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Technology and Policy Options to Address Climate Change
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By

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Introduction: the Emerging Critical Role of Renewable Energy and Energy Efficiency

Mr. Chairman and members of the Committee, thank you for this opportunity to appear before you today to provide testimony on how renewable energy and energy efficiency technologies can address climate change. My name is Daniel Kammen, and I am Professor of Energy and Society in the Energy and Resources Group and in the Department of Nuclear Engineering, as well as Director of the Renewable and Appropriate Energy Laboratory (RAEL) at the University of California, Berkeley[1]. I am pleased to be able to present information on how to utilize the many important advances in renewable energy and energy efficiency technology, economics, and management for the formulation of a strong national climate change mitigation policy. This critical initiative is long overdue, and is particularly relevant today. The recent release of the IPCC Third Assessment Report[2] as well as the analysis by the National Academy of Sciences on climate change science[3] both conclude that climate change is real and needs to be addressed now. The clean energy technology options and policies I will discuss are needed to address the challenge of global environmental sustainability. Despite dramatic technical and economic advances, we have seen far too little R&D, and too few incentives and sustained programs to build markets for renewable energy technologies and energy efficiency programs. We stand today at a critical juncture where clean, low-carbon, energy choices make both economic and environmental sense, and where policy action can place us on a path to a clean energy future.

There is a growing understanding that an effective climate mitigation policy is also a responsible energy policy. I am concerned that the current crisis mentality pervading the discussions of energy issues in the country has fostered an ill-founded rush for "quick fix" solutions that, while politically expedient, will ultimately do the country more harm than good from both a climate change and an energy policy perspective. California's energy crisis has focused attention and raised fundamental questions about regional and national energy strategies. Rising demand suggests the need for new energy supplies. However, there is a wide range of options for achieving supply and demand balance, and some of these options have not being given adequate attention. It is clear that an energy policy weighted towards increasing the supply of traditional forms of energy will do little to decrease our greenhouse gas (GHG) emissions and will create a host of other environmental, health and national security problems.

In the last decade the case for renewable energy has become compelling economically, socially, and environmentally. For many years renewables were seen as environmentally and socially attractive options that at best occupied niche markets due to barriers of cost and available infrastructure. That situation has *dramatically* changed. Renewable energy resources and technologies – notably solar, wind, small-scale hydro, and biomass based energy, as well as advanced energy conversion devices such as fuel cells – have undergone a true revolution in technological innovation, cost improvements, and in our understanding and analysis of appropriate applications[4]. There are now a number of energy sources, conversion technologies, and applications, where renewable energy options are either equal, or better, in price and services provided than are prevailing fossil fuel technologies. For example, in a number of settings in industrialized nations, wind energy is now the *least cost* option across *all* energy technologies with the added benefit of being quick to install and bring on-line, as well as being modular. In fact, some farmers in the Midwest have found that they can generate more income per hectare from the electricity generated by a wind turbine on their land than from their crop or ranching proceeds. Furthermore, photovoltaic panels and solar hot water heaters placed on buildings across America can: dramatically shave peak-power demands; produce a healthier living environment; and increase our energy supply while managing our energy demand.

The potential for renewable energy technologies and energy efficiency to have a significant role in protecting our climate as well as our energy future is an example of the type of energy options that demand far greater examination and commitment to implementation than we have seen to date. And so, I am particularly pleased Mr. Chairman that you are holding this hearing to discuss how we can effectively and efficiently bring these technologies to market.

Energy Policy Recommendations

- **Increase Federal R&D Funding for Renewable Energy and Energy Efficiency Technologies**

Federal investment in renewable energy and energy efficient technologies has been sparse and erratic, with each year producing an appropriations battle that is often lost. A combination of a federal program for steadily increasing funding and active political leadership would transform the clean energy sector from a good idea to a pillar of the new economy.

- **Provide Tax Incentives for Companies the Develop and Use Renewable Energy and Energy Efficiency Technologies**

Support for the production and further development of renewable fuels, all found domestically, would have a greater long-term effect on the energy system than any expansion of fossil-fuel capacity, with major health and environmental benefits as an added bonus. We should extend the existing production tax credits (PTC) for electricity generated from windpower and closed loop biomass for five years. Also, this production credit should be expanded to include electricity produced by open loop biomass (i.e., agricultural and forestry residues but excluding municipal solid waste), geothermal energy, and landfill gas. The same credit should be provided to closed loop biomass co-fired with coal, and a smaller credit (one cent per kWh) should be provided for electricity from open-loop biomass co-fired with coal. These provisions (in part or full) are included in the Murkowski-Lott (S. 389) bill, Bingaman-Daschle bill (S. 596), Grassley bill (S. 530), Reid bill (S. 249), Dorgan bill (S. 94), Collins bill (S. 188), Filner bill (HR. 269), Foley bill (HR 876), Herger-Matsui bill (HR 1657), and Dunn bill (HR 1677). I also support a minimum of a 15% investment tax credit for residential solar electric and water heating systems. This proposal was introduced by Senator Allard (S. 465) and Representative Hayworth (HR 2076). It also is included in the Murkowski-Lott (S. 389) bill. In addition, I support a 30% investment tax credit being proposed for small (75 kW and below) windpower systems as in the proposal in the Bingaman-Daschle (S. 596) bill.

- **Improved Federal Standards for Vehicle Fuel Economy and Increased Incentives for High Fuel Economy Vehicles**

I believe that a 40 mpg combined car and light truck fuel economy standard could be easily accomplished in the 2008 to 2012 timeframe with negligible net cost. I support tax credits of up to $5,000 for hybrid electric vehicles, up to $6,000 for battery electric vehicles, and $8,000 for fuel cell vehicles, or an incentive scheme for energy-use performance that rewards both fuel savings and lower emissions. I support the CLEAR Act, S. 760, introduced by Senators Hatch, Rockefeller, and Jeffords, and the companion bill (H.R. 1864) introduced by Rep. Camp.

- **A Federal Renewable Portfolio Standard (RPS) to Help Build Renewable Energy Markets**

I support a 20 percent RPS by 2020. A number of studies indicate that this would result in renewable energy development in every region of the country with most coming from wind, biomass, and geothermal sources. A clear and properly constructed federal standard is needed to set a clear target for industry research, development, and market growth. I recommend a renewable energy component of 2 percent in 2002, growing to 10 percent in 2010 and 20 percent by 2020 that would include wind, biomass, geothermal, solar, and landfill gas. This standard is similar to the one proposed by Senators Jeffords and Lieberman in the 106th congress (S. 1369).

Energy Policy Recommendations (continued)

- **Federal Standards and Credits to Support Distributed Small-Scale Energy Generation and Cogeneration (CHP)**

Small scale distributed electricity generation has several advantages over traditional central-station utility service, including reducing line losses, deferring the need for new transmission capacity and substation upgrades, providing voltage support, and reducing the demand for spinning reserve capacity. In addition, locating generating equipment close to the end use allows waste heat to be utilized to meet heating and hot water demands, significantly boosting overall system efficiency. I support a 10 percent investment tax credit and seven-year depreciation period for renewable energy systems or combined heat and power systems with an overall efficiency of at least 60-70 percent depending on system size. Similar proposals are included in the Murkowski-Lott energy bill (S. 389), the Bingaman-Daschle energy bill (S. 596), as well as bills targeted to CHP promotion introduced by Rep. Wilson (H.R. 1045) and Rep. Quinn (H.R. 1945).

- **Enact New and Strengthen Current Efficiency Standards for Buildings, Equipment, and Appliances**

Significant advances in heating and cooling systems, motor and appliance efficiency have been made in recent years, but more improvements are technologically possible and economically feasible. A clear federal statement of desired improvements in system efficiency is needed to remove uncertainty and reduce the economic costs of implementing these changes. Under such a federal mandate, efficiency standards for equipment and appliances could be steadily increased, helping to expand the market share of existing high efficiency systems.

