with most of the discussion that the vulnerability evaluation does not fit well into the NEMS framework.

Carbon constraint case is misleading. The demand shifting has adverse carbon consequences in the BAU, but desirable consequences in the constrained case. Yet this flip would not be true for a more moderate carbon constraint.

It might be more reasonable to produce a carbon constraint based on CO_2 price rather than a cap.

Calculation of savings in "cost of carbon allowances" is not particularly meaningful. Better to calculate estimated savings under the marginal cost of abatement schedule (e.g., ½ (change in carbon price) (volume of abatement)).

B. Discussion

DSI technologies involve load shifting. Why is period 5 so large? Perhaps abandon this type of approach for a more traditional one. The graphics are not helpful; NEMS is the wrong model; need more detailed power flow model.

Hard time grasping this as a technology issue – real-time pricing issue? Cost of curtailing emissions?

Where does the 3% discount rate come from? It does not seem appropriate. Should be different rates for different analyses.

Carbon constraint and adverse consequences are good things to think about.

Capture current grid efficiencies – off-peak and on-peak. Tom Long at FERC is running some models.

Contingency analysis distorts the analysis because it is an engineering-driven approach that ignores important market-driven factors.

Summary of Reliability Infrastructure Sector Benefits slide numbers need to be clarified better.

Baseline needs to be consistent across all programs.

Familiarity with AEO is necessary – need crosscutting synthesis.

Is the cost of carbon allowance the correct measure of greenhouse gas emissions benefits?

Load shifting encompasses synergies between programs. Are these reflected in the program goals and the analysis of each program's portfolio?
Distributed energy technologies involve subtle complexities. Since intake fractions are greater for distributed generation (DG), the solution may be to employ combined heat and power.
How reasonable is the penetration impact?

C. DOE Response and Action

METHODOLOGY:

Issue 1. Questions about whether NEMS is really the right platform for some of this analysis.

Response: We agree with the reviewers' comments, especially those recommending that the OE program consider adopting alternative methods for calculating benefits, as a complement or replacement to the National Energy Modeling System (NEMS). The reviewers understand that OE's research and development programs are focused on improving the reliability and efficiency of the electricity transmission and distribution system and, at this time, NEMS does not provide an adequate representation of the grid. As a result, OE has undertaken an effort to develop reliability metrics and more appropriate methodologies to estimate benefits. This effort includes examining available models of the transmission and distribution systems to determine if they can serve the program's needs.

Issue 2. Benefits must be analyzed in fundamentally different ways from the other offices.

Response: OE has assembled a team to tackle the development of suitable benefits estimation methodologies. The goal is to establish reliability metrics and a modeling framework measuring benefits derived from OE's programs to support GPRA, program planning, and budget formulation requirements. OE is in the process of determining the activities, schedule, and resource requirements for this effort. OE is also conducting analysis of existing studies of reliability and estimates of the benefits of advanced technologies, including case studies.

METRICS:

Issue 3. Need to develop metric relative to reliability if the current ones are not appropriate.

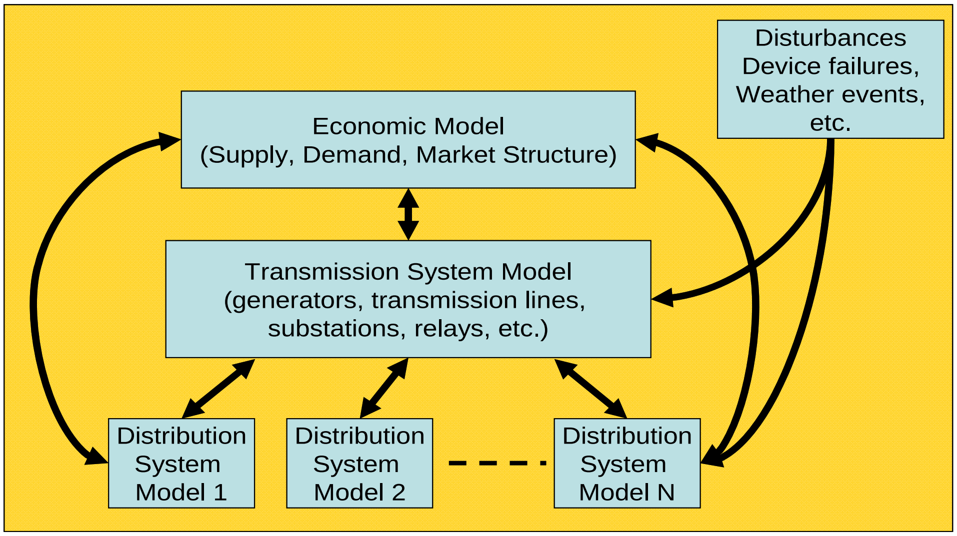
Response: The reliability metrics will incorporate costs associated with power outages, power quality fluctuations, and transmission congestion, where possible. Developing such metrics will be challenging as there are large gaps in and significant uncertainties associated with reliability data. Systematic approaches to collecting reliability data are being considered.

MODELS:

Issue 4. Don't try to shoehorn analysis into NEMS. Your work presents a strong case for developing new analytic tools.

Response: OE is considering separate, but linked, models to represent the transmission and distribution systems, as shown conceptually in Figure 1. Sufficiently detailed models are necessary to capture the effects of technological advances on system performance with satisfactory accuracy, and to map the physical effects with economic or value implications. Regional differences in market structures will need to be considered, particularly, at the distribution system level where estimating the magnitude of potential benefits becomes highly dependant on local electric system conditions. Developing a set of distribution models that can interact with the larger transmission system model may be required.

Figure 1 – A Conceptual Design for a Transmission and Distribution System Model



In developing a new methodology, OE will examine how to best join its grid models with NEMS to utilize shared projections of energy demand and supply and compare benefits, in concert with other programs within the purview of the Department's Office of the Under Secretary for Energy and the Environment. In addition, the grid models should demonstrate the additional benefits OE's programs provide which are derived from the integration of technologies into the grid, for example, distributed generation devices (like wind or solar energy), which are being developed by other DOE programs.

ASSUMPTIONS:

Issue 5. Need for more drilling down on the key assumptions; for example, the HTS assumptions.

Response: OE has continued to improve upon the methodology used for estimating program benefits in its FY08 budget request. Specifically, upgrades to assumptions associated with both the High Temperature Superconductivity and Distributed Systems Integration activities have been incorporated in the FY09 NEMS analysis. In addition, OE will use MARKAL this year to measure benefits to 2050 to be more consistent with the other ESE offices, using a similar approach, i.e., set of calculations, as in the NEMS analysis.

Title: Open Discussion and Recommendations for Imporvement
Presenter: All
Overall Rating: Not Applicable

A. Review Panel Comments

This section includes detailed comments from some (but not all) panel members who wanted to offer a few additional remarks about some topics in the general discussion.

Leon Clarke
No comments provided.
Joseph DeCarolis
No comments provided.
Alexander Farrell
No comments provided.
Hillard Huntington
I would like to recommend that DOE consider holding a workshop that would broaden their view on research and development evaluation. I would see this meeting as an opportunity to bring together a few types of individuals who could describe their experiences. One group would be corporate staff who have conducted studies on the effects of R&D expenditures on their companies operations. Possible participants might be staff from an energy technology company like Schlumberger as well as a representative from a pharmaceutical company like Baxter. A second group would be experts who have evaluated federal and state agricultural research efforts. A final group might be policy economists who have conducted cost-benefit analysis of programs in certain key sectors and who might have useful perspectives on incorporating economic surplus measures. Finding the right participants and appropriately summarizing the discussion for DOE's use would require some time, but would be well worth the effort.
Andy Kydes
No comments provided.
Dan Loughlin
The EERE report has a nice structure, and I feel it may be a good template for including consideration of all of the DOE programs together (as EERE compares the programs in their portfolio). There are some changes that could be made to improve the EERE usefulness in documenting the assumptions, methodology, and results. Some suggestions include: • The implementation of the Energy Expenditures NPV metric should be explained. Typically NPV is presented as a single value that represents the costs of the entire horizon, discounted to a particular year. In the graphs presented, NPV is not provided in this manner. If I am correct in my interpretation, the cumulative benefits/costs of the program through each output year were determined and the NPV of the cumulative values are what is reported for each end-year. This is non-intuitive, however. • Whether mercury controls costs are included is confusing. It is mentioned that it is included in one part of the text but is not mentioned in another. • It is not clear how MARKAL and NEMS were harmonized. This is useful given the differences between the approaches taken by the models.

- In many of the figures that show both MARKAL and NEMS results, there are very visible discontinuities. It would be helpful to have a footnote or other explanation where these appear to let the reader evaluate whether these discontinuities are due to model structure (and what difference in model structure was the reason) or if they are explainable by differences in technology or other assumptions.
- There should be an explicit description of the BAU base scenario up front before the description of the effects of the programs on changing the values of the metrics.
- The graphs typically show changes in various metrics as absolute values. Without an understanding of the BAU baseline values (or showing changes as %s) it is difficult to interpret the magnitude of the benefits.
- When referring to cost calculations in year 2000 dollars, the text uses "$2000". This is a little confusing, and I think there may be more conventional ways of representing this info.
- Once in the text, the word "risk" is inserted where I think that the author's intent was to mention "uncertainty". These are very distinct concepts, and great care should be taken.
- There are two scenarios referred to as "BAU"… the BAU base and BAU portfolio scenarios. In some of the figures, however, scenario results are referred to only as "BAU", and thus it is confusing which scenario is being referenced. Another example of changing terminology is "High Fuel Price" and "Hi Oil".
- For many figures involving the alternative scenarios, it would be helpful to show 4 lines, not 2… For example, tracking changes in expenditures should show "BAU base", "BAU portfolio", "Carbon Base", and "Carbon Portfolio" (actually, the BAU base might be the origin… If this is the case, there would be three lines on the figure, but there should be some clear indication that the origin represents the BAU base.)
- The graphs showing the sub-program contributions to various metrics are very nice. The only difficulty in interpreting them is where there are negative benefits. It may be helpful to explain where these happen and how to interpret (e.g., the negative areas show up as darker segments now)
- I wonder if it would be helpful to have some kind of metric that evaluates the competition of programs? For example, there are many instances where the sum of the program benefits is considerably greater than the benefits when all are considered simultaneously. A ratio of the two values provides insight on the level of competition.
- There is a comment about a data point not being shown because it is "not significant with respect to model error." This does raise the question of whether this is a quantitative determination (e.g., statistically insignificant) or if it is qualitative. If qualitative, then maybe the wording should be changes. It also raises the question of whether there is any kind of estimation on the quantification of model error. I would suspect that there is not.

Frederic Murphy

Here are some additional comments on assessing DOE's research effectiveness and planning research investments for the future.

Currently, DOE is developing its ability to measure the energy-market impacts of its research into energy technologies using NEMS and Markal. This represents only a portion of the potential contribution of the research in that this method does not look at the role of this research funding in expanding the research of other organizations. The economic analysis makes assumptions on the lag for the technologies to be developed without DOE funding. These assumptions are mechanical and are not supportable by any data.

A good way to measure the impact of funding is to look at the centrality of the research ideas supported by the funding. If the ideas are central, then the funding has value beyond some assumed lag. If the ideas funded are not central, then DOE can ascertain the central themes and direct its funding into more productive areas. Furthermore, it is possible to look at the size of the funding activity relative to other sources. If the other funding sources in an area are large relative to DOE expenditures, then DOE probably adds little to the growth of knowledge in the area and should move money to underserved areas or to riskier projects. If the DOE research is both central and a significant portion of the funds in an area, then DOE is making a major contribution far more valuable than the rule of advancing the technology several years.

The centrality of research can be evaluated using the referencing relationships in scientific articles and the cited literature in patent applications. Richard Klavans has built tools to find the ontological relationships in the literature. See his website http://www.mapofscience.com. This work has been used by pharmaceutical firms to manage their R&D efforts. DOE has an added problem in relation to corporate R&D. It funds research through an RFP process rather than manage internal R&D. Thus, DOE needs to see the link between the questions posed in the RFP's and the research output. Steven Kimbrough at Wharton has been developing techniques for linking disparate data sources through given ontologies. By joining the work of Kimbrough and Klavans, it is possible to relate the funding stream as represented in the Federal RFP's in the Radius database with the patent and scientific-literature databases.

Another aspect of the marketplace should be examined. Venture capitalists are now investing billions in new technologies. It is possible to access the prospectuses of the funded companies and mine them. The results can show the extent to which DOE funding of research is providing the critical technologies for new businesses that provide new energy technologies. Again with the combination of the two technologies described above, it is possible to relate DOE research to the prospectuses used in venture funding of new technologies.

