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Impacts of Energy Research and Development (S.1766 Sections 1211-1245, and Corresponding Sections of H.R.4) With Analyses of Price-Anderson Act and Hydroelectric Relicensing

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Introduction

On December 20, 2001 and February 6, 2002, Sen. Frank Murkowski, the Ranking Minority Member of the Senate Committee on Energy and Natural Resources, requested an analysis of selected portions of Senate Bill 1766 (S. 1766, the Energy Policy Act of 2002) and House Resolution 4 (H.R.4, the Securing America's Future Energy Act of 2001)[1]. In response, the Energy Information Administration (EIA) has prepared a series of analyses showing the impacts of each of the selected provisions of the bills on energy supply, demand, and prices, macroeconomic variables where feasible, import dependence, and emissions. The analysis provided is based on the *Annual Energy Outlook 2002*[2] (AEO2002) midterm forecasts of energy supply, demand and prices through 2020. This report deals primarily with the Research and Development provisions of S. 1766, organized across four areas: energy efficiency, renewable energy, fossil energy, and nuclear energy. The provisions are assessed using the results from AEO2002 and other side cases, rather than a direct quantitative analysis. Also included are qualitative discussions of the Price-Anderson Act and streamlined hydroelectric relicensing, both of which are contained in S. 1766.

Because of the rapid delivery requested by Sen. Murkowski, each requested component of the Senate and House bills was analyzed separately, that is, without analyzing the interactions among the various provisions. Because of the approach taken:

- The combined impact of the individual policies cannot be determined by simply adding the individual policy impacts together. For example, a provision establishing a renewable portfolio standard (RPS) for electricity production, and one that establishes a bio-diesel program for transportation fuels, each increases the use of biomass. The simultaneous enactment of the two provisions would be likely to increase biomass costs because of the competition for land and other needed resources. The estimated fossil energy displaced will therefore be lower than the sum of the two individual policy impacts because of the higher resource costs. Stated another way, the impacts of multiple simultaneous policies are non-linear.

- Some policies will interact to increase the overall response while others may interact to mitigate the impacts of each other. For example, when two separate policies increase demand and, consequently, production of an advanced technology, the reductions in manufacturing costs expected from increased production are likely to be accelerated, making the manufactured items even

[1] Letters from Sen. Murkowski to Mary J. Hutzler, dated December 20, 2001 and February 6, 2002. See Appendix A for a copy of the original letters.
[2] *Annual Energy Outlook 2002, With Projections to 2020,* U.S. Department of Energy, Energy Information Administration, DOE/EIA-0383(2002), December 2001.

more attractive in later years. The total adoption of the advanced technology in this case could be greater than the sum of the parts.

In addition, some R&D provisions of S.1766 and H.R.4 indicate qualitative goals, or goals without specific quantitative targets. For example, the provisions pertaining to natural gas transportation research (Section 1235) seek greater reliability, efficiency, safety, and integrity for the gas infrastructure, R&D for railroads seeks greater fuel economy and reduced emissions but without specific targets (Section 1214), and a program for advanced coal mining safety requires prioritization of goals (Section 1233). Consequently, EIA has concentrated on those goals that lend themselves to measurement.

EIA's projections are not statements of what will happen but rather what might happen, given known technologies and current demographic trends, laws, and regulations. Thus, the *AEO2002* provides a policy-neutral Reference Case that can be used to analyze energy policy initiatives, as has been done for each of these studies. EIA does not propose, advocate or speculate on future legislative or regulatory changes. Laws and regulations are assumed to remain as currently enacted or in force in the Reference Case; however, the impacts of emerging regulatory changes, when clearly defined, are reflected.

Models are simplified representations of reality because reality is complex. Projections are highly dependent on the data, methodologies, model structure and assumptions used to develop them. Because many of the events that shape energy markets are random and cannot be anticipated (including severe weather, technological breakthroughs, and geo-political disruptions), energy market projections are subject to uncertainty. Further, future developments in technologies, demographics, and resources cannot be foreseen with any degree of certainty. These uncertainties are addressed through analysis of alternative cases in the *AEO2002*.

Provisions Covered in This Report

This paper addresses the provisions of S. 1766 and H.R. 4 that pertain to research, development, and deployment goals for a range of energy technologies (Table 1, p. 3). Specific draft language is taken from S. 1766. Quantitative description is offered for some of the goals and programs, while the remaining provisions are discussed qualitatively. Following the discussion of R&D, two separate topic areas specifically requested in the February 6 letter are analyzed: the Price-Anderson Act (S.1766, Sec. 501-508, H.R. 2983), and Hydro Relicensing (S.1766, Sec. 301-308, H.R. 4, Sec. 401-402).

Uncertainties Associated with R&D Cost-Benefit Analysis

S. 1766 contains numerous sections calling for increased research and development efforts, including programs aimed at improving the efficiency of energy consumption devices, the cost and performance of renewable, fossil and nuclear energy production technologies, together with safety, environmental and basic science research programs.

Table 1. R&D Programs in Two Legislative Proposals		
	S.1766	**H.R. 4**
Energy Efficiency	**Section Reference**	
Buildings (Residences)	1211	2181
Industrial efficiency	1211	2004
Transportation	1211	2004
Distributed Generation	1211	2123
Next Generation Lighting	1213	2153
Railroad Efficiency	1214	152
Renewable Energy		
(wind, PV, solar thermal, biomass power,	1221	2004, 702
geothermal, biofuels, hydrogen, hydropower,	1221	2123, 2205
transmission systems)	1221	2241
Bioenergy (biopower, biofuels)	1222	2224
Hydrogen R&D	1223	2205
Fuel Cell integration	1223	2461
Fossil Energy		
Power Plant Improvement	1232	5006
Coal Mining	1233	none
Ultra Deepwater	1234	2421, 2443
Natural Gas Transportation	1235	2422
Nuclear Energy		
University Science and Engineering	1242	2302
Research Initiative	1243	2341
Plant Optimization Program	1244	2342
Energy Technology	1245	2343
Advanced Fuel Recycling Program	1245	2321

Some of these programs are new while others are extensions or expansions of existing programs.

Because it is difficult to relate levels of funding for research and development directly to specific improvements in the characteristics, benefits, and availability of energy technologies, the analysis in this report does not attempt to assess the overall impact of the proposed $6.2 billion R&D funding authorized by S.1766 in FY 2003. In general, increased research and development would be expected to lead to technological advances, but it is impossible to determine which programs would or would not be successful or how successful they might be.

It is also difficult to determine if the programs would lead to advances beyond those already incorporated in the AEO2002 Reference Case used in the quantitative analyses in this series of reports. The National Energy Modeling System (NEMS) incorporates improvements in technology cost and performance over time in all sectors of the US energy-economy. These improvements are meant to capture the impacts of technology improvement trends seen in historical data and those expected to occur because of current levels of research and development. For example, the residential and commercial submodules assume improvements in the cost and performance of new lighting, heating, air conditioning, and office equipment over the next 20 years. Similarly, the fuel supply and conversion submodules incorporate improvements in drilling, mining, refining, and electricity generation technologies. It is possible that the programs called for in S. 1766 could lead to greater improvements than are projected in the AEO2002 Reference Case, but their impact is unknown because the exact relationship between Federal R&D expenditures and technological improvements is not clear.

In addition to the difficulty in quantifying the potential impact of any individual research and development program, estimating the combined impact of a wide array of programs is even more difficult. Though it is possible that several programs may produce synergistic results, the opposite conclusion seems more likely because, when analyzed together some programs may have smaller combined impacts than analysis of each individual program might suggest.[3] The R&D provisions of S. 1766 are broadly distributed across sectors and fuels so that if all technologies supported by S. 1766 were to improve their cost and performance at a similar rate, the market penetration of those technologies would likely remain similar.

Finally, public sector R&D programs may mitigate certain market failures, and yet remain ineffective against other market barriers. Market failures addressed directly by R&D investment include less emphasis on basic research in the private sector, and consumers' lack of information. However, market barriers also pose a secondary and equally large challenge to the penetration of new technologies. Consumers may be fully aware of potential cost savings from a more efficient technology but still prefer other characteristics of the less efficient technology. The current trend for larger, more powerful personal vehicles is just one example of consumers' apparent preference for product attributes that compete with energy efficiency.[4] Other barriers to the penetration of new technologies include uncertainty as to the reliability, performance, and costs of new equipment; uncertainty about the availability of next generation technology which may be of much higher quality; and apprehension concerning the infrastructure for

[3] For example, efficiency improvements in electricity generation would be expected to reduce the price of electricity, consequently devaluing investment in end-use energy efficiency.

[4] Consumer perceptions regarding the length of payback periods apparently exceed actual payback periods, discouraging new equipment purchases, as does the fact that consumers may base their decisions on current, rather than future, prices.

support and maintenance of the technology. R&D expenditures are generally not effective against these market barriers.

The following is a review of the various R&D provisions of S. 1766, grouped in four main headings: energy efficiency, renewable energy, fossil energy, and nuclear energy. Each section includes a description of the program goals, and a discussion on progress in meeting those goals including assessments of feasibility. Where appropriate, AEO2002 projections are compared with sensitivity cases, notably the Frozen and High Technology Cases, the High Renewables Case, and the High Fossil Case. The Frozen Technology Case assumes that all future equipment purchases are based only on the range of equipment available in 2002. In the residential and commercial sectors, building shell efficiencies are assumed to be fixed at 2002 levels. In the industrial sector, the Frozen Technology Case holds the energy efficiency of plant and equipment constant at the 2002 level over the forecast. For the transportation section, the Frozen Technology Case assumes efficiencies for new equipment in all modes of travel are fixed at 2002 levels. In the generation sector, new advanced technologies are assumed not to improve over time. In contrast, the High Technology assumptions in these sectors generally assume earlier availability of technology, reduced costs, higher efficiencies, and in some sectors, more rapid improvement of efficiencies, thereby modeling the expected results of increased R&D expenditure relative to the reference case.[5] The Integrated Technology Cases[6] combine these assumptions. Key results of these cases are presented in Table 2. Without any technological improvement, the Frozen Technology Case projects consumption which is 4.6 percent higher, energy intensity which is 5.1 percent higher, and carbon dioxide emissions 6.4 percent higher than Reference Case levels (Figure 1, p. 6). In contrast, the High Technology Case, incorporating improvements that might follow R&D investments at higher than Reference Case levels, projects consumption 5.7 percent lower, energy intensity 5.1 percent lower, and carbon dioxide emissions 6.6 percent lower than reference levels by 2020.

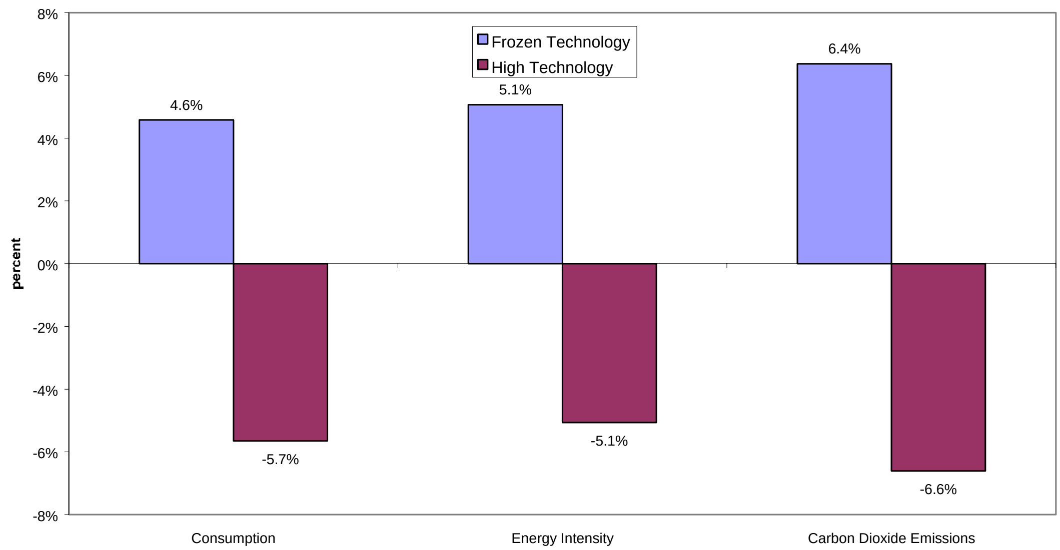
Table 2. Key Results from Integrated Technology Cases, 2000 and 2020

	2000	2020		
		Frozen Technology	Reference	High Technology
Consumption (quadrillion Btu)	99.3	136.9	130.9	123.5
Energy Intensity, Total (thous. Btu per 1996 dollar of output)	10.8	8.3	7.9	7.5
Carbon Dioxide Emissions (million metric tons carbon equivalent)	1,562	2,221	2,088	1,950

Source: Energy Information Administration, Annual Energy Outlook 2002, runs LTRKITEN.D102501A, AEO2002.D102001B, HTRKITEN.D102501A.