- **Institute a National Public Benefits Fund**

I recommend a public benefits fund financed through a $0.002/kWh charge on all electricity sales. Such a fund could match state funds to assist in continuing or expanding energy efficiency, low-income services, the deployment of renewables, research and development, as well as public purpose programs the costs of which have traditionally been incorporated into electricity rates by regulated utilities.

Renewable Energy

Conventional energy sources based on oil, coal, and natural gas have proven to be highly effective drivers of economic progress, but at the same time highly damaging to the environment and to human health. These traditional fossil fuel-based energy sources are facing increasing pressure on a host of environmental fronts, with perhaps the most serious being the looming threat of climate change and the need to set GHG emission targets. It is now clear that any effort to maintain atmospheric CO_2 concentrations below even doubled pre-industrial levels[5] cannot be accomplished in an oil and coal-dominated global economy, barring radical and problematic carbon sequestration efforts.

The potential of renewable energy sources is enormous as they can in principle meet many times the world's energy demand. Renewable energy sources such as biomass, wind, solar, hydropower, and geothermal can provide sustainable energy services while meeting the challenges of energy security, diversity, and regional as well as global environmental quality. A transition to a renewable-intensive energy economy is now possible given the consistent progress in cost and performance of renewable energy technologies, new methods for managing distributed energy generation, and a transformation of the transportation system. Costs of solar and wind power systems have dropped substantially in the past 30 years, and continue to decline, while the price of oil and gas continue to fluctuate. In fact, fossil fuel and renewable energy prices are heading in opposite directions when social and environmental costs are included. Furthermore, the economic and policy mechanisms needed to support the widespread dissemination of renewable energy systems have also rapidly evolved Financial markets are awakening to the future growth potential of renewable and other new energy technologies, and this is a harbinger of fully competitive renewable energy systems.

In addition, renewable energy systems are ideal components of a decentralized power system that can result in lower capital and environmental costs and improved opportunities for highly efficient cogeneration (combined heat and power) systems. As an alternative to customary centralized power plants, renewable systems based on PV arrays, windmills, biomass or small hydropower, can be mass-produced “energy appliances” capable of being manufactured at low cost and tailored to meet specific energy loads and service conditions. These systems can have dramatically reduced as well as widely dispersed environmental impacts, rather than larger, more centralized impacts that in some cases are serious contributors to ambient air pollution, acid rain, and global climate change. This evolution of our ability to meet energy needs with clean sources is only in its infancy, and policies that reward R&D, power generation from clean sources, and a leveling of the playing-field with existing power providers are all critical components of a sound energy strategy.

Recent Progress in Renewable Energy System Cost and Performance

There has been significant progress in cost reductions made by wind and photovoltaic (PV) systems, while biomass, geothermal, and solar thermal technologies are also experiencing significant cost reductions. In general, renewable energy systems are characterized by low or no fuel costs, although operation and maintenance (O&M) costs can be considerable. It is important to note, however, that O&M costs for all new technologies are generally high, and can fall rapidly with increasing familiarity and operational experience. Renewable energy systems such as photovoltaics contain far fewer mechanically active parts than comparable fossil fuel combustion systems, and therefore are likely in the long-term to be less costly to maintain. Figure 1 presents U.S. DOE projections for the levelized costs of electricity production from these same renewable energy technologies, from 1997 to 2030.[6]

Given these potential cost reductions, recent analyses have shown that additional generating capacity from wind and solar energy can be added at low incremental costs relative to additions of fossil fuel-based generation. The economic case for renewables looks even better when environmental costs are considered along with capital and operating costs. As shown in Figure 2, geothermal and wind can be competitive with modern combined-cycle power plants, and geothermal, wind, and biomass all have lower total costs than advanced coal-fired plants, once approximate environmental costs are included.

The remarkable difference between the setting for renewable energy today, relative to the past 30 years, is that renewable and other clean energy technologies are now becoming economically competitive, and the push to develop them is no longer being driven solely by environmental concerns. With regard to prospects for investing in companies developing clean energy resources, Merrill Lynch's Robin Batchelor recently stated:

> “This is not an ethical investment opportunity, it's a straightforward business opportunity.”

Mr. Batchelor also noted that the traditional energy sector has lacked appeal to investors in recent years because of heavy regulation, low growth, and a tendency to be cyclical. He has identified 300 companies worldwide whose aim is to develop wind, solar, and wave power technologies and to advance capabilities in energy storage, conservation, and on-site power generation. Over the past decade the U. S. has lost its leadership position in the development and production of many clean energy systems – notably wind and solar energy – due to lack of support for innovative new companies and the signals that U. S. energy markets are biased against new entrants. With an expanding global energy market, this is precisely the wrong time not to support the clean energy industry, which could become a world-leading industry akin to that of U. S. semi-conductors and computer systems.

Despite their recent success, renewable energy sources have historically had a difficult time breaking into markets that have been dominated by traditional, large-scale, fossil fuel-based systems. This is partly because renewable and other new energy technologies are only now being mass produced, and have previously had high capital costs relative to more conventional systems, but also because coal, oil, and gas-powered systems have benefited from a range ofsubsidies over the years. These include military expenditures to protect oil exploration and production interests overseas, the costs of railway construction that have enabled economical delivery of coal to power plants, and a wide range of subsidies such as tax breaks.

One argument used to limit the attention paid to renewable energy systems has been the intermittent nature of some sources, such as wind and solar. A solution to this problem is to develop diversified systems that maximize the contribution of renewable energy sources but that also uses clean natural gas and/or biomass-based power generation to provide base-load power. In fact, this greatest disappointment in the response to the California energy crisis and in the Administration’s recent National Energy Policy Plan has been the focus on expanding the *gas* supply without any attention to the economic and security benefits of building a diverse energy system. The Administration’s plan would add one to two new gas-fired power plants a week for the next several years, making us far more dependent on gas than we were on oil even at the height of the OPEC crisis in the 1970s.

In essence, renewable energy technologies face a similar situation confronting any new technology that attempts to dislodge an entrenched technology. For many years, we have been “locked-in” to a suite of fossil fuel and nuclear-based technologies, and many of our secondary systems and networks have been designed and constructed to accommodate only these sources. Particularly in the absence of targeted policy interventions (discussed below), we will likely remain locked-in to existing technologies, even if the benefits of technology switching *overwhelm* the costs.

Level the Playing Field for Renewables: Public and Private Sector Investments and Market Transformations

As shown in Figure 2, renewable energy technologies are characterized by low environmental costs. In an ideal world, this would aid them in competing with conventional technologies, but of course many of these environmental costs are “externalities” that are not reflected in market prices. Only in certain areas and for certain pollutants do these environmental costs enter the picture, and clearly further internalizing these costs would benefit the spread of renewables. The international effort to limit the growth of greenhouse emissions through the Kyoto Protocol may lead to some form of carbon-based tax, and this could prove to be an enormous boon to renewable energy industries. However, any proposed carbon-based taxation scheme continues to face stiff political opposition in the U.S. Perhaps more likely, concern about particulate matter emission and ozone formation from fossil-fuel power plants will lead to expensive mitigation efforts, and this would help to tip the balance toward cleaner renewable systems.

There are two principal rationales for government support of research and development (R&D) to develop renewables and other clean energy technologies. First, conventional energy prices generally do not reflect the social cost of pollution. This provides the rationale, based on a well-accepted economic argument, to subsidize R&D for alternatives to polluting fossil fuels. Second, private firms are generally unable to appropriate all the benefits of their R&D investments. Consequently, the social rate of return for R&D exceeds available private returns, and firms therefore do not invest enough in R&D to maximize social welfare. Thus, innovation “spillover” among clean energy firms is a form of positive externality that justifies public R&D investment. These provide compelling arguments for public funding of Market Transformation Programs (MTPs) that subsidize demand for some clean energy technologies in order to help commercialize them.