Different technologies have different risks in two different ways. The first is that the success of the technology itself is inherently risky. The second is that to become commercial, a technology depends on either another technology or special infrastructure to succeed. At the same time alternative technologies can mitigate the economic risks of a technology failing. It may be possible to mine for those relationships with these methodologies.

The risks could be evaluated by using two similar concepts, the notion of substitutes and complements in economics and series and parallel circuits in electricity. Alternative technologies are the equivalent of parallel circuits where a failure of one bulb does not lead to all bulbs turning off. Technologies that are dependent form series circuits where if one fails the others cannot be used. The corresponding notion in economics is that the technologies are substitutes if users in the marketplace can use one or the other. Complements are products that reinforce the sales of each other. For example, delivery technologies for hydrogen are in series with technologies for generating hydrogen while biofuels are substitutes or in parallel with hydrogen. Douglas Hale, George Lady, John Maybee, James Quirk in *Nonparametric Comparative Statics and Stability* show how these relationships can be analyzed with just sign patterns that express relationships rather than requiring detailed data sets. It may be possible to link their work with the technologies and classic input-output analysis. For example, the biofuels business has had a negative impact on the edible oils business, cooking oils and margarine. Doing this would improve the ability of DOE to address issues of energy/economic security of R&D.

Developing an energy policy from a collection of programs is complicated by these interactions between programs. There is no single value that can be used as a best estimate of the contribution of a single policy, despite the ability to estimate the impact of the complete suite. An example that tries to reconcile these complexities can be found in Frederic H. Murphy and Edward C. Rosenthal, "Allocating the Added Value of Energy Policies," The Energy Journal. Vol. 27, No. 2, 2006.

William Pizer

No comments provided.

B. Discussion

Comments on the Expert Peer Process:

The review process had too much energy expertise and not enough expertise in public policy and process of innovation.

This process should be biennial, not annual.

At every cycle of the analysis, review the process that you have put in place.

Comments on the Benefits Report:

Clearly lay out assumptions. What questions are useful for decision makers? Ask what will be done with all the information gathered. Pull out something meaningful from the post-processing of the numbers.

Need a summary of the scale of the budget R&D research and the allocation between the different programs .

Rare to find modeling savvy in those who are decision makers. Must find a way to tell a story.

Condense the information – need a way to present office-specific results that is more realistic.

Comments on the Benefits Estimates:

External validation of numbers lends credibility.

It would be important to develop correlations between program levels.   Insight from Monte Carlo analysis might help to think about the appropriate combination of different programs.

What is the current thinking in DOE regarding risk? NRC uses decision analytical framework to organize information about risks and payoffs. They use NEMS to provide demand estimates.

Stochastics can help to determine what contributions lead to good or bad outcomes.

Metrics should be reviewed by outside experts. Are oil import levels (which are always used) really measuring security?

To improve the measurement of economic benefits, include individuals who can provide a broad view of the topic. It would be desirable to have a net measure in calculations of societal effects that exclude transfers between groups.

Two levels of concern: consumer savings is cost to government; economists would say to measure welfare. Percentage of energy expenditure relative to income class.

It is understandable why the process has focused on evaluating large programs and benefits. But what about smaller projects with potentially large payouts?

C. DOE Response and Action

GENERAL RESPONSE:

The value of holding a workshop with external experts to broaden the DOE analysts’ view and understanding of research and development evaluation in years when there is no external peer review planned will be assessed.

Evaluate adding information on the degree of centrality of the research conducted by DOE using referencing relationships in scientific articles and the cited literature in patent applications to the current benefits approach. Another approach to consider is to show the extent to which DOE funding of research is providing critical technologies for new businesses that provide new energy technologies.

Appendix A. External Expert Peer Review Panel

HILLARD G. HUNTINGTON

Energy Modeling Forum
450 Terman Engineering Center
Stanford University
Stanford, CA 94305-4026
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HillH@stanford.ed

PROFESSIONAL INTERESTS:

Energy and Environmental Economics
Business and Public Policy Modeling and Analysis

EDUCATION:

Cornell University, Ithaca, N.Y. B.S. 1967
School of Engineering (1962-1964)
School of Industrial and Labor Relations (1964-1967)

State University of New York, Binghamton, N.Y. M.S. 1972, Ph.D. 1974
Graduate Program in Economics

PRESENT POSITION:

Department of Management Sciences and Engineering and Energy Modeling Forum (EMF), Stanford University, Stanford, CA.
Executive Director, EMF, 1985-present.
Senior Research Associate and Director, EMF Affiliates Program, 1980-1985.

PREVIOUS POSITIONS:

University of Cambridge, Cambridge, England
Visiting Fellow, Clare Hall, 1996.

Data Resources, Inc., Washington, D.C. (now Global Insight, Inc.)
Director of Washington Energy Office, 1978-1980.
Senior Economist, 1977-1978.

Office of Economic Impact, Federal Energy Administration, Washington, D.C.
Staff Economist, 1974-1977.

Institute for Development Studies, University of Nairobi, Kenya.
Visiting Research Associate, 1972-1973.

Power Transmission and Distribution Division, Public Utilities Authority, Monrovia, Liberia, West Africa (U.S. Peace Corps Volunteer).
Assistant to the Operations Engineer, 1967-1969.

COURSES TAUGHT:

Seminar in Energy and Economic Modeling (Stanford)
Economic Analysis Seminar (Stanford)
Economic Analysis Practice (Stanford)

PANELS/WORKING GROUPS:

Member and Study Coordinator, Energy Modeling Forum Working Groups, numerous panels, Stanford University, Stanford, California, 1980-.

Expert Presentation, Board of Commissioners, California Energy Commission, Natural Gas Modeling and Analysis, Sacramento, CA, December 16, 2004.

Expert Panel, Western Interstate Energy Board, Western Gas Assessment, Rancho Cordova, CA, October 12-13, 2004.

Member, Environmental Assessment Advisory Group, Commission for Environmental Cooperation of North America, 2002-2004.

Member, Expert Peer Review Panel, U.S. Department of Energy Fossil Energy Benefit Analysis, Washington, D.C., February 25, 2004.

Member, Expert Review Panel, U.S. Energy Information Administration, Analysis of Strategies for Reducing Multiple Emissions from Power Plants: Sulfur Dioxide, Nitrogen Oxides, and Carbon Dioxide, 2000.

Member, Advisory Review Panel, Joint National Laboratory Study on the Potential for Reducing Carbon Emissions, 1996-97.

Member, American Statistical Association Committee on Energy Statistics, 1992-94.

Member, American Delegation, Joint USA USSR National Academy of Sciences Panel on Energy Conservation Research and Development, 1986-90.

Participant, U.S. Congressional Budget Office Board of Economic Advisors Meeting, Washington, D.C., December 5, 1990.

Participant, U.S.-Brazil Energy Workshop on survey Design and Projection Methodologies, Washington, D.C., December 4-6, 1990.

Participant, Office of Technology Assessment (OTA) Workshop on Greenhouse Warming and Industrial Energy Use, Washington, D.C., May 11, 1989.

Member, Peer Review Panel, Networks of Centres of Excellence, Government of Canada, Montreal, Canada, March 31, 1989.

Member, Peer Review Panel, National Acid Precipitation Assessment Program, Task Group on Emissions and Control, Boston, Massachusetts, May 25-26, 1988.

Participant, National Science Foundation Workshop on Model Acceptance, Washington, D.C., April 22-23, 1981.

OTHER PROFESSIONAL ACTIVITIES:

American Economic Association
Member, National Petroleum Council
Member, American Statistical Association Committee on Energy Statistics, 1992-1994.
Life Member, Clare Hall, University of Cambridge, United Kingdom
Senior Fellow, United States Association for Energy Economics, 2000.
International Journal of Global Energy Issues, Editorial Board, 2004-.
Energy Journal, Best Paper Award for 2002.
United States Association for Energy Economics
- President, 1997
- Council Member, 1993-97
- Strategic Planning Committee, 2001-
- Adelman-Frankel Award for outstanding contribution to energy economics; presented to the Energy Modeling Forum.

International Association for Energy Economics
- Vice-President for Publications, 1990-92
- Program Chairman, International Conference of the International Association for Energy Economics, Washington, D.C., July 1995
- Conference Chairman, International Conference of the International Association for Energy Economics, San Francisco, California, September 1997.
- Chairman, Best Paper Award Committee, Energy Journal, 1989.

Consultant to numerous organizations including:
- Abt Associates
- Applied Decision Analysis
- Argonne National Laboratory (Energy and Environmental Systems Division)
- Arthur Andersen, & Co. (Management Information Consulting Division)
- Booz Allen Hamilton
- California Energy Commission
- Data Resources, Inc.
- Electric Power Research Institute
- Office of Technology Assessment
- Putnam, Hayes & Bartlett
- Shell Oil Company
- U.S. Department of Energy

Academic Advisor for Freshmen and Sophomores, 2003 -
Faculty Member, Executive Seminar on Energy Decisionmaking, Stanford University, Stanford, CA, 1981-88.

Faculty Member, International Atomic Energy Agency Course on Electricity Demand Modeling, Argonne National Laboratories, Argonne, IL, 1985-87.
Certificate of Special Achievement, Federal Energy Administration, 1976.
Certificate of Merit, Federal Energy Administration, 1975.

CONGRESSIONAL/COMMISSION TESTIMONY:

Testimony, U.S. Senate Committee on Foreign Relations, “The Hidden Costs of Oil,” March 30, 2006.

Expert Presentation, Board of Commissioners, California Energy Commission, “Natural Gas Modeling and Analysis,” Sacramento, CA, December 16, 2004.

PUBLICATIONS:

Journal Articles

1. “A Note on Price Asymmetry As Induced Technical Change,” *Energy Journal*, July 2006.

2. “U.S. Carbon Emissions, Technological Progress and Economic Growth Since 1870,” *International Journal of Global Energy Issues,* 2005, 23(4): 292-306.

3. “After the Natural Gas Bubble: An Economic Evaluation of the Recent U.S. National Petroleum Council Study,” with Ken Costello and James F. Wilson, *Energy Journal*, April 2005, 26(2): 89-109.

4. “Shares, Gaps and the Economy’s Response to Oil Disruptions,” *Energy Economics,* Volume 26, Issue 3, May 2004, Pages 415-424.

5. “Energy Security and Global Climate Change Mitigation,” with Stephen P.A. Brown, *Energy Policy*, 2004, 32(6): 715-718.

6. “Terms of Trade and OECD Policies to Mitigate Global Climate Change,” with Stephen P. A. Brown, Federal Reserve Bank of Dallas *Economic and Financial Policy Review*, 2003, Vol. 2, No. 1, http://dallasfedreview.org/articles/v02_n01_a01.html

7. “Energy Disruptions, Interfirm Price Effects and the Aggregate Economy,” *Energy Economics*, March 2003, 25(2): 119-136.

8. “The Asymmetric Effects of Changes in Price and Income on Energy and Oil Demand” with Dermot Gately, *Energy Journal*, 23 (1), January 2002.

9. “Crude Oil Prices and U.S. Economic Performance: Where Does the Asymmetry Reside?” *Energy Journal*, 1998, 19(4): 107-132.

10. “Some Implications of Increased Cooperation in World Oil Conservation,” with Stephen P.A. Brown, Federal Reserve Bank of Dallas *Economic Review*, 2nd Quarter, 1998.

11. “Introduction,” special issue, *Utilities Policy,* September 1997, 6(3).

12. “Been Top Down So Long Looks Like Bottom Up to Me,” *Energy Policy,* November 1994, 22(10): 833-839.

13. “LDC Cooperation in World Oil Conservation Policies,” with Stephen P.A. Brown, *Energy Journal,* Fall 1994, pp. 310-328.

14. “The Economic Cost of U.S. Oil Conservation,” with Stephen P.A. Brown, *Contemporary Economic Policy,* July 1994, Vol. 12, pp. 42-53.

15. “Oil Price Forecasting in the 1980s: What Went Wrong?” *Energy Journal,* June 1994, 15(2): 1-22 (feature article, also published in The Economics of Energy, edited by Paul Stevens, Northampton, MA: Edward Elgar, 2000).

16. “Limiting Oil Imports: Cost Estimates,” *Contemporary Policy Issues,* July 1993, Vol. 11, pp. 12-29.

17. “OECD Oil Demand: Estimated Response Surfaces for Nine World Oil Models,” *Energy Economics,* January 1993, pp. 49-56.

18. “A Comparison of Aggregate Energy Demand Models for Global Warming Policy Analyses,” with Ronald D. Beaver, *Energy Policy,* June 1992, 20(6): 568-574.

19. “U.S. Natural Gas Markets: A Structural Model Comparison,” *Journal of Policy Modeling,* Volume 14, Issue 1, February 1992, Pages 13-39.

20. “Substitution Between Activities with Different Energy Intensities,” *Resources and Energy,* April 1991, Vol. 13, No. 1, pp. 23-37.