[5] The level of increased R&D was not estimated in the High Technology cases.
[6] Energy Information Administration, *Annual Energy Outlook 2002* (DOE/EIA-0383(2002), Washington, DC, December 2001, Table F4.

Figure 1. Key Results from Integrated Technology Cases, Percent Change from Reference Case Projections 2020



Source: Energy Information Administration, Annual Energy Outlook 2002, runs LTRKITEN.D102501A, AEO2002.D102001B, HTRKITEN.D102501A.

In the electricity generation sector, the High Renewables Case assumes greater improvements for central-station nonhydroelectric generating technologies using renewable resources than in the Reference Case, while other technology costs remain the same as the Reference Case.[7] In the High Fossil case, capital costs and/or heat rates for coal gasification combined-cycle units and natural gas-fired advanced combustion turbine and combined-cycle units are assumed to be lower and decline faster than in the Reference Case. These values are based on the Vision 21 program for new generating technologies developed by the Department of Energy's Office of Fossil Energy.[8]

Energy Efficiency (Title XII, Subtitle A, Sections 1211 through 1214)

S. 1766 distributes R&D for energy efficiency over six areas: housing, industrial, transportation, distributed generation, Next Generation Lighting, and railroad efficiency. With the exception of the last two items, specific authorization levels are not enumerated. Total proposed authorization for FY 2003 is $810 million, and over the period FY2003 to FY2011, the total authorized is $3.925 billion.

<u>Housing</u>. Subsection (b)(1) states that the "goal of the energy-efficient housing program shall be to develop, in partnership with industry, enabling technologies (including lighting technologies), designs, production methods, and supporting activities that will,

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[7] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, and Electric Power Research Institute, *Renewable Energy Technology Characterizations*, EPRI-TR-109496 (Washington, DC, December 1997).

[8] Energy Information Administration, *Assumptions to the Annual Energy Outlook 2002*, DOE/EIA-0554(2002), Table 45, p. 77. http://www.eia.doe.gov/oiaf/aeo/assumption/pdf/0554(2002).pdf

by 2010 cut the energy use of new housing by 50 percent, and reduce energy use in existing homes by 30 percent."

The housing goals of S. 1766 echo those articulated in the Partnership for Advancing Technology in Housing (PATH),[9] a national public-private partnership designed to improve the development, dissemination, and use of new housing technologies. The goal for new housing, a 50 percent reduction, was analyzed previously by EIA.[10] To demonstrate the impact that increased efficiency in the housing sector might have, a case was developed for that study in which 70 percent of all new single-family homes constructed by 2010 were assumed to be 50 percent more energy-efficient in heating and cooling than today's new homes. By 2020, savings relative to the corresponding Reference Case amounted to 278 trillion Btu of energy, $2.5 billion (1998 dollars) in consumer energy bills, and 5.7 million metric tons of carbon emissions. The High Technology Case in AEO2002, which includes lower costs and earlier availability as well as the PATH goals, projects delivered energy savings of about 970 trillion Btu by 2020 over reference levels of consumption.[11]

Many technologies exist today that can substantially decrease residential energy use in both new and existing housing. In new construction, the most efficient heating and cooling technologies, combined with advanced windows and increased insulation in walls and ceilings, can cut energy use for space conditioning in new construction by 50 percent in most climates. The cost to achieve these savings, however, curtails widespread adoption of these technologies. For other appliances, such as cooking equipment and miscellaneous electronics, a 50 percent decrease in energy use would be very difficult to achieve, limiting the ability to achieve a total decrease of 50 percent per household. For existing housing, replacement of decades-old equipment with new equipment can achieve a 30 percent energy savings for some appliances; however, as with new housing, certain appliances cannot achieve this percent reduction in energy use, making it difficult to meet the goal outlined in the bill.

Industrial. Subsection (b)(2) specifies a goal of developing, in partnership with industry, "enabling technologies, designs, production methods, and supporting activities that will, by 2010, enable energy intensive industries…to reduce their energy intensity by at least 25 percent." Industries of the Future, an ongoing Department of Energy (DOE) program, works in partnership with several energy-intensive industries to develop technologies aimed at increasing efficiency. Targeting the same industries as those enumerated in Section 1211, this program also seeks a 25 percent reduction in energy intensity.

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[9] http://www.pathnet.org/topics/energy.html

[10] Energy Information Administration, *Analysis of the Climate Change Technology Initiative: Fiscal Year 2001*, (SR/OIAF/2000-01) Washington, DC, April 2000, p. 61.

[11] Energy Information Administration, *Annual Energy Outlook 2002* (DOE/EIA-0383(2002), Washington, DC, December 2001, Table F1. The Reference Case, which includes the PATH goals, projects savings of 370 trillion Btu compared to the 2002 Technology Case, which assumes future equipment purchases are based on equipment available in 2002, and existing shell efficiencies are fixed at 2002 levels.

Some of the technologies pursued through Industries of the Future are represented in the National Energy Modeling System (NEMS). For example, near-net-shape casting, a major steel industry initiative, is represented in both the AEO2002 Reference Case and the High Technology Case. Advanced aluminum reduction cells[12] and black-liquor gasification,[13] a technology that could increase electricity production at pulp mills, are both represented in the High Technology Case. The High Technology Case assumes that increased R&D expenditures will accelerate the penetration, or lead to the introduction of these technologies. However, the High Technology Case also considers many other efficiency improvements, so it is difficult to determine the impact of any particular technology in the projections. Compared with the AEO2002 Frozen Technology Case,[14] industrial energy intensity in the High Technology Case is about 3.5 percent lower by 2010.[15] For the specific industries (Table 3), the AEO2002 Reference Case projects declining intensities, ranging from 3 percent (bulk chemicals) to 20 percent (aluminum) by 2010. Consequently, a 25 percent reduction in energy intensity, while possible for one or two industries, seems highly ambitious, even if the critical technologies were developed and deployed.

Table 3. Decreases from 2000 Baseline in Industrial Energy Intensity in Three Technology Cases, 2005 and 2010 (percent)

	2005			2010		
Industry	Frozen Tech	Reference	High Tech	Frozen Tech	Reference	High Tech
Bulk Chemicals	-0.5	-1.4	-1.8	-0.8	-2.7	-3.8
Food	-1.2	-2.5	-3.2	-2.0	-4.7	-6.5
Other Manufacturing	-2.0	-3.2	-3.9	-3.8	-6.3	-8.3
Cement	-2.6	-4.6	-5.4	-3.4	-7.6	-9.8
Glass	-1.4	-4.4	-4.9	-2.1	-8.8	-10.0
Paper	-3.1	-6.4	-7.6	-4.0	-10.5	-10.9
Metal Based Durables	-4.9	-5.8	-6.4	-8.7	-10.6	-12.3
Steel	-4.2	-6.9	-10.3	-7.8	-13.1	-21.3
Aluminum	-5.8	-9.0	-9.9	-13.6	-20.1	-22.4

Sources: Energy Information Administration, Annual Energy Outlook 2002 (DOE/EIA-0383(2002), Washington, DC, December 2001, runs AEO2002.d102001b, LTRKITEN.d102501a, and HTRKITEN.d102501a.

Transportation. Section 1211 Subsection (b)(3) calls for the development of government and industry partnership programs that will enable dramatic efficiency improvements in highway vehicles. By 2010, these provisions would require a passenger car to achieve 80 miles per gallon (mpg) and a light truck to achieve 60 mpg. By 2010, these provisions would also triple the efficiency (ton-miles per gallon) of medium freight trucks, and double the efficiency of heavy freight trucks.

The light vehicle fuel economy goals defined in this provision echo a recent Federal program. The Partnership for a New Generation of Vehicles (PNGV) was a cooperative research and development program among seven Federal agencies and the United States Council for Automotive Research (USCAR), which comprises DaimlerChrysler, Ford

[12] http://www.oit.doe.gov/factsheets/aluminum/pdfs/advcells.pdf
[13] http://www.oit.doe.gov/forest/pdfs/quarterlyhighlights.pdf
[14] Efficiency of plant and equipment fixed at 2002 levels.
[15] Energy Information Administration, Annual Energy Outlook 2002 (DOE/EIA-0383(2002), Washington, DC, December 2001, Table F2.

Motor Company, and General Motors Corporation. The program was initiated in 1993 and stated as one of its goals, the tripling of fuel efficiency for midsize cars without sacrificing affordability, performance or safety. In 2000, concept cars were demonstrated to show that the PNGV fuel economy goals could be met without sacrificing other vehicle attributes.[16] Although the concept vehicles achieved the PNGV fuel economy goals, it was reported that the incremental cost of producing these vehicles would exceed $7,500, making them impractical for most consumers.

While the PNGV program made progress in the development of advanced technologies to enable a cost effective tripling of light vehicle fuel economy, the limited focus embodied in R&D programs led to the demise of the program early in 2002. It was replaced by the FreedomCAR program, which maintains a long-term goal of increasing fuel economy through fuel cell technology and adds additional funding to support the development of a hydrogen infrastructure. Without the PNGV program and its mid-term efficiency goals coupled with product development lead times, and the apparent consumer preference for increased vehicle power rather than efficiency, tripling fuel economy from today's level by 2010 seems highly improbable. Although it is plausible that manufacturers could institute commercial-scale production of such vehicles, it is highly unlikely that all new light vehicles could achieve this goal cost effectively.

The freight truck efficiency goals mirror those outlined in the 21st Century Truck Program, which establishes cooperative research and development efforts between Federal agencies and industrial partners. The program's goals are to triple the fuel efficiency of medium trucks and double the fuel efficiency of heavy trucks.[17] The program's Technology Roadmap anticipates that achieving its goals would require annual Federal government expenditures of $300 million to $350 million for 10 years, with an equal amount from industry.[18] The Technology Roadmap also states that these goals "are aggressive, and there is no certainty that they can be achieved." (p. 1-2). In part because there is no assurance of the funding levels that may be required, tripling medium truck fuel efficiency and doubling heavy truck fuel efficiency by 2010 appear problematic.

<u>Distributed Generation</u>. Section 1211 of S.1766 states that, "The goals of the energy efficient on-site generation program shall be to help remove environmental and regulatory barriers to on-site- or distributed generation and combined heat and power by developing technologies by 2015 that achieve:" 40 percent efficiency for on-site distributed natural gas-fired technologies, combined heat and power total efficiencies of more than 85 percent, fuel flexibility including hydrogen, biofuels and natural gas, packaged system integration at end user facilities, and increased reliability and stability of the electricity grid.

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[16] Web address, http://www.ta.doc.gov/PNGV/AboutPNGV/intro.htm.

[17] *Technology Roadmap for the 21st Century Truck Program*, 21CT-001, December 2000, p. 1-1, web address http://www.osti.gov/hvt/21stcenturytruck.pdf.

[18] *Technology Roadmap for the 21st Century Truck Program*, 21CT-001, December 2000, p. 5-1, web address http://www.osti.gov/hvt/21stcenturytruck.pdf.

All of these projects are currently being pursued in DOE's Distributed Energy Resources (DER) program, and the operational goals are theoretically within reach. The challenge is to implement these programs in places where vertically integrated utilities still operate or where a newly-deregulated market may not be providing proper cost signals.[19] Economically, the beneficiaries of these distributed systems are not limited to the immediate site: utilities may benefit through avoided costs and voltage support, while other consumers may benefit in the form of reduced emissions and delayed or avoided rate increases. Distributed generation technologies are modeled in NEMS, in both the generation sector and the demand sectors. In the generation sector, two distributed technologies compete against central station technologies, where the distributed generators are used to partially offset transmission and distribution costs.[20] In the commercial sector, end-use power costs are compared to several distributed generation technologies.[21] The projected adoption of these systems is a function of how quickly the investment is recovered through savings of purchased electricity and, in the case of combined heat and power, reduced thermal energy requirements. By 2015, AEO2002 projects 27 GW of distributed generation, most of which is forecast in the industrial and electric generator sectors.[22] AEO2002 did not assess the efficiency goals (40 percent) or the fuel-flexibility goals for distributed generation.