A principal motivation for considering MTPs is inherent in the production process itself. When a new technology is first introduced it is invariably more expensive than established substitutes. There is, however, a clear tendency for the unit cost of manufactured goods to fall as a function of cumulative production experience. Cost reductions are typically very rapid at first, but taper off as the industry matures. This relationship is called an ‘experience curve’ when it accounts for all production costs, and it can be described by a progress ratio where unit costs fall by a certain percent with every doubling of cumulative production. Gas turbines, photovoltaic cells and wind turbines have both exhibited the expected price-production relationship, with costs falling roughly 20% for each doubling of the number of units produced (Figure 3).

If firms retain the benefits of their own production experience they have an incentive to consider experience effects when deciding how much to produce. Consequently, they will “forward-price,” producing at a loss initially to bring down their costs and thereby maximize profit over the entire production period.

In practice, however, the benefits of production experience often spill over to competitor firms, causing private firms to under-invest in bringing new products down the experience curve. Among other channels, experience spillovers could result from hiring competitors’ employees, reverse engineering rivals’ products, informal contacts among employees of rival firms, or even industrial espionage.

Strong experience effects therefore imply that output is less than the socially efficient level. MTPs can improve social welfare by correcting the output shortfall associated with these experience effects.[7]

This suggests a role for MTPs in national and international technology policies MTPs are best limited to emerging technologies with steep industry experience curves, a high probability of major long-term market penetration once subsidies are removed, and price elastic demand of approximately unity or greater. The condition that they be clean technologies mitigates the risk of poor MTP performance by adding the value of displaced environmental externalities. The recent technical and economic advances seen for a range of renewable energy products make them ideal candidates for support through market transformation programs, and I strongly urge federal action to reward the early production and use of clean energy technologies. Finally, as with energy R&D policy, public agencies should invest in a portfolio of new clean energy technologies in order to reduce overall MTP program performance risk through diversification.

Energy Efficiency

To adequately address climate change we must decrease our dependence on fossil fuels and increase our use of clean renewable systems as well as cut energy waste and improve energy efficiency. What the U.S. wastes simply in the production of electricity (~24 Quads, quadrillion BTUs, annually) is more energy than is used by the entire Japanese economy for all end uses. According to DOE's recent Interlaboratory Working Group study, *Scenarios for a Clean Energy Future*[8], cost effective end-use technologies could reduce electricity consumption by ~1,000 billion kWh by 2020, which would almost entirely offset business as usual projected growth in electricity use. This level of savings, more than Japan now uses for its entire economy, would reduce U. S. carbon emissions by approximately 300 million metric tons of carbon compared to a business-as-usual scenario.

There is often confusion about the definition of energy efficiency and energy conservation that is important to clarify. Energy efficiency means improving equipment and systems to get the same output (e.g., miles traveled or widgets produced) but with less energy input. Energy conservation means reducing energy use, and at times may mean reducing the services received. Examples of energy conservation include changing thermostat settings, reducing lighting levels, and driving less. To the extent energy conservation eliminates waste it is generally desirable. For example, many commercial buildings are excessively lit and over air-conditioned, wasting large amounts of energy without providing any useful service.

Energy efficiency has been the single greatest asset in improving the U.S. energy economy. Based on data from the Energy Information Administration (EIA), U.S. primary energy use per capita in 2000 was almost identical to that in 1973, while over the same period economic output (GDP) per capita increased 74 percent. Between 1996 and 2000, GDP increased 19 percent while primary energy use increased just 5 percent. In addition, national energy intensity (energy use per unit of GDP) fell 42 percent between 1973 and 2000. About 60 percent of this decline is attributable to real energy efficiency improvements and about one-quarter is due to structural changes and fuel switching. These statistics clearly indicate that energy use and GDP do not have grow or decline in lock step with each other, but rather that GDP can increase at a much while energy use does not.

If the United States had not dramatically reduced its energy intensity over the past 27 years, consumers and businesses would have spent at least $430 billion more on energy purchases in 2000. Energy efficiency improvement has contributed a great deal to our nation's economic growth and increased standard of living over the past 25 years, and there continues to be much potential for energy efficiency increases in the decades to come. It certainly represents the best short-term option for addressing today’s environmental and energy concerns. The U.S. Department of Energy (DOE) estimates that increasing energy efficiency throughout the economy could cut national energy use by 10 percent or more in 2010 and about 20 percent in 2020, with net economic benefits for consumers and businesses. The American Council for an Energy-Efficient Economy (ACEEE) estimates that adopting a comprehensive set of policies for advancing energy efficiency could lower national energy use by as much as 18 percent in 2010 and 33 percent in 2020, and do so cost-effectively. Many of these changes can be accomplished at *negative cost*, while others can be realized for only a few cents per kWh, far less than the cost delivered by new power plants.

Increasing the efficiency of our homes, appliances, vehicles, businesses, and industries must be an important part of a sound national energy policy. Increasing energy efficiency reduces energy waste without forcing consumers to cut back on energy services or amenities, lowers U.S. GHG emissions; saves consumers and businesses money since the energy savings more than pay for any increase in first cost, reduces the risk of energy shortages, reduces energy imports, and reduces air pollution. Furthermore, increasing energy efficiency does not present a trade-off between enhancing national security and energy reliability on the one hand and protecting the environment on the other, as do a number of energy supply options. Increasing energy efficiency is a “win-win” strategy from the perspective of economic growth, national security, reliability, and environmental protection.

The market barriers to energy efficiency technologies will continue to persist if we do not invest in tax and market incentives to encourage their implementation in all sectors of our economy. Interested consumers – both residential and commercial -- lack access to information on energy efficient options. Consequently market barriers to implementation of energy efficient technologies persist and policies are needed to help remove them.

Climate Change Policy

With proper policy support, investments in renewable energy and energy efficiency can increasingly be justified based on economic arguments alone. At the same time, the U. S. is currently squandering a critical opportunity to provide global environmental leadership that is also good business. The need for leadership on the global climate issue has become particularly apparent with President Bush’s recent rejection of the Kyoto Protocol. Domestic political opposition to U.S. leadership in this area has been based on outdated views of the science and economics of climate change. First the science is now widely accepted and, second several recent comprehensive analyses have shown that while the *costs* of inaction on global warming can be catastrophic the economic *benefits* of innovative actions to reduce the health and environmental impacts of energy use can be substantial. This represents the classic 'win-win' scenario. Unfortunately, significant action on climate change mitigation is in jeopardy unless the administration returns to the promise made by President Bush to take steps to control greenhouse gas emissions. I applaud the Chairman and ranking member on this committee and others in the Senate for their attempts to do just that.

The U.S. can reduce GHG emissions while improving our economic efficiency, creating jobs and saving consumers money, maintaining our technological leadership, and achieving other environmental benefits. Policies to encourage the extensive development and deployment of renewable energy and energy efficiency technologies are a critical part of this equation.

I strongly support the recent bills introduced in Congress to reduce pollutant emissions from electricity generation by Senators Jeffords and Lieberman (S.556) and Representatives Boehlert and Waxman (H.R. 1256). This legislation contained provisions that addressed the environmental impact and competitive distortions created by the patchwork of unequal and inadequate standards that currently apply to electric power plants nationwide. The bill puts a national cap on emissions from power plants of nitrogen oxides, sulfur oxides, mercury, and carbon dioxide, and allows market-oriented mechanisms such as emissions trading to meet the reduction requirements. The reductions in carbon dioxide would bring emissions levels back to 1990 levels by 2007, the same level implied by the non-binding targets of the Rio Treaty of 1992, as ratified by the U.S. Senate. Our analysis indicates that if implemented in an expedient but planned process, consistent with these legislative beginnings, that the costs would likely be dwarfed by the resulting benefits of industrial innovation[9,10].