21. “North American Natural Gas Markets: A Summary of an Energy Modeling Forum Study,” with G.E. Schuler, *Energy Journal,* April 1990, Vol. 11, No. 2, pp. 1-21.

22. “On Economic Policy Responses to Disruptions: A Reply to Harry Saunders,” with B.G. Hickman and J.L. Sweeney, *Energy Journal,* October 1989, Vol. 10, No. 4, pp. 189-198.

23. “The Impact of Sectoral Shifts in Industry on U.S. Energy Demands,” *Energy,* June 1989, Vol. 14, No. 6, pp. 363 372.

24. “Should GNP Impacts Preclude Oil Tariffs?” *Energy Journal,* April 1988, Vol. 9, No. 2, pp. 31-44.

25. “A Reply: The U.S. Dollar and the World Oil Market,” *Energy Policy,* April 1987.

26. “The U.S. Dollar and the World Oil Market,” *Energy Policy,* August 1986, pp. 299-306.

27. “Oil Prices and Inflation,” *Annual Review of Energy,* Volume 10, 1985, pp. 317-339.

28. “Real Oil Prices During 1980 82,” *Energy Journal*, July 1984, Volume 5, No. 3, pp. 119-131.

29. “Modeling for Insights, Not Numbers: The Experiences of the Energy Modeling Forum,” with J.P. Weyant and J.L. Sweeney, *Omega: The International Journal of Management Science,* Volume 10, No. 5 (feature article), 1982, pp. 449-462.

30. “Federal Price Regulation and the Supply of Natural Gas in a Segmented Field Market,” *Land Economics,* August 1978, Volume 54, No. 3, pp. 337-347.

31. “Time Allocation, Time Value and Factor Intensity,” with A.C. DeSerpa, *Australian Economic Papers,* June 1978, pp. 124-131.

32. “An Empirical Study of Ethnic Linkages in Kenyan Rural Urban Migration,” Nairobi, Kenya: Institute for Development Studies Discussion Paper Series, No. 260, December 1977 (Refereed series).

33. “The Rate of Return on the Basseri's Livestock Investment,” *Man: Journal of the Royal Anthropological Institute,* September 1972, Volume 7, No. 3.

Books and Contributions to Books

34. “The Geopolitics of Natural Gas: An Energy Modeling Forum Study,” in Shanghai Forum, *Economic Globalization and the Choice of Asia*, edited by the Shanghai Forum Organizing Committee, Shanghai, China: Fudan University Press, forthcoming.

35. “Modeling Energy Markets and Climate Change Policy,” with John P. Weyant, in *Encyclopedia of Energy,* edited by Cutler J. Cleveland, Academic Press/Elsevier Science, forthcoming.

36. “Market-Based U.S. Electricity Prices: A Multi-Model Evaluation,” in *Electricity Pricing in Transition,* edited by Kelly Eakin and Ahmad Faruqui, Boston: Kluwer Academic Press, 2002.

37. “Projecting Energy Trends Into the Twenty First Century,” with Mark Rodekohr, in *Our Fragile World: Challenges and Opportunities for Sustainable Development,* forerunner to the Encyclopedia of Life Support Systems by Koïchiro Matsuura, Director-General of UNESCO, May 2001, UNESCO, Paris, Eolss Publishers.

38. *Designing Competitive Electricity Markets,* Co-Editor (with Hung-po Chao), Boston: Kluwer Academic Press, 1998.

39. *International Symposium on Transmission Pricing,* Editor, *Utilities Policy,* September 1997, 6(3).

40. *Markets for Energy Efficiency,* Co-Editor (with Lee Schipper and Alan Sanstad), *Energy Policy,* Special Issue, November 1994.

41. “Oil: Alternative Perspective on the Decade,” in *An Economic Perspective of the Southwest: Defining the Decade,* edited by Gerald P. O'Driscoll, Jr., and Stephen P.A. Brown, Boston: Kluwer Academic Press, 1992.

42. “The Effects of Changes in the Economic Structure on Energy Demand in the USSR and the U.S.,” with Yu D. Kononov, E.A. Medvedeva, and G.A. Boyd, in *International Energy Economics,* edited by Thomas Sterner, London: Chapman & Hall, 1992.

43. “Inferred Demand and Supply Elasticities from a Comparison of Nine World Oil Model,” in *International Energy Economics,* edited by Thomas Sterner, London: Chapman & Hall, 1992.

44. Energy Markets in the 1990s and Beyond, edited with A.B. Baker, *Proceedings of the 11th Annual North American Conference,* International Association for Energy Economics, October 16 18, 1989.

45. *North American Natural Gas Markets: Selected Technical Studies,* edited with G.E. Schuler, Energy Modeling Forum, Stanford University, Stanford, California, April 1989.

46. “Energy Economics.” In *The New Palgrave,* edited by J. Eatwell, M. Milgate, and P. Newman. London: Macmillan Press, 1987.

47. “Sectoral Shift and Industrial Energy Demand: Key Findings from an Energy Modeling Forum Study,” with J.G. Myers. In *Papers and Proceedings of the Eighth Annual North American Conference: The Changing World Energy Economy,* edited by David O. Wood, Massachusetts Institute of Technology, Cambridge, Massachusetts, May 1987.

48. “Sectoral Shift and Industrial Energy Demand: What Have We Learned?” with J.G. Myers. In *Forecasting Industrial Structural Change and its Impact on Electricity Consumption,* edited by A. Faruqui and J. Broehl, Battelle Press, 1987.

49. *Macroeconomic Impacts of Energy Shocks.* Editor (with B.G. Hickman and J.L. Sweeney). Contribution to Economic Analysis Series No. 163, Amsterdam: North Holland, 1987.

50. “Study Design for Macroeconomic Impacts of Energy Shocks,” with B.G. Hickman. In *Macroeconomic Impacts of Energy Shocks,* Amsterdam: North Holland, 1987.

51. “Energy Policy Issues and Macroeconomic Models,” with J.E. Eschbach. In *Macroeconomic Impacts of Energy Shocks,* Amsterdam: North Holland, 1987.

52. *Macroeconomic Impacts of Energy Shocks: Contributions from Participating Modelers,* Editor (with B.G. Hickman), Energy Modeling Forum, Stanford University, Stanford, California, 1987.

53. *Macroeconomic Impacts of Energy Shocks,* Energy Modeling Forum Report 7, Volume I, Stanford University, Stanford, California, 1986 (Principal Contributor); also published in Macroeconomic Impacts of Energy Shocks, Amsterdam: North Holland, 1987, pp. 1-123.

54. "OPEC and the U.S. Economy: Insights From a Comparison of Macroeconomic Models." In *The Energy Industries in Transition: 1985-2000,* edited by J.P. Weyant and D.B. Sheffield. Boulder, Colorado: Westview Press, 1985.

55. "Integration of Energy/Economic Models For Environmental Assessments and Policy Analysis," with D.A. Hanson, C.M. Macal, and H.W. Hochheiser. In *The Energy Industries in Transition: 1985-2000,* edited by J.P. Weyant and D.B. Sheffield. Boulder, Colorado: Westview Press, 1985.

Selected Technical Reports

56. *Macroeconomic Consequences of Higher Oil Prices*, Energy Modeling Forum Special Report 9, Stanford University, Stanford, California, August 2005.

57. *Oil Disruption Risk Assessment*, with Phillip Beccue, Energy Modeling Forum Special Report 8, Stanford University, Stanford, California, August 2005.

58. *Natural Gas, Fuel Diversity and North American Energy Markets,* Energy Modeling Forum Report 20, Summary Report, Stanford University, Stanford, California, September 2003 (principal contributor).

59. *Review of the Current Status of Power Market Reforms in the United States and Europe,* with Hung-po Chao, Robert Entriken, Shmuel Oren, Alexis Papalexopoulos, Steven Wan, and Robert Wilson, EPRI, Palo Alto, CA: 2002. 1007332.

60. *Prices and Emissions in a Restructured Electricity Market*, Energy Modeling Forum Report 17, Summary Report, Stanford University, Stanford, California, April 2001 (principal contributor).

61. "An International Comparison of Market Power Models," with J. Bushnell, C. Day, M. Duckworth, R. Green, A. Halseth, E.G. Read, S. Rogers, A.Rudkevich, T. Scott, and Y. Smeers, Energy Modeling Forum Working Paper 17.1 (revised WP 15.1), Stanford University, Stanford, CA, March 1999.

62. *A Competitive Electricity Industry,* Energy Modeling Forum Report 15, Summary Report, Stanford University, Stanford, California, April 1998 (principal contributor).

63. "Quantifying Oil Disruption Risks Through Expert Judgment" with John Weyant, Antje Kann and Phil Beccue, Energy Modeling Forum Special Report 7, Stanford University, Stanford, California, April 1997.

64. *Markets for Energy Efficiency,* Energy Modeling Forum Report 13, Summary Report, Stanford University, Stanford, California, February 1996 (principal contributor).

65. *International Oil Supplies and Demands*, Report 11, Summary Report, Energy Modeling Forum, Stanford University, Stanford, CA, September 1991 (principal contributor).

66. "International Oil Supplies and Demands: An Analysis of the Results," Energy Modeling Forum, Stanford University, Stanford, CA, February 1991 (principal contributor).

67. "Economic Impacts of U.S. Oil-Replacement Policies: Methodology and Results for the OTA Analysis," with John P. Weyant, Energy Modeling Forum, Stanford University, Stanford, CA, April 1991.

68. "Emerging Competition in California Gas Markets," Prepared for the California Energy Commission, February 1991.

69. *North American Natural Gas Markets,* Energy Modeling Forum Report 9, Volumes I & II, Stanford University, Stanford, California, February 1989 (Principal Contributor).

70. *The Demand for Energy in the Commercial Sector,* with E. Soffer, Palo Alto, California: Electric Power Research Institute, EA 2330, 1982.

71. *A Price Forecasting System for Refined Petroleum Products,* with G.R. Doenges, E.R. Novicky, and J.L. Sweeney, Washington, D.C.: Data Resources, Inc., July 1978.

72. "Analysis of the Natural Gas Compromise," *Data Resources Topics in Energy*, June 1978.

73. "Natural Gas Outlook," *Data Resources Energy Review*, various issues, 1977-80.

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75. *The Natural Gas Market in 1974,* with J.A. Neri, National Energy Information Center, Federal Energy Administration, Washington, D.C., May 1976, Technical Report PB 253-038.

76. *Project Independence Report,* contributor, Federal Energy Administration, Washington, D.C., November 1974.

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Stanford University
Ph.D. in Engineering-Economic Systems & Operations Research (2002)
M.S. in Engineering-Economic Systems & Operations Research (1998)

University of California, Berkeley
M.S. in Mechanical Engineering (1990)
B.S. in Mechanical Engineering (1988)

Pacific Northwest National Laboratory, 2003-present, *Senior Research Economist, Joint Global Change Research Institute*.

Lawrence Livermore National Laboratory, 2002-2003, *Systems and Decision Scientist: Applied Statistics and Economics Group*.

Pacific Gas & Electric Company, 1993-1996, *Senior Project Manager: Customer Energy-Efficiency, Policy and Evaluation Group*.

RCG/Hagler, Bailly, Inc., 1991-1993, *Associate*.

Pacific Gas & Electric Company: *Gas Planning Engineer, Summer Intern*, Summer, 1987.

Dissertation Research: Stanford University, 1999-2002. *"Emerging Environmental Technologies and Environmental Technology Policy"*.

Research Assistant: Energy Modeling Forum, Stanford University, 1999-2002.

Research Assistant: Stanford University, 1997-1999, through a grant from the American Automobile Manufacturers Association

International Association of Energy Economists

L. Clarke, M. Wise, S. Kim, A. Thomson, C. Izaurralde, J. Lurz, M. Placet, S. Smith, (2006), *Climate Change Mitigation: An Analysis of Advanced Technology Scenarios*, Technical Report PNNL-16078, Pacific Northwest National Laboratory.

L. Clarke, J. Edmonds, J. Jacoby, H. Pitcher, R. Richels, and J. Reilly, (2006), *Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations*, CCSP Synthesis and Assessment Product 2.1, Part A, Climate Change Science Program, Draft for public comment available at http://www.climatescience.gov/Library/sap/sap2-1/default.htm.

E. Baker, L. Clarke, J. Keisler, E. Shittu, (2006), "Uncertainty, Technical Change, and Policy Models", submitted for publication.

E. Baker, L. Clarke, E. Shittu, (2006), "Technical Change and the Marginal Cost of Abatement", submitted for publication

P. Runci, L. Clarke, J. Dooley, (2006), "Energy R&D Investment in the Industrialized World: An Update", *Issues in Science and Technology: Forum*, Spring 2006.