Next Generation Lighting Initiative. Section 1213 of S. 1766 establishes a Next Generation Lighting Initiative in the Department of Energy to "research, develop, and conduct demonstration activities on advanced solid-state lighting technologies based on white light emitting diodes." The general objective of the provision is to develop, by 2011, advanced solid-state lighting technologies based on white light emitting diodes that are cost competitive with incandescent and fluorescent lighting technologies in addition to being longer lasting and more energy-efficient. The first specific objective is to develop an inorganic white light emitting diode that has an efficiency of 160 lumens per watt and a 10-year lifetime. The second objective is to develop an organic white light emitting diode with an efficiency of 100 lumens per watt with a 5-year lifetime that illuminates over a full color spectrum; covers large areas over flexible surfaces; and does not contain harmful pollutants typical of fluorescent lamps such as mercury.[23] Section

[19] http://www.eren.doe.gov/der/full_value.html. For example, (potential) owners of distributed systems might also seek to recover any reliability benefits provided by the generator to the system.

[20] A generic "base" microturbine ($623/kW), and a generic "peak" microturbine ($599/kW). http://www.eia.doe.gov/oiaf/aeo/assumption/pdf/0554(2002).pdf, Table 38. As modeled, these technologies perform at 31 and 32 percent efficiency in 2000.

[21] Distributed generation technologies represented in the commercial sector include solar photovoltaic systems and fossil fuel-fired systems ranging from engines and turbines to gas-fired microturbines and fuel cells. http://www.eia.doe.gov/oiaf/aeo/assumption/pdf/0554(2002).pdf, Table 18. The generic base-load system improves from 31 percent to 37 percent, short of the efficiency goals of S. 1766. The peaker obtains a very slight improvement.

[22] Energy Information Administration, Annual Energy Outlook 2002 (DOE/EIA-0383(2002), Washington, DC, December 2001, Tables A9 and F1. About 14 GW is projected in the industrial sector, 11 GW in the electric generator sector and about 1.5 GW of natural gas distributed generation is projected commercially, the majority of which are microturbines and fuel cells. Additional quantities of photovoltaic distributed generation, about 300 kW, are also projected for the commercial sector.

[23] Organic light emitting polymers may be less costly to produce than inorganic materials.

1213 authorizes $50 million in each Fiscal Year 2003 through 2011 for these activities, totaling $450 million over the period.

Solid-state lighting devices that use light emitting diode (LED) technology are currently used in many applications requiring colored light, such as exit signs, traffic signals, and vehicle brake lights. Recent technological breakthroughs have started to establish solid-state sources of white light; however, additional technology and cost breakthroughs must occur for the goals stated in S.1766 to be achievable. Currently, white LEDs are one third more efficient than incandescent lamps (about 20 lumens per watt compared to 15 lumens per watt) and last at least 10 times as long.[24] However, the cost of an LED-based light source is roughly $100 per thousand lumens of light compared to $0.33 per thousand lumens for incandescent lighting. The comparison to fluorescent lighting is even less favorable. Although first costs exceed those of incandescent lighting, standard fluorescent bulbs produce 80 lumens per watt and last 20,000 hours for under $1.00 per thousand lumens, putting the cost and efficiency goals of S.1766 at a severe disadvantage.[25,26]

Analysts at Sandia National Laboratories and Agilent Technologies project that the penetration of LEDs into signaling applications will drive continued evolutionary improvements in performance and cost, leading white LEDs to reach an efficiency of 50 lumens per watt in 2010 with costs dropping by at least 10 percent per year to less than $50 per thousand lumens.[27,28] If these improvements are realized, LEDs could compete in some incandescent applications without an additional government R&D program, provided LED "lighting quality" also meets user expectations. However, evolutionary improvements will not meet the objectives of the legislative provision. Nothing short of revolutionary advances in both cost and efficiency would be required for solid state lighting to meet the specific goals of S. 1766 and be competitive in general fluorescent applications.

Solving technical problems related to the materials and processes used to manufacture the semiconductors that make up LEDs is crucial to reducing the cost of LED lamps. In addition, the efficiencies of the green and blue components of LEDs must be improved by factors of 5 to 10 and 2 to 3, respectively, in order to meet the S.1766 goals. Organic light emitting diodes (OLEDs) may be more amenable to inexpensive, large scale processing; however, efficiency, lifetime, brightness, and degradation problems must all be solved for OLEDs to be viable. As is typical for research and development programs, the timing and degree of success in solving these issues is highly uncertain. The competitive success of solid state lighting in general lighting applications and meeting the

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[24] Lamp life estimates for current LED technology range from 10,000 hours of use to 100,000 hours of use while incandescent bulbs last about 1,000 hours.
[25] Haitz, R., F. Kish, J. Tsao, J. Nelson, *The Case for a National Research Program on Semiconductor Lighting*, Sandia National Laboratories/Agilent Technologies White Paper (April 2000).
[26] Kendall, M. and M. Scholand, *Energy Savings Potential of Solid State Lighting in General Lighting Applications*, U.S. Department of Energy (Washington, DC, April 2001).
[27] Haitz, et.al..
[28] Haitz, R., F. Kish, J. Tsao, J. Nelson, "Another Semiconductor Revolution: This Time It's Lighting!" *Compound Semiconductor* Magazine Issue 6, No. 2 (March 2000).

goals of the S.1766 provision depend not just on solving one particular technical problem, but on major technological breakthroughs affecting both the cost and performance of inorganic and organic white light emitting diodes.

Railroad Efficiency Improvements. Subsection 1214 of S. 1766 establishes a public-private research partnership involving the federal government (DOE, U.S. Department of Transportation, Department of Defense, and the U.S. Environmental Protection Agency), railroad carriers, locomotive manufacturers, and the Association of American Railroads. The goals of the program are broad: "developing and demonstrating locomotive technologies that increase fuel economy, reduce emissions, improve safety, and lower costs." Authorizations are $60 million for FY2003 and $70 million for FY2004.

The energy efficiency of freight railroads (ton-miles per thousand Btu) increased by 1.9 percent per year during 1989-1999.[29] As a result, even though ton-miles increased by 3.5 percent per year over that period, energy consumption increased by only 1.6 percent per year, reaching 520 trillion Btu in 1999. Much of this efficiency improvement may be attributable to industry consolidation. Further significant efficiencies attributable to locomotive improvements are not anticipated.

Renewable Energy (Subtitle B, Sections 1221 to 1223)

S. 1766 distributes R&D for renewable efficiency over nine areas: wind power, photovoltaics, solar thermal technologies, biomass power, geothermal power, biofuels, hydrogen-based fuels, hydroelectricity, and energy systems and storage. With one exception,[30] specific authorization levels within each area are not enumerated. S. 1766 would also amend the Spark M. Matsunaga Hydrogen Research, Development, and Demonstration Act of 1990, providing for authorizations totaling $420 million over the period FY2003 to FY2006 for hydrogen research and the integration of fuel cell research with a hydrogen production system. Total authorization for these renewable R&D activities in FY 2003 is $590 million, and over the period FY2003 to FY2006, the total authorized is $2.931 billion.

Wind Power. The goals of the wind power program are "to develop, in partnership with industry, a variety of advanced wind turbine designs and manufacturing technologies that are cost-competitive with fossil-fuel generated electricity, with a focus on developing advanced low wind speed technologies that, by 2007, will enable the expanding utilization of widespread class 3 and 4 winds."[31]

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[29] Computed from U.S. Department of Energy, Oak Ridge National Laboratory, *Transportation Energy Data Book*, Edition 21, September 2001, Table 12.7.
[30] Hydrogen-based fuels programs.
[31] Class 3 wind resources include areas where average wind speed ranges from 14.3 to 15.7 mph; average wind speeds of class 4 resources range up to 16.8 mph. Elliot, D.L., L.L. Wendell & G.L. Gower, "An Assessment of the Available Windy Land Area and Wind Energy Potential in the Contiguous United States," Pacific Northwest National Laboratory, August 1991.

The goal as stated is largely consistent with the current focus of the DOE Wind Program. It is not clear if the time target (2007) applies to the goal for "cost-competitiveness with fossil-fuel generation", but the AEO2002 Reference Case forecasts that, in some regions, wind will be cost-competitive compared to other available generation technologies in the 2015-2020 timeframe. The EIA High Renewables Case, a forecast based on the cost goals of the DOE Office of Energy Efficiency and Renewable Energy, indicates that wind power could be competitive with fossil-generated electricity by 2007. EIA considers the Reference Case forecast as the "most likely" scenario under current policy conditions, including current levels of funding for research and development efforts. EIA provides the High Renewables Case to indicate the effect of less likely, but more optimistic, projections for the renewable technologies.[32] Although not likely, it is plausible that some combination of key technology breakthrough, cumulative technology advances, or higher than expected fossil fuel prices could accelerate the timeframe in which wind power becomes competitive with other fossil-fuel generated electricity. Notably, despite the 250 percent increase in wind capacity from 1998 to 2002, installed costs for wind turbines have remained more or less constant. Performance of wind units, however, has noticeably improved over the past 5-10 years.

The challenges of using low-speed wind classes are more economic than technological in nature. Currently available wind turbine technology can be "tuned" or otherwise optimized to operate in specific wind regimes, including low- and high-speed. The global wind industry has largely developed in Denmark, a country notable for its moderate-to-poor quality wind resources (at least compared to the Northwest or Upper Great Plains regions of the U.S.). While developing technology to make Class 3 and 4 winds economically competitive raises some significant engineering challenges, it seems likely that in an "open" market (one free of subsidy or other external incentives), the higher quality wind resources will be used in preference to the lower quality. Higher quality wind classes enable higher utilization rates and/or greater ability to extract energy from wind, leading to lower costs on an output basis. Furthermore, the same technologies that improve the economics of utilizing poor wind resources will likely benefit the economics of utilizing better wind resources (although perhaps not proportionately), thus reinforcing the relative attractiveness of high-speed wind regimes.

Market pressures of deregulation also will tend to lessen the value of low-quality local resources relative to the high-quality resources that are abundant in a few, well-defined geographic regions of the country. In a regulated market, wind resources are more likely to compete against a finite set of local generation options, and the value of reducing the cost of class 3 or 4 winds to compete with some locally high-cost conventional resources may be well justified. However, in a deregulated market, low-quality wind resources have to compete against low-cost conventional technology and wind resources from a much broader geographical area. Finally, the credit-trading process associated with the RPS provision of this legislation will create further market pressures to meet the target by utilizing high-quality resources located anywhere in the country in preference to lower-quality local resources.

[32] One of the reasons why the High Renewables Case is "less likely" is that, in this scenario, fossil technologies improve only at Reference Case rates.

Photovoltaics. Section 1221 of S. 1766 directs the Department of Energy to "conduct balanced energy research, development, demonstration, and technology deployment programs to enhance the use of renewable energy." The program goal stated in Section 1221 for the photovoltaic program is to develop, in partnership with industry, total photovoltaic (PV) systems with installed costs of $4000 per peak kilowatt by 2005 and $2000 per peak kilowatt by 2015. PV systems produce electricity by the direct conversion of solar rays to electricity through a semi-conductor cell.

In the case of customer-sited PV systems, unsubsidized installed prices for on-grid systems currently range from $7,000 to $12,000 per peak kilowatt.[33] At the other end of the price spectrum, Sacramento Municipal Utilities District (SMUD) has reported total installed costs to the customer as low as $3,500 per peak kilowatt. In addition to price advantages due to large volume purchases, the SMUD program includes subsidies in the form of an additional "buy down" provided through SMUD's Public Goods Funds with some additional financial support provided to SMUD through the U.S. DOE/Utility PhotoVoltaic Group TEAM-UP program.[34]

The feasibility of reaching the S.1766 cost goals for PV systems depends on the intended scope of the goals. The 2005 goal of $4,000 per peak kilowatt does not seem within reach if purchases are not subsidized, though subsidy programs such as SMUD's, or State and/or local incentives such as California's cash rebates of up to $3.00 per watt may help to meet the goal. A reduction of 50 percent or more – from current levels of $7,000-$12,000 to $4,000 per peak kilowatt – in the installed costs for widely available, unsubsidized PV systems seems unlikely by 2005.

Reaching an installed cost of $2000 per peak kilowatt by 2015 would require significant cost reductions, over and above any potential subsidies. The 2015 goal specified in S.1766 represents an average cost reduction of 9 percent per year from 2001 to 2015 using a representative, current retail price of $8000 per peak kilowatt. Using the lowest installed costs to the customer reported by the SMUD PV program, which includes subsidies, still requires an annual cost reduction of at least 4 percent to meet the 2015 goal. Substantial declines in the price of PV systems are not unprecedented. The lowest price for PV systems in 1995 was less than half the system price in 1985. However, with the expiration of Federal tax credits in 1985, PV systems were no longer competitive with purchased electricity in most instances, and an increasing share of U.S. PV module production has been exported. Conversely, unsubsidized system prices have recently seen little decline due to increased worldwide demand for PV modules and constrained manufacturing capacity. Prices for balance-of-system components (e.g. inverter, installation and wiring) that account for about half of the system costs have remained stable as well. The longer the current trend continues, the steeper price declines must be -

[33] Maycock, P., and W. Bower, *The 2000 National Survey Report of Photovoltaic Power Applications in the United States*, The International Energy Agency Co-Operative Programme on Photovoltaic Power Systems, April 2001.
[34]Ibid.

in both module and balance-of-system components - in order to realize the 2015 cost goal, making its achievement even more difficult.