Legislation that controls the four major power plant pollutants in an integrated package will help reduce regulatory uncertainties for electric generators and will be less costly than separate programs for each pollutant. Integrated control encourages system-wide efficiency improvements and increased utilization of cleaner fuels. And while voluntary action by American companies is an attractive option to consider, in the last ten years voluntary actions have failed to reduce carbon dioxide emissions in the U.S. Instead, emissions have increased by 15.5 percent since 1990 and continue to increase. The EIA recently released data showing a substantial increase in U.S. carbon dioxide emissions in 2000 of 2.7 percent from the preceding year, with the annual average since 1990 being 1.5 percent. This demonstrates the need for mandatory emissions reductions now and shows that solutions will be more costly and difficult if we continue to stall. Last December an EIA analysis concluded that such mandatory carbon dioxide caps would cause a large increase in future electricity prices that President Bush then used as a justification for abandoning his campaign promise to regulate carbon emissions from utilities. A more recent analysis by EPA/DOE using the same model but instead allowing for the use of advanced technologies to reduce emissions, as opposed to just the standard reference case of today's technologies, finds that this simple adjustment substantially decreases the resulting price increases. Furthermore, as will now be discussed, if additional policies for encouraging the development and use of renewable and energy efficiency technologies to reduce GHG emissions are included in the analysis the average consumer electricity price will be comparable to business as usual projections.

Policy Options for Renewable Energy and Energy Efficiency Technology Development

I firmly believe that the ultimate solutions to cost-effectively reducing our GHG emissions must be based on private sector investment bolstered by well-targeted government R&D and incentives for emerging clean energy technologies. This must be coupled with policies that *open* markets to new clean generating capacity. We now have the opportunity to build a sustainable energy future by engaging and stimulating the tremendous innovative and entrepreneurial capacity of the U.S. private sector. To accomplish this, we must pursue policies that guarantee a stable and predictable economic environment for advancing clean energy technologies. This can be further bolstered by market incentives to reward actions that further the public good.

With these thoughts in mind, I present several options that will start us down a path of GHG reducing reduction while at the same time creating a sustainable, economic and environmentally sound U.S. energy policy.

1) Increase federal R&D funding for renewable energy and energy efficiency technologies
To date, federal investment in renewable energy and energy efficient technologies has been sparse and erratic, with each year producing an appropriations battle that is often lost. The resulting financial and policy uncertainty discourages effective energy technology development and deployment in the marketplace[11]. With energy now a clear national priority, and I hope climate change quickly becoming one, funding for the U.S. DOE's Energy Efficiency and Renewable Energy Program must be substantially and systematically increased. The realization that R&D funding provides a critical driver to economic growth has resulted in important commitments in Congress, particularly in the life sciences, to double R&D funding in five to ten years. The same return on investment exists in the energy sector, but it has not been translated into increased R&D funding for new renewable and energy efficiency technologies. If the U.S. expects to be a world leader in this industry, as it is in the biomedical and high-tech sectors, such investments in renewable energy and energy efficiency are essential.

DOE recently documented 20 of its most successful energy efficiency projects as having saved the nation 5.5 quads of energy. This is worth about $30 billion in avoided expenses, mostly over the last decade, with a cost to tax payers of only $712 million, less than 3 percent of the energy bill savings so far. Study after study concludes that spending of taxpayer's money on energy efficiency R&D has been a very sound investment[12,13]. The Bush Administration's proposed deep cuts in their FY2002 budget for DOE's renewable energy and energy efficiency programs must be reversed and turned into budget increases. Such cuts would harm existing public-private partnerships as well as the R&D at the national labs and elsewhere. Thankfully, some of these cuts are being restored to current funding levels, in current appropriations bills. This budgetary roller-coaster harms all investments, sends mixed signals to industry, and as a result is the least efficient form of both energy and financial policy. In order to address climate change seriously we must at a minimum double this funding in the next five years (a 15 - 20 percent increase per year), as was recommended by PCAST[14]

Federal funding and leadership for renewable energy and energy efficiency projects has resulted in a small number of notable successes, such as the EPA's *Energy Star* and *Green Lights Programs* that has now been emulated in a number of countries. For example, 15 percent of the public sector building space in the country has now signed up for Energy Star Buildings Program and saved more than 21 billion kWh of energy in 1999 or about 4.4 million metric tons of carbon, resulting in $1.6 billion in energy bill savings according to EPA. Despite these achievements, funding in this area has been both scant, and so uneven that private sector involvement has actually been discouraged. By increasing funding for these EPA programs their scope could be considerably expanded resulting in substantially greater savings.

A combination of a federal program for steadily increasing funding for clean energy and energy efficiency R&D and active political leadership would transform the clean energy sector from a good idea to a pillar of the new economy. In particular, promising technologies such as fuel cells deserve special attention. Fuel cell development is attracting significant public and private funding and offers the promise of being a keystone technology for the ultimate transition from natural gas, petroleum, and coal energy to a renewable and hydrogen based energy economy.

2) Provide tax incentives for companies and individuals that develop and use renewable energy and energy efficiency technologies

The R&D tax credit has proven remarkably effective and popular with private industry, so much so that there is a strong consensus in both Congress and the Administration to make this credit permanent. The importance of private sector R&D in commercializing new technologies, an additional tax incentive for R&D investment in renewable and energy efficiency technologies is exactly the type of well-targeted federal policy that is needed. To compliment this, tax incentives directed toward those who use the technologies would provide the 'demand pull' to accelerate the technology transfer process and rate of market development. The U.S. has largely lost its position as the global leader in energy innovation, resulting in the loss of jobs and earning potential for U.S. companies precisely at the time when the international market for clean energy technologies is booming. Our domestic industries as well as the global energy economy would both benefit directly and significantly from a clear commitment to U.S. clean energy leadership.

Currently, Federal tax expenditures have an unequal distribution across primary energy sources, distorting the market in favor of many conventional energy technologies. The dollar apportionment of expenditures, including income and excise tax credits as well as direct subsidies (such as the Renewable Energy Production Incentive) does not reflect the market distribution of fuels nor does it encourage the establishment of a market niche for disadvantaged emerging technologies. For example, renewable fuels make up four percent of the US primary energy supply, and yet receive only one percent of Federal tax expenditures and direct expenditures combined. (See Table below) This does not include the Alcohol Fuels Excise Tax, directed towards ethanol production. The largest single tax credit in 1999 was the Alternative Fuel Production Credit[15], which totaled over one billion dollars. This income tax credit was designed to reduce dependence on foreign energy imports by encouraging the production of gas, coal, and oil from non-conventional sources (such as tight gas formations and coalbed methane) found within the United States. However, support for the production and further development of renewable fuels, all found domestically, would have a greater long-term effect on the energy system, with major health and environmental benefits as an added bonus.

FUEL SOURCE	PRIMARY ENERGY SUPPLY 1998 CONSUMPTION		DIRECT EXPENDITURES and TAX EXPENDITURES (1999)	
	VALUE (quads)	PERCENT	VALUE (million $)	PERCENT
Oil	36.57	40%	263	16%
Natural Gas *Alternative Fuels Credit*	21.84	24%	1,048 *(1,030)*	64%
Coal	21.62	24%	85	5%
Oil, Gas, Coal Combined			205	12%
Nuclear	7.16	8%	0	-
Renewables	3.48	4%	19	1%
Electricity			40	2%
Total	**90.67**	**100%**	**1660**	**100%**

Energy Information Administration, *Federal Financial Interventions and Subsidies in Energy Markets 1999: Primary Energy*, (Washington, DC: DOE, 1999)

3) Improve federal standards for vehicle fuel economy and increase incentives for high fuel economy vehicles

New vehicles types based on hybrid gasoline-electric and fuel cell-electric power systems are now being produced in commercial (gasoline hybrid) and prototype (fuel cell) quantities. These vehicles are combining high-efficiency AC induction or permanent magnet electric motors with revolutionary power systems to produce a new generation of motor vehicles that are vastly more efficient than today's simple cycle combustion systems. The potential for future hybrid and fuel cell vehicles to achieve up to 100 miles per gallon is believed to be both technically and economically viable in the near-term, and with continued commitments from industry, only clear federal guidelines and support are needed to move from planning to reality. In the longer term, fuel cell vehicles running directly on hydrogen promise to allow motor vehicle use with very low fuel-cycle emissions, and again better government and industry coordination and cooperation over the next ten years could do much to hasten the development of this promising technology.