L. Clarke, J. Weyant, J. Edmonds, (2006), “On Sources of Technological Change: What Do the Models Assume?”, *Energy Economics* (forthcoming)

L. Clarke, J. Weyant, A. Birky, (2006), “On the Sources of Technological Change: Assessing the Evidence”, *Energy Economics* (forthcoming)

E. Baker, L. Clarke, J. Weyant, (2006), “R&D as a Hedge against Climate Damages”, *Climatic Change*, (78) 1, pp. 157-179.

J. Edmonds and L. Clarke. (2005), “Endogenous Technological Change in Long-term Emissions Stabilization Scenarios”, *IPCC Expert Meeting on Emissions Scenarios*, M. Hoogwijk (ed.), IPCC, Bildhoven, The Netherlands. Pp.63-69. PNNL-SA-43916.

L. Clarke, J. Weyant, A. Birky, S. Peabody, (2004), “Modeling the Sources of Technological Advance in the Climate Context”, GTSP Working Paper 2004-7, Global Technology Strategy Program.

G. Blanford and L. Clarke, (2003), “On the Allocation of R&D Resources for Climate Change Technology Development”, Lawrence Livermore National Laboratory Working Paper, UCRL-TR-200982.

L. Clarke and J. Weyant, (2002), "Modeling Induced Technological Change: An Overview", in A. Grubler, N. Nakicenovic, and W. Nordhaus (Eds.), *Technological Change and the Environment*, Resources for the Future, Washington, D.C.

L. Clarke (2002), “Emerging Environmental Technologies and Environmental Technology Policy”, Ph.D. Dissertation, Stanford University, Stanford, CA.

L. Clarke (2002), “Emerging Environmental Technologies and Environmental Technology Policy”, Working Paper 19.2, Energy Modeling Forum, Stanford University.

M. Baker, R. Ridge, L. Clarke, B. Tso, (1996), “1994 Impact Evaluation of PG&E's Commercial-Sector HVAC Energy Efficiency Programs”, Proceedings of the 1996 ACEEE Summer Study on Energy-Efficiency in Buildings, Asilomar, CA.

F. Coito, F. Powell, L. Clarke, (1996), “Impact Evaluation of Pacific Gas and Electric's Industrial Process, Refrigeration, and Miscellaneous Measures Programs”, Proceedings of the 1996 ACEEE Summer Study on Energy-Efficiency in Buildings, Asilomar, CA.

R. Mowris, F. Powell, J. Regester, L. Clarke, (1996), “Impact Evaluation of Pacific Gas and Electric Company's 1994 Industrial HVAC Programs”, Proceedings of the 1996 ACEEE Summer Study on Energy-Efficiency in Buildings, Asilomar, CA.

K. Randazzo, R. Ridge, K. Train, L. Clarke, (1996), “How Many Mills Ratios Does it Take to Estimate Net Savings?”, Proceedings of the 1996 ACEEE Summer Study on Energy-Efficiency in Buildings, Asilomar, CA.

L. Clarke, (1990), “Evaluation of the Data Reduction Methodology for Determining Single-Phase Heat Transfer Coefficients for Compact Heat Exchangers”, Master’s Thesis, U.C. Berkeley, Berkeley, CA.

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Education

- Ph.D. (2004). Engineering and Public Policy, Carnegie Mellon University. Thesis title: "The Economics and Environmental Impacts of Large-Scale Wind Power in a Carbon Constrained World."
- B.A. (2000). Physics (high honors) and Environmental Science & Policy (highest honors), Clark University, summa cum laude.

Work Experience

2004-present: Environmental Scientist, U.S. Environmental Protection Agency, Office of Research and Development.
2002-2004: Research Assistant, Carnegie Mellon Electricity Industry Center
2000-2002: Research Assistant, Center for Integrated Study of the Human Dimensions of Global Change
1998-2000: Research Assistant, Clark University Pulsed Field Facility
1997-1998: Research Assistant, Clark University Computer Simulation Laboratory

Teaching Experience

2005: Duke University, Instructor, *Energy and the Campus*
2002: Carnegie Mellon, Project Manager, *Evaluating the Environmental Effectiveness of Recycling in Pittsburgh*
1999: Clark University, Teaching Assistant, *Astronomy*
1999: Clark University, Teaching Assistant, *Computer Simulation Laboratory*
1998: Clark University, Teaching Assistant, *Energy and the Campus*
1998: Clark University, Teaching Assistant, *Looking into Mathematics*

Awards and Honors

- Most Innovative Research Paper: "Is the Answer to Climate Change Mitigation Blowing in the Wind?" Presented at the First International Doctoral Consortium on Technology, Policy, and Management at Delft University, 2002.
- Erickson Scholar, 2000.
- Phi Beta Kappa, 2000.
- Carlson Scholar, 1996-2000.

Publications

Cooter, E., Eder B., Rosenzweig C., Lynn B., Goldberg R., Knutson C., Hayes M., Wilhite D., DeCarolis J., and Barnett T. (2005). Effects of Climate Change on Weather and Water. *EM (AWMA's Magazine for Environmental Managers)*, October 2005.

DeCarolis, J.F. and Keith, D.W. (2006). The Economics of Large Scale Wind Power in a Carbon Constrained World. *Energy Policy*, **34**: 395 – 410.

DeCarolis, J.F. and Keith, D.W. (2005). The Costs of Wind's Variability: Is There a Threshold? *The Electricity Journal*, **18** (1): 69-77.

Keith, D.W., DeCarolis J.F., Denkenberger D.C., Lenschow, D.H., Malyshev, S.L., Pacala, S., Rasch, P.J. The influence of large-scale wind-power on global climate. *Proceedings of the National Academy of Sciences*, **101** (46): 16115-16120.

DeCarolis, J.F. and Keith, D.W. (2002). Is the Answer to Climate Change Mitigation Blowing in the Wind? *Proceedings of the first International Doctoral Consortium on Technology, Policy, and Management*. E. F. t. Heuvelhof (ed.). Delft, The Netherlands, Delft University, 199-215.

DeCarolis, J.F. and Keith, D.W. (2001). The real cost of wind energy. *Science*, **294** (5544): 1000-1001.

DeCarolis, J.F., Goble R.L., Hohenemser C. (2000). Searching for energy efficiency on campus - Clark University's 30-year quest. *Environment*, **42** (4): 8-20.

Coffey, T., Bayindir Z., DeCarolis J.F., Bennett M., Esper G., Agosta C.C. (2000) Measuring radio frequency properties of materials in pulsed magnetic fields with a tunnel diode oscillator. *Review of Scientific Instrumentation*, **71** (12): 4600-4606.

Invited Talks

- "Representing SO_X and NO_X Control Technologies in MARKAL Using an Engineering-Cost Model." Presented at the Energy Technology Systems Analysis Program (ETSAP) Summer Meeting, Cape Town, South Africa, June 30, 2006.
- "U.S. EPA MARKAL: An Update and Case Study of Wind and Nuclear." Presented at the Energy Technology Systems Analysis Program (ETSAP) Summer Meeting, Kyoto, Japan, July 4, 2005.
- "Is the Answer to Anthropogenic Climate Change Blowing in the Wind?" Presented the Fall 2005 Sigma Xi Lecture at Indiana University of Pennsylvania (IUP), Indiana, Pennsylvania, November 10, 2004.
- "The Economics and Climate Impacts of Large Scale Wind Power." Presented at the U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, June 10, 2004.
- "The Economics of Large Scale Wind Power in a Carbon Constrained World." Presented at Electric Power 2004, Baltimore, Maryland, March 31, 2004.
- "Wind Power." Presented to the Carnegie Mellon Electricity Industry Center (CEIC), Pittsburgh, PA, February 6, 2002.
- "Is the Answer to Climate Change Mitigation Blowing in the Wind?" Presented at a symposium titled "Toward a Sustainable World: Physics and Technology Assessment A Celebration in Honor of Christoph Hohenemser**",** Clark University, Worcester, MA, April 19, 2002.
- "Is the Answer to Climate Change Mitigation Blowing in the Wind?" Presented at the First International Doctoral Consortium on Technology, Policy, and Management, TUDelft, Delft, The Netherlands, June 18, 2002.

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EDUCATION

University of Pennsylvania. Ph.D. in Energy Management and Policy. 1996

U.S. Naval Nuclear Power School. Chief Engineer (equivalent to MS in Nuclear Engineering). 1988.

U.S. Naval Academy. BS in Systems Engineering. 1984.

EXPERIENCE

University of California Berkeley
Energy and Resources Group — Assistant Professor, 2003-present

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Carnegie Mellon Electricity Industry Center — Executive Director, 2001-2003
Department of Engineering and Public Policy — Research Engineer, 1998-2003

Harvard University
John F. Kennedy School of Government — Research Fellow, 1997-1998

American Association for the Advancement of Science — Research Fellow, 1997

University of Pennsylvania — Lecturer, 1995-1997

Wharton Risk Management and Decision Processes Center — Research Fellow, 1995-1996

Air Products and Chemicals, Inc. — Project Engineer, 1989-1991

U.S. Navy — Nuclear Submarine Officer**,** 1984-1989

AFFILIATIONS

Director, Joint Center for Transportation Sustainability Research, UC Berkeley (2006 – present)
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Affiliate, Institute of Transportation Studies, UC Berkeley (2005 – present)
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Investigator, Climate Decision Making Center, Carnegie Mellon University (2004-present)
Investigator, California Climate Change Center, UC Berkeley (2003 – present)

RESEARCH AND TEACHING INTERESTS

My primary research interest is in improving our understanding of the environmental and social aspects of energy systems, and in the development of energy systems that support the world we desire to live in. I am particularly interested in better characterizing environmental impacts of energy production and transformation, especially air pollution and greenhouse gases, and in the economic, political, and other social aspects of energy systems that have low environmental impacts. Questions of energy security; how to define it, how to measure it, how to achieve it; are also an area of interest. I also study incentive-based environmental policies, especially emission trading. This is part of a general interest in understanding how to manage greenhouse gas reductions. I also research the social processes by which energy and environmental policy is created and implemented. My teaching interests are in the education of professionals and scholars who wish to work in the general area of energy and the environment through the use of interdisciplinary approaches.

REFEREED PUBLICATIONS

Farrell, A.E. and A.R. Brandt. (2006) Environmental Implications of the Oil Transition. Invited for the inaugural issue of *Environmental Research Letters.*

Zerriffi, H., H. Dowlatabadi, and A.E. Farrell. (2006) Incorporating Stress In Electric Power System Reliability Models. *Energy Policy*. In press.

Strachan, N.D. and A.E. Farrell. (2006) Emissions from Distributed vs. Centralized Generation: The Importance of System Performance. *Energy Policy*. 34: 2677–2689.

Farrell, A.E., R.J. Plevin. B.T. Turner, A.D. Jones, M. O'Hare, and D. Kammen (2006) Ethanol can contribute to energy and environmental goals. *Science.* **311**:506-508.

Farrell, A.E. and J.A. McAllister. (2005) Electricity consumption by battery-powered consumer electronics: A household-level survey. Accepted with revisions by *Energy*.

Brandt, A. R. and A.E. Farrell (2005) Scraping the Bottom of the Barrel: CO_2 Emission Consequences of a Transition to Low-Quality and Synthetic Petroleum Resources. Accepted with revisions by *Climatic Change*

Winebrake, J.J., J.J. Corbett, C. Wang, A.E. Farrell, and P. Woods (2005) Optimal Fleet-wide Emission Reductions for Passenger Ferries: Mixed-Integer Non-Linear Programming Model for the New York-New Jersey Harbor. *J. of the Air & Waste Management Association*. **55**: 458-466.

Farrell, A.E. (2005) Learning to see the invisible: Discovery and measurement of ozone. *Environmental Monitoring and Assessment*. **106:** 69-80.

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HONORS

Energy and Resources Group, "Spherical Cow" award. 2003, 2006
Navy Achievement Medal. 1988.
Arctic Expeditionary Medal. 1988.
Navy Expeditionary Medal. 1985, 1988.
National Merit Scholarship. 1980. (Declined)

ANDY S. KYDES

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WORK HISTORY

1992 - Present	US DOE/EIA Senior Technical Advisor
1989 - 1992	Con Edison of New York Manager, Gas Planning Department
1987 - 1989	Argonne National Lab Senior Advisor & Group Leader
1976 - 1987	Brookhaven National Lab Division Director
1974 – 1976	SUNY at STONY BROOK Faculty-OR/Transportation Planning
1971 - 1974	SUNY at STONY BROOK (Graduate Student/Lecturer)
1968 - 1971	Milton Academy Faculty - Mathematics and Physics

QUALIFICATIONS

- Effective Management and Planning
- Over 20 Years Management Experience
- Energy-economy Systems Analysis
- Electric/Gas Industry Experience
- Excellent Interpersonal Skills
- Excellent Communication

ACTIVITIES AND ACCOMPLISHMENTS

ADMINISTRATION - Evaluated and directed migration plan from MVS system to RISC 6000/590 for all forecasting activities and later to PC-based systems at EIA. Directed all gas-related long-range and strategic planning, contingency planning, risk analysis, and supply adequacy studies for Con Edison; directed the development, proposal and implementation of long-range gas supply strategies. Directed the research activities of Energy-Economy Systems Analysis Division at Brookhaven National Laboratory. Provided high-level policy advice to US DOE officials. Managed interdisciplinary staff. Headed a team to develop an annual forecasting system used by the Energy Information Administration (EIA). Created and implemented annual budgets. Marketed new research programs. Evaluated and determined all microcomputer software and hardware purchase decisions for my division and departments.

