NRDC responses to the House Energy and Commerce Committee on modeling assumptions
Revised November, 2009*

Preface

NRDC used versions of the National Energy Modeling System (NEMS-NRDC) and the Market Allocation (MARKAL) models to provide two illustrations of the impact of the American Clean Energy and Security Act (ACES) on our energy system and economy. NEMS-NRDC and MARKAL are similar in that both simulate energy markets from the "bottom-up." They differ in important ways, however, in scope and how they model choices, which should be considered in interpreting the results.

NEMS-NRDC is a forecasting model that uses observed historical behavior to estimate how individual market participants will act in response to changing market conditions and imposed constraints through 2030. It combines detailed energy markets with a macroeconomic model to estimate the impacts of changes in how energy is produced and used (the energy system) on the economy as a whole.

In contrast, MARKAL is a long-term, cost-optimization model, which minimizes total energy system costs through 2050 while accounting for the constraints imposed by such factors as energy resource availability and carbon emission limits.

While NEMS-NRDC attempts to forecast what would happen under ACES if market participants behave in a manner that mirrors past patterns, MARKAL finds the least-cost outcome and thus provides a roadmap for attaining our emissions reduction goals at the lowest long-term cost. While the imperfections of our energy market mean that the "optimal" scenario outlined in MARKAL will likely not be achieved, its results can help us develop and advocate smart policies. For example, MARKAL shows that solar power can be a large source of cost-effective generation in the long run, which suggests that policies driving investments in solar power today can have major long-term benefits, despite the fact that these technologies are more expensive than other alternatives in the short run.

Attachment A provides a more in depth discussion of the two models.

*The table describing how allocations were modeled in the NRDC-NEMS modeling was revised to include more information and correct errors discovered after our initial response was submitted. A column was added to indicate how an allocation was treated within the NEMS macroeconomic module, as assumptions about every allocation were made within the macroeconomic module. Some allocations were also modeled in other modules. For example, allocations toward energy efficiency and renewable energy were modeled as personal tax reductions in the macroeconomic module, but also using EIA's High Technology assumptions in the residential and commercial demand modules. We removed the column indicating whether the allocation was modeled or not, and if so, whether it was modeled indirectly—with the macroeconomic column added, this information can be deduced. A correction was made to the Deficit Reduction and Climate Change Consumer Refund. The original table indicated both were modeled as Federal spending, when in fact they were modeled separately. Deficit Reduction was modeled as (negative) Federal spending, and the Consumer Climate Change Refund as a personal tax reduction. A correction was also made with respect to concentrating solar power: we did not decrease the rate at which cost could decrease with every doubling of capacity.

Details on the analytical approach behind the economic model(s) used in the analysis

1. **Does the model quantify any benefits of avoided climate change? If so, how?**

   No, neither NEMS-NRDC nor MARKAL model any benefits of avoided climate change.

2. **Does the model quantify the benefits of reductions in air pollution (Clean Air Act criteria or hazardous air pollutants) which will occur as a result of the policy? If so, how?**

   Neither NEMS-NRDC nor MARKAL quantify public health or welfare benefits from reductions in air pollution.

   NEMS-NRDC:

   NEMS-NRDC tracks emissions of SO2, NOx and Hg and their associated regulations in accordance with the Clean Air Act. The model quantifies changes in these emissions under the NRDC policy scenarios including changes in associated compliance costs.

   MARKAL:

   MARKAL has the capacity to track these pollutants but was not yet updated to do so in the version we used.

3. **Does the model quantify benefits from provisions that remove barriers to cost-effective energy efficiency measures? If so, how?**

   Yes, indirectly. While neither NEMS-NRDC nor MARKAL explicitly model benefits from provisions that remove barriers to cost-effective energy efficiency measures, we have attempted to address these benefits in both models. The following approaches were taken in each model to approximate the effect of the collective energy efficiency measures in ACES:

   NEMS-NRDC:

   i) **The High Technology Case assumptions from the AEO 2009 Published Release (March) were adopted in place of the Reference Case assumptions in our core run of ACES.**

      The High Technology Case assumes that more efficient devices come onto the market faster than in the Reference Case. More information on the High Technology Case can be found in the AEO 2009 documentation, available at: http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2009).pdf.

      To provide a sense of the magnitude of these changes between the Reference Case and the High Technology Case, here is an excerpt describing its impact on the residential sector (from page 63 of the previously-linked document): "*The high technology case* *assumes lower costs, higher efficiencies, and earlier availability of some advanced equipment. In the reference case, residential energy use per capita is projected to fall below the 2006 level (the lowest since 1990) after 2012. In the high technology case, delivered energy use per capita in the residential sector falls below the 2006 level after 2011, reaching a 2030 level that is 5 percent below the reference case projection."*

ii) **In order to test an alternative way of modeling the effect of the energy efficiency provisions in NEMS-NRDC, we also ran a sensitivity case in which we assumed 10 percent of allowance value would be used to subsidize residential and commercial consumers' purchases of more efficient devices in space heating, space cooling, water heating, and commercial lighting.** The resulting decrease in total consumption was fairly similar to that in our core run of ACES, which leads us to believe that using the high technology case is a good proxy for estimating the effect of the energy efficiency provisions.

MARKAL:

In MARKAL, we reflected the energy efficiency measures in ACES in two ways:

i) To approximate ACES' impact on the adoption of more efficient appliances, we assumed that some end-use devices would become 5% more efficient per decade than baseline AEO assumptions, with 2020 being the first year affected, and no change in cost assumptions.

The residential and commercial sectors in MARKAL have end-use energy demands for each of several end-use categories (e.g. space heating, refrigeration). The energy demand levels are taken from AEO 2009. In order to meet that demand, the model must choose from various end-use devices that are available (with each device having a specified cost, efficiency, and lifetime). Those end-use devices, as well as their characteristics, are also taken from AEO (2009 for commercial and 2008 for residential). There were a few exceptions where our appliance experts told us that a certain category of appliances was near its ceiling in terms of efficiency, so in those cases, we did not assume any improvements over time.

ii) To reflect energy efficiency measures resulting from building codes or other provisions that would lead to building shell improvements, we lowered demand for space heating and space cooling devices in each of the residential and commercial devices.

We modeled such improvements through lowering demand for space heating and space cooling devices in each of the residential and commercial sectors, with the assumption that such improvements could lower a household's (or business's) end-use energy consumption by 20%, for a cost of $4000 per household and $40,000 per business. These costs and level of savings per household from weatherization and building shell improvements are consistent with government estimates. (see Table ES.1. on Page xi of the following: http://weatherization.ornl.gov/pdf/Con-479%20May22-FINAL.pdf). We assumed that 1.5 million homes would see this improvement each year (since that's the number of new homes built each year). Similarly, we assumed that 150,000 commercial buildings would see this improvement each year (since that's the number of new commercial buildings built each year).

4. Does the model capture increased private sector investments in research and development as a result of the legislation and new carbon market? If so, how?