The improvements in fuel economy that these new vehicle types offer will help to slow growth in petroleum demand, reducing our oil import dependency and trade deficit. While the Partnership for a New Generation of Vehicles helped to generate some vehicle technology advances, an increase in the Corporate Average Fuel Economy (CAFE) standard, which has been stagnant for 12 years now, is required to provide an incentive for companies to bring these new vehicles types rapidly to market. Tax credits and incentives are an important complement to raising CAFE, but I do not believe that they alone can accomplish the key goal of simultaneously stimulating production of high fuel economy vehicles and provide strong incentives for consumers to purchase them.

Now, after five years of Congressional bans, studies on the potential for increases in CAFE standards to cost-effectively reduce petroleum demand are now underway by the Department of Transportation and the National Academy of Sciences. These studies, with results expected later this summer, will help to suggest optimal levels of increased standards, given the costs and benefits of higher fuel economy, as well as phase-in schedules that will protect the competitive interests of domestic automakers.

In the meantime, other recent analyses of the costs and benefits of providing higher fuel economy motor vehicles have been conducted by the Union of Concerned Scientists,[16][17] MIT,[18] OTA,[19] and Oak Ridge National Lab/ACEEE.[20] These studies have generally concluded that with longer-term technologies, motor vehicle fuel economy can be raised to 45 mpg for cars for $500 to $1,700 per vehicle retail price increase,[21] and to 30 mpg for light trucks for $800 to $1,400 per vehicle retail price increase.[22] These improvements could be the basis for a new combined fuel economy standard of 40 mpg, which could be instituted after first removing the separate fuel economy standards for cars and light trucks (i.e. closing the light truck 'loophole' as proposed in S. 804 by Senators Feinstein and Snowe). I believe the 40 mpg combined car and light truck standard could be easily accomplished in the 2008 to 2012 timeframe with negligible net cost once fuel savings are factored in, given adequate lead time for the auto industry to re-tool for this new generation of vehicles.

I also support tax credits of up to $5,000 for hybrid electric vehicles, up to $6,000 for battery electric vehicles, and $8,000 for fuel cell vehicles. These funds could in principle be raised through a revision of the archaic 'gas guzzler' tax, which does not apply to a significant percentage of the light duty car and truck fleet. The tax penalty and tax credit in combination could be a revenue-neutral 'fee-bate' scheme, similar to one recently proposed in California, that would simultaneously send two strong price signals rewarding economical vehicles (particularly those using advanced drive systems) and penalizing uneconomical ones. Furthermore, this would help jump start introduction and purchase of the most innovative, fuel-efficient technologies. However the incentives are designed, they should be based primarily on energy-use performance and ideally provide both fuel savings and lower emissions. I support the CLEAR Act, S. 760, introduced by Senators Hatch, Rockefeller, and Jeffords, and the companion bill (H.R. 1864) introduced by Rep. Camp.

4) Establish a federal Renewable Portfolio Standard (RPS) to help build renewable energy markets

The RPS is a renewable energy content standard, akin to efficiency standards for vehicles and appliances that have proven successful in the past. A gradually increasing RPS provides the most economically efficient way of ensuring that a growing proportion of electricity sales are provided by renewable energy, and is designed to integrate renewables into the marketplace in the most cost-effective fashion. In this manner, the market picks the winning and losing technologies and projects, not administrators. With all the discussion and hype about market forces, a RPS provides the one true means to use market forces most effectively. I recommend a renewable energy component of 2 percent in 2002, growing to 10 percent in 2010 and 20 percent by 2020 that would include wind, biomass, geothermal, solar, and landfill gas. A number of studies indicate that this 20% in 2020 level of an RPS is broadly good for business and can readily be achieved[23,24]. This standard is similar to the one proposed by Senators Jeffords and Lieberman in the 106th congress (S. 1369). This bill has not been reintroduced nor has any other RPS legislation been introduced in this Congress yet. States that decide to pursue more aggressive goals – many of which make economic and environmental sense – could be rewarded through an additional federal incentive program. To achieve compliance a federal RPS should use market dynamics to stimulate innovation through an active trading program of renewable energy credits. Renewable credit trading is analogous to the sulfur allowance trading system established in the Clean Air Act. Like emissions trading, it is designed to be administratively simple and to increase flexibility and decrease the cost of compliance with the standard. Electricity suppliers can generate renewable electricity themselves, purchase renewable electricity and credits from generators, or buy credits in a secondary trading market.

The coal, oil, natural gas, and nuclear power industries are mature; yet continue to receive considerable government subsidies. Moreover, the market price of fossil and nuclear energy does not include the cost of the damage they cause to the environment and human health. Conversely, the market does not give a value to the environmental and social benefits of renewables. Without the RPS or a similar mechanism, many renewables will not be able to compete in an increasingly competitive electricity market focused on producing power at the lowest direct cost. The RPS is designed to deliver renewables that are most ready for the market. Additional policies are still needed to support emerging renewable technologies, like photovoltaics, that have enormous potential to eventually become commercially competitive through targeted investment incentives. Smart investors typically acquire a portfolio of stocks and bonds to reduce risk. Including renewables in America's power supply portfolio would do the same by protecting consumers from fossil fuel price shocks and supply shortages. A properly designed RPS will also establish a viable market for the long-term development of America's renewable energy industries, creating jobs at home and export opportunities abroad.

The RPS is the surest market based approach for securing the public benefits of renewables while supplying the greatest amount of clean power for the lowest price. It creates an ongoing incentive to drive down costs by providing a dependable and predictable market, which has been lacking in this country. The RPS will reduce renewable energy costs by:

- Providing a revenue stream that will enable manufacturers and developers to obtain reasonable cost financing and make investments in expanding capacity to meet an expanding renewable energy market.
- Allowing economies of scale in manufacturing, installation, operation and maintenance of renewable energy facilities.
- Promoting vigorous competition among renewable energy developers and technologies to meet the standard at the lowest cost.
- Inducing development of renewables in the regions of the country where they are the most cost-effective, while avoiding expensive long-distance transmission, by allowing national renewable energy credit trading.
- Reducing transaction costs, by enabling suppliers to buy credits and avoid having to negotiate many small contracts with individual renewable energy projects.

Analysis of the 20 percent RPS target in 2020 that I strongly support would result in renewable energy development in every region of the country with most coming from wind, biomass, and geothermal sources. In particular, the Plains, Western, and Mid-Atlantic States would generate more than 20 percent of their electricity as shown in Figure 4. Electricity prices are projected to fall 13 percent between 1997 and 2020 under this RPS. While this is not as much as the projected 18 percent decrease under business-as-usual without an RPS, it is nonetheless a substantial decrease and has added nation-wide environmental and health benefits (see Figure 5). This increase in renewable energy would also reduce some of the projected rise in natural gas prices for all gas consumers by 5 percent in 2020 again saving households money who heat with natural gas.