PROJECT MANAGEMENT - EIA: I am currently acting as senior technical manager in the development of the international energy modeling system capability using MARKAL as the core modeling unit; I managed NEMS reduced form model development projects and NEMS algorithmic enhancement projects to accelerate NEMS convergence. At Con Edison, I managed the design of a Gas Management Information System (GASMIS) for the Gas Supply Department. Used Joint Application Design approach for design phase and Rapid Application Development to implement GASMIS. I managed the gas-related portion of a gas rate case and marginal cost study and testified to the NY Public Service Commission. As a BNL employee, I managed the streamlining of the software and data base structure of a large gas market model which reduced computer operating costs by 80%. Provided technical data processing support to staff of the EIA. I managed model and supporting data base refinements to four large forecasting models used by the US Department of Energy. I analyzed model convergence properties of energy models and used findings to recommend faster and more stable solution algorithms. I performed multi-objective analysis. Analyzed market penetration of new energy technologies.

I managed the modeling, implementation, and testing of urban growth processes and the associated energy required by the evolving region.

MODELING AND IMPLEMENTATION - Senior Technical Advisor to senior EIA management on all matters relating to forecasting and analysis for the mid- and long-term. I currently lead the development of the international energy modeling capability in OIAF. Mathematically modeled and implemented prototype of DOT Bus mass transit planning system to determine more effective procedures for estimating the capital and operating cost of proposed transportation systems. Designed and implemented the algorithm which generated passenger schedule. Assisted in the design and implementation of the vehicle and manpower scheduler. Modeled and implemented the Winter Planning System, a PC-based winter-season gas screening tool for determining gas supply adequacy to meet projected customer demands.

COMMUNICATIONS - Taught mathematics at high school, undergraduate and graduate level; taught courses in finite mathematics, basic programming, numerical analysis, probability and statistics, and modeling for over seven years. Gave numerous briefings at professional conferences, workshops and sponsor briefings; extensive publications in reviewed journals; organized and hosted technical international conferences; edited two books on energy.

EDUCATION

B.A., Engineering and Applied Physics, Harvard University, Cambridge, Massachusetts
Ph.D. & M.S. State University of NY at Stony Brook, Department of Applied Mathematics and Statistics; doctorate in numerical analysis.

Special Training/Courses Taken:

Executive Development Seminar: June 6 - 17, 1994, December 2004.
Bob Boylan Presentation Course: 1993
Seven Habits of Highly Successful People: February 1995

Citizenship: United States

MEMBERSHIPS

Full member of the Institute For Operations Research and Management Science
The International Association of Energy Economists

AWARDS

Rated Outstanding every year employed by U.S. DOE (since 1992)
Numerous ASpot Awards@ for Outstanding Performance
Nominated twice for Griffin Mentoring Award by 11 EIA staff in 2003. Awarded with Special Act or Service Award.

SELECTED REFERENCES AVAILABLE ON REQUEST

SELECTED PUBLICATIONS - Andy S. Kydes

"Outlook for U.S. Energy Consumption and Prices in the Mid-term," Chapter 7 of Handbook on Conservation and Renewable Energy, Kreith, F and Goswami,Y. editors, CRC Press, LLC, to appear late 2006- early 2007.

"An Overview of Two National Energy Modeling Systems - NEMS and MARKAL," Spring 2004, Encyclopedia of Energy, Academic Press/Elsevier Science, San Diego, CA.

"Impact of a 20 Percent Renewable Portfolio Standard on U.S. Energy Markets," *May 2002, Oxford Energy Forum*, Issue 49, pp 6-8.

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"Modeling Technology Learning in the National Energy Modeling System," *Asian Journal of Energy and Environment*, summer 2000.

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“The Outlook for U.S. Energy Supply, Demand, and Prices Through 2010,” with S. Sitzer and L. Bonadies, CRC Handbook of Energy Efficiency, CRC Press, (1996).

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"SIMBID: An Alternative, Simplified Model for Bidding and Awarding of New Natural Gas Reserves," with B. Wing, Energy Markets in the Longer-term:Planning Under Uncertainty, A.S. Kydes and D.M. Gareghty, editors, North Holland Publishing Co., 1985.

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"Operating Cost Model for Transit Based on Direct System Characteristics," with L. Bodin and D. Rosenfield, Elements in the Transportation Planning Programming Process in the Public Forum, Transportation Research Record 654, TRB, National Academy of Sciences, pp. 28-30, 1977.

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Experience Curves for Energy Technology Policy, March 11, 2002, Pew Center of Global Climate Change, Arlington, Virginia.

Energy Modeling and Simulation, sponsored by the International Association of Mathematics and Computers in Simulation, August 1982, Montreal, Canada.

Energy Markets In the Longer Term: Planning Under Uncertainty, sponsored by the International Association of Mathematics and Computers in Simulation, August 1984, Brookhaven National Laboratory, Upton, New York.

DANIEL H. LOUGHLIN

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Atmospheric Protection Branch, Air Pollution Prevention and Control Division
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Education

Doctor of Philosophy, Environmental Systems Analysis, Civil Engineering
North Carolina State University, Raleigh, North Carolina, 5/98
Dissertation: "Genetic algorithm-based optimization in the development of tropospheric ozone control strategies: least cost, multiobjective, alternative generation, and chance-constrained applications."

Master of Science, Civil Engineering
North Carolina State University, Raleigh, North Carolina, 12/95

Bachelor of Science in Civil and Environmental Engineering
Duke University, Durham, North Carolina, 5/93

Employment history

Environmental Scientist, US Environmental Protection Agency, 10/03-present
Adjunct Assistant Professor, North Carolina State University, Raleigh, North Carolina, 6/03-present
Research Associate/Adjunct Assistant Professor, University of North Carolina at Chapel Hill, 11/02-9/03
Research Scientist, MCNC – Environmental Modeling Center, Research Triangle Park, North Carolina, 11/01-9/02
Research Assistant Professor, North Carolina State University, Raleigh, North Carolina, 6/98-6/03
Graduate Research Assistant, North Carolina State University, 9/93-7/98

Research Interests

- **energy system modeling** and **technology assessment** in the context of global change and air quality
- combining environmental models into **integrated modeling systems** to support environmental decision-making
- simulating and comparing the performance of alternative environmental management policies, such as **command-and-control regulations**, **subsidies**, **charges**, and **trading programs;**
- examining the effects of uncertainty and variability on design/decisions using a variety of **uncertainty analysis** techniques, such as **Monte Carlo simulation** and **decision trees**;
- applying heuristic optimization approaches, such as **genetic algorithms**, **simulated annealing**, and **particle swarm optimization**, to engineering problems for which traditional optimization has proven intractable;
- developing and improving genetic algorithm techniques for **multiobjective optimization**, **chance-constrained optimization**, and **alternative generation**;
- examining the effects of various policies for strengthening **recycling markets;**

Selected Publications

Yeh, S., D. H. Loughlin, C. L. Shay, and C. Gage. (2006). "An integrated hydrogen scenario analysis: Impacts on transportation, energy, and air emissions." To appear in *Proceedings of the IEEE - Special Issue: Hydrogen Economy*.

Loughlin, D. H., and M. Barlaz. (2006). "Policies for strengthening markets for recyclables: A worldwide perspective." *Critical Reviews in Environmental Science and Technology*, 36, 287-326.

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Barlaz, M., and D. H. Loughlin. (2005). “Recycling Worldwide.” *Waste Management World*. 7-2-05.

Doby, T. A., D. H. Loughlin, J. J. Ducoste, and F. L. de Los Reyes III (2001). “Optimization of activated sludge designs using a genetic algorithm.” In Proceedings of the 5th Kollekolle Seminar on Activated Sludge Modelling: Modelling of Activated Sludge Processes in Theory and Practice. Copenhagen, Denmark, Sept 10-12. Note: A revised version of this paper appeared in Water Science and Technology, listed above.

Houyoux, M. R., M. Strum, N. Possiel, W. G. Benjey, R. Mason, G. Pouliot, D. Loughlin, A. Eyth, and C. Ceppanen. (2005). “EPA’s new emissions modeling framework.” In *Proceedings of 2005 A&WMA Annual Meeting*, Los Vegas, NA, June, 2005.

Hanna, A.F., J.M. Vukovich, S.A., Arunchalem, D.H. Loughlin, H.C. Frey, and V. Isakov. (2004) “Assessment of uncertainty in Benzene concentration estimates in the Houston, TX, area.”, In *Proceedings of 2004 A&WMA Annual Meeting*, Indianapolis, Indiana, June, 2004.

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Fu, J. S.-Y., D. H. Loughlin, E. D. Brill, Jr., S. Ranjithan, and J. W. Baugh, Jr. (1999) "A conjunctive use approach for developing tropospheric ozone control strategies." In the Proceedings of *A&WMA Annual Meeting and Exhibition*, St. Louis, Mo., June.

Schubert, P. J. and D. H. Loughlin. (1999). "Efficient optimization of large k real-time control algorithm.", In Proceedings of *Uncertainty '99: The Seventh International Workshop on Artificial Intelligence and Statistics*. Ft. Lauderdale, FL.

Loughlin, D. H., and C. Gage. “Investigating the implications of hydrogen fuel cell vehicle penetration using U.S. EPA MARKAL.” Invited presentation for the Hydrogen Pathways Program Workshop: What have we learned from The Hydrogen Pathways Program? Univ. of California, Davis, Sept 26th-27th, 2006.

Schubert, P. J. and D. H. Loughlin. (2000). "Development of automated airbag calibrations using evolutionary computation.", N. Callaos, T. Pham, M. Kudo, N. Funabiki and D. Andina, eds., ISAS 2000/SCI 2000 - the 6th Conference on Information Systems Analysis and Synthesis/The 4th Conference on Systematics, Cybernetics, and Informatics, vol. Volume 3. Virtual Engineering and Emergent Computing. Orlando, FL, July 23-26, 2000: International Institute of Informatics and Systemics (IIIS), 531-535.

Reports

Loughlin, D.H. (2006). *Developing emissions growth factors for the ORD Global Change Air Quality Assessment*. Sept 2006.

Johnson, T.L., J.F. Decarolis, C.L. Shay, D.H. Loughlin, C.L. Gage, and S. Vijay. (2006). *MARKAL scenario analyses of technology options for the electric sector: The impact on air quality*, EPA-600/R-06/387, Sept 2006.

Gage, C.L., T. L. Johnson, E. L. Wright, D. H. Loughlin, C. L. Shay, R. J. Spiegel, and L. L. Beck. (2004). *Demonstration of a scenario approach for technology assessment: Transportation sector,* EPA-600/R-04/135, Jan 2004.

Loughlin, D. H., and H. C. Frey. (2003). *Implementation requirements for the development of a sensitivity/uncertainty analysis tool for MIMS*. Report for the US Environmental Protection Agency National Exposure Research Laboratory. Project Officer: Steven Fine.

Brill, E. D., Jr., J. W. Baugh, Jr., S. R. Ranjithan, D. H. Loughlin and S. S. Fine. (2000). *Advancement of environmental decision support systems through HPCC: Final report*, USEPA, High Performance Computing and Communications, Project Officer: Christopher Saint, ed., http://es.epa.gov/ncerqa/final/grants/96/high, no. USEPA Grant R-825196-01-0. Civil Engineering Department, North Carolina State University, December 15.

Others

Weatherhead, D.A., B. Hubbell, D. Loughlin, S. Mazur, D. Misenheimer, P. Dolwick. (2005). "Air Strategy Assessment Program (ASAP): An integrated screening tool for air quality planning." 4th Annual CMAS Conference, Chapel Hill, N.C., Sept. 26th-27th.

Yeh, S., and D. H. Loughlin. "An integrated hydrogen scenario analysis: Impacts on transportation, energy use, and air emissions." Presentation to the International Energy Workshop, Kyoto, Japan. July 7th, 2005.

Loughlin, D. H. "The global change air quality assessment: A collaborative, cross-laboratory effort to evaluate future air quality." Presentation at the USEPA Office of Research and Development Science Forum 2005, Washington, D.C.