NEMS-NRDC:

The NEMS-NRDC model policy scenarios use the EIA AEO 2009 High Technology case assumptions for the residential and commercial sectors as a proxy for the energy efficiency measures outlined in the Waxman-Markey bill. As described in the response to the previous question, the EIA High Technology cases assume that residential and commercial end-use technologies will cost less and become more efficient over time than the AEO Reference case assumptions. EIA does not specify the source of these improvements, which are likely due to a combination of both private sector and public sector investments in research and development. In addition, the NRDC policy scenarios assume vehicle technology improvements to meet an accelerated CAFE requirement for light-duty vehicles and cellulosic ethanol production improvements needed to meet the EISA renewable fuel standards, which are likely to rely in part on private sector investments. All other technology improvements in the NRDC cases, such as for electric generation technologies with carbon capture and sequestration, are a direct result of the EIA AEO cost and performance assumptions which include the associated "learning by doing" algorithms (i.e. the "progress ratios") developed by EIA.

MARKAL:

MARKAL models technology learning, which is the reduction in investment cost as the cumulative installed capacity increases. Historically, these cost reductions result from institutional learning, economies of production and private sector investments in design, engineering and construction techniques. Therefore, MARKAL captures these effects, but only indirectly.

5. What assumptions are made about international actions to reduce emissions?

In both NEMS-NRDC and MARKAL, assumptions about international actions were made in order to estimate the amount of competing demand for the available supply of international offsets that international emissions reduction targets generate over time (based on EPA methodology). We base both industrialized and developing country targets on a global "division of work" proposed by the Union of Concerned Scientists (UCS)[1] in order to achieve a 450 parts per million CO_2e stabilization target, with several modifications:

[1] For more information see: http://www.ucsusa.org/global_warming/solutions/big_picture_solutions/a-target-for-us-emissions.html

- For Group 1, defined as EU-25, Japan, Canada, Australia and New Zealand (based on EPA categorization), emissions are assumed to peak and begin declining by 2010, with a target of reducing emissions 80% below 2005 levels by 2050. (We use a base year of 2005 throughout vs. 2000 in the UCS proposal to reflect the base year used in ACES).

- For Group 2, defined as the Rest of World (based on EPA categorization), emissions are assumed to peak in 2025 at approximately 2015 emissions levels and begin declining thereafter, with a target of reducing emissions 30% below 2005 levels by 2050. In addition, we add a "pre-condition" to Group 2 emissions levels whereby developing countries must commit to reducing emissions 10% below business as usual (BAU) by 2020 as a precondition for selling offsets in the U.S. carbon market. This is based on our view that such a carbon market access rule will be a significant negotiating tool for the United States in ensuring that a strong international agreement on climate change is reached. By 2025, we assume that all countries have binding emissions reduction commitments in place.

6. **Have you reported a state or regional level analysis within the United States? If so, describe the additional assumptions used.**

NEMS-NRDC:

We did one analysis in which we reported the effect of ACES on monthly electricity bills per household in each state, which can be found in Figure 2 of our "Clean Energy Bargain", available here: http://www.nrdc.org/globalWarming/cap2.0/files/bargain.pdf. The numbers from that analysis were based on regional results from our NEMS-NRDC model (which are the same North American Electric Reliability Council regions and sub-regions for which EIA reports out regional results in its AEO). The additional assumptions used for that analysis are described here:

- Electricity bill savings (or costs) are the difference in residential electricity expenditures (price multiplied by consumption) between the Business-as-usual (BAU) and ACES cases, per household. Changes in expenditures on energy-using devices are not included.
- Business-as-usual state-specific electricity prices and consumption levels are projected to 2020 by scaling state-specific 2007 data in proportion to changes in the electricity prices and consumption levels of the region in which the state is located. [Sources: 2007 state data from EIA. Projected electricity prices and consumption levels of each region from NRDC-NEMS Reference case based on AEO2009.]
- The percentage changes in electricity prices and consumption levels per state under ACES are assumed to be the same as the percentage changes in electricity prices and consumption levels of the region in which the state is located. [Sources: Projected changes in electricity prices and consumption levels of each region from NEMS-NRDC modeling of ACES.]

- State-specific number of households is projected to 2020 using 2000 state-specific data scaled in proportion to the projected change in the national total [Sources: 2000 data from U.S. Census. Projected growth in number of households in total U.S. from EIA.]
- If a state falls into more than one region then its projections are calculated through taking a population-based weighted average of the two or more regions into which it falls.

MARKAL:

The version of MARKAL we used is only at the national level. As such, no analysis was done at the regional or state level.

7. **Many models are calibrated against a single base year. If this is the case with your model, what year is used?**

NEMS-NRDC:

The EIA AEO 2009 projections for 2008 and 2009 incorporate short-term projections from their November 2008 Short-Term Energy Outlook (STEO). However, the model is not calibrated against any single base year.

MARKAL:

MARKAL runs from 2000 to 2050 in 5-yr periods and is calibrated to historical data for the 2000 and 2005 model periods. In addition, the business-as-usual case for USNM-50 is benchmarked out to 2030 against the AEO-2009 Standard Release Reference Case results.

Reference case assumptions

1. **Does the analysis rely on a preexisting, public set of reference case assumptions (e.g. Annual Energy Outlook (AEO) 2009)? If so, please provide the source information and list, in detail, all modifications that were made to the reference case.**

NEMS-NRDC:

We use the Energy Information Administration's (EIA) March Annual Energy Outlook (AEO) 2009 Published Release (with some modifications to reflect the extended renewable tax credits specified in the stimulus bill) as our business-as-usual (BAU) reference case. The April AEO 2009 Updated Release included changes to reflect stimulus bill provisions, as well as an updated economic forecast (reflecting the growing recession) and updated world oil prices. Because we did not perfectly replicate the changes made between the March and April releases of the AEO 2009 in developing our BAU case, there are modest differences between our BAU case and the April AEO 2009 updated release with the stimulus bill. For example, our BAU case forecasts slightly higher total primary energy consumption and energy-related carbon dioxide (CO_2) emissions in 2030 relative to the AEO 2009 updated release by 2.0 percent and 3.5 percent, respectively. Otherwise, NEMS-NRDC used all of the same baseline and technology cost and performance assumptions as the AEO 2009 Published Release.

Additional Information: As in AEO 2009, costs are assumed to decline relative to how much capacity has been built, to reflect the tendency for costs to decline more sharply in the early phase of a technology's development than later when the technology becomes more mature. To capture this, "learning ratios" (also called progress ratios) are applied to a technology's cost over time according to how much has been built. Learning ratios specify how much costs are assumed to decline for a given doubling in installed capacity. For example, if total installed capacity for a particular technology doubles and there is a learning ratio of 90%, the technology will cost 90% of what it originally cost. AEO 2009 further refines learning by components within a technology, with some components achieving cost reductions faster than others. For example, the cost of combustion turbines within IGCC with CCS decline faster than heat recovery steam generators. (For more information, see pages 90 and 91 of the following: http://www.eia.doe.gov/oiaf/aeo/assumption/pdf/0554(2009).pdf).

In NEMS-NRDC, we follow EIA's NEMS assumptions, which classify learning rates into three general stages, and though the learning rates in each stage vary across technologies, they tend to be ~80% in Stage 1, ~90%-95% in Stage 2, and 99% in Stage 3. Each technology component is designated into one of three technology types, each moving through one or more learning stages. To cite an example, the cost of a very new technology component would be designated as "revolutionary" and would start in Stage 1, declining to ~50% (~80%^3) of its original cost after its total installed capacity has doubled 3 times (i.e., if the original cost is $1,000/kW, then after three doublings of total installed capacity, the cost will now be $512/kW, assuming an 80% learning rate). The technology would then enter Stage 2 and continue to improve up to a maximum learning rate that varies by technology type: Revolutionary technologies are limited to 50% learning (so in the previous example cited, its cost could only lower to $500/kW); evolutionary technologies are limited to 30% (i.e., 70% of the original cost); and conventional technologies are limited to 10% learning through 2030.