Texas has been a leader in developing and implementing a successful RPS that then Governor Bush signed into law in 1999. The Texas law requires electricity companies to supply 2,000 MW of new renewable resources by 2009. The state may meet this goal by the end of 2002, seven years early. The RPS has also been signed into law in Arizona, Connecticut, Maine, Massachusetts, Nevada, New Jersey, New Mexico, Pennsylvania, and Wisconsin. Minnesota and Iowa also have minimum renewables requirements similar to an RPS. Bills with the RPS are also pending in several states. Variations in the details of these programs have kept them from being overly successful. A clear and properly constructed federal standard would correct these problems, and set a clear target for industry research, development, and market growth[25].

5) Institute federal standards needed to support distributed small-scale energy generation and cogeneration (CHP)

Small scale distributed electricity generation has several advantages over traditional central-station utility service. Distributed generation reduces energy losses incurred by sending electricity through an extensive transmission and distribution network (often an 8-10 percent loss of energy), defers the need for new transmission capacity and substation upgrades, provides voltage support, and reduces the demand for spinning reserve capacity. In addition, the location of generating equipment close to the end use allows waste heat to be utilized to meet heating and hot water demands, significantly boosting overall system efficiency.

Distributed generation has faced several barriers in the marketplace, most notably from complicated and expensive utility interconnection requirements. These barriers have led to a push for national safety and power quality standards, currently being finalized by the Institute of Electrical and Electronics Engineers (IEEE). Although adoption of these standards would significantly decrease the economic burden on manufacturers, installers, and customers, the utilities are allowed discretion in adopting or rejecting these standards. Therefore, a Federal mandate to require utilities to accept these standards, along with tax incentives for utilities and customers who use distributed generation systems, would ease their acceptance into the marketplace.

While all distributed generation systems have the advantage of lower line losses, there is large variability in the overall efficiencies of the systems based on system type and installation. It is important to design credits based on overall efficiency and offset emissions compared to central station generation. This is accomplished by giving highest priority to renewable systems or fossil fuel systems that utilize waste heat through combined heat and power designs. While a distributed generation system may achieve 35-45 percent electrical efficiency, the addition of heat utilization can raise overall efficiency to 80 percent. U.S. CHP capacity in 1999 totaled 52,800 MW of power, but the estimated potential is several times this. Industrial CHP potential is estimated to be 88,000 MW, the largest sectors being in the chemicals and paper industries. Commercial CHP potential is estimated to be 75,000 MW, with education, health care, and office building applications making up the most significant percentages[26] (See Figure 6) This tremendous resource has the advantage of offsetting separate electric and fossil fuel heating systems, but CHP applications are only feasible through the use of onsite distributed electricity generation.

I support a 15 percent investment tax credit and seven-year depreciation period for *renewable energy systems* or combined heat and power systems with an overall efficiency of at least 60-70 percent depending on system size. This proposal is similar to one included in the Murkowski-Lott energy bill (S. 389), the Bingaman-Daschle energy bill (S. 596), as well as bills targeted to CHP promotion introduced by Rep. Wilson (H.R. 1045) and Rep. Quinn (H.R. 1945). It is important to note again that these measures would be most effective coupled with mandated utility interconnection requirements.

The U. S. should pursue a policy of not only net-metered energy use, but also *real-time pricing* where homeowners, businesses, and industry can all participate fully in supplying their excess power generation into the market. Homes with solar photovoltaic, wind, or fuel-cell systems should be able to sell their excess energy. Opening the energy supply markets to local generation will provide strong, economically sound, signals to the utilities, the Qualifying Facilities, and homeowners that the energy market is fair, accessible, and one where clean energy generation will be rewarded. The investment in the grid, largely in the form of upgrades to local sub-stations, will lead to further energy efficiency benefits as an added bonus. Federal leadership and standards are needed to guide this transformation.

6) Enact new and strengthen existing efficiency standards on buildings, equipment, and appliances

Buildings, appliance, and equipment standards are an important strategy for promoting energy efficiency. Tax credits, while important, do not necessarily remove the market barriers that prevent clean energy technologies from spreading throughout the marketplace. Minimum efficiency standards were adopted by President Reagan in 1987, and then expanded under President Bush in 1992, because market barriers inhibit the purchase of efficient appliances and equipment. These barriers may include lack of awareness, rush purchases when an existing appliance breaks down, and purchases by builders and landlords. Figure 7 shows how federal standards dramatically increased the market share of highly efficient magnet ballasts used for lighting.

Significant advances in heating and cooling system, motor, and appliance efficiency, have been made in recent years, but more improvements are technologically possible and economically feasible. A clear federal statement of desired improvements in system efficiency is needed to remove uncertainty and reduce the economic costs of implementing these changes. Under such a federal mandate, efficiency standards for equipment and appliances could be gradually increased, helping to expand the market share of existing high efficiency systems[27].

Historically, building, appliance, and equipment standards have proven to be one of the federal government's most effective energy-saving programs. Analyses by DOE and others indicate that in 2000, appliance and equipment efficiency standards saved 1.2 quadrillion BTUs of energy (1.3 percent of U.S. electric use) and reduced consumer energy bills by approximately $9 billion with energy bill savings far exceeding any increase in product cost. By 2020, standards already enacted will save 4.3 quadrillion BTU/year (3.5 percent of projected U.S. energy use), and reduce peak electric demand by 120,000 MW (more than a 10 percent reduction). ACEEE estimates that energy will be reduced in 2020 by 1.0 quadrillion BTU by quickly adopting higher standards for equipment currently covered, such as central air-conditioners and heat pumps, and new standards for equipment not covered, such as torchiere (halogen) light fixtures, commercial refrigerators and reduction of appliances standby power consumption (see Figure 8 for standby power used by today's televisions). This is nearly a 1 percent reduction in projected U.S. energy use, resulting in a savings of nearly 20 million metric tons of carbon. Consumers and businesses would see their energy bills decline by approximately $7 billion per year by 2020. Savings in 2010 would be a little less than half this amount. Additional savings can be achieved by future updates and expansions to the appliance standards program; the savings estimated here just apply to actions that can be taken in the next few years.

7) Institute a National Public Benefits Fund based on revenue collected from a national, competitively neutral wires charge

Electric utilities have historically funded programs to encourage the development of a host of clean energy technologies. Unfortunately, increasing competition and deregulation have led utilities to cut these discretionary expenditures in the last several years. Total utility spending on demand side management programs fell more than 50 percent from 1993 to 1999. Lack of investment in the future has been a hallmark of utility 'planning' in face of deregulation, and needs to be reversed through rewards (such as tax incentives) for companies that re-invest profits and invigorate the power sector[28]. I recommend national a public benefits fund funded through a $0.002/kWh charge. This concept and amount were put forth in bills sponsored by Senator Jeffords (S. 1369) and Rep. Pallone (H.R. 2569) in the last ccongress and in the Bingaman-Daschle energy bill (S. 597). Furthermore, there should be federal matching of state funds which could be used for some of the programs listed below:

- R&D
- Low-cost financing or financing guarantees
- Grants, production incentives, or buy-downs for project costs
- Infrastructure development
- Develop uniform standards for siting, permitting, and connection with the electrical grid
- Educate the public on the benefits and costs of clean energy technologies and efficiency
- Incentives, such as rebates, to help establish markets for new products
- Installation, operation, and maintenance of renewable energy and energy efficient technologies

Cost and Benefit Analysis of Clean Energy Policies on Electricity Generation

I agree wholeheartedly with the findings of the Union of Concerned Scientists', report, *Clean Energy Blueprint: A Smarter National Energy Policy for Today and the Future*[29], which examines the costs, environmental impacts, and effects on fossil fuel prices and consumer energy bills of a package of clean energy polices. These policies include: incentives for consumers to purchase more efficient appliances; stricter energy codes for buildings; residential and commercial building retrofits; voluntary programs with industry to reduce energy use meaningfully; a RPS requiring electricity providers to obtain 20 percent of their supplies from renewables power sources by 2020 using tradable renewable energy credits; an expanded production tax credit to include all renewables; and a public benefits fund funded through a $0.002/kWh charge to customers.