Wilson, E., D. Loughlin, G. Kleiman, R.-T. Young. "Regional energy-environmental modeling." Poster, presented at the USEPA Office of Research and Development Science Forum 2005, Washington, D.C.

Yeh, S, and D. H. Loughlin. "Hydrogen scenario analysis: Impacts on energy and air pollution." Presentations to the World Renewable Energy Congress VIII, Denver, CO, August 31st, 2004, and to the Hydrogen Modeling Workshop, Davis, CA, Sept. 21st, 2004.

Loughlin, D.H., and G. Goldstein. "Generation and analysis of alternative technology scenarios using MARKAL-MGA: Application to the transportation sector." Presentation to the International Energy Workshop, Paris, France, June 24th, 2004.

Loughlin, D.H., and G. Goldstein. "Exploring near-equilibrium solutions: The MARKAL-MGA algorithm and use." Presentation to the Energy Technology Systems Analysis Program (ETSAP) Spring Meeting, Paris, France, June 21st, 2004.

Loughlin, D.H., T. Fox, and S. S. Fine. "Phoenix Framework for Integrated Air Quality Assessment and Policy Analysis." Poster, presented at the USEPA Office of Research and Development Science Forum 2004, Washington, D.C.

TEACHING

Teaching Experience:
Civil Engineering Systems (Sp99/Sp00/F00/F01) – Quantitative tools for decision-making and design
Hydraulics (F99/Sp01) - Properties and analysis of water in static and dynamic conditions for Civil Engineering applications.
Statics (F00) - Resultants and equilibrium of force systems, analysis of structures, centroids, and moments of inertia.

Other

Awards and Honors:
Administrator's Award for Excellence, USEPA, 2006
Post-doctoral research fellow, USEPA, 2003-2005
Phi Kappa Phi Honor Society, NCSU Chapter, 1995
Kimley-Horn Scholarship, NCSU, 1995
Dean's Fellowship, NCSU, 1993
William B. Snow Award for Environmental Engineering, Duke Univ., 1993
Graduation with Departmental Distinction, cum laude, Duke Univ., 1993
Chi Epsilon Civil Engineering Honor Society, Chapter Pres., Duke Univ., 1992-93

Professional Activities:
Review panels: ASCE Journal of Civil Infrastructure Systems, Journal of Environmental Management, International Conference on Genetic Algorithms, Genetic and Evolutionary Computation Conference, IEEE Transactions on Environmental Computation

FREDERIC HOLMES MURPHY

Professor
Temple University

I. **Personal**

Birthdate: October 3, 1946
Citizenship: United States

II. **Education**

A. Institutions

Yale University, Mathematics, B.A., 1968
Yale University, Administrative Sciences, M.A., 1969
Yale University, Administrative Sciences, Ph.D., 1971

Dissertation title:

Topics in Nonlinear Programming: Penalty Function and Column Generation Algorithms

B. Academic awards

Graduated Cum Laude
NDEA Title IV Fellowship

III. **Employment**

A. Academic

Rutgers University, Assistant Professor, 1971-1972
Northwestern University, Assistant Professor, 1972-1975
Temple University, Associate Professor, 1982-1986
Temple University, Professor, 1986-present

B. Non-Academic

1975-1982: Department of Energy, Energy Information Administration

1975-1978, Analyst, Midterm Forecasting (GS-14)

Designed and implemented representations of alternative regulatory policies in a partial equilibrium model of U.S. energy markets, developed forecasting models of Alaskan and Outer-Continental Shelf oil and gas supply and industrial boiler fuel consumption.

1978-1981, Senior Analyst, Office of Analysis Oversight and Assessment (GS-15)
Developed techniques for assessing the quality of forecasting models. Coordinated, managed and participated in the writing of a 15-volume study on the collective impacts of energy policies. Co-author of regulatory analyses of new energy legislation produced in that period.

1981-1982, Head of Operations Branch, Longer-Term Forecasting Division (GS-15)
Developed market models and analyses of natural gas to evaluate different regulatory alternatives. Designed and managed the implementation of a new energy market forecasting system used in producing the Energy Information Administration *Annual Energy Outlook*.

June-August 1983, Summer Research Fellow, Resources for the Future

Participated in the Oil Security Project funded by the Office of Policy, Department of Energy. Developed Nash game models of domestic and world oil inventories and studied policies for managing strategic oil reserves.

1982-2005, Consultant to the Energy Information Administration

Contributing author to forecast an analysis reports and consultant on forecast model improvements.

IV. **Honors and Awards**

Lifetime Achievement in Research Award, Annual Research Achievement Award, Researcher of the Year Award, Temple University, 1999

Award for outstanding analytical achievements in modeling and analysis while at EIA, 1982.

V. **Dissertations**

Chair, Alan Bohl on the subject of portfolio models, 1985.

Committee member, Robert Nydick on the subject of goodness of heuristics, 1985.

Committee member, Pai-Chun Ma (New York University) on artificial intelligence techniques for formulating linear programs, 1988.

Committee member, Robert Lovelace on the effect of certain management actions on enhancing research and development productivity, 1987.

Committee member, Ajay Asthana (New York University) on using graphics in formulating linear programs, 1989.

Committee member, Jae Sik Lee (University of Pennsylvania) on organizing a model base for mathematical programming models, 1989.

Chair, Jyoti Paul "Scheduling of Jobs on Computerized Document Processors in Bank Check Processing System," 1989.

Chair, Zhong-Xian Wang "Electric Utility Capacity Expansion Planning: A Multiperiod Policy Model with Uncertainty," 1990.

Outside reader, Yu Wu (University of Waterloo) "A Multi-period Equilibrium Model with Geometric Distributed Lag Demand and an Algorithm for Its Solution," 1992.

Chair, Ruth Schwartz "LPKNOW a Knowledge-based System for the Retrieval of Generic Linear Programming Models," 1993.

Chair, Murthy Mudrageda "Decomposition Approaches to Solving Large-Scale Economic Equilibrium Models," 1995

Member, Wei Jing-Yuan "Spatially Oligopolistic Expansion and Domestically Regulated Markets' Integration: Models and Applications to Electricity Supply Market," 1996, University of Louvain, 1996.

Member, Ruijin Qi, "Generalized Spatial Price Equilibria with Semicontinuous Market Structures," University of Pennsylvania, 1996.

Member, Xiaopei Wang, "Improving Planning for Railroad Yard, Forestry, and Distribution," University of Pennsylvania, 1997

Chair, David Haas, “Evaluating the Efficiency of Municipal Reverse Logistics Channels: An Application of Data Envelopment Analysis,” 1998

VI. **Service**

A. Temple

Faculty Senate Steering Committee 1985-1988

Search Committee for Dean of the Business School 1986-1987
Business School Research Committee 1984-1986
Business School Ph.D. Admissions Committee 1984-1986
Research Programs and Policies Committee 1987-1991
Faculty observer Board of Trustees Committee on University Development 1987-1991
University Personnel Committee 1988-1991
SBM Dean's Advisory Committee 1989-1994
Chair Merit Committee 1992-1993
SBM Strategy Committee 1991-1992
Faculty Senate Committee on Computers and Information Systems Dept. 1992
SBM Committee on Information Systems 1992
MSOM representative for prospective students at Open Houses 1991-1996
SBM representative on Graduate School Fellowships committee, 1993-6
SBM Strategic Planning Committee 1993-1994
Undergraduate Affairs Committee 1994-present
SBM Technology Committee 1994-5
Faculty Development Committee 1995
SBM Promotion and Tenure Committee 1999-2005
Member of the search committee for the new director of TUCC 1999
Director Cochran Research Center, 2003-2004
Chair Promotion and Tenure Committee 2004&2005

B. Outside of Universities

National Program co-chairman for Colorado Springs
ORSA/TIMS meeting Nov. 1980
President Operations Research Society Special Interest Group on Energy 1979-1981
An organizer of ORSA/SIG meetings on energy and natural resources June 1983 and April 1986
Organizing Committee for biannual international meeting of the Mathematical Programming Society, August 1985
Reviewed proposals for National Science Foundation
Reviewed articles for *Operations Research*, *Management Science* and *Naval Research Logistics Quarterly*
Reviewed books for *Interfaces*
Panel for selecting post-doctoral research fellows for the American Society for Engineering Education, 1989
Organizing committee for Computer Science Technical Section special meeting, Williamsburg, VA 1992
Search committee for editor in chief of the *ORSA Journal on Computing*, 1991-1992
Chair, ORSA publications Committee, 1993-1994
ORSA/TIMS merger subcommittee on publications, chair, 1993
Co-chair search committee for editor in chief of *Operations Research*, 1994-1995
INFORMS publications committee, 1995-1999
INFORMS information technology committee, 1995

Member College of the Practice of Management Science board, 1993-present
Co-chair Academic/Practitioner Committee of INFORMS 1995-1999
Program committee IFORS meeting on Energy Economics, 1995
Chair search committee *Interfaces*, 1999
Member search committee *Journal on Computing*, 1999
Member of the search committee for *INFORMS* case collection, 1999
Member, Transition Team on the New Economy, for Mayor Street, 1999
Member of the Center City Residents Association board, 2003-present
Advisor to the Philadelphia Tax Reform Commission, 2003
Vice president of Publications in INFORMS, 2004

C. Editorships

Associate editor, *Operations Research*, 1978-1982
Contributing editor *International Abstracts in Operations Research*, 1983-present
Area Editor *ORSA Journal on Computing*, 1987-1992
Editor *Interfaces*, 1988-1994
Contributing editor, *Interfaces*, 1995-present
Area editor *Operations Research*, 2001-present

VII. **Research Contributions**

A. Books

Author

Economic Behavior of Electric Utilities, (with A. Soyster) Prentice-Hall, June 1983.

Editor

Advanced Techniques in the Practice of Operations Research (with H. Greenberg and S. Shaw) North-Holland, 1982.

Analytic Techniques for Energy Planning, (with B. Lev, A. Gleit, and J.Bloom) North-Holland, 1984.

Strategic Planning in Energy and Natural Resources, (with B. Lev, A. Gleit, J. Bloom and C. Shoemaker) North-Holland, 1987.

B. Articles, refereed

1. "Column Dropping Procedures for the Generalized Programming Algorithm," *Management Science*, July 1973.

2. "A Column Generation Algorithm for Nonlinear Programming," *Mathematical Programming*, December 1973.

3. "A Class of Exponential Penalty Functions," *S.I.A.M. Journal of Control*, December 1974.

4. "On Measuring Economic Interrelatedness," (with J.M. Blin), *Review of Economic Studies*, November 1974.

5. "Improved Convergence Rate Results for a Class of Exponential Penalty Functions," *Naval Research Logistics Quarterly*, September 1976.

6. "A Dynamic Programming Algorithm for Check Sorting," (with E.A. Stohr), *Management Science*, September 1977.

7. "A Mathematical Programming Approach to the Scheduling of Check Sorting Operations," (with E.A. Stohr), *Naval Research Logistics Quarterly*, March 1978.

8. "Multiproduct Lot-Size Scheduling with Proportional Product Demands," (with A. Soyster), *Naval Research Logistics Quarterly*, March 1979.

9. "Sensitivity Analysis of the Costs in the Dynamic Lot Size Model," (with A. Soyster) *AIIE Transactions*, September 1979.

10. "Modeling the National Energy Plan" (with H. Greenberg) *Operational Research Quarterly*, Vol. 31, Fall, pp. 965-973, 1980.

11. "Modeling Natural Gas Regulatory Proposals Using the Project Independence Evaluation System," (with R. Sanders, S. Shaw and R. Thrasher), *Operations Research*, September - October 1981.

12. "A Mathematical Programming Approach for Determining Oligopolistic Equilibrium," (with H. Sherali and A. Soyster) *Mathematical Programming*, 1982, pp.92-106.

13. "Optimal Output of the Averch-Johnson Model," (with A. Soyster) *Atlantic Economic Journal*, December 1982.

14. "Estimating Operational Costs in an Electric Utility," (with K. Campbell and A. Soyster) *Omega*, Vol 10, No. 4, pp.373-382, 1982.

15. "Electric Utility Capacity Expansion Planning with Uncertain Load Forecasts," (with S. Sen and A. Soyster) *AIIE Transactions*, Vol. 14, No. 1, March 1982.

16. "Linear Programming Based Analysis of Marginal Cost Pricing in Electric Utility Capacity Expansion," (with H. Sherali and A. Soyster), *European Journal of Operations Research*, 1982, pp. 349-360.

17. "The Averch-Johnson Model with Leontief Production Functions," (with A. Soyster)

Energy Economics, July 1982.

18. "Net Effects of Government Intervention in Energy Markets," (with P. Dickens, D. McNicol and J. Zalkind) *The Energy Journal*, vol. 4, no. 2, pp. 135-151, 1983.