Utility-scale PV systems, also called “Central Station PV” can achieve somewhat better economies-of-scale than roof-top systems, and thus have considerably lower system costs. However, while these systems achieve lower costs, they also must compete against considerably lower “wholesale” power costs (that is, power costs at the transmission bus-bar), rather than the retail costs that customer-sited systems compete against. Because of their prohibitive cost relative to other wholesale power options, there has been little market demand for central-station PV. However, EIA estimates system costs for such a configuration are already below the $4,000/kW target set for 2005. EIA further expects that continued demonstration projects and other subsidized installation of these systems could be sufficient to reduce costs to about $2,300/kW by 2015, although even this cost is not likely to make these systems competitive on an unsubsidized basis in the wholesale market. Given the apparently poor prospects for central-station PV, it is uncertain whether sufficient market activity (including demonstration and other subsidized projects) in this sector would actually occur to realize the projected price path. However, if such market activity does occur, it is plausible that a successful research and development program on top of normal market learning could reduce costs to the $2,000/kW target for 2015, at which price the systems would still likely be uncompetitive in a deregulated wholesale power market. Niche applications for PV will remain, in remote areas lacking access to electric system infrastructure, in remote communication relay stations, and in electronic equipment.

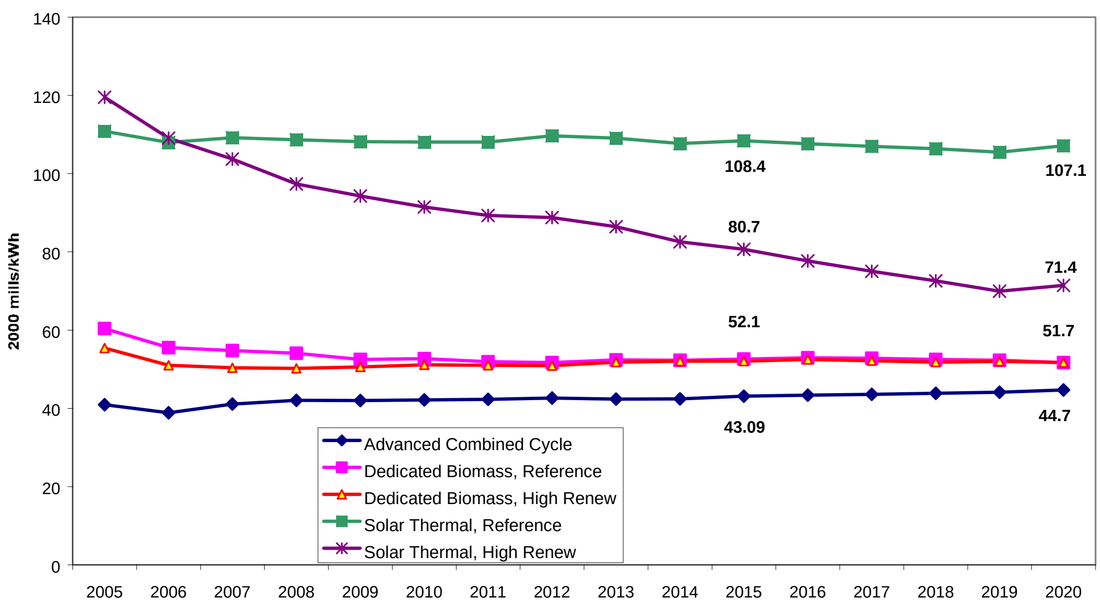
Solar Thermal. The goal of the solar thermal electric systems program is “to develop, in partnership with industry, solar power technologies (including baseload solar power) that are competitive with fossil-fuel generated electricity by 2015, by combining high-efficiency and high-temperature receivers with advanced thermal storage and power cycles.”

Solar thermal electric power systems, also called concentrating solar power (CSP), is a class of technologies that concentrate solar rays to produce thermal power generation (such as through a steam turbine or other external-heat source engine). It has several operating characteristics that make it an attractive technology relative to photovoltaic technology; in particular, it has a higher conversion efficiency (the ratio of “watts out” to “watts in”), can easily incorporate thermal storage to improve dispatchability (that is, for some additional cost, it can be used when needed rather than just when the sun is shining), and it can also easily incorporate a back-up fuel source. However, relative to fossil-based generation technologies, CSP faces substantial economic hurdles.

Currently, only one commercial solar thermal plant exists in the U.S. (actually a series of small facilities generally considered to be a single plant), which was constructed, under heavy subsidies, in California during the 1980s. Several technologies are undergoing research and development efforts to address key developmental barriers, especially cost. EIA currently estimates the levelized cost of a new "commercial" CSP unit at about 12 cents per kilowatthour. Total overnight capital costs for the technology are $2,539/kW (2000 dollars). With no near-term commercial growth expected with current costs, EIA expects cost declines to primarily come from continued research, development, and demonstration activity. Based on the currently projected level of activity, and assuming no change in the cost and performance basis of the technology, EIA expects the cost to decline to about 10 cents per kilowatthour late in the forecast (all costs in year 2000 dollars). If the cost and performance targets of the EE/EPRI Renewable Energy Technology Characterizations report could be met (especially the addition of significant storage),[35] the 2015 cost could be as low as 7 cents per kilowatthour (Figure 2). At this time, EIA projects the cost of advanced combined cycle units remaining at just over 4 cents per kilowatthour by 2015. Reference Case projections for solar thermal technology imply about a 1 percent per year cost decline; DOE projections imply about a 3 percent per year cost decline; by comparison, the S. 1766 goal of cost-competitiveness implies a cost decline of about 7 percent per year.

With no new commercial installations for over a decade and little recent demonstration activity, it is difficult to accurately gauge the potential for such significant, sustained cost

Figure 2. Comparison of Levelized Costs, Advanced Combined Cycle with Dedicated Biomass and Solar Thermal, 2005-2020



Source: Energy Information Administration, Annual Energy Outlook 2002, runs AEO2002.D102001B and HIRENEW02.D102301A.

[35] Assumed in EIA's High Renewables case.

decreases or to estimate the possibility of a single "breakthrough" advance that could result in such a decline. Much of the cost improvement forecast in the EE/EPRI cost projections (which are half the legislative target) relies on integration of thermal energy storage into the systems. Given the inefficiencies, both economic and performance, inherent in all energy storage systems, achievement of these targets seems unlikely in the 2015 timeframe.

Biomass Power. Section 1221 (b)(4) further states, "The goal of the biomass program shall be to develop, in partnership with industry, integrated power-generation systems, advanced conversion, and feedstock technologies capable of producing electric power that is cost-competitive with fossil-fuel generated electricity by 2010, together with the production of fuels, chemicals, and other products under paragraph (6)".

DOE's Biopower program is working with industry to reach the following goals: "Improve the efficiency of the energy system; Ensure against energy disruptions; Promote energy production and use in ways that respect health and environmental values; Expand future energy choices; and Cooperate internationally on global issues". The technologies being considered are biomass cofiring, biomass gasification, and modular biomass systems.[36] Additional program areas include bioenergy feedstock development and technology supporting elements (which includes energy conversion research, regional biomass energy programs, international activities, and a bioenergy initiative).[37] DOE estimates that this would result in 45,000 MW of new biomass capacity by 2020 (cofiring 26,000 MW, industrial pulp and paper 7,000 MW, biomass gasification 6,000 MW, and modular systems 6,000 MW). The EIA S.1766 RPS Case indicates that by 2020 biomass capacity is projected to grow to approximately 24,600 MW,[38] or 55 percent

[36]Biomass cofiring involves mixing biomass with coal in an existing feed system and burning them together in a boiler, or providing a separate boiler feed system for the biomass. The effect of cofiring is that the biomass displaces some coal. Biomass gasification involves heating biomass in an oxygen-starved environment to produce a medium or low calorific fuel gas. This fuel gas is then used in a combined cycle power generation system that includes a gas turbine topping cycle and a steam turbine bottoming cycle. Modular biomass systems are advanced biomass conversion systems with capacities of less than 5 MW. Various biomass conversion technologies are being assessed to fuel micro-turbines, Stirling engines, gas engines, and fuel cells.

[37] "DOE Biopower Program: A Strategy for the Future", September 2000, available at http://www.eren.doe.gov/biopower/bplib/library/biopower_strat_plan_for_web_ver_2.pdf. This represents biomass IGCC capacity, industrial pulp and paper capacity, biomass cofiring capacity, and modular biomass capacity. It should be pointed out that in the FY03 budget, DOE's research and development program in biomass cofiring and bioenergy feedstock development have been zeroed out. The impact that this would have on achieving DOE's program goals is uncertain.

[38] NEMS does not calculate a capacity value for biomass cofiring since it is assumed to take place at existing coal-fired power plants where the biomass is used to augment the coal thereby increasing generation but not capacity. Therefore, in order to compare the NEMS projections to the DOE program goals a calculation has been made to convert generation due to biomass cofiring to an equivalent capacity number. The assumption made in these calculations is that the capacity factor of the plant combusting biomass in a cofiring application would be 80 percent. Therefore, for example, in the AEO2002 Reference Case, by 2020, biomass cofiring generates 4.03 billion kWh of electricity. Assuming an 80 percent capacity factor, this translates to 4.03×10^9 kWh/{8760(0.8)} hrs = 575,060 kW of equivalent capacity, or 0.58 GW of equivalent capacity. In the AEO2002 Reference Case, dedicated biomass capacity by 2020 = 1.97 GW and industrial cogeneration biomass capacity = 8.43 GW. Therefore, total biomass capacity =

of DOE's capacity goal.[39] The AEO2002 Reference Case, which represents an unsubsidized growth scenario, shows biomass capacity at about 11,000 MW by 2020, or 24 percent of DOE's capacity goal. In the AEO2002 High Renewables Case, which represents a more optimistic resource availability scenario, biomass capacity grows to about 13,000 MW or 29 percent of DOE's capacity goal. An examination of the corresponding levelized costs for biomass and gas-fired advanced combined cycle technology (Figure 2, p. 16) indicates a persistent cost differential over the forecast period. Therefore, both DOE's capacity goal of 45,000 MW and the legislative goal of cost-competitiveness appear difficult to achieve over the mid-term.

Geothermal Technology. The goal of the U.S. DOE's geothermal program is "to develop, in partnership with industry, technologies and processes based on advanced hydrothermal systems and advanced heat and power systems, including geothermal heat pump technology, with a specific focus on (A) improving exploration and characterization technology to increase the probability of drilling successful wells from 20 percent to 40 percent by 2006; (B) reducing the cost of drilling by 2008 to an average cost of $150 per foot; and (C) developing enhanced geothermal systems technology with the potential to double the useable geothermal resource base."

These goals echo program goals that have been pursued for a number of years. And progress in increasing success rates and lowering drilling costs appears to be occurring. However, the highly ambitious goals, the scale of current public R&D investment, and minimal commercial geothermal growth all suggest the difficulty in meeting the S.1766 geothermal R&D goals within the demanding time constraints described above. Breakthroughs necessary to double the successful geothermal drilling rate by 2006 have yet to be identified or demonstrated. Prospects of cutting drilling costs 50 percent in eight years - from an estimated $300 per foot today – appear difficult to achieve.

Biofuels (Cellulose Feedstocks). S. 1766 includes a research program to improve conversion technology for cellulose feedstocks. The stated goal is liquid or gaseous fuel that is cost competitive with petroleum-based fuels. EIA incorporates the use of biomass for electricity generation and ethanol production in the *Annual Energy Outlook 2002* (AEO2002).

Table 4 summarizes two sets of assumptions about cellulose ethanol technology. The Reference Case assumptions are those that EIA thinks are most likely. The high technology assumptions are more optimistic and are part of the AEO2002 High Renewables side case. This analysis assumes that the excise tax exemption for blending ethanol into gasoline remains in place from 2005 through 2020 at a nominal $0.51 per

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1.97 + 8.43 + 0.58 = 10.98 GW, or about 11,000 MW. Note however, that industrial cogeneration biomass likely is not of the character envisioned by S. 1766, so that the amount of qualifying biomass is less than 11,000 MW. Similar calculations are made for the AEO2002 High Renewables Case and for the S.1766 RPS Case, in all cases assuming a plant capacity factor of 80 percent for biomass cofiring plants.