This analysis is based on the Energy Information Administrations National Energy Modeling Systems (NEMS) with modifications used in the Interlaboratory Working Group's study to accurately account for the growth and costs of renewable technologies model. Under the business-as-usual scenario the nation would increase its reliance on coal and natural gas to meet strong growth in electricity use with an increase of 42 percent by 2020 as shown in Figure 9. To meet this demand it is estimated that 1,300 300-MW power plants would need to be built. Electricity generation from non-hydro renewables increases from 2 percent today to only 2.4 percent of total generation in 2020. This amounts to a policy of energy and economic stagnation. If, on the other hand, the set of clean energy polices listed above are implemented energy efficiency and renewables will meet a much larger share of our future energy needs (at least 20%) with energy efficiency measures almost completely offsetting the projected business-as-usual growth in electricity (Figure 10). Unlike the Bush-Cheney energy plan, this clean energy strategy plan builds energy security for the U. S. by supporting energy diversity and domestic supplies.. The result is a large decrease in emissions from the utilities sector compared to business-as-usual projections with declines continuing beyond 2020. Figure 11 shows the projected power plant carbon dioxide reductions with the level proposed by the Senator Jeffords and Representative Waxman's 4-pollutant power plant emission reduction bills (S. 556 and H.R. 1256). Through a steady shift to clean energy production, the requirements of these bills would not be difficult or expensive, and if anything are expected to increase U. S. economic activity.

Finally the more efficient use of energy and the switch from fossil fuels to renewable energy sources saves consumers money by decreasing energy use in homes, businesses, and industry while the fuel switching also decreases the demand for fossil fuels resulting in price drops as shown for natural gas in Figure 12. This results a lower household electricity bill than business-as-usual predicts as shown in Figure 13 while average consumer prices are about the same. One of the greatest advantages that energy efficiency and renewable energy sources offer over new power plants, transmission lines, and pipelines is the ability to deploy these technologies very quickly. Consequently we can begin to deploy these technologies now and so reap the benefits all that much sooner.[30] CO_2 emission reductions will have a 'clean cascade' effect on the economy as well; many other pollutants are emitted in concert with carbon from fossil fuel use.

A range of studies are all coming to the conclusion that simple but sustained standards and investments in a clean energy economy are not only possible but would be highly beneficial to our nation's future prosperity.[31] A recent analysis of the whole economy shows that we can easily meet Kyoto type targets with a net increase of 1 percent in the Nation's GDP 2020.[32] The types of energy efficiency and renewable technologies and policies described have already proven successful and cost-effective at the national and state level. I argue that this is even more reason to increase their support. Figure 14 shows how a combination of readily available options can be used to meet the Kyoto Protocol. This type of strategy would cost-effectively enable us to meet goals of GHG emission reductions[33] while providing a sustainable clean energy future.

Conclusions

We stand at a critical point in the energy, economic, and environmental evolution of the United States. Renewable energy and energy efficiency are now not only affordable, but their use will also open new areas of innovation and technological and economic leadership for the U. S., if we choose to embrace these options. Creating opportunities and – critically -- a fair market place for a clean energy economy requires leadership and vision. The tools to implement this evolution are now well known, and are listed in the previous section. I look forward to the opportunity to work with you to put these cost-effective measures into effect.

Biographical Sketch: Daniel M. Kammen

Daniel M. Kammen received his undergraduate degree physics from Cornell University 1984, and his Masters (1986) and Doctorate (1988) degrees in physics, from Harvard University. He was a Bantrell & Weizmann Postdoctoral Fellow at the California Institute of Technology, and then a lecturer in the Department of Physics at Harvard University. From 1992 – 1998 Kammen was on the faculty of the Woodrow Wilson School of Public and International Affairs at Princeton University, where he was Chair of the Science, Technology and Environmental Policy Program. Kammen is now Professor of Energy and Society in the Energy and Resources Group (ERG), and in the Department of Nuclear Engineering at the University of California, Berkeley. At Berkeley Kammen is the founding director of the Renewable and Appropriate Energy Laboratory (http://socrates.berkeley.edu/~rael), and is campus representative to the University of California Energy Institute. He has been a Lecturer in Physics and Natural Science at the University of Nairobi.

Kammen's research centers on the science, engineering, economics and policy aspects of energy management, and dissemination of renewable energy systems. He also works on the health and environmental impacts of energy generation and use; rural resource management, including issues of gender and ethnicity; international R&D policy, climate change; and energy forecasting and risk analysis. He is the author of over 110 journal publications, a book on environmental, technological, and health risks (*Should We Risk It?*, Princeton University Press, 1999) and numerous reports on renewable energy and development. Kammen received the *1993 21st Century Earth Award* and is a Fellow of the American Physical Society. He is a Permanent Fellow of the African Academy of Sciences. For information of any of these activities and for copies of Professor Kammen's writings, see http://socrates.berkeley.edu/~dkammen.

Figure 1. Levelized cost of electricity forecast for renewable energy technologies (U.S. DOE, 1997)