19. "Stackelberg-Nash-Cournot Equilibria: Characterizations and Computations," (with H. Sherali and A. Soyster and S. Sen) *Operations Research*, Vol 31, No. 2, pp. 253-276, 1983.

20. "The Outer Continental Shelf (OCS) Oil and Gas Supply Model of the Energy Information Administration," (with R. Farmer and C. Harris) *European Journal of Operations Research*, Vol. 18, pp. 184-197, 1984.

21. "Intertemporal Allocation of Capital Costs in Electric Utility Capacity Expansion Planning under Uncertainty" (with H. Sherali, A. Soyster and S. Sen) *Management Science*, Vol. 30, No. 1, January 1984.

22. "The Capital Supply Curve in Capacity Expansion Models: Some Economic and Algorithmic Aspects" (with S. Sen, S. Saraf and S. Soyster) *Naval Research Logistics Quarterly*, Vol. 31, 1984.

23. "A Class of Stochastic Mathematical Programs with Correlated Scale Parameters in the Objective Function and Right-Hand Side" (with A. Soyster and R. Foley) *Operations Research*, Vol 32, No. 6, 1984.

24. "The Replication of Multi-year Solutions Using Single Period Models of Electric Utility Capacity Expansion Planning" (with S. Saraf and A. Soyster) *IIE Transactions*, Vol. 17 No. 4, 1985.

25. "Computing Regulated Market Equilibria with Mathematical Programming" (with H. Greenberg) *Operations Research*, Vol. 33, No. 5,pp. 935-955, 1985.

26. "International Cooperation in Tariffs and Stockpiles for Coping with Oil Supply Disruptions" (with M. Toman and H. Weiss) *Journal of Policy Modeling*, Vol. 7, No. 4, Winter 1985.

27. "An Intelligent System for Formulating Mathematical Programs" (With E. Stohr) *Decision Support Systems*, Vol. 2, No. 1, pp. 39-48 1986.

28. "A Conceptual View of Model Assessment in the Context of Policy Analysis" *OMEGA*, Vol 14, No. 1, 1986.

29. "An Integrated Analysis of U. S. Oil Security Policies" (with M. Toman and H. Weiss) *Energy Journal*, Vol. 7 No. 3, July 1986.

30. "End Effects in Capacity Expansion Models with Finite Horizons" (with A. Soyster)

Naval Research Logistics Quarterly, Vol. 33 pp. 373-384, August, 1986.

31. "Mathematical Analysis of the Interactions between Oligopolistic Players and a Competitive Fringe" (with H. Sherali and A. Soyster) *American Journal of Mathematical and Management Sciences*, Vol. 7, nos. 1&2, pp. 149-174, 1987.

32. "Electric Utility Expansion Planning in the Presence of Existing Capacity: A Nondifferentiable Convex Programming Approach," (with S. Sen and A. Soyster) *Computers and Operations Research*, Vol. 14, No. 1 pp. 19-31, January 1987.

33. "A Nash Model of Consuming Nations' Strategic Petroleum Reserves" (with M. Toman and H. Weiss) *Management Science*, vol. 33, no. 4 pp. 484-499, April 1987.

34. "Equation Partitioning Techniques for Solving Partial Equilibrium Models" *European Journal of Operations Research*, Vol. 32 No. 3, pp. 380-392, December, 1987.

35. "Using Dynamic Programming for Aggregating Cuts in a Single Drillhole" (with M. Gershon) *International Journal of Surface Mining*, vol. 1, no. 1, pp. 35-40, 1987.

36. "Understanding the Future of United States Electricity Markets" (with R. Sanders) *Energy Policy*, Vol. 11, pp. 61-76, 1987.

37. "Computer-assisted Formulation of Linear Programs" (with P. Ma and E. Stohr) *IMA Journal of Management Mathematics*, vol. 1, no. 1, pp 147-161, 1987.

38. "Modeling and Forecasting Energy Markets with the Intermediate Future Forecasting System," *Operations Research*, vol. 36, no. 3, pp. 406-420, 1988, (with J. Conti, R. Sanders and S. Shaw).

39. "A Dynamic Nash Game Model of Oil Market Disruptions and Strategic Stockpiling" (with M. Toman and H. Weiss) *Operations Research*, November-December 1989.

40. "Optimizing Single Hole Mine Cuts Using Dynamic Programming" (with M. Gershon) *European Journal of Operations Research*, Vol. 38, No. 1, pp. 56-62, January 1989.

41. "Representing Knowledge about Linear Programming Formulation" (with P. Ma and E. Stohr), *Annals of OR*, Vol. 21 pp. 149-172, 1989.

42. "A Graphics Interface for Linear Programming," *Communications of ACM*, (with P. Ma and E. Stohr) Vol. 32 No. 8 pp. 996-1012, August 1989.

43. "An Approach to Modeling Electric Utility Capacity Expansion Planning" *Naval Research Logistics Quarterly* (with H. Weiss) Vol. 37, no.6, pp. 827-846, December 1990.

44. "The Effect of the Mix of Equity and Debt on the Selection of Projects" *Engineering Economist* (with A. Bohl) vol. 37 No. 1, pp. 61-77, Fall 1991.

45. "Approaches to Diagnosing Infeasible Linear Programs" *ORSA Journal on Computing* (with H. Greenberg) Vol. 3, no. 3, pp. 253-261, 1991.

46. "Exploiting Special Structure in Primal Dual Interior Point Methods," *ORSA Journal on Computing* (with J. Hurd) Vol. 4 no. 1, pp. 38-44, 1992.

47. "Representation Schemes for Mathematical Programming Models" *Management Science* (with A. Asthana and E. Stohr) Vol. 38, No. 7, pp. 964-991, July 1992.

48. "Composition Rules for Building Linear Programming Models from Component Models" *Management Science* (with E. Stohr and P. Ma), Vol. 38, No. 7, pp. 948-963, July 1992.

49. "A Comparison of Mathematical Programming Modeling Systems" *Annals of Operations Research* (with H. Greenberg), Vol. 38, pp. 177-238, 1992.

50. "Large-scale Modeling from an Operations Management Perspective," *Operations Research*, vol. 41, no. 2, pp.241-252, 1993.

51. "A Network Reformulation of An Electric Utility Expansion Planning Model" *Naval Research Logistics* (with Z. Wang), vol. 40, no. 4, pp.451-458, June, 1993.

52. "The Promise of OR is Helping to solve Problems," *ORSA Journal on Computing*, (with H. Greenberg), vol. 6, no. 3, pp. 269-272, Summer, 1994.

53. "Views of Mathematical Programming Models and their Instances," *Decision Support Systems* (with H. Greenberg), vol. 13, no. 1, pp. 3-34, January 1995.

54. "The Evolution of Energy Modeling at the Federal Energy Administration and the Energy Information Administration," *Interfaces*, (with Susan Shaw), vol. 25, no. 5, pp. 173-193, September/October, 1995

55. "An Implementation of LPFORM," *ORSA Journal on Computing*, (With P. Ma and E.A. Stohr), vol. 8, no. 4, pp. 383-401, Fall, 1996.

56. "Organizing a Model Base of Linear Programming Models Using Analogical Processes," *International Journal of Intelligent Systems in Accounting, Finance, and Management*, (with R. Schwartz), vol. 5, no. 4, pp. 217-228, December 1996.

57. "Modeling Crude Oil Lightering in Delaware Bay," (with S. Andrews, X. Wang, and S. Welch), *Interfaces*, vol. 26, no. 6, pp. 68-81, November-December, 1996.

58. "Annotated Bibliography on Linear Programming Models" *Interactive Transactions*

of OR/MS, vol. 1 no. 4, 1996.

59. "Understanding Linear Programming Modeling through an Examination of the Early Papers on Model Formulation," *Operations Research*, (with V. Panchanadam), vol. 45, no.3, pp. 341-356, May/June, 1997.

60. "Modeling the Impacts of the 1990 Clean Air Act Amendments," *Interfaces*, (with S. Holte, T. Luong, R. Sanders, and P. Whitman), vol. 28, no. 2, pp.1-20, March-April, 1998.

61. "On the Convergence of the Decoupling Algorithm for Multiperiod Equilibrium Models," (with D. Fuller) *Operations Research Letters*, vol. 22, no. 1, pp. 33-39, February, 1998.

62. "A Decomposition Approach for Computing Large-Scale Economic Equilibria" *Operations Research*, (with M. Mudrageda), vol. 46, no.3, pp. 368-377, May-June, 1998.

63. "Using Analogical Reasoning and Schema formation to Improve the Success of Formulating LP Models," *Operations Research* (with V. Panchanadam), Sept.-Oct. 1999.

64. "Rebuilding the Coal Model in the Energy Information Administration's National Energy Modeling System." (with M. Hobbs, M. Mellish, R. Newcombe, R. Sanders, and P. Whitman), *Interfaces,* vol. 31, no. 5, pp. 24-42, Sept.-Oct., 2001.

65. "The Practice of Operations Research and the Role of Practice and Practitioners in INFORMS," *Interfaces*, vol. 31, no. 6, pp. 98-110, Nov.-Dec. 2001.

66. "Compensating for Non-Homogeneity in Decisionmaking Units in Data Envelopment Analysis," (with D. Haas), *European Journal of Operations Research*, vol. 144, pp. 530-544, 2003.

67. "Managing Reverse Logistics Channels with Data Envelopment Analysis," (with D. Haas and R. Lancioni), *Transportation Journal*, vol. 42, no. 3, pp. 59-69, 2003.

68. "Developing Strategies for Maritrans' Business Units," *Interfaces*, (with M. Mudrageda and S. Welch) Vol.34, No. 2, Mar/Apr 2004 pp. 149-161.

69. "Generation Capacity Expansion in Imperfectly Competitive Restructured Electricity Markets," (with Y. Smeers), *Operations Research*, Vol. 53, No. 4, July August 2005, 646-661.

70. "A Study of the Philadelphia Knowledge Economy," *Interfaces*, (with S. Kimbrough), Vol. 35, No. 3, May-June 2005, 248-259.

71. "ASP, The art and Science of Practice: Elements of a theory of Practice of Operations

Research: a Framework," *Interfaces*, 35, 2, March-April 2005 154-163.

72. "Elements of a theory of Practice of Operations Research: Expertise in Practice," *Interfaces*, July-August 2005, 313-322.

73. "Elements of a theory of Practice of Operations Research: Practice as a Business," *Interfaces*, 35, 6, November-December 2005, 524-530.

74. "Energy Policies and the Allocation of Their Value Added" (with E. Rosenthal) *Energy Journal*, Vol. 27, No. 2, 2006, 143-156.

75. "Designing Safety Space in a Supply Chain to Handle System-wide Disruptions," (with M. Mudrageda) *Naval Research Logistics*, to appear.

C. Contributions to Edited Books

"Optimal Selection and Scheduling of Sort Patterns" (with E. Stohr) in *Pattern Recognition in Economics: Theory and Practice*, eds. K.S. Fu and A. Whinston, Noordhof-Leyden, 1977.

"Design Strategies for Energy Market Models" in B. Lev, ed. *Energy Models and Studies*, North Holland, 1983.

"The Sensitivity of the Shape of the Long-run Supply Curve of Coal to Different Assumptions on Seam Thickness" (with B. Lev) in B. Lev, ed. *Energy Models and Studies*, North Holland, 1983.

"Games for Studying Strategic Petroleum Reserve Issues" (with M. Toman and H. Weiss) in B. Lev et al *Strategic Planning in Energy and Natural Resources*, North Holland, 1987.

"Economics and Operations Research" in S. Gass and C. Harris *Encyclopedia of Operations Research*, 1995.

"Economics and Operations Research" (revised) in S. Gass and C. Harris *Encyclopedia of Operations Research*, 2nd edition, 1999.

"Qualitative Implications of Uncertainty in Economic Equilibrium Models," in D.N. Arnold and F. Santosa, eds., *Decision Making Under Uncertainty, Energy and Power*, The IMA volumes in Mathematics and Its Applications, Springer 2002, NY, pages 135-153.

"Learning and Tacit Collusion by Artificial Agents in Cournot

Duopoly Games," with Steven O. Kimbrough and Ming Lu, in S. O. Kimbrough and D. J. Wu, eds. *Formal Modelling in Electronic Commerce*, Springer, 2004, Berlin, Germany pages 477-492.

D. Proceedings, National and International, Refereed

"The Structure and Solution Techniques of the Project Independence System" in W.W. White, ed. *Computers and Mathematical Programming*, sponsored by ACM, SIGMAP and the National Bureau of Standards, NBS Special Publication 502, 1977.

"Validity as a Measure if Goodness" (with H. Greenberg) in S. Gass, ed. *Proceedings on Validation and Assessment Issues in Energy Modeling*, National Bureau of Standards Publication 569, 1979.

