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# Strategies for cost-effective carbon reductions: a sensitivity analysis of alternative scenarios ☆

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**Abstract**

Analyses of alternative futures often present results for a limited set of scenarios, with little, if any, sensitivity analysis to identify the factors affecting the scenario results. This approach creates an artificial impression of certainty associated with the scenarios considered, and inhibits understanding of the underlying forces. This paper summarizes the economic and carbon savings sensitivity analysis completed for the *Scenarios for a Clean Energy Future* study (Interlaboratory Working Group, 2000). Its 19 sensitivity cases provide insight into the costs and carbon-reduction impacts of a carbon permit trading system, demand-side efficiency programs, and supply-side policies. Impacts under different natural gas and oil price trajectories are also examined. The results provide compelling evidence that policy opportunities exist in the United States to reduce carbon emissions and save society money. Published by Elsevier Science Ltd.

*Keywords:* Sensitivity analysis; Energy policy; Carbon emissions

## 1. Background and Purpose

The *Scenarios for a Clean Energy Future* (CEF) study is the most comprehensive assessment to date of policy- and technology-based opportunities to address the energy challenges facing the United States (Brown et al., 2001; Interlaboratory Working Group (IWG), 2000). This work builds on previous analysis such as the Five-Lab Study (Interlaboratory Working Group, 1997) and a previous analysis for the EPA using the LBNL NEMS framework (Koomey et al., 1998). It explores three policy scenarios using modified versions of the National Energy Modeling System (NEMS) model used for the Annual Energy Outlook 1999 (EIA, 1998a). The Business-as-Usual (BAU) scenario assumes a continuation of current energy policies and a steady, but modest pace of technological progress. In contrast, the Moderate and Advanced scenarios are defined by policies that are consistent with increasing levels of public commitment and political resolve to solve the nation's energy-related challenges.

This paper extends the CEF analysis by presenting an expanded range of policy scenarios composed of different subsets of policy interventions and different energy price forecasts. These analyses assess the consequences of futures other than those portrayed by the BAU, Moderate, and Advanced scenarios. This allows policy-makers and the public an opportunity to study the advantages and disadvantages of a wide array of different policy choices within the context of alternative energy price trajectories. Two key outcomes or metrics are presented for each of the "sensitivity" cases: carbon emissions and direct costs. By comparing and contrasting these metrics it is possible to identify important policy clusters and to assess the benefits and costs associated with a wide range of different policy approaches.

## 2. Methodology

To untangle the driving forces behind the CEF scenarios, we analyze different bundles of

☆The Excel spreadsheets containing all scenario results are posted on the web at http://enduse.lbl.gov/projects/cef.html

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Table 1
Illustrative demand- and supply-side policies

| Demand-side policies: Moderate scenario | Supply-side policies: Moderate scenario |
|---|---|
| –50% increase in cost-shared, federal R&D on energy efficiency technologies<br>–Implement new efficiency standards for building equipment, beyond those already planned<br>–Expand voluntary labeling and deployment programs by 50%<br>–Voluntary agreements with individual industries and trade associations to reduce energy intensities of production by 0.5% per year over the BAU scenario<br>–Mandate upgrades of all motors to standards set by the 1992 Energy Policy Act, by 2020<br>–Tax credits for the purchase of more fuel-efficient vehicles | –50% increase in cost-shared, federal R&D on clean electric supply technologies<br>–Production tax credits of 1.5c/kWh (1992$) for the first 10 years of operation from wind and biomass power generation installed through 2004<br>–Full electric industry restructuring in 2008 |
| **Demand-side policies: Advanced scenario** | **Supply-side policies: Advanced scenario** |
| –100% increase in cost-shared, federal R&D on energy efficiency technologies<br>–More end-uses covered by building standards; another round of standards for some products<br>–Expand voluntary labeling and deployment programs by 100%<br>–Voluntary agreements with individual industries and trade associations to reduce energy intensities of production by 1.0% per year over the BAU scenario<br>–Mandate upgrades of all motors to standards set by the Consortium for Energy Efficiency, by 2020<br>–Voluntary fuel economy agreements with auto manufacturers<br>–"Pay-at-the-pump" auto insurance | –100% increase in cost-shared, federal R&D on clean electric supply technologies<br>–Renewable energy portfolio standards mandating 7.5% of all electricity sales from wind, biomass, solar, and geothermal for the years 2010–2015<br>–$SO_2$ ceiling reduced in steps by 50% between 2010 and 2020 to represent tighter particulate matter standards |

demand- and supply-side policies, as well as a range of domestic carbon permit trading programs.

The demand- and supply-side policies are divided into those that were modeled in the BAU, Moderate and Advanced scenarios. In the BAU forecast, current energy policies and programs are assumed to continue, resulting in a steady but modest pace of technological progress and improved efficiencies. In the Moderate scenario, policies were designed to reflect a modest shift in political will and public opinion. In the Advanced scenario, policies reflected the presumption of a nationwide sense of urgency to meet significant goals relative to energy productivity, oil supply vulnerability, air quality, and greenhouse gas mitigation. Table 1 illustrates these Moderate and Advanced policies.

The domestic carbon trading programs examined here differ only in terms of the assumed carbon permit trading price $0, $25, $50, or $100 per metric ton of carbon (in $1997). Emissions trading programs work by allocating allowances that permit the release of limited quantities of emissions during a specified period (e.g., annually). A firm's response will depend on its costs of control compared with the market price of carbon permits. We assume that the domestic carbon trading program is announced in 2002 and is implemented in 2005. Each year, beginning in 2005, permits are sold in a competitive auction run by the federal government. The federal government collects the carbon permit revenues and transfers them back to the public. The goal of the carbon permit rebate is to leave people's "incomes" intact while changing the relative price of carbon-based fuels.

We create 16 of the 19 sensitivity cases by combining the following policy options and carbon permit values in different ways:

1. Demand side policies—BAU, Moderate, or Advanced scenario
2. Supply side policies—BAU, Moderate, or Advanced scenario
3. Carbon permit trading price—$0, $25, $50, or $100 per metric ton of carbon

These 16 combinations are shown in Table 2. We define a policy implementation level as the combination of demand and supply policies. Five out of the possible nine levels are analyzed.

Each of these five policy implementation levels is examined with three different carbon trading prices ($0, $25, and $50). We only apply a $100 carbon permit price to the BAU implementation. The BAU $100 sensitivity is included so that this analysis can be compared with the Energy Information Agency's Impacts of Kyoto study (EIA, 1998b). The Impacts of Kyoto study evaluates six goals for 2010 carbon reductions, and meeting these goals require carbon prices between $67

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