[39] EIA's dedicated biomass plants are modeled as 40 percent efficient, with nth of a kind overnight capital costs of $1,303/kW by 2020.

Table 4. Cost Analysis of Cellulose Production

Element	Reference 2010	Reference 2020	High Renewables 2010	High Renewables 2020
Conversion Rate (gal/ton feedstock)	100	103	110	120
Feedstock (per gallon)	$ 0.18	$ 0.15	$ 0.25	$ 0.18
Operating costs (per gallon)	$ 0.45	$ 0.41	$ 0.37	$ 0.28
Capital costs, including return to capital (per gallon)	$ 0.39	$ 0.37	$ 0.35	$ 0.32
Plant gate price of cellulose ethanol (per gallon)	$ 1.02	$ 0.93	$ 0.97	$ 0.78
Plant gate price of ethanol (per gallon gasoline equiv.)	$ 1.53	$ 1.40	$ 1.46	$ 1.17
Ethanol blenders' tax credit (per gallon gasoline equiv.)	$ 0.60	$ 0.45	$ 0.60	$ 0.45
Effective price of ethanol to blenders (per gallon gasoline equiv.)	$ 0.93	$ 0.95	$ 0.86	$ 0.72
Refinery Gate Price of motor gasoline (per gallon)	$ 0.91	$ 0.96	$ 0.91	$ 0.96

Source: Energy Information Administration, Annual Energy Outlook 2002, runs AEO2002.d102001B, and HIRENEW02.D102301A

gallon of ethanol blended.[40] Because ethanol has only about 2/3 the Btu content of gasoline, the equivalent of a gallon of gasoline for use in an internal combustion engine is 1.5 gallons of ethanol.

Cellulose ethanol cannot compete on price with gasoline without the aid of the blenders' tax credit. With the tax credit, cellulose ethanol's effective price to buyers is projected to be $0.01 per gallon less than gasoline in 2020 under the Reference Case. Under the high renewable case, cellulose ethanol's effective price is projected to be $0.05 lower in 2010 and $0.24 lower per gallon gasoline equivalent in 2020. While cellulose ethanol could be described as price-competitive under these conditions, it cannot be said to be cost-competitive, because the equivalent amount of ethanol costs more to produce than gasoline regardless of time and technology. The subsidy is required to make ethanol price-competitive.

Higher conversion rates could result from the proposed research program, but the conversion rates and capital costs assumed in the high renewable case already reflect an ambitious research program. It appears difficult to meet the goal of cost-competitiveness with gasoline.

<u>Hydrogen-based Fuels</u>. The S. 1766 goals for the hydrogen program are modest, "to support research and development on technologies for production, storage, and use of hydrogen, including fuel cells and, specifically fuel cell vehicle development."

Much work, however, remains before hydrogen production can be pursued efficiently. Currently most of the hydrogen used in industrial processes is produced from natural gas through a steam reforming process for about $7 to $8 per million Btu, several times more than the natural gas itself. New photobiological and photoelectrochemical (PEC) processes for producing hydrogen are being researched and tested: one recent PEC

[40] Currently the excise tax exemption is $0.53 per gallon of ethanol, scheduled to be reduced to $0.52 in 2003, and $0.51 in 2005. Costs and prices are in year 2000 dollars.

water-splitting test yielded 12 percent efficiency using concentrated light.[41] Hydrogen storage systems for transportation also face significant economic challenges. Hydrogen has very low energy density at normal temperature and pressure conditions and consequently, mobile fuel tanks will have to operate at very high pressure. "No approach currently satisfies all the efficiency, size, weight, cost, and safety requirements for transportation or utility use,"[42] though research is continuing. Hydrides are capable of storing hydrogen at sufficiently high density, but additional research into appropriate alloys which would release the hydrogen at low temperatures is necessary. In the long run, beyond 2020, hydrogen could be an important source of energy in the United States, but in the near term, economic applications do not seem likely.

Hydroelectric Power. S. 1766 Subtitle B, Section 1221 (b)(8) sets the goal "to develop, in partnership with industry, a new generation of turbine technologies that are less damaging to fish and aquatic systems."

The Department of Energy is partnering with industry and progressing in developing turbines that are less damaging to fish and aquatic systems. Because S.1766 is very general and without explicit deadlines, current progress appears to meet the stated goal for hydroelectric turbine advances.

Electric Energy Storage and Efficiency. Paragraph (9) of Section 1221 envisions several types of R&D projects whose goal is to develop, in partnership with industry, advanced technologies to increase the efficiency of electric transmission, to make better use of distributed generation resources, to develop superconducting materials for use in transmission, distribution cables, and generation, and to develop real-time system control technologies linking generation, transmission, distribution, and end-use consumption. These technologies generally seek to reduce losses associated with generation and transmission of electric power, thereby reducing fuel use and emissions associated with fuel combustion.

Of these technologies, superconductivity holds the most promise for yielding significant efficiency gains. Before the discovery of high temperature superconductive materials in 1986, superconducting materials had to be cooled to below –400° F; more recently, materials with the appropriate superconductive properties have been developed at temperatures near –200° F, an advancement that reduces cost by replacing liquid helium with relatively inexpensive liquid nitrogen. Developing cost-effective, long-length superconducting ceramic wire represents the biggest challenge and potentially the biggest return.

Many of these technologies have been successfully demonstrated and several have recently received DOE support for field testing and development. For example, a 77 megawatt ampere (MWA) pre-commercial superconducting cable system will be installed in a substation on Long Island, N.Y., to demonstrate that long-length

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[41] http://www.eren.doe.gov/hydrogen/research.html. The same process yielded about 8 percent efficiency using sunlight.

[42] http://www.eren.doe.gov/hydrogen/research.html.

superconducting cable can reliably improve power delivery in congested urban areas. In Ohio, a 1000-foot long, 3-phase, superconducting cable will be installed at the AEP substation at Bixby Road, in Columbus, replacing an existing oil-filled, underground power cable with limited current-carrying capacity.[43] And in Detroit, 14,000 customers of Detroit Edison are served in part by 1,200 feet of superconductive cable routed through the Frisbie Substation as of May 2001.

The cost of superconductive materials is quite high. American Superconductor, which supplied the wire for the Frisbie Substation project, sells the wire for about $200/meter; copper wire with similar capacity features sells for about $25/meter.[44] It is possible that high-temperature superconductive materials could be deployed in some high value applications,[45] but further cost reductions will be needed to permit broad applications in the mid-term.

Fossil Energy (Subtitle C, Sections 1231 and 1232)

S. 1766 distributes R&D for fossil energy over three main areas: core research designed to reduce emissions associated with fuel combustion for electricity generation, oil and gas exploration—both onshore and offshore—and transportation fuels. Total authorization for these activities in FY 2003 is $485 million, and over the period FY2003 to FY2006, the authorization is $2.083 billion. Additionally, the Power Plant Improvement Initiative is authorized $200 million in each Fiscal Year 2003 to 2011. Total authorization for these R&D activities is $3.91 billion over the period FY2003 to FY2011.[46]

<u>Electricity Generation</u>. The goals of the R&D program for core fossil energy research are to reduce emissions by developing technologies with the following capabilities by 2015: electricity generating efficiencies of 60 percent for coal and 75 percent for natural gas; combined heat and power thermal efficiencies of more than 85 percent; fuels utilization efficiency of 75 percent for the production of liquid transportation fuels from coal; near zero emissions of mercury and other emissions; reduction of carbon dioxide emissions by at least 40 percent through efficiency improvements and 100 percent with sequestration; and improved reliability, efficiency, reductions of air pollutant emissions, or reductions in solid waste disposal requirements.

Technologies such as advanced gasification combined-cycle, pressurized fluidized bed, and gasification fuel cell generating units may lead to significant improvements in efficiency. Fluidized-bed combustion evolved from efforts to find a combustion process able to control pollutant emissions without external emission controls (such as scrubbers). Prior R&D[47] led to the initial market entry of first generation pressurized fluidized bed technology, with an estimated 1000 megawatts of capacity installed worldwide. These

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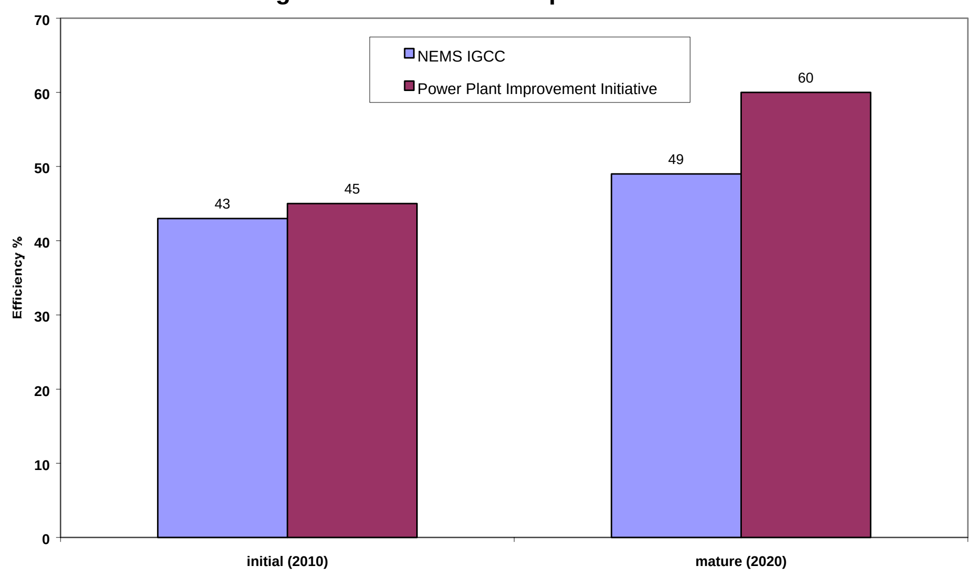
[43] http://www.energy.gov/HQPress/releases01/seppr/pr01161.htm
[44] Guy Gugliotta, "A Milestone Moment for an Energy Bonanza?" *The Washington Post*, May 20, 2001, page A3.
[45] Motors, generators, and cable on ships, or as superconducting filters used to boost ground signals for cellular telephones.
[46] Includes $27 million in FY 2003 and FY2004 for exploring mining research priorities.
[47] Clean Coal Technology Program.

systems pressurize the fluidized bed to generate sufficient flue gas energy to drive a gas turbine and operate it in a combined-cycle. A second generation pressurized fluidized bed combustor, currently under development, uses "circulating fluidized-bed" technology and a number of efficiency enhancement measures. Circulating fluidized-bed technology has the potential to improve operational characteristics by using higher air flows to entrain and move the bed material, and recirculating nearly all the bed material with adjacent high-volume, hot cyclone separators. Second generation pressurized fluidized bed combustion is expected to achieve a 52 percent fuel-to-electricity efficiency level and have near-zero emissions of nitrogen oxides, sulfur dioxide, and particulates. Market entry is projected for 2008.

The DOE Advanced Turbine System effort, in support of central electric power systems, is developing advanced technologies that enhance the efficiency and environmental performance of utility-scale gas turbines. The utility-scale Advanced Turbine Systems program objectives call for 60 percent efficiency or more in a combined-cycle mode, nitrogen oxide emission levels less than 9 parts per million, and a 10 percent reduction in the cost of electricity; these goals have already been met under full speed, no load conditions.[48] Completion of prototype system testing to evaluate combustion, heat transfer, and aerodynamic design under actual operating conditions was scheduled for 2001. Commercial units are scheduled for market entry in 2002 to meet increasing demands for natural gas-based power.[49] Additionally, DOE's Vision 21 program is working for breakthrough R&D that would enable the S.1766 goal of 60 percent

Figure 3. Power Plant Improvement Initiative



Source: Energy Information Administration, Assumptions to the Annual Energy Outlook, Table 38, and S. 1766, section 1232.

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[48] U.S. Dept. of Energy, Office of Fossil Energy, National Energy Technology Laboratory, *Advanced Turbine Systems*, Washington, DC, November 2000.
http://www.netl.doe.gov/publications/brochures/pdfs/scng/ATS_Brochure.pdf
[49] http://www.fe.doe.gov/coal_power/turbines/index.shtml

efficiency for coal and 75 percent efficiency for natural gas, with near zero emissions.[50] Note that 60% efficiency in an integrated coal gasification generator would require efficiencies greater than the 60% combined-cycle efficiency demonstrated in 1999.