"Modeling the National Energy Plan" (with H. Greenberg) in J.F. Roberts, ed. *Energy Modeling and Net Energy Analysis*, Institute of Gas Technology, 1981.

"Accounting for Uncertain Load Forecasts in Electric Utility Capacity Expansion: A Deterministic Equivalence" (with A. Soyster and S. Sen) in J.F. Roberts *Energy Modeling III: Dealing with Energy Uncertainty*, Institute of Gas Technology, 1981.

"Technical Structure of Energy Models" as head of working group 3, in E.A. Cherniavsky, M.A. Laughton and L.E Ruff *Energy Policy and Planning*, NATO Conference Series, Plenum, 1981.

"A Knowledgebase for Formulating Linear Programs," *Mathematical Models for Decision Support*, NATO-ASI Series, Springer-Verlag, 1988.

"Semantic Structures in Linear Programs" (with P. Ma and E. Stohr), *Proceedings of the 22nd Annual Conference on Systems Sciences*, vol. 3, pp. 459-466, January 1989.

Appendix B. Conflict of Interest Statements

HILLARD G. HUNTINGTON

DOE Conflict-of-Interest Policy and Form
External Expert Review of DOE Benefits Forecasts

It is important for programs to be aware of expert reviewers' possible conflicts of interest. *Having a conflict of interest in one area does not necessarily exclude a person from serving as a reviewer.* This agreement must be completed by individuals prior to their participation in DOE peer reviews. This policy and agreement have been formulated based on advice from the DOE General Counsel's Office and recognize that (1) expert reviewers of programs in-progress do not make funding decisions and (2) programs often must balance perceived conflict of interest and the need for expert advice from a small community of experts.

Please forward this form, along with your Curricula Vita to the DOE review leader (Charles J. Drummond, Drummond@netl.doe.gov).

You have been nominated by DOE to serve as a Peer Reviewer for DOE Benefits Forecasts. Your participation in this review will be greatly appreciated. However, it is possible that your personal affiliations and involvement in certain activities could pose a conflict of interest or create the appearance that you lack impartiality in your evaluations and recommendations for this peer review. In order to assess if you have a real or perceived conflict of interest in regard to the program/projects that will be evaluated in this peer review, please complete the information below. This information will be reviewed by the peer review leader in order to identify potential conflicts of interest and assure that you are not placed in a position to review and evaluate projects that may present the appearance of partiality.

SECTION 1: AFFILIATIONS, ACTIVITIES AND PROGRAM INVOLVEMENT

At the end of this section you will be asked to list those specific projects or areas on the agenda where a conflict or appearance of conflict could exist and explain the nature of that conflict. A conflict in one area does not necessarily exclude you from serving as a reviewer in another area. The review leader may call you for more information.

Affiliations or activities that could potentially lead to conflicts of interest may include the following:

a) Work or known future work for parties that could be affected by your judgments on projects or program developments that you have been asked to review.

b) Any personal benefit you (or your employer, spouse or dependent child) might gain in a direct or predictable way from the developments of the program/projects you have been asked to review.

c) Any previous involvement you have had with the program/projects you have been asked to review, such as having participated in a solicitation to the program area that was

subsequently not funded, or having a professor, student, or collaborator relationship with the program or its research staff.

d) Any financial interest held by you (or your employer, spouse or dependent child) that could be affected by your participation in this matter.

e) Any financial relationship you have or have had with DOE such as research grants or cooperative agreements.

Personal involvement with a DOE research program or program areas.

	Yes	No
I previously was involved in research funded by one or more of the DOE program offices involved.	See (a)	______
I participated in a solicitation sponsored by one or more of the DOE program offices involved.	______	X
I reviewed one or more of these programs previously.	See (b)	______
I am a former professor or student of Federal or contractor staff performing benefits forecasts for DOE.	______	X
I previously collaborated with Federal or contractor staff performing benefits forecasts for DOE.	______	X

DOE Program Office Participating in Review	Nature of Conflict of Interest
Office of Electricity Delivery and Energy Reliability	None
Office of Energy Efficiency and Renewable Energy	(a) EMF grant from DOE supporting model-comparison studies was funded in past years by EERE among other DOE groups.
Office of Fossil Energy	(a) EMF grant from DOE supporting model-comparison studies is funded by Fossil Energy among other DOE groups. (b) I served on expert panel in 2004 that reviewed Fossil Energy benefit analysis.
Office of Nuclear Energy	None
Office of Science	(a) EMF grant from DOE supporting model-comparison studies is funded by Office of Science among other DOE groups.

(Continue on another sheet if necessary)

SECTION 2: CONFLICT OF INTEREST AGREEMENT

CONFLICT OF INTEREST AGREEMENT

This agreement must be completed by individuals prior to their participation in DOE peer reviews. Please send to Charles J. Drummond, Review Manager (phone: 412-386-4889; e-mail: Drummond@netl.doe.gov) at your earliest convenience, but no later than October 27, 2006; or contact the Review Manager to discuss any conflict of interest questions and potential issues.

I have reviewed the information contained on this form and to the best of my knowledge I have disclosed any actual or potential conflicts of interest that I may have in regard to the DOE Benefits Forecast activities that I have been nominated to evaluate. In addition, prior to my participation as a peer reviewer, I agree to disclose any actual or perceived conflicts of interest as soon as I am aware of the conflict.

Hillard G Huntington ____________ 10/24/06

Signature Date

Hillard G. Huntington

Printed Name

LEON E. CLARKE

DOE Conflict-of-Interest Policy and Form
External Expert Review of DOE Benefits Forecasts

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SECTION 1: AFFILIATIONS, ACTIVITIES AND PROGRAM INVOLVEMENT

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subsequently not funded, or having a professor, student, or collaborator relationship with the program or its research staff.

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e) Any financial relationship you have or have had with DOE such as research grants or cooperative agreements.

Personal involvement with a DOE research program or program areas.

	Yes	**No**
I previously was involved in research funded by one or more of the DOE program offices involved.	X	
I participated in a solicitation sponsored by one or more of the DOE program offices involved.	X	
I reviewed one or more of these programs previously.		X
I am a former professor or student of Federal or contractor staff performing benefits forecasts for DOE.	See Below	
I previously collaborated with Federal or contractor staff performing benefits forecasts for DOE.	See Below	

<u>Summary of Potential Conflicts of Interest</u>:

(1) I work for a national laboratory, Pacific Northwest National Laboratory (PNNL). All of the national laboratories obtain the majority of their funding from DOE.
(2) The group I work for at PNNL conducts research on climate change. One facet of this work is research to explore the potential century-scale impacts of improved technology for addressing climate change. We have received funding to support this work from DOE offices, including EERE and FE. We also receive support for our broader integrated assessment computer modeling capabilities from the Office of Science.
(3) I recently participated in a scenario analysis for the Climate Change Technology Program that, among other things, illustrated the potential century-scale, global impacts of improved energy technologies in reducing the costs of constraining greenhouse gas emissions.
(4) I am a former student of Professor Jim Sweeney, who participated in the National Research Council study, *Energy Research at DOE: Was it Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000*.

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I have reviewed the information contained on this form and to the best of my knowledge I have disclosed any actual or potential conflicts of interest that I may have in regard to the DOE Benefits Forecast activities that I have been nominated to evaluate. In addition, prior to my participation as a peer reviewer, I agree to disclose any actual or perceived conflicts of interest as soon as I am aware of the conflict.

____________________________________ ________________
Signature Date

Leon E. Clark
Printed Name

JOSEPH F. DECAROLIS

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Personal involvement with a DOE research program or program areas.

	Yes	No
I previously was involved in research funded by one or more of the DOE program offices involved.	X	
I participated in a solicitation sponsored by one or more of the DOE program offices involved.		X
I reviewed one or more of these programs previously.		X
I am a former professor or student of Federal or contractor staff performing benefits forecasts for DOE.		X
I previously collaborated with Federal or contractor staff performing benefits forecasts for DOE.		X

DOE Program Office Participating in Review	Nature of Conflict of Interest
Office of Electricity Delivery and Energy Reliability	
Office of Energy Efficiency and Renewable Energy	
Office of Fossil Energy	I collaborated with NETL's Office of Systems, Analyses and Planning in an effort to model the electric dispatch of wind and IGCC. The collaborative effort began formally in Spring 2005 and continued through Summer 2005.
Office of Nuclear Energy	

Office of Science	Our modeling group has an informal collaboration with Brookhaven National Laboratory. We have no cooperative agreements or financial arrangements with BNL, but we informally share data and information related to MARKAL energy modeling. The collaboration was ongoing when I began at EPA in 2004 and continues today.

(Continue on another sheet if necessary)

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Signature — 12/20/06
Date

Joseph DeCarolis
Printed Name

ALEXANDER E. FARRELL

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Personal involvement with a DOE research program or program areas.

	Yes	No
I previously am currently involved in research funded by one or more of the DOE program offices involved.	X	
I participated in a solicitation sponsored by one or more of the DOE program offices involved.		X
I reviewed one or more of these programs previously.		X
I am a former professor or student of Federal or contractor staff performing benefits forecasts for DOE.		X
I previously collaborated with Federal or contractor staff performing benefits forecasts for DOE.		X

DOE Program Office Participating in Review	Nature of Conflict of Interest
Office of Electricity Delivery and Energy Reliability	
Office of Energy Efficiency and Renewable Energy	I am one of several Co-PI's for the Pacific Southwest Regional CHP Application Center. This project is partially (mostly, I think) funded by EERE, and partially by the California Energy Commission, which is the primary contractor.
Office of Fossil Energy	
Office of Nuclear Energy	
Office of Science	

(Continue on another sheet if necessary)

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AEFarrell ______________________ 12/20/06

Signature Date

Alexander E. Farrell

Printed Name

ANDY S. KYDES

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Personal involvement with a DOE research program or program areas. If the question pertained to the past 10 years, the answers here would all be NO.

	Yes	No
I previously was involved in research funded by one or more of the DOE program offices involved.		X
I participated in a solicitation sponsored by one or more of the DOE program offices involved.		X
I reviewed one or more of these programs previously.	X (EERE)	
I am a former professor or student of Federal or contractor staff performing benefits forecasts for DOE.		X
I previously collaborated with Federal or contractor staff performing benefits forecasts for DOE.		X

DOE Program Office Participating in Review	Nature of Conflict of Interest
Office of Electricity Delivery and Energy Reliability	
Office of Energy Efficiency and Renewable Energy	Participated as expert reviewer once when invited in the early 1990's by Eric Petersen.
Office of Fossil Energy	We have set up runs for FE using NEMS to facilitate their benefits analysis.
Office of Nuclear Energy	
Office of Science	

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______________________________ 11/7/06

Signature Date

Andy S. Kydes, Senior Technical Advisor, OIAF, EIA

Printed Name

DANIEL H. LOUGHLIN

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I participated in a solicitation sponsored by one or more of the DOE program offices involved.	______	X
I reviewed one or more of these programs previously.	______	X
I am a former professor or student of Federal or contractor staff performing benefits forecasts for DOE.	______	X
I previously collaborated with Federal or contractor staff performing benefits forecasts for DOE.	X	______

DOE Program Office Participating in Review	Nature of Conflict of Interest
Office of Electricity Delivery and Energy Reliability	
Office of Energy Efficiency and Renewable Energy	EPA's MARKAL modeling team, of which I am a member, has an informal collaboration with Brookhaven National Laboratory's MARKAL modeling team. BNL is a DOE National Laboratory, and the BNL MARKAL modeling team performs modeling for DOE's EERE program and potentially other DOE programs. Our groups have shared information and assumptions regarding MARKAL modeling. Further, a BNL MARKAL modeler previously served as a peer reviewer of the U.S. EPA MARKAL database.
Office of Fossil Energy	
Office of Nuclear Energy	
Office of Science	I do not believe this to be a conflict of interest: I served on a DOE Office of Science review panel in 2005 to evaluate extramural applications for integrated assessment modeling activities.

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____________________________________ 11/8/06

Signature Date

Daniel H. Loughlin

Printed Name

FREDERIC HOLMES MURPHY

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I reviewed one or more of these programs previously.	______	X
I am a former professor or student of Federal or contractor staff performing benefits forecasts for DOE.	______	X
I previously collaborated with Federal or contractor staff performing benefits forecasts for DOE.	X	______

DOE Program Office Participating in Review	Nature of Conflict of Interest
Office of Electricity Delivery and Energy Reliability	
Office of Energy Efficiency and Renewable Energy	
Office of Fossil Energy	2 years ago I worked on an FE-sponsored project to develop a methodology for including hydrogen fuel in NEMS. I just completed a review of the NETL methodology of using decision trees to analyze carbon sequestration programs.
Office of Nuclear Energy	
Office of Science	

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Signature ______________________ Date 12/20/06

Frederic H. Murphy
Printed Name