We do not make any changes to the learning assumptions in NEMS-NRDC. However, we explain the process here to highlight an implication for policy scenarios: to the extent that a policy increases adoption of new technologies, costs should go down relative to the reference case due to increasing capacity and moving down the learning curve. However, in some studies, analysts do not clarify whether the costs of technologies are the same between the reference and policy case (even if there are significant differences in deployment between the two cases), or whether the assumptions about how technologies' costs change over time are the same. For example, some studies simply say that AEO 2009 cost assumptions were used. But it is not clear whether this means that costs were assumed to be the same between the policy and reference cases, or whether the initial costs are the same, but they evolve differently due to different speeds of deployment.

MARKAL:

We use the Energy Information Administration's (EIA) March Annual Energy Outlook (AEO) 2009 Published Release, with a few exceptions that are due either to the difficulty of translating data into the MARKAL format, the availability of data, or because we concluded that the AEO assumptions do not best reflect the literature and we made adjustments to those selected assumptions in MARKAL (rationale noted, where applicable):

- The cost, efficiency, and lifetime characteristics of residential end-use appliances are from AEO 2008.

- Costs and supply of imported coke are from AEO 2008.

- Overnight capital costs for geothermal generation technologies were increased from $3,766/kW in AEO 2009 to $4,046/kW to better reflect the literature (all in 2007$).

- Biomass supply was adjusted, with biomass having the subcategories of woody biomass and agricultural residues and energy crops:

    - Woody biomass supply was reduced (such that it flattens out around ~100 million dry tons, instead of AEO 2009's 200 million dry tons). This change was made to account for constraints on land use that are enacted in law but not reflected in the biomass assessment. The federal RFS prohibits regulatory compliance using biomass grown on ecologically-important protected federal lands.

    - Supply of agriculture residues and energy crops was increased very slightly, reflecting two assumptions that work in opposite directions: 1) We assumed higher use of winter cover crops and crops grown on degraded lands, increasing supply; 2) On the other hand, we eliminated certain feedstocks from being eligible for compliance with the RFS due to high GHG impacts resulting from indirect land-use changes, which lowered supply.

- For the cost of more efficient light-duty vehicles, MARKAL uses AEO 2009's High Technology Case assumptions (instead of the Reference Case assumptions), with the High Technology Case costs being slightly lower than those in the Reference Case, and more in-line with estimates from the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA).

- We modified AEO 2009 technology learning, because the version of MARKAL that we used cannot handle the three distinct stages discussed above in the "Additional Information" part of the NEMS-NRDC section to this question (with each having a separate learning rate). We also believe that NEMS-NRDC's practice of limiting learning (e.g., very new emerging technologies cannot have their prices drop more than 50% through the model timeframe) is overly conservative and inconsistent with what we have seen (e.g., solar cells have experienced far more than a 50% reduction in costs in a timeframe shorter than that of NEMS-NRDC, as shown at: http://www.tf.uni-kiel.de/matwis/amat/semi_en/kap_3/illustr/i3_2_2.html), so we did not impose those maximum limits on learning in MARKAL. In order to figure out a way to translate the AEO 2009 approach to a format that MARKAL could use, we did the following: For all stages of a given technology's capacity increase, we used a constant learning rate, such that the same cost decrease would occur as would with the NEMS algorithm. As an example, assume that in NEMS, a technology had a learning ratio of 80% for three doublings, then 90% for five doublings. In order to get the same reduction in cost for the same amount of increased capacity over 8 doublings (i.e., 80%^3*90%^5=30%), in MARKAL we would apply a constant learning ratio of 86% for each doubling (86%^8 =30%). Following AEO, for each generation technology we determined which components it was made up of, and applied the comparable learning ratios. However, there were two technologies for which we changed the calculated learning rate: 1) For solar photovoltaic, the calculated learning ratio was 89%, and we changed it to 80%; 2) For onshore wind, the calculated learning rate was 99%, and we changed it to 95%.

- MARKAL included two concentrating solar thermal technologies: one without storage (derived from AEO), and one with thermal storage capacity and a 60% annual capacity factor derived from industry studies with associated cost increases compared to AEO.

- MARKAL included a remote wind technology which incorporated the cost of a dedicated 250-mile transmission interconnection.

- The calibration of the MARKAL reference case to AEO was inexact, but we felt close enough to be comparable. Primary energy use is 1.9% lower, and CO2 emissions 4.7% lower, in our reference case, than NEMS-NRDC. This is due to more ethanol, and greater hybrid and plug-in hybrid penetration rates we assumed to reflect elements of the stimulus that were not reflected in our NRDC-NEMS reference case.

- We also made some modifications to reflect the stimulus bill (since most of MARKAL's assumptions were based on the March AEO 2009, which didn't yet reflect the stimulus bill, as described above in the NEMS-NRDC response to this same question). We reflected the following provisions of the stimulus bill in our MARKAL model:

    a. Weatherization assistance program (and $250 million to increase energy efficiency in HUD-sponsored low income housing): This was modeled in three parts: First, we assumed that 700,000 homes would be affected (which is the number of homes that our efficiency experts believe could be covered by the available funding) in 2010. Second, we divided up the funding equally to each home, with $6,500 spent on each. We divided up efficiency improvements for each home as follows (the stimulus bill does not explicitly allocate funding toward these three sources, but we felt they reflected good estimates of how that funding might be used). We assumed that there would be building shell improvements made to each of the 700,000 homes, at a cost of $4,000 per home, with the effect of lowering the homes' demand for space heating and space cooling (with a resulting 20% reduction in the household end-use energy demand); $500 was applied toward purchasing more efficient refrigerators. Finally, to reflect other energy efficiency provisions, we assumed that each of 700,000 homes would have $2,000 spent toward reducing demand slightly across all end-use categories (e.g., space heating, refrigeration), assuming a resulting 15% reduction in end-use energy demand.

b. State Energy Program: Of the $3.1 billion for the State Energy Program, we assumed that 40% would go toward residential efficiency. We applied that funding to provide $2000 to each of 620,000 homes in 2010 to reduce demand slightly across all end-use categories (e.g., space heating, refrigeration), such that total end-use energy demand for the affected homes was decreased by 15%.
c. Greening of General Service Administration-operated buildings: We assumed the 75% of General Service Administration-operated buildings would have their end-use energy demand decreased by 20% due to energy efficiency improvements, which would cost $700,000 per building.
d. Removal of dollar caps in the investment tax credit for geothermal heat pumps and solar water heaters: The cost of geothermal heat pumps and solar water heaters was lowered 30% through 2020 to reflect the investment tax credit.
e. Extension of the renewable energy production tax credit: The PTC was extended through 2012.

2. If a preexisting set of reference case assumptions was not used, what are the reference case assumptions for changes in gross domestic product, population, emissions, energy (fossil and renewable fuel) use and energy prices? What are the assumed costs and performance of technology options (wind, solar, nuclear, biomass, carbon capture and sequestration (CCS))?

Not applicable; see the response to the prior question.

3. Are existing federal and state policies included in the model (e.g. Corporate Average Fuel Economy (CAFE), other Energy Independence and Security Act of 2007 (EISA) provisions, state renewable portfolio standards, state cap and trade systems, utility decoupling)? If so, how?