EIA includes these technologies in its modeling and analyses.[51] Integrated coal gasification (IGCC), the most efficient coal technology, achieves some market penetration in the AEO2002 Reference Case in the period after 2010. Because new natural gas-fired plants are much more economical, coal's contribution to new capacity is 14 GW by 2015, of which about 2 GW are IGCC. The IGCC technology modeled in the Reference Case has an overnight capital cost of $1,338/kW and reaches an efficiency of about 49 percent, far below the stated goal of 60 percent (Figure 3, p. 21). In the AEO2002 High Fossil Case, DOE's Vision 21 goals are modeled,[52] and IGCC penetration improves to 34 GW by 2015. If the efficiency improvements stated in S.1766 could be achieved and widely deployed, the carbon reduction goals (40 percent reduction) could be achievable. The 60 percent efficiency goal for coal implies carbon emissions of 323 pounds per MWh output, and the 75 percent goal for natural gas implies an emission rate of 145 pounds per MWh. Both of these rates are far below the most efficient technologies currently modeled in NEMS, which models efficiency under actual operating conditions in the field, rather than test conditions.

Oil and Gas Extraction. The goals for the oil and gas resources programs are to speed technological advances for exploration and production of domestic petroleum resources, both onshore and offshore, especially in the ultra-deepwater of the Gulf of Mexico. Effective use of improved exploration and production technologies has aided the discovery and development of oil and natural gas resources. Major advances have occurred in data acquisition, data processing, and the display and integration of seismic data with other geologic data. These advances, combined with lower cost computer power and experience gained with new techniques, continue to put downward pressure on costs while significantly improving finding and success rates. Some drilling technological improvements include horizontal drilling, fracturing, polycrystalline diamond compact drill bits, and coiled tubing. In addition, new rig designs, such as jackup rigs, semisubmersible drilling rigs, and modular rigs, have enabled drilling in ever deeper offshore waters of the Gulf of Mexico. Other technologies, such as 3-D seismic, 4-D seismic, and remote sensing, have boosted success rates as well as allowed the targeting of higher quality prospects, thus improving the overall well productivity and finding rate. Although many of these technologies have been around since the 1970s, further improvements and refinements have been necessary to allow them to penetrate the industry and become more widely used. Some emerging technologies, such as micro drilling technologies, smart drill pipe technology, tight sands sweet spot detection, and neural net interpretation technology, as well as continued advances in reservoir analysis

[50] http://www.fe.doe.gov/coal_power/vision21/index.shtml. In S. 1766, the Power Plant Improvement Initiative, Subtitle C, Section 1232.
[51] http://www.eia.doe.gov/oiaf/aeo/assumption/pdf/0554(2002).pdf, Table 38.
[52] IGCC modeled as 60 percent efficient and overnight capital costs are reduced by 34 percent from reference. Advanced combined cycle modeled as 70 percent efficient, with similar capital costs to Reference Case.

and stimulation techniques, are expected to improve the development of crude oil and natural gas resources for some time to come.

Although oil and gas research and development programs have contributed to the advancement and deployment of innovative technologies, it is difficult to quantify the impact. One reason is that not all technological advancements that have had significant impact on oil and gas exploration and development, such as improved computer technology, were funded through oil and gas research and development. However, continued investment in oil and natural gas research and development programs will help in the discovery, development, and deployment of future technological breakthroughs as well as the advancement and penetration of current oil and gas technologies.

Transportation Fuels. S. 1766 to focus research on reducing the cost of producing transportation fuels from coal and natural gas, and through indirect liquefaction of coal and biomass.

Liquid fuels have long been produced from coal; however the cost of producing useful liquid fuels from coal (the sum of feedstocks, conversion, and refining) has typically been much higher than the costs of petroleum products derived from the refinement of crude oil. For the last thirty years, the world oil price has remained low enough to deter large-scale production of coal liquids, primarily because of the tremendous quantities of low-cost crude oil reserves available in those Organization of Petroleum Exporting Countries (OPEC) member States of the Persian Gulf. Producers in these countries currently have a reserve-to-production ratio in excess of 85 years with average production costs of approximately $1.50 per barrel.[53] In 1999, OPEC's Persian Gulf producers accounted for 27 percent of total world oil production and an estimated 30 percent of the world's production capacity. As a result of relatively low world oil prices, large-scale production of liquid fuels from coal primarily has been limited to situations where countries have been isolated politically from the rest of the world, and, therefore, lacked access to world oil markets.

Non-fuel production of coal-derived liquids generated as a byproduct of coke-making (e.g., solvents, wood preservatives, and coal-tar dyes) dates back to the 1840s with operations in both Germany and the United Kingdom, while large-scale production of coal liquids for transportation fuels is more recent, dating back to the beginning of World War II (WWII) with the operation of large-scale coal-to-liquids plants primarily in Germany but also in the United Kingdom.[54] By the end of WWII, Germany's nine indirect and 18 direct liquefaction plants were producing approximately 4 million tonnes of liquids per year, satisfying 90 percent of Germany's total petroleum consumption. Following WWII, the political isolation of South Africa from the 1950s through the mid-1980s led to the development of a sizeable coal-to-liquids industry there. At its peak, the

[53] Energy Information Administration, *International Energy Outlook 2001*, DOE/EIA-0484(2001) (Washington, DC, March 2001), pp. 34-35

[54] UK Department of Trade and Industry, *Coal Liquefaction*, Technology Status Report 10 (London, UK, October 1999).

combined output of South Africa's three coal-to-liquids facilities reached approximately 10 million tonnes of liquid transportation fuels per year, supplying as much as 60 percent of the country's annual requirements.

In the United States, a dramatic rise in the world oil price following the Arab oil embargoes in the mid- to late-1970s prompted a considerable amount of research in the area of coal-to-liquids production technologies; however, none of the processes was deployed commercially. The sudden collapse of world oil prices in the mid-1980's led to the abandonment of most of the pilot and process development scale coal-to-liquid facilities built in the United States during the 1970s and early 1980s. Additionally, the U.S. Synthetic Fuels Corporation (SFC), a quasi-public corporation established by the U.S. Government in 1980 to help fund development of both liquid and gaseous synthetic fuels technologies, was terminated in 1985. Some of the most promising coal-to-liquids research undertaken in the United States from the late 1970s to the present include: the Solvent Refined Coal process (Gulf Oil), the Exxon Donor Solvent process, and the H-Coal process (Hydrocarbons Technologies Incorporated).

In general, coal liquefaction technology can be divided into two generic types: direct and indirect. Direct liquefaction is the reaction of coal with hydrogen (usually in the presence of some liquid solvent) to produce a synthetic crude oil, or syncrude. No intermediate gasification step is needed. Direct liquefaction, however, is a very difficult process to carry out, involving temperatures over 400°C, pressures of over one hundred atmospheres and an appropriate catalyst. The syncrude can be refined to produce gasoline, as well as diesel fuel and fuel oils.

Indirect liquefaction involves the gasification of coal to produce a mixture of carbon monoxide and hydrogen, called synthesis gas. The synthesis gas can then be converted into liquid hydrocarbons using one of several conversion technologies such as the Fischer-Tropsch liquefaction process or the Mobil Methanol-to-Gasoline (MTG) process. At present, the only commercial-scale coal liquefaction process in operation in the world is Sasol's indirect-Fischer-Tropsch-based process used to produce coal-based liquid transportation fuels in South Africa.

Coal-to-liquids technologies are not currently represented in NEMS; however, in response to a recent request from the U.S. Department of Energy's (DOE's) Office of Fossil Energy, work is underway to add this modeling capability. Recent reports completed for the Office of Fossil Energy by Mitretek Systems indicate that coal liquefaction should become viable if the world oil price rises to and remains above $25 per barrel.[55] The reports focus on the development of a coal-to-liquids coproduction plant (producing both coal liquids and electricity) where a slurry-phase Fischer-Tropsch indirect liquefaction reactor is placed between the coal gasification section and the combined cycle block of an Integrated Gasification Combined Cycle (IGCC) facility.

[55] D. Gray and G. Tomlinson, *Coproduction: A Green Coal Technology*, MP 2001-28 (report prepared for the U.S. Department of Energy's National Energy Technology Laboratory, March 2001); and D. Gray and G. Tomlinson, *Coproduction: Producing Electric Power and Ultra-Clean Transportation Fuels in One Facility*, MP 2000-39 (report prepared for the U.S. Department of Energy's National Energy Technology Laboratory, August 2000).

Recent DOE studies place the estimated cost of producing coal liquids at approximately $30 per barrel. Coal liquids, if they could be produced economically, would have a slight cost advantage relative to crude oil, in that the cost of upgrading coal liquids using conventional petroleum refining technologies is less than the cost associated with the refinement of crude oil. In the AEO2002, the world price of oil is projected to rise from $22.48 per barrel in 2000 (2000 dollars) to $24.68 per barrel in 2020 in the Reference Case.

Major hurdles facing the start-up of a U.S. coal-to-liquids industry are the high capital costs associated with the construction of a commercial-sized plant, and the fact that no such plants have yet been built in the United States. DOE estimates the capital costs of a coal-to-liquids facility with generating capacity of 1,000 megawatts and daily liquids production capacity of 33,200 barrels at approximately $2.2 billion. Thus, a U.S. coal-to-liquids industry capable of producing one million barrels of coal-derived liquids per day (equivalent to 17 percent of U.S. crude oil production and 11 percent of net crude oil imports in 2000) would require the construction of 30 such plants at a total capital cost of $66 billion. Total annual coal requirements for these 30 plants, taken as a whole, would approach 180 million tons for bituminous-grade coal, with additional quantities required for the conversion of lower ranked subbituminous coal or lignite. The potential impacts resulting from the additional supply of transportation fuels to the U.S. market would be some decrease in the U.S. dependence on foreign oil but would probably have little impact on gasoline or diesel fuel prices, absent a massive U.S. coal-to-liquids program. With world oil production currently in excess of 75 million barrels per day, an additional one million barrels of supply would have a small impact on the world oil price, and, subsequently, the price of gasoline at U.S. service stations.

Nuclear Energy (Subtitle D, Section 1241)

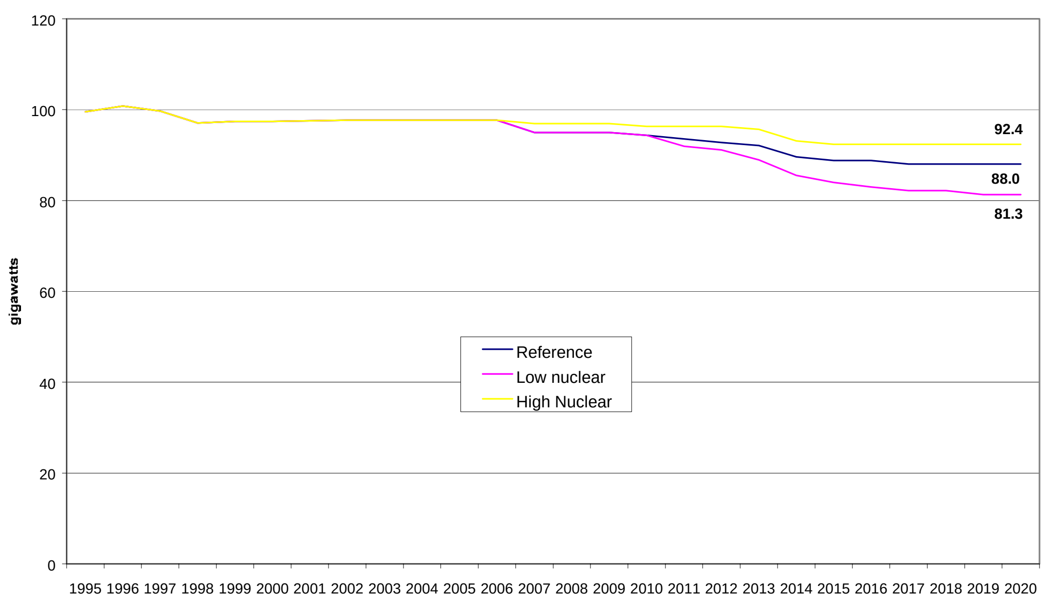
S. 1766 proposes R&D for nuclear energy in two main areas: core nuclear research programs, and supporting nuclear activities. Core research is related to extending lifetimes, increased reliability, and optimized operations, as well as new nuclear designs with higher efficiencies. Supporting nuclear activities are defined as research to produce medical isotopes, research to support future space and satellite missions, and maintaining a balanced nuclear R&D infrastructure. Total authorization for these activities in FY 2003 is $300 million, and over the period FY2003 to FY2006, the total authorized is $1.281 billion.