NEMS-NRDC:

The NEMS-NRDC model reference case is based on EIA's AEO Reference case published in March 2009 (which doesn't include the ARRA Stimulus package), modified to reflect the extended renewable tax credits specified in the Stimulus package. The AEO 2009 projections are based on Federal, State, and local laws and regulations in effect as of November 2008. Near-term increases in the corporate average fuel economy (CAFE) standards pursuant to the 2007 energy bill (EISA) are included in the reference case.

MARKAL:

The MARKAL reference case includes the CAFE and RFS provisions in EISA 2007, and it has an aggregated national RPS measure that is designed to account for the aggregate effect of the state RPS provisions, but it does not include the CAR or RGGI cap and trade measures.

4. **Are any recently enacted or adopted energy or climate policies not represented in the model (e.g. H.R. 1 or recently revised CAFE standards)? Are the recently proposed greenhouse gas standards for light duty vehicles incorporated into the reference case?**

   NEMS-NRDC AND MARKAL:

   Aside from the items mentioned in the previous question, no other recently enacted or adopted energy or climate policies were represented in the models. The recently proposed greenhouse gas standards for light-duty vehicles were not incorporated into the reference case.

5. **Does the reference case capture how concerns over greenhouse gas emissions, especially expectations of greenhouse gas regulation, impact the behavior of investors? If so, how is this modeled (e.g., AEO 2009 adds a cost penalty when assessing investments in greenhouse-gas intensive technology)?**

   Both the NEMS-NRDC and the MARKAL reference cases are built on the AEO 2009 reference case that includes a capital carrying cost penalty for investments in new conventional coal-fired power plants, but no other impacts of expected GHG regulations on investor behavior.

6. **Does your reference case include any regulations that would be adopted by EPA, as required under the current Clean Air Act authority (i.e. Massachusetts vs. EPA), or any other clean energy policies likely to be adopted by Congress over the time scale of the model?**

   No, neither the NEMS-NRDC nor MARKAL reference cases include EPA regulations of greenhouse gases or clean energy policies likely to be adopted by Congress over the time scale of the model.

Policy case assumptions

1. **Does the analysis model H.R. 2454? If so, which version of H.R. 2454 (discussion draft, as introduced, reported from committee, reported from the House of Representatives) is modeled?**

   For both models, we used H.R.2454 as reported from the House of Representatives. We don't believe that the differences between the version reported from the Committee and the version reported from the House would significantly affect our results.

2. **Does the model constrain the adoption of new or existing technologies in the policy case (e.g. nuclear, CCS, solar, biomass or wind)? Please describe any limits in detail.**

NEMS-NRDC:

Constraints are identical to the constraints in AEO 2009. AEO 2009 does not establish "hard limits" on the adoption of technologies, though it does ratchet up the cost of those technologies at various points (which effectively serves as a "soft limit"). More specifically, the model looks at the amount of capacity that has been added in every year over the last ten years (and it does this every year, so the ten-year period is constantly shifting forward), and in particular it is looking for the greatest amount of capacity that has been added in a single year over the last ten years – for the purposes of this explanation, let's refer to that amount of capacity as the "base amount." So in any given year, it will allow up to 120% of that "base amount" to be added at the reported overnight capital cost. If between 120% and 200% of that "base amount" is added, then the cost goes up by 40% (e.g., from $1,000/kW to $1,400/kW); and if between 200% and 300% of the "base amount" is added, then the cost goes up 130% relative to the original cost (e.g., from $1,000/kW to $2,300/kW).

MARKAL:

In MARKAL we set maximum growth rates at which each technology could technologically grow (generally starting around 50% per year for emerging technologies, then ramping down to 10% for more developed technologies). These maximum growth rate constraints did not turn out to be binding in our runs. Technical experts reviewed the actual growth rates projected by MARKAL to ensure that they were reasonable.

3. **Does the model capture the benefits of federal research & development expenditures on technology deployment and cost? If so, how?**

NEMS-NRDC:

As noted in Section 1 question 4, the NRDC policy case uses the EIA High Technology case assumptions, as well as vehicle improvements needed to meet accelerated CAFE standards and cellulosic ethanol production improvements needed to meet the EISA renewable fuel standards, all of which may be dependent in part on federal investment in research and development.

MARKAL:

MARKAL does not model the benefits of federal R&D spending, except as it in incorporated into the technology efficiency improvements in future vintages of advanced technologies. For example, coal gasification with carbon capture and sequestration has an initial cost and efficiency for 2015 and an improved cost and efficiency projected for 2025, which is assumed to be due to federal R&D spending.

4. **How does the model capture supplemental energy efficiency policies in the legislation? Please list any energy efficiency provisions which have been modeled.**

Please see the response to Question 3 in the section on "Details on the analytical approach behind the economic model(s) used in the analysis". The approach we took was intended to approximate the impact of all of the energy efficiency provisions in ACES, including appliance standards, building codes, SEAD funding, and the EERS. Though as described in the aforementioned response to Question 3, these policies were not modeled one-for-one in either NEMS-NRDC or MARKAL.

5. **How does the model capture supplemental policies in the transportation sector? Please list the transportation sector provisions which have been modeled.**

BOTH NRDC-NEMS AND MARKAL:

Near-term increases in the corporate average fuel economy (CAFE) standards pursuant to the 2007 energy bill (EISA) are included in the reference case for both NEMS-NRDC and MARKAL (reaching 35 mpg by 2020). However, in both models, under the policy case, we assumed higher efficiency standards in the ACES runs because: 1) The national program for passenger vehicle efficiency announced by President Obama in May 2009 moves up the schedule for reaching 35 mpg to 2016 instead of 2020 and 2) ACES has incentives to promote continued improvements in vehicle efficiency. ACES adds $25 billion to the EISA efficient vehicle manufacturer loan guarantees and also allocates another $28 billion in allowance value for automaker clean vehicle technology programs. These investments in clean, efficient vehicles pave the way for higher standards beyond those currently included in the base case, even though such higher standards are not explicitly required in ACES. In both models, we assumed vehicle efficiency standards of 42 mpg in 2020 and 55 mpg in 2030. It is important to note, however, that these standards are not fully achieved in NEMS-NRDC. Given the vehicle cost and performance assumptions in that model, NEMS-NRDC finds that it would be cheaper for vehicle manufacturers to pay non-compliance fines than fully meet the standard. As a result, vehicle efficiency reaches 40 mpg in 2020 and 48 mpg in 2030 in NEMS-NRDC, whereas MARKAL assumes that the specified standards will be achieved.

NEMS-NRDC ONLY:

The plug-in hybrid (PHEV) subsidy provided by ARRA (up to $7500 per vehicle depending on battery size) was included in the policy case. In order to simulate a momentum effect, the credit was modeled as continuing indefinitely rather than allowing PHEV sales to fall once the credit expires. The NRDC policy case also assumes that more rapid expansion rates are possible for cellulosic ethanol and biomass-to-liquids than the EIA reference case assumptions, in order to meet more closely the RFS targets as specified by EISA. However, waivers are still necessary in a few years, and the 36 billion gallon target with 16 billion gallons from cellulosic sources is reached in 2023 rather than 2022.

MARKAL ONLY:

In addition to the above, in MARKAL, we assumed continued improvements in vehicle efficiency standards past 2030, to 80 mpg in 2050. Additionally, MARKAL assumes that transportation system policies will reduce vehicle miles traveled (VMT) by 5 percent in 2020, 9 percent in 2030, and 12 percent in 2050 relative to BAU. Of this reduction in VMT, we assume that 15 percent will shift to public transit (the shift is split 55 percent rail and 45 percent bus), with the remaining 85 percent representing a net reduction in VMT overall.

Those assumed VMT reductions are similar in magnitude to what can be achieved through smart growth and land use planning strategies, as evaluated in the July 2009 Moving Cooler report.[i] That report estimates that smart growth could result in a 6–10 percent reduction in national light-duty VMT by 2030. Though ACES does not mandate a reduction in driving, it does provide funding for developing strategies to improve regional transportation efficiency, potentially resulting in VMT reductions. Whereas we take a conservative approach in NEMS-NRDC and do not include these impacts because they are not directly specified in ACES, our MARKAL modeling assumes that some reductions will occur.

6. **How does the model capture supplemental policies in the electric power sector? Please list the power-sector policies which have been modeled.**

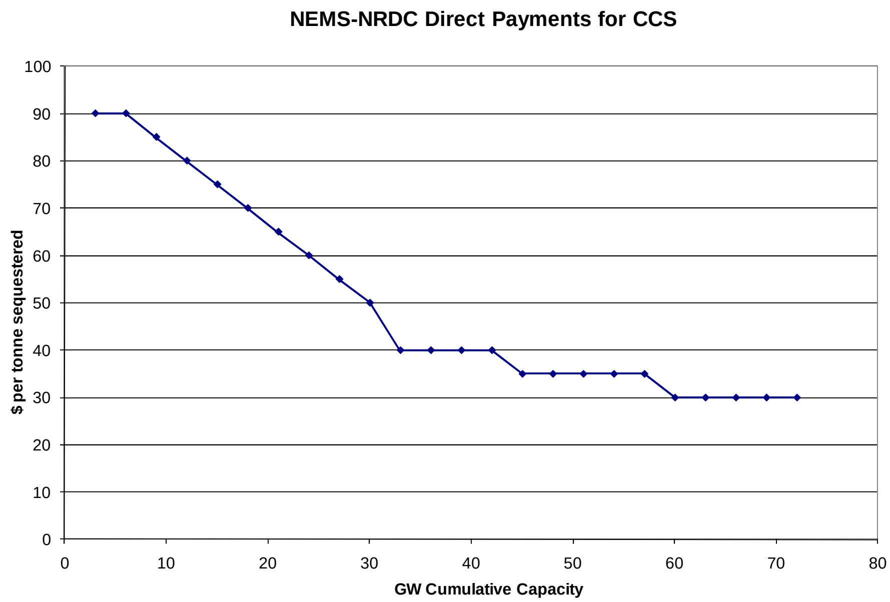
BOTH NEMS-NRDC AND MARKAL:

Two policies affecting the electric power sector were modeled in both NEMS-NRDC and MARKAL: the renewable electricity standard (RES) and incentives for the deployment of carbon capture and storage (CCS).

ACES requires retail electricity distributors to meet a rising fraction of demand with renewable energy sources and improved efficiency, starting with 6 percent in 2012 and rising to 20 percent in 2020, then remaining at that level thereafter. At least three-quarters of that amount must come from renewable resources. However, the Federal Energy Regulatory Commission (FERC) may, on a governor's petition, lower the renewable component to three-fifths of a utility's obligation, with the remainder to come from efficiency. Because of that ability for energy efficiency to meet part of the requirement, in both NEMS-NRDC and MARKAL, we assume that the "effective" RES level is at 75% of the stated standard (i.e., 15% in 2020, as opposed to 20%).

Regarding CCS, ACES has provisions that provide incentives for the successful deployment of carbon capture and sequestration (CCS). Those provisions were modeled as incentive payments per ton of CO_2 captured that decline as a function of cumulative installed capacity. Payments to eligible facilities are paid annually over a 10-year period.

The incentive payments are available to the first 72 GW of CCS capacity built, both IGCC coal and natural gas combined cycle with CCS, beginning at $90 per ton (in 2008 dollars) for the first 6 GW and declining thereafter according to the schedule shown in the following figure.



NEMS-NRDC ONLY:

In NEMS-NRDC, an RES triple credit was assumed through the year 2030 for distributed generation.

7. **How does the model capture supplemental policies in the industrial sector (e.g. output-based rebates)? Please list the supplemental policies in the industrial sector which have been modeled.**

NEMS-NRDC:

The EIA AEO 2009 reference case assumptions for the industrial sector were used without modification.

MARKAL:

MARKAL models potential industrial process efficiency improvements in the industry sector through investment technologies in each major industry sector that reduce their overall steam, process heat, motive power and other energy requirements. However, rebates or other incentives are not modeled.

8. **How does the model incorporate the banking and borrowing provisions of the bill? If the model's outlook is shorter than that of the bill, how is the bank balance determined for the last year of the model? What interest rate is used to determine banking behavior?**

NEMS-NRDC:

The NEMS-NRDC model simulates allowance bank deposits and withdrawals on an annual basis from 2012 (the start year of the policy) to the year 2030. A bank balance of 5 billion tons in 2030 was required for this analysis for use in meeting post-2030 requirements. Allowance prices escalate at 7.4 percent per year in real terms.

MARKAL:

MARKAL incorporates the banking and borrowing provisions of the bill by allowing the annual cap in each period to be exceeded by a maximum of 550 million MT of CO2, while requiring that the model meet the cumulative CO2 cap from 2012 through 2050. Thus, the model banks as many allowances up to this limit that it calculates are cost-effective. A 5 percent interest rate was used to determine banking behavior provided that the constraint on using banked allowances was not binding, however allowance prices increased by almost 12 percent per year from 2045 to 2050 due to this constraint.

9. Please list any sections of the legislation which have not been modeled. List separately any policies assumed in the policy case which are not in the legislation.

We modeled most of the major provisions in ACES. We did not model the following (as well as some allocations—see next question):

- CCS regulation and R & D, except to the extent described previously
- Smart grid and electricity transmission
- In NEMS-NRDC, we did not model industrial efficiency, however we did do so in MARKAL
- Supplemental reductions from funding to reduce tropical deforestation
- Strategic reserve
- Minimum auction price, but there were no time periods in which allowance prices hit the minimum price.

In terms of policies assumed in the policy case which are not in the legislation, we assumed more aggressive CAFE standards (see question 5 above for details).

10. How are allocations of emissions allowances or revenues from auctions of such allowances recycled into the economy in the model?

NEMS-NRDC:

NEMS-NRDC has different modules in which allowance allocations are assigned. The following table describes how the allocations were modeled within the different modules in NEMS-NRDC. Many allocations were only indirectly captured through general government expenditures and tax benefits, as shown in the column describing how allocations were treated within the macroeconomic module. For example, allocations to oil refineries were modeled as "uncollected federal revenue," which simulates the rebate of allowance value back to that sector.