DOE's Office of Nuclear Energy budgeted $5 million in 2001 for its Nuclear Energy Plant Optimization (NEPO) program. Both S.1766 and H.R.4 propose to continue this program, and increase its funding. The goal of the NEPO program is to ensure that current nuclear plants can continue to deliver adequate and affordable energy supplies up to and beyond their initial 40-year license period by resolving open issues related to plant aging and by applying new technologies to improve plant economics, reliability, and productivity. NEPO is carried out cooperatively by DOE and the nuclear industry with joint management and cost sharing. Through increased R&D for existing nuclear plants, NEPO aims to increase generation from current reactors and to increase their operating lives.

Nuclear power plants achieved record power generation in 2000, with an average capacity factor of 88 percent, compared to less than 60 percent in the early 1980s. For the first 10 months of 2001, their average capacity factor reached 89 percent. The AEO2002 Reference Case assumes that current gains in productivity will be maintained through the short-term, and improved to a national average of 90 percent throughout the forecast. Much of the improvements have already been achieved through shortening outages for planned maintenance and refueling.

Without license renewal a large number of existing plants will reach the end of their current operating licenses by 2020. However, the Nuclear Regulatory Commission has created a streamlined procedure for license renewal applicants, and a total of six units have already obtained a 20-year renewal to their original license. Applications for another 17 units are currently under review, and another 25 units have indicated the intention to apply over the next 3 years.[56] While license renewal is a necessary step to operating beyond 40 years, it does not assure that they will continue to be economic generators throughout their extended lifetime. As nuclear units continue to age, components and structures age and material degradation may occur. Research will provide a better understanding of the potential aging problems, and the development of cost-effective aging management strategies. The AEO2002 Reference Case assumes that aging related

Figure 4. Nuclear Capacity in Three Cases



Source: Energy Information Administration, Annual Energy Outlook 2002, runs AEO2002.D102001B, LNUC02.D102201A, and HNUC02.D102201A.

[56] http://www.nrc.gov/reactors/operating/licensing/renewal/applications.html

costs of $50/kW/year will be incurred by nuclear operators each year after 30 years of operation, over and above normal operating and fuel costs. Retirements are then determined purely on an economic basis, comparing future operating costs of a nuclear plant to the cheapest available new technology. About ten percent of current nuclear capacity is projected to retire by 2020 (Figure 4, p. 26). The AEO2002 also includes cases based on alternative aging related cost assumptions for nuclear power plants, to address the uncertainties in this area. With no aging related costs, the High Nuclear Case projects only 5 percent of existing nuclear units would retire by 2020. However, with higher aging related costs (increasing from $50/kW/year after 30 years to $100/kW/year after 40 years in the Low Nuclear Case), an additional 9 units are projected to retire compared with the Reference Case.

S. 1766 also proposes increased funding for the DOE's Nuclear Energy Research Initiative (NERI), which had a budget of $35 million in 2001. The NERI program sponsors new and innovative research and development to address issues affecting the future of nuclear energy. The primary objective is to develop advanced reactor and fuel cycle concepts to expand future use of nuclear energy, and advance the technology to maintain a competitive position in overseas markets and a future domestic market. In developing cost estimates for new generating technologies, EIA uses currently available technologies, because it is impossible to include all potential future designs, even though R&D is occurring for all technologies. EIA does include learning assumptions, which reduce the costs of a given technology based on the amount of penetration in the market, and includes a minimum level of cost reduction even without new construction. In the Reference Case, new nuclear capacity of the AP600 type is not economic through 2020, given the currently available technology. A sensitivity case was run that used cost goals from the Office of Nuclear Energy that were much lower than the Reference Case assumptions, and in that case one new nuclear unit was projected to be built by 2020.

Research and development of new nuclear designs is being undertaken by private industry as well. For example, the pebble bed modular reactor (PBMR) is a 110 MW graphite-moderated, helium-cooled reactor that is planned for construction in South Africa. The joint venture is led by Eskom, the state-run utility in South Africa, and includes British Nuclear Fuels and Exelon, the largest U.S. nuclear utility. Exelon is in the early stages of applying with the U.S. Nuclear Regulatory Commission for a license for the PBMR design.

Overall, nuclear power currently accounts for 20 percent of electricity generation in the United States. It produces reliable electricity generation with no greenhouse gas emissions. In 2000, nuclear generation displaced roughly 180 million metric tons of carbon, 3.8 million tons of sulfur dioxide and 2.3 million tons of nitrogen oxide, assuming the displaced capacity was based on average fossil fuel generation. In evaluating the future impact on emissions, the replacement fuel for retiring nuclear plants is of key importance. Given technology costs and fuel prices expected over the next 20 years, they would likely be replaced by natural gas-fired, combined-cycle plants with relatively low emission rates, compared to coal plants. In the AEO2002, carbon emissions varied from 3 million tons lower to 6 million tons higher in the high and low nuclear life extension cases, relative to the Reference Case. Greater shifts in nuclear generation, either decreasing through increased retirements, or increasing through new construction, could have a bigger impact on future emissions.

Conclusions Related to R&D Provisions

In the past, research and development programs have helped to develop more efficient and advanced technologies at lower cost than might otherwise occur, and to reduce the costs and improve the operating characteristics of existing technologies. In addition to scientific R&D, there have been a number of information programs, voluntary programs, partnerships, and similar initiatives to encourage the penetration and adoption of improved technologies, some of which--fuel cells, turbine generators, seismic imaging and directional drilling, and coal bed methane production--appear to have achieved success. Together, these initiatives have contributed to improvements in energy production and efficiency, air quality, energy security, international competitiveness, quality of life, and a reduction of carbon emissions and other pollutants.

EIA incorporates the impacts of ongoing research, development, and deployment programs into its Reference Case, assuming support for these activities at historical levels. Therefore, changes in the funding levels of these programs or the rate of diffusion of R&D could alter projections of future energy consumption and emissions. In fact, the AEO2002 High Technology Case, incorporating more optimistic assumptions regarding R&D applications, projects an average annual growth in delivered energy consumption that is about 0.3 percent lower over the period 2000-2020 compared to the Reference Case.[57]

While recognizing the success of past and current research, development, and deployment programs, it is difficult to establish a quantitative relationship between levels of funding and specific improvements in the characteristics, availability, and adoption of energy technologies. By its nature, research and development is highly uncertain. Seemingly plausible avenues of research may not achieve success, though genuine breakthroughs remain possible. Further, if all technologies were to penetrate at the same rate, the relative dynamics of market performance would remain similar.

Some of the R&D goals of S.1766 seem feasible, if not already in evidence: while not deployed, vehicle fuel economies described in Section 1211 have already been demonstrated, and distributed generation technology, though not of the targeted efficiency, is already sited. Many existing nuclear generation units have demonstrated capacity factors that exceed the goals in Section 1241. Some of the program areas state goals which are both reasonable and possible given the progress of current technology, prevailing market conditions, and R&D funding levels. Many other goals, however, seem highly unlikely for a variety of reasons: dramatic cost reductions of hydrogen production, solar thermal technologies, and biofuels production would have to be realized before these technologies, absent national portfolio standards, would achieve much

[57] Energy Information Administration, *Annual Energy Outlook 2002* (DOE/EIA-0383(2002), Washington, DC, December 2001, Tables F1, F2 and F3.

penetration. In addition, the relative success of individual programs could have a large impact on the success of others. For example, if programs targeted at renewable fuels were extremely successful, it might prove difficult for programs targeted at fossil fuels to have much market impact.

Provisions Related to Renewal of the Price-Anderson Act

The Price-Anderson Act, first passed in 1957 as an Amendment to the Atomic Energy Act of 1954, and renewed three times since, will expire on August 1, 2002. The goals of the Price-Anderson Act were to ensure that adequate funds would be available to the public to satisfy liability claims in a nuclear accident, and to permit private sector participation in nuclear energy by removing the threat of potentially enormous liability in the event of such an accident. Each operator of a nuclear reactor is required to purchase the maximum liability insurance available from private insurers (currently $200 million), which serves as the primary insurance layer. Additionally, each operator may be required to pay into a pool up to $88 million, if needed to cover damages in excess of the primary insurance coverage. If coverage beyond the current $200 million primary layer is needed, all reactors are retrospectively assessed, not just the site where the accident occurred. Today, the total protection available in the event of a nuclear accident is over $9 billion. The nuclear industry is not responsible for any claims above the maximum liability set by the Act, although responding organizations may petition Congress for additional disaster relief. The Price-Anderson Act covers all currently licensed reactors throughout their lifetimes. However, any new units will not be covered after August 1, 2002, unless Congress approves a renewal of the Act. The Act also covers transportation of fuel to a reactor site, and transportation of nuclear waste removed from reactors.

The Act is essentially a subsidy to investors in nuclear power, because it limits the liability of the industry in the event of a nuclear accident, and the cost of the insurance required under the Act is much less than would be required by the insurance market for full coverage. EIA does not explicitly model this subsidy in NEMS or the costs of liability coverage for electricity generators, so we cannot quantify how much of a difference it would make to new nuclear investment if the Act were not renewed. However, the nuclear industry is actively lobbying for renewal, and it is widely perceived that no new nuclear plants would be built in the United States without the cap on liability provided by the Price-Anderson Act.[58]

S.1766 only extends the Price-Anderson Act for Department of Energy contractors, and not for private licencees. The extension for DOE contractors would cover, for example, future contracts for transporting nuclear waste to the Yucca Mountain storage facility. The lack of extension for civilian reactors means that existing reactors would remain covered, but any new nuclear capacity would be required to obtain full liability insurance at market rates. Although the proposed bill, S.1766, includes R&D provisions to stimulate new nuclear development, it does not provide potential investors the additional benefit of the Price-Anderson liability cap. Similarly, H.R. 4 includes proposals for increased R&D for nuclear power, but no mention of the Price-Anderson Act at all. A

[58] Rebecca Smith, "Nuclear Power: Revival or Relapse?" *Wall Street Journal*, May 2, 2001.

separate bill, H.R. 2983, the Price-Anderson Reauthorization Act of 2001, does specifically address renewal of the Act and nuclear safety issues. H.R. 2983 reauthorizes Price-Anderson for 15 years, until August 1, 2017. It also raises the liability amounts, and requires that they be adjusted for inflation every five years. Another important change is that small, modular reactors are treated as a single reactor under this proposal. Groups of modular reactors, of 100 to 300 MW each, that are located at the same site will be counted as one unit (up to 1,300 MW total) for liability insurance purposes. Without this provision, there would be a disadvantage to the modular designs, such as the pebble bed reactor under development in South Africa, because they would be required to purchase the maximum liability insurance for each individual module. For example, six 100 megawatt modules would be required to obtain six times the insurance of one 600 megawatt light water reactor.

EIA's AEO2002 reference case indicates that new nuclear power is not economically competitive with other electricity generating technologies through 2020. Although renewal of the Price-Anderson provisions would be beneficial, and probably necessary, to new nuclear power investment, it is not likely to be the primary factor in determining what types of new electricity generating capacity should be built in this time period. Passage of H.R. 2983, by itself, is not expected to result in new nuclear capacity, and therefore would not change future energy supply, demand, emissions or prices from current Reference Case projections.

Provisions Related to Hydroelectric Relicensing

Non-Federal hydroelectric facilities – such as privately or municipally-owned – are Federally-licensed by the Federal Energy Regulatory Commission (FERC) under the Federal Water Power Act of 1920 and successor acts, for periods up to 50 years. Federally-owned hydroelectric facilities – such as those of the U.S. Army Corps of Engineers, the U.S. Department of the Interior's Bureau of Reclamation, and the Tennessee Valley Authority – are exempt from the FERC licensing process. Overall, roughly half of U.S. hydroelectric generation (about 150 billion kilowatthours a year in 1999 and 2000) is provided by about 1000 licensed, non-Federal hydroelectric facilities.

Many expiring FERC hydroelectric licenses are now subject to relicensing. However, because of increased environmental and water use issues, the FERC-managed relicensing process has become long, complex, costly, and contentious. Water is a multipurpose resource, needed for urban water supply, industry, agriculture, transportation, environmental priorities, fishing, recreation, and other purposes in addition to energy needs. Water's use is significantly affected by multiple Federal, tribal, State, and local government interests. Critical Federal interests alone include the U.S. Department of the Army Corps of Engineers, the Bureau of Reclamation, the U.S. Fish and Wildlife Service, the U.S. Forest Service, the National Park Service, the National Marine Fisheries Service, the Bureau of Indian Affairs, and the Federal power marketing administrations (such as the Bonneville Power Administration). State and local agencies also play a role in relicense approvals.

FERC must balance these competing interests during relicensing, a process that requires coordination and is time consuming. According to the National Hydropower Association, relicensing typically takes eight to ten years, and results in changes in hydro facilities' structures, operations, and water use. Relicensed facilities often face additional costs in changing the amounts or timing of water storage and water use, and in adding structures to preserve fish species, to maintain appropriate water temperatures and oxygen levels, and to provide fishways to facilitate passage up and down stream.