	How represented in macro economic module	Any other or additional method/module used (blank if none)	Did allocations vary by year? (Yes or No)
Int'l Forestry Set-Asides	Federal spending		Y
Electricity Consumers	Personal tax reduction	LDC pass-through to prices in electricity module	N
Electricity Consumers (Merchant Coal)	Personal tax reduction		Y
Natural Gas Consumers	Personal tax reduction		Y
Natural Gas Consumers (Energy Efficiency)	Personal tax reduction	EIA High Tech Case assumptions	Yes, but not exactly as specified in the bill
Home Heating Oil & Propane Consumers	Personal tax reduction		Y
Home Heating Oil & Propane Consumers (EE)	Personal tax reduction	EIA High Tech Case assumptions	Yes, but not exactly as specified in the bill
Low Income Consumers	Federal transfer payments to households		Y
Energy Intensive Trade-Vulnerable Industries	Uncollected federal revenue		Y
CCS Bonus Alowances	Federal spending	Production tax credits to CCS technologies in electricity module	Yes, but not exactly as specified in the bill
Energy Efficiency & Renewable Energy Investments	Personal tax reduction	EIA High Tech Case assumptions	Not applicable
Building Codes	Personal tax reduction	EIA High Tech Case assumptions	Not applicable
Clean Energy Innovation Centers	Federal spending		Y
Investment in Clean Vehicle Technology	Federal spending	CAFÉ standards increased	Y
Domestic Fuel Production (oil refiners)	Uncollected federal revenue		Y
Investment in Workers	Uncollected federal revenue		Y
Domestic Adaptation	Federal spending		Y
Wildlife & Natural Resource Adaptation	Federal spending		Y
International Adaptatioin	Transfer payments abroad		Y
International Clean Technology Deployment	Transfer payments abroad		Y
Deficit reduction	Endogenously determined (i.e. the model determines the amount of allowance revenue needed to maintain the deficit at current levels)		Y
Climate Change Consumer Refund	Personal tax reduction		Y

MARKAL:

MARKAL is not a macroeconomic model, so the full value of allowance allocations are not represented. Allocations were modeled indirectly through assuming that resources for various provisions were available and spent (e.g. CCS subsidies, production tax credits, etc.). Note that households and government are not explicitly represented in MARKAL, so there would be no way to represent allocations other than in those cases where they influence technology choices.

11. Are any rebates to households (or firms) through local distribution companies (LDCs), tax cuts, dividend checks, or other mechanisms captured in the model?

Yes, in NEMS-NRDC but not MARKAL. See discussion in previous question.

12. What are the assumptions for domestic and international offset supply and cost (i.e. what offset marginal abatement cost curves are used and have they been modified in any way for the purposes of this analysis)? Please describe, in detail, any limits placed on the supply or usage of offset for compliance.

BOTH NEMS-NRDC AND MARKAL:

Our assumptions for domestic offsets supply and cost are based on EPA's updated March 2009 Marginal Abatement Cost (MAC) Curves for agricultural and forestry offsets (4 out of the 5 categories of domestic offsets), estimated using the Forest and Agriculture Sector Optimization Model with Greenhouse Gases (FASOMGHG), the primary model EPA has used to estimate domestic offsets from land use and land use change, and EPA 2006 MAC curves for landfill methane offsets (this category was not updated by EPA in 2009 so these are the most recent). Our assumptions for international offsets were based on EPA's March 2009 International forest carbon sequestration MAC curves for the 3 categories of international forestry-based offsets (afforestation, avoided deforestation and forest management) and EPA 2006 MAC curves for international landfill methane offsets, international coal mine methane offsets and international fossil energy-related offsets. In our core modeling runs of ACES, we assumed that international projects in avoided deforestation and forest management would not generate international offsets until 2020. We imposed that constraint to reflect a conservative view about the amount of time that developing countries will need before being able to produce and sell tradable offsets in those categories that meet the standards of the U.S. offsets program. As a result, the only international forestry offsets assumed to be available for purchase in the U.S. from 2012-2019 are those based on afforestation. (It is important to note that in their previous modeling of climate bills, EPA imposed this constraint through 2025, so that our modification actually relaxes this constraint by 5 years). From 2020 onward, all three categories of forestry offsets are made available on the market (afforestation, avoided deforestation, and forest management). For all core runs, we maintained the ACES overall 2 billion ton annual limit on the use of offsets, split evenly between domestic and international offsets, and applied the ACES 1.25:1.00 discount factor on international offsets beginning in 2018. Throughout, all international offsets are pooled so that international demand for offsets (based on the domestic emissions reduction commitments made by other countries) competes with the United States for the available supply of international offsets in any given year.

NEMS-NRDC ONLY:

In the NEMS-NRDC policy case, sources for domestic offsets include reductions in methane emissions from landfills, natural gas and oil systems, and agriculture and livestock, and reductions in nitrous oxide emissions from agriculture and waste management. Domestic offsets available from reductions in methane from landfills were discounted 75 percent to reflect the bill's performance standard.

13. Please outline the key differences between the primary policy scenario and any sensitivity scenarios.

We ran several sensitivity scenarios in each of NEMS-NRDC and MARKAL (all relative to the core policy case), which are described briefly below. Please note that except for the modifications ("sensitivities") that we explicitly mention, no other modifications were made. As a result, any differences in the results can be attributed directly to the change in the variable(s) that we are testing in each case.

NEMS-NRDC:

- *Cap Alone:* Imposed the declining emissions cap on BAU, without reflecting the impact of other complementary policies (e.g., RES, energy efficiency provisions).
- *20% in 2020:* Increased the 2020 emissions target from 17% below 2005 levels to 20% below 2005 levels.
- *International Offsets:* In our core NEMS-NRDC run of ACES, we assumed that international projects in avoided deforestation and forest management would not generate international offsets until 2020. We imposed that constraint to reflect a conservative view about the amount of time that developing countries will need before being able to produce and sell tradable offsets in those categories that meet the standards of the U.S. offsets program. As a result, the only international forestry offsets assumed to be available for purchase in the United States from 2012 to 2019 are those based on afforestation (though other types of offsets based on reducing direct emissions remain available). From 2020 onward, all three categories of international forestry-based offsets are assumed to be available on the market (afforestation, avoided deforestation, and forest management). For this sensitivity case we made two changes to international offsets supply: 1) We assumed that all offset categories would be available beginning in 2012 based on the EPA's supply curve; and 2) We raised the international limit to 1.5 billion tons from 1 billion tons since ACES provides that international offsets can be purchased up to 1.5 billion tons if domestic offset supply is insufficient to meet the domestic 1-billion-ton limit.

- *2x Nuclear Costs:* In the ACES core case, the nuclear overnight capital cost is $3,375 per kW for a plant coming online in 2016 (in 2007 dollars). For this sensitivity, we doubled that overnight capital cost.
- *Rebates:* In our core NEMS-NRDC run of ACES, we approximated the effect of the energy efficiency provisions in the bill by adopting the EIA's high technology case, which has more efficient devices coming into the market faster than in the base case. In order to test an alternative way of modeling the effect of the energy efficiency provisions, we ran a sensitivity in which we assumed that 10 percent of allowance value would be used to subsidize residential and commercial consumers for purchasing more efficient devices in space heating, space cooling, water heating, and commercial lighting.
- *Energy Efficiency Hybrid:* As another approach to approximating the effect of the energy efficiency provisions, we used EIA's Residential and Commercial High Technology assumptions (as we did in the ACES core run), except with respect to residential and commercial space heating, space cooling, water heating, and commercial lighting, for which rebates (similar to in the "Rebates" run) were used instead of the High Technology equipment improvements.

MARKAL:

- *Cap Alone:* Imposed the declining emissions cap on BAU, without reflecting the impact of other complementary policies (e.g., RES, energy efficiency provisions).
- *20% in 2020:* Increased the 2020 emissions target from 17% below 2005 levels to 20% below 2005 levels.
- *CAFE - 65mpg:* In the core ACES run of MARKAL, we assumed that CAFE standards would rise to 80 mpg in 2050. In this run, we tested the effect of changing that 2050 standard to 65mpg.
- *CAFE - 55mpg:* In the core ACES run of MARKAL, we assumed that CAFE standards would rise to 80 mpg in 2050. In this run, we tested the effect of changing that 2050 standard to 55mpg.
- *Full VMT:* In our core ACES run in MARKAL, we assumed that the vehicle miles traveled of light-duty vehicles would be reduced 5 percent vs. BAU in 2020 and 8 percent in 2030 —with 85 percent of that reduction coming from an elimination of VMT and the remaining 15 percent being redirected to public transit. We ran a sensitivity in which we tested a higher VMT case, with LDV VMT reduced 23 percent vs. BAU in 2020, going to 31 percent in 2030. For this full VMT case we maintained the assumption that 85 percent of the VMT reduction would be eliminated and the remaining 15 percent would be redirected to public transit.
- *No VMT:* In our core ACES run in MARKAL, we assumed that the vehicle miles traveled of light-duty vehicles would be reduced 5 percent vs. BAU in 2020 and 8 percent in 2030 —with 85 percent of that reduction coming from an elimination of VMT and the remaining 15 percent being redirected to public transit. We ran a sensitivity in which we tested "no VMT" case (with no reductions in LDV VMT vs. BAU).
- *Lower Nuclear Costs:* In the ACES core case, the nuclear overnight capital cost is $3,375 per kW for a plant coming online in 2016 (in 2007 dollars), which is the

AEO2009 assumption. However, unlike in NEMS-NRDC, nuclear power plant capacity did not expand in our MARKAL core policy case. For this sensitivity, we lowered the overnight capital cost by 15% to test the sensitivity of the results to changes in nuclear costs.

- *Shorter Nuclear Lifetime:* In our ACES core run, we assumed the lifetime of a nuclear plant was 60 years in order to determine at what point existing nuclear capacity will face the decision about whether to shut down or repower. In this run, we shortened that assumed lifetime to 50 years.

Details on the interpretation and presentation of results

1. Are policy case outputs presented in comparison to the appropriate corresponding reference case scenario (e.g., is a high oil price reference case used for comparison to a policy case with high oil price assumptions)?

Yes, the policy case outputs are presented in comparison to the appropriate corresponding reference case scenario for both NEMS-NRDC and MARKAL. The two models each have just one reference case scenario, and one core policy case. The only differences between the two are the imposition of the emissions cap and the introduction of offsets, and the main policies specified in ACES (most of which have been mentioned in more detail already through the various responses, but a list is included below). Regarding the sensitivity runs on the policy case, as mentioned in the previous response, no changes were made to the assumptions and modeled policies except for those that are explicitly mentioned.

Here is a list of the policies modeled in both NEMS-NRDC and MARKAL policy cases:

- Declining emission limits
- Renewable Electricity Standard
- Carbon capture and disposal incentives
- Energy efficiency provisions
- Vehicle efficiency standards
- Plug-in hybrid (PHEV) subsidy provided by ARRA (just NEMS-NRDC)
- More rapid expansion rates for cellulosic ethanol and biomass-to-liquids to meet EISA RFS standards (just NEMS-NRDC)

2. Are statements about the impact of the legislation made relative to current levels or relative to the appropriate reference year?

In both NEMS-NRDC and MARKAL, all data is presented relative to the BAU reference case and in the appropriate reference year (e.g. the amount of solar generation in year 2020 under the policy case would be given along side the amount in 2020 for the reference case). For household costs we present the impact of the legislation relative to both current levels and relative to the BAU reference case, with one exception. In presenting household costs, the present discounted values are provided (following EIA and EPA presentation), but we presented these costs next to increases in household income over current levels under the policy case.

3. **Consumers pay energy bills, not energy prices. Are net household energy expenditures presented or only changes in per unit energy prices? Do these expenditures or prices reflect the impact of allowance allocations (e.g. LDC allocations)?**

   We present energy bill impacts in Figure 2 of our "Clean Energy Bargain," available here: http://www.nrdc.org/globalWarming/cap2.0/files/bargain.pdf. The numbers presented there reflect net household energy expenditures (bills, not just prices), and they reflect the impact of allowance allocations to electric LDCs.

4. **Do predictions about household expenditures account for the effect of energy efficiency policies in the legislation?**

   Yes, the map showing household monthly electricity bills (from Figure 2, as cited in the previous question) takes into consideration how both energy consumption and energy prices change under ACES in NEMS-NRDC. Energy consumption is affected by the energy efficiency policies, with residential electricity consumption 5.4% lower under ACES than BAU in 2020, and 7.5% lower in 2030 (mostly due to energy efficiency policies, but slightly due to demand response to higher energy prices). So yes, the predictions about household expenditures do account for the effect of energy efficiency policies in the legislation.

5. **Are energy price changes presented as wholesale prices or the retail prices consumers actually pay?**

   In the aforementioned map from Figure 2 of our "Clean Energy Bargain," as cited two responses ago, the electricity bills take into consideration both energy consumption and energy prices, with the energy prices being the retail prices (not wholesale prices).

6. **Describe in detail what is (and is not) included in your measure(s) of welfare, income, or consumption. Do reported changes in household income, welfare or consumption reflect any rebates, allowance allocations or tax credits?**

   NEMS-NRDC:

   NEMS-NRDC reports net effects of allocations and energy costs on consumers in their measure of consumption losses. This differs from the general equilibrium models used in other analyses, such as EPA. NEMS-NRDC does not model household utility or firm production functions, where such agents are assumed to maximize their well being over time. Instead, it simply tracks where energy costs and allocations change actual levels of consumption and profit. Other measures of welfare represented in economic theory, such as "consumer surplus" in the economic theory of utility maximization, are not calculated. Consumer surplus measures the difference between the maximum amount a consumer is willing to pay for a good and what the consumer actually has to pay (the competitive market price).

MARKAL:

MARKAL is not a macroeconomic model, and does not provide any estimates of consumer welfare.

7. **If job impacts are discussed in your report, please describe in detail how any job impacts are calculated and provide the number of jobs in the model for 2009. For any year in which job impacts are discussed, please provide the total number of jobs in the model output for both the reference and policy scenario(s).**

   We do not report jobs estimates from either NEMS-NRDC or MARKAL.

Appendix A: Difference between the NEMS-NRDC and MARKAL models

NRDC used versions of the National Energy Modeling System (NEMS-NRDC) and the Market Allocation (MARKAL) models to provide two illustrations of the impact of the American Clean Energy and Security Act (ACES) on our energy system and economy. NEMS-NRDC and MARKAL are similar in that both simulate energy markets from the "bottom-up." They differ, however, in scope and how they model choices. NEMS-NRDC is a forecasting model that uses observed historical behavior to estimate how individual market participants will act in response to changing market conditions and imposed constraints through 2030. It combines detailed energy markets with a macroeconomic model to estimate the impacts of changes in how energy is produced and used (the energy system) on the economy as a whole. In contrast, MARKAL is a long-term, cost-optimization model, which minimizes total energy system costs through 2050 while accounting for the constraints imposed by such factors as energy resource availability and carbon emission limits.