Both S.1766 (Sections 301 – 308) and H.R.4 (Section 401) contain provisions that touch upon the relicensing process, mainly to increase interagency coordination with the FERC and to acquire additional information. S. 1766 provisions falling into this category include:

Section 302	Charges for Tribal Lands. Requires that licenses shall not be issued for projects on Indian lands until annual charges have been fixed.
Section 303	Disposition of Hydroelectric Charges. Redirects some annual license charges away from the general treasury to protection of water resources
Section 304	Annual Licenses. Requires the Commission to explain issuing annual licenses and indicate whether additional annual licenses are expected.
Section 305	Enforcement. Requires FERC to monitor and investigate the conditions of each hydroelectric licensing compliance order.
Section 306	Establishment of Hydroelectric Relicensing Procedures. Requires the Commission, together with the resource agencies (Secretaries of Agriculture, Interior and Commerce), to issue coordinated regulations governing the hydroelectric re-licensing process.
Section 307	Relicensing Study. Requires the Commission together with the resource agencies (Secretaries of Agriculture, Interior and Commerce) to prepare a study of all new licensing projects since January 1, 1994.
Section 308	Data Collection Procedures. Requires the Commission together with the resource agencies (Secretaries of Agriculture, Interior and Commerce) to develop data collection procedures to ensure that accurate information concerning the time and cost to parties of the hydroelectric licensing process are collected and maintained.

While these provisions might simplify or speed up the relicensing process, it is unlikely that they would noticeably increase U.S. hydroelectric capacity overall.

Other provisions, such as sections 401 of HR.4 and 301 of S. 1766, could impact hydroelectric capacity. These sections allow license applicants to propose less costly compliance alternatives to mandatory conditions imposed by other Federal agencies, in particular those to modify water use or to construct and operate fishways.

The impacts of section 401 in H.R. 4 and section 301in S. 1766 are difficult to quantify, especially until the study, procedures, and data collection called for in Sections 306, 307 and 308 of S. 1766 are complete. The proposals may speed up the re-licensing process for some U.S. hydroelectric facilities, and the opportunity to offer less costly alternative fishway compliance actions could help preserve or slightly increase output and profitability at some facilities. Though the results of the proposed studies could yield cost-effective improvements in the future, none of the hydroelectric provisions in HR.4 and S.1766 is likely, either alone or in concert with the other proposed changes, to significantly increase overall U.S. hydroelectric capacity or generation in the near future. Altogether about two-thirds of all U.S. hydroelectric capacity is unaffected by the proposed changes, either because it is Federal capacity not subject to licensing or because current FERC licenses do not expire for at least the next ten years. Most significantly, none of the proposals materially changes either the overall conditions or the costs of relicensing projects, and coordination requirements are not relaxed. Proposed fishway alternatives do not have to be accepted, and relicensed projects for which alternatives are accepted are still required to fully meet new fishway and other requirements. As a result, while the S.1766 and H.R.4 proposals can be expected to increase information about licensed projects and be helpful in the disposition of some charges by not materially changing either the process or the costs of relicensing, neither proposal materially changes prospects for future U.S. hydroelectric capacity.

Appendix A. Letters of Request from Senator Murkowski

12/20/2001 18:38 FAX 202 224 4068 ENERGY & NAT RES 002

United States Senate

COMMITTEE ON
ENERGY AND NATURAL RESOURCES
WASHINGTON, DC 20510–6150

ENERGY.SENATE.GOV

December 20, 2001

Dr. Mary Hutzler
Acting Administrator
Energy Information Administration
1000 Independence Avenue, SW
Washington, DC, 20585

Dear Acting Administrator Hutzler:

The Senate is considering comprehensive legislation to update U.S. national energy strategy in light of the volatility of energy markets in calendar year 2000 and the growing energy security concerns in light of recent events that highlight our dependence on foreign imported oil. To this end, there have been several legislative proposals introduced in the 107th Congress on the subject of national energy policy, and the Majority Leader has indicated that the Senate will debate energy policy early in the next session of Congress. Our decisions will benefit from an analysis of the strengths and weaknesses of the various energy policy proposals that have been introduced to date.

With that in mind, I request that the Energy Information Administration (EIA) analyze the potential costs and benefits of proposed legislation to update and revise our national energy strategy, namely, H.R. 4 as passed by the House of Representatives in August 2001, and S. 1766 as proposed by Senators Daschle and Bingaman earlier this month. I understand that EIA has the ability to conduct such analysis, including the use of both sectoral and economy-wide energy models. Using the most recent *Annual Energy Outlook 2002* as a reference case, I ask that EIA assess the impacts of these energy policy proposals on, at minimum:

- macroeconomic indicators (jobs, Gross Domestic Product, trade balance, etc.);
- energy supply and demand by fuel and process;
- energy prices to consumers (residential, industrial, and commercial) by fuel;
- dependence on foreign oil imports and impacts on energy security;
- impacts on energy infrastructure (transmission, pipelines, refineries, etc.); and
- emissions of greenhouse gases and air pollutants.

As the Daschle/Bingaman bill (S. 1766) contains several "placeholders" reserved for future legislative proposals, I ask that for the purposes of your analysis, you include for Section 801 of S. 1766, S. 804, introduced by Senators Feinstein, Snowe and Reed making changes to the Corporate Average Fuel Economy (CAFE) program. For Section 1821 of S. 1766, use the provisions contained in S. 1746, introduced by Senator Reid on nuclear facility security. Also, to ensure a consistent comparison, please exclude from your analysis of H.R. 4 the amendments to the tax code contained in Division C of that bill. I expect to request from EIA a follow-up analysis of the tax-related proposals contained in H.R. 4 and an expected Senate Finance Committee mark at a subsequent date.

When assessing the costs and benefits of these legislative proposals, please be sure to point out which specific policy actions have the most significant positive or negative impacts on the factors outlined above. In order to inform our deliberations on national energy policy which are due to begin in the next several weeks, I ask that the requested information be made available by January 23, 2002. In addition, I request that a briefing of your results prior to release of any written report.

If you have any questions regarding this request, or desire further clarification with respect to translating legislative proposals into assumptions you will use in your analysis, please contact Bryan Hannegan with my Senate Energy and Natural Resources Committee staff at 224-7932. Thank you for your timely attention to this request, and for your efforts to ensure that our Nation's energy policy decisions are informed with the best available analysis.

Sincerely,

Frank H. Murkowski

Frank H. Murkowski
Ranking Member

United States Senate

COMMITTEE ON
ENERGY AND NATURAL RESOURCES
WASHINGTON, DC 20510-6150

ENERGY.SENATE.GOV

February 6, 2002

Dr. Mary Hutzler
Acting Administrator
Energy Information Administration
1000 Independence Avenue, SW
Washington, DC, 20585

Dear Acting Administrator Hutzler:

As a follow-up to my letter of December 20, 2001 in reference to analysis of comprehensive energy legislation, please find below additional information to assist you in your analysis of key portions of S. 1766 and H.R. 4 identified as follows:

Renewable Portfolio Standard (RPS): For H.R. 4, assume no changes in current law. For S. 1766, assume a 2.5% mandate for new renewable electricity starting in 2005, increasing 0.5% each year through 2020 (10% new renewables by 2020). In addition, please provide analysis of a new scenario that reflects a 20% RPS by 2020 under the same provisions as in S. 1766. Key analysis questions include: whether or not such amounts of new renewable energy are possible with reasonable technology improvements, what renewable technologies benefit most, whether consumer retail electricity costs are affected by the RPS, and how the higher incremental costs of renewable electricity generation are absorbed by generators, utilities and/or consumers. Also, please describe the effect of the civil penalty imposed for failing to meet the RPS and whether that affects estimates of renewable electricity production, economic impacts, and macroeconomic effects.

Alaska Oil Production: For S. 1766, please provide your baseline Annual Energy Outlook 2002 (AEO) forecast without production from ANWR and compare it with several scenarios for H.R. 4: (1) median USGS ANWR production estimate and AEO 2002 world oil prices; (2) high-range USGS ANWR production estimate and AEO 2002 world oil prices; (3) high-range USGS estimate, using your "High Oil Price" side case; and (4) high-range USGS estimate, using your AEO 2002 "High Technology" side case that assumes rapid transportation technology development. Key variables to consider include the percentage of U.S. foreign oil dependence, and a summary of crude oil supply, demand, and disposition.

Alaska Natural Gas: For H.R. 4, assume no changes in law. For S. 1766, please analyze the impact of the proposed $10 billion loan guarantee (Sec. 6501-6512) on project economics and timing of construction assuming that the "over the top" route for the pipeline is prohibited (Sec. 701). Key analysis variables should include: the date at which natural gas from Alaska is first delivered to market in the Lower 48, the impact of the pipeline on the price of natural gas, and the sensitivity of these variables to higher or lower natural gas prices in the U.S. market.

Automobile Fuel Economy Standards (CAFE): For H.R. 4, assume increases in CAFE standards for model years 2004 through 2010 so as to decrease total gasoline consumption by 5 billion gallons over that period of time. For S. 1766, assume the adoption of provisions of S. 804 (Feinstein) – require 25 mpg for SUVs and light trucks produced between model years 2005 and 2007 and 27.5 mpg for SUVs and light trucks produced thereafter. Use as a reference case technology frozen at model year 2002 levels and performance, and assume further no change in fuel economy for passenger vehicles. Please analyze a second case which assumes a 5% increase in fuel economy standards over model year 2000 levels by model year 2005 for both passenger vehicles and SUVs/light trucks, with a further 5% increase for all vehicles by model year 2010. In all cases, please provide analysis on total net costs to consumers (e.g. up-front additional costs minus life-cycle fuel economy savings), macroeconomic effects on non-agricultural jobs, whether such fuel economy goals can be meet through reasonable technology assumptions, and estimates of carbon dioxide emissions.

Renewable Fuels/MTBE: For H.R. 4, assume no change in current law, and use the Annual Energy Outlook 2002 reference forecast as the base case. For S. 1766, assume a renewable fuel standard of 2.3 billion gallons renewable fuel by 2004 increasing per Section 818 of the legislation to 5.0 billion gallons by 2012. Include in your analysis of S. 1766 a ban on MTBE within four years and assume that, given the opportunity to opt out of the 2% oxygenate requirement, California RFG and East Coast RFG areas do so. Also, please analyze a third case where the renewable fuel standard is as proposed in Section 818 of S. 1766, but assume complete repeal of the 2% oxygenate standard, and that States are given the ability to ban MTBE if they wish starting in 2003 or 2004. Key analysis variables should include effects on motor gasoline and RFG prices and fuel imports, GDP, and energy expenses, and estimates of carbon dioxide emissions.

Air Conditioning/Heat Pump Standard: For H.R. 4, assume a 12 SEER/7.4 HSPF standard for air conditioners and heat pumps manufactured for Federal agency use only on or after date of enactment, and for S. 1766 assume a 13 SEER/7.7 HSPF standard enacted for all air conditioners and heat pumps manufactured on or after January 23, 2006. Key analysis variables include: electricity savings, net energy cost savings (increased up-front stock cost minus life cycle energy bill savings), and carbon dioxide emissions evaluated relative to the current 10 SEER standard.

Other Provisions: Pursuant to my letter of December 20, 2001, please also provide qualitative analyses for the following provisions:

Price-Anderson Act	S. 1766 (Sec 501-508) and H.R. 2983
Energy R& D	S. 1766 (Sec. 1211-1245) H.R. 4 (Corresponding provisions in Division B)
Other Consumer Product Standards	S. 1766 (Sec. 921- 929) H.R. 4 (Sec. 142-143)
Alternative Fuel Programs	S. 1766 (Sec. 811, 812, 814-819) H.R. 4 (Corresponding provisions in divisions A,B)
Hydro Relicensing	S. 1766 (Sec 301-308) H.R. 4 (Sec. 401- 402)

Pursuant to your conversations with my Energy Committee staff, I understand that your analysis will be issued in phases once available, starting with the Air Conditioning/Heat Pump Standard analysis delivered to me on January 23, 2002. As the Senate appears to be moving towards consideration of S. 1766 during the week of February 11th, I hope you can deliver as many of these phases as you and your staff are able to complete prior to that time and brief interested staff and Senators as appropriate at the earliest opportunity.

If you have any further questions regarding this request, or desire further clarification, please contact Bryan Hannegan with my Senate Energy and Natural Resources Committee staff at 224-7932. Thank you for your continued timely attention to this request, and for your efforts to ensure that our Nation's energy policy decisions are informed with the best available analysis.

Sincerely,

Frank H. Murkowski
Ranking Member