NEMS-NRDC attempts to forecast what would happen under ACES if market participants behave in a manner that mirrors past patterns, while MARKAL finds the least-cost outcome and thus provides a roadmap for attaining our emissions reduction goals at the lowest long-term cost. While the imperfections of our energy market mean that the "optimal" scenario outlined in MARKAL will likely not be achieved, its results can help us develop and advocate smart policies. For example, MARKAL shows that solar power can be a large source of cost-effective generation in the long run, which suggests that policies driving investments in solar power today can have major long-term benefits, despite the fact that these technologies are more expensive than other alternatives in the short run.

Models are based on slightly different business-as-usual (BAU) assumptions

In NEMS-NRDC, we use the Energy Information Administration's (EIA) March Annual Energy Outlook (AEO) 2009 published release (with some modifications to reflect the extended renewable tax credits specified in the stimulus bill) as our business-as-usual (BAU) reference case.[ii] The April AEO2009 updated release included changes to reflect stimulus bill provisions, as well as an updated economic forecast (reflecting the growing recession) and updated world oil prices. Because we did not perfectly replicate the changes made between the March and April releases of the AEO2009 in developing our BAU case, there are modest differences between our BAU case and the April AEO2009 updated release with the stimulus bill. For example, our BAU case forecasts slightly higher total primary energy consumption and energy-related carbon dioxide (CO_2) emissions in 2030 relative to the AEO2009 updated release by 2.0 percent and 3.5 percent, respectively. Otherwise, NEMS-NRDC used all of the same baseline and technology cost and performance assumptions as the AEO2009 published release, except for when we explicitly changed variables in our sensitivity analysis (as discussed below).

In MARKAL, BAU is also calibrated to the March AEO2009 published release, and was modified to reflect the stimulus bill (including provisions for weatherization, the State Energy Program, the greening of General Service Administration-operated buildings, the removal of dollar caps in the investment tax credit for geothermal heat pumps and solar water heaters, and the extension of the renewable energy production tax credit), higher overnight capital costs for geothermal generation technologies, lower progress ratios for solar photovoltaic (PV) and onshore wind generation technologies (i.e. increased the rates at which costs could go down with every doubling), a more constrained biomass supply, and slightly lower cost assumptions for more efficient light-duty vehicles (LDVs). In this case, total primary energy and energy-related CO_2 emissions in 2030 are 2.9 percent and 3.5 percent lower, respectively, than in the April AEO2009 reference case.

MODELS SHOW DIFFERENT RESULTS FOR FOUR MAIN REASONS

1) Model Architecture

- NEMS-NRDC uses historical behavior and assumes "stickiness" in markets to predict how individual market participants will behave going forward. Investment decisions are based on relatively short time horizons in an effort to reflect observed behavior.
- MARKAL has "perfect foresight" (it chooses the outcome that minimizes the total energy system cost to society over the full time-period of the model, while adhering to limitations on the speed of change that are imposed in the model). In other words, it makes decisions based on finding the least-cost energy path for the entire economy through 2050.
- MARKAL as used for NRDC is a national model, while NEMS is regional. This requires the user to specify limits for selected technology (e.g., geothermal, wind and solar) that captures the regional variation in the availability and costs of these resources. Finally, for electricity, MARKAL uses a very simplified representation of load duration that requires both the reserve margin and the use of selected technology (i.e., natural gas fired) be artificially user driven.

2) Assumptions: While NEMS-NRDC and MARKAL share many of the same assumptions, there are important differences.

- NEMS-NRDC assumptions follow those presented in the Energy Information Administration's (EIA) Annual Energy Outlook (AEO) in order to facilitate a comparison between our results and those published by EIA.
- MARKAL also generally follows the EIA-AEO assumptions, but in a few instances, we concluded that the AEO assumptions do not best reflect the literature and we made adjustments to those selected assumptions in MARKAL. The primary changes relate to electricity generation technologies, vehicle costs, and biomass supply (see answers to questions for details).
- MARKAL has a less detailed representation of the energy system than NEMS-NRDC, which results in faster run times and makes MARKAL a more nimble model for the analysis of various scenarios. The NEMS-NRDC model, on the other hand, provides more granularity in its assumptions and output.

3) Policies Modeled: In both NEMS-NRDC and MARKAL, we modeled most of the major complementary policies in ACES, including the renewable electricity standard (RES), carbon capture and sequestration (CCS) deployment incentives, and energy efficiency provisions. There are, however, some differences in how these policies are represented in the two models.

- Transportation system efficiency improvements are reflected only in MARKAL: ACES does not mandate a reduction in driving, but does provide funding for developing strategies to improve regional transportation efficiency, potentially resulting in reduced driving (often referred to as “vehicle miles traveled”). Whereas we take a conservative approach in NEMS-NRDC and do not include these impacts because they are not directly specified in ACES, our MARKAL modeling assumes that some reductions will occur.
- In both NEMS-NRDC and MARKAL, the 2007 energy bill vehicle efficiency standards are included in the BAU baseline, and we assume that these standards are extended under ACES, reaching 42 mpg in 2020 and 55 mpg in 2030. These extended standards are not fully achieved under NEMS-NRDC because the model projects that manufacturers will choose to pay fines rather than fully comply.
- In MARKAL, we incorporated estimated supply and costs of economic CO_2-enhanced oil recovery potential, establishing this as a market option for captured CO_2 that results from CCS deployment incentives in ACES.
- In some cases we use different approaches to model certain policies due to differences in the model architectures (see answers to questions for details).

4) Stimulus in Baseline: MARKAL’s baseline was calibrated to the March 2009 AEO published release and then adjusted to reflect both the extended renewable energy tax credits and energy efficiency provisions of the stimulus bill. NEMS-NRDC just reflects the tax credits. As a result, the post-stimulus baselines for each model are slightly different, with MARKAL reflecting greater efficiency measures.

USING TWO DISTINCT MODELS INSTEAD OF ONE PROVIDES GREATER INSIGHT

Taking all of these elements into consideration, NEMS-NRDC and MARKAL should not be expected to have identical results. Instead, they should be viewed as representing different parts of the spectrum of possible results. NEMS-NRDC takes a more conservative approach, adopting EIA’s AEO assumptions, and only reflecting provisions clearly specified in ACES. Meanwhile, MARKAL shows what is possible from the bill if market barriers are reduced and participants take a longer-term view to making decisions than has typically been observed. Reality will likely fall somewhere between the two.

NRDC’s modeling was carried out by OnLocation (for NEMS-NRDC) and International Resources Group (for MARKAL). More details on the assumptions in both models are available in a Technical Appendix at www.nrdc.org/cap2.0.

[i] Moving Cooler, "Moving Cooler: Analysis of Transportation for Reducing Greenhouse Gas Emissions," July 2009, at http://movingcooler.info/.

[ii] AEO2009 generally reflects all current legislation and regulation that are defined sufficiently to be modeled as of November 5, 2008, including EISA 2007 and EPAct 2005. In addition, also reflect selected State legislation and regulations where implementing regulations are clear such as the October 2008 decision by the California Air Resources Board (CARB) on California's Low Carbon Fuel Standard (LCFS) requiring a 10-percent ethanol blend, by volume, in gasoline. For more information on what is included in AEO2009, please see: http://www.eia.doe.gov/oiaf/aeo/assumption/index.html