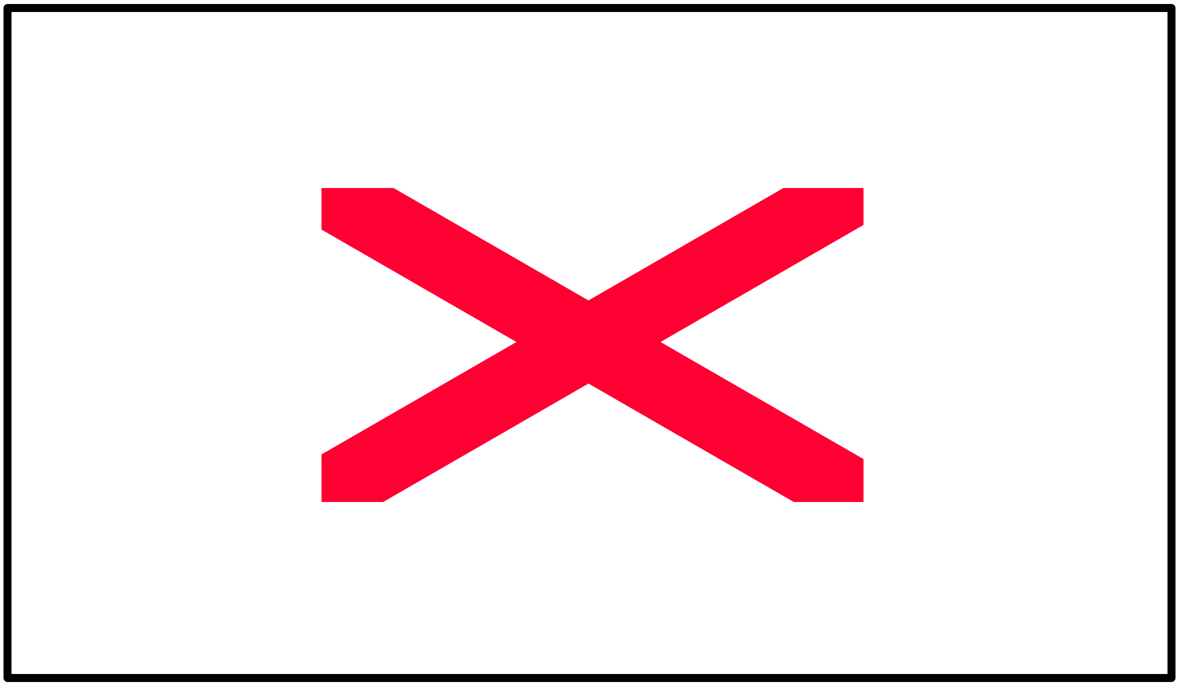
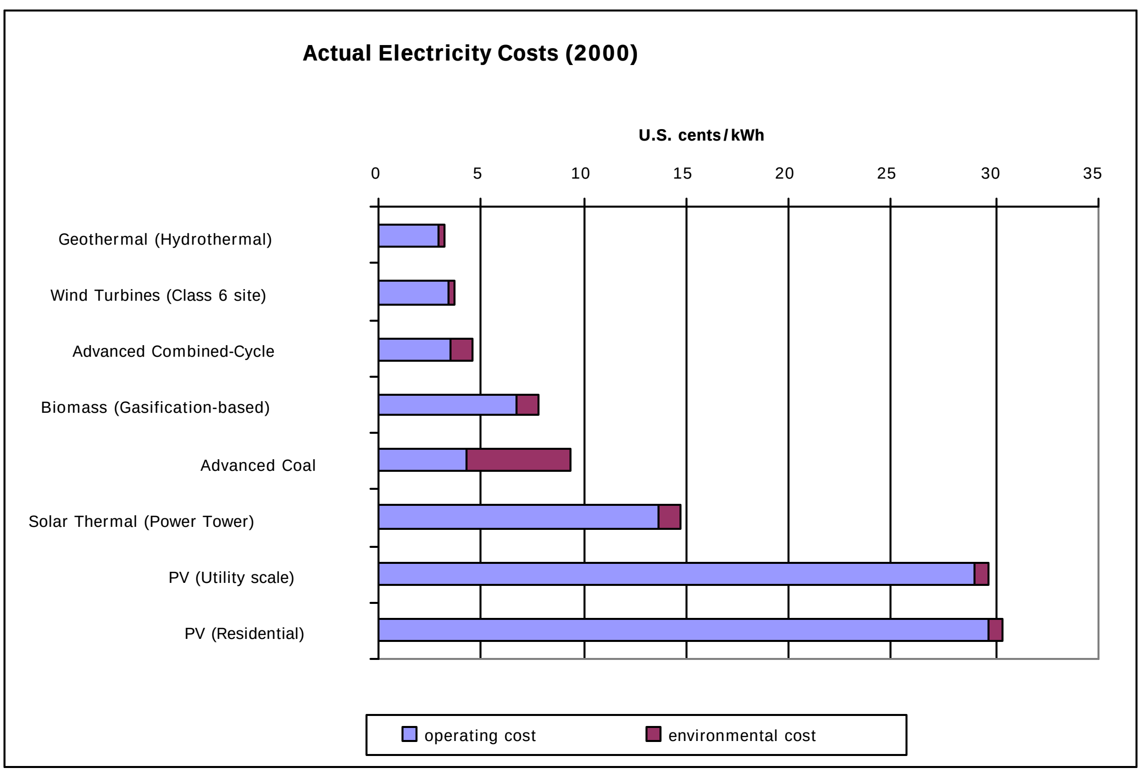
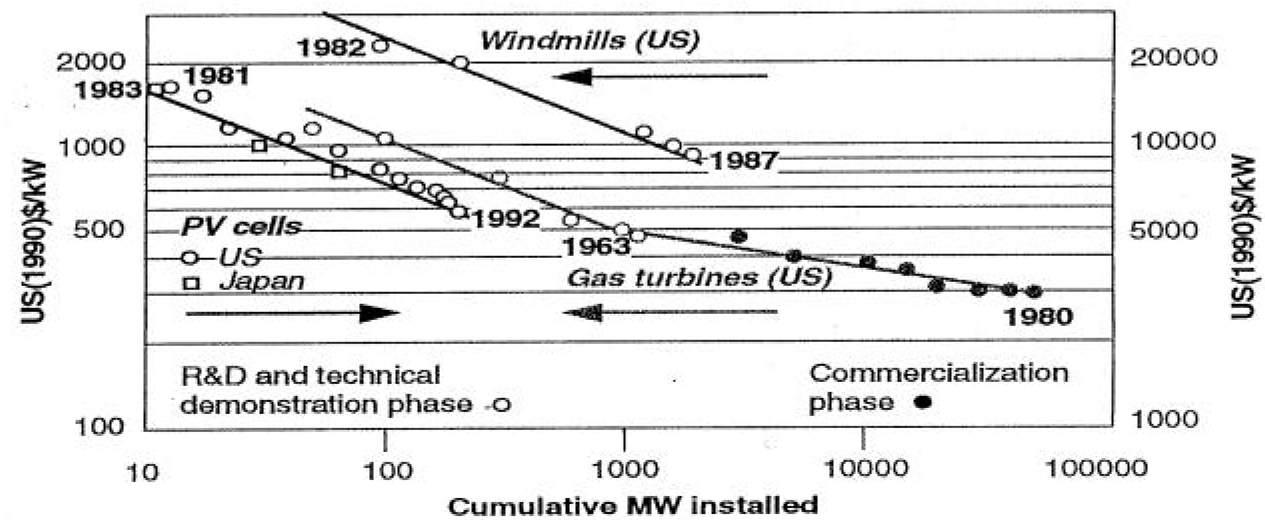


Figure 2. Actual electricity costs in year 2000



Source: Ottinger, 1985; U.S. DOE, 1997; 2000.

Figure 3. Progress ratios (experience curves) for photovoltaics, windmills, and gas turbines



Source: IIASA/WEC (1995) *Global Energy Perspectives to 2050 and Beyond* (Laxenburg, Austria and London, UK).

Figure 4. Renewable energy generation in the U.S. by region for a RPS with a 20 percent target in 2020 (Clemmer, 1999)

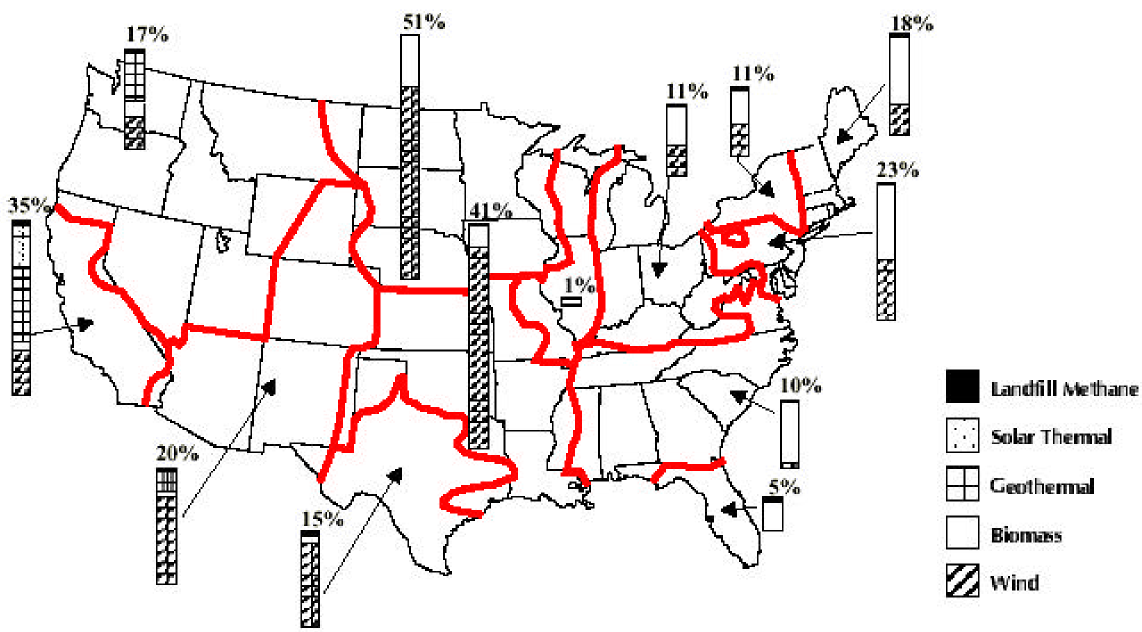


Figure 5. Average monthly electricity bill for typical nonelectric heating household (Clemmer, 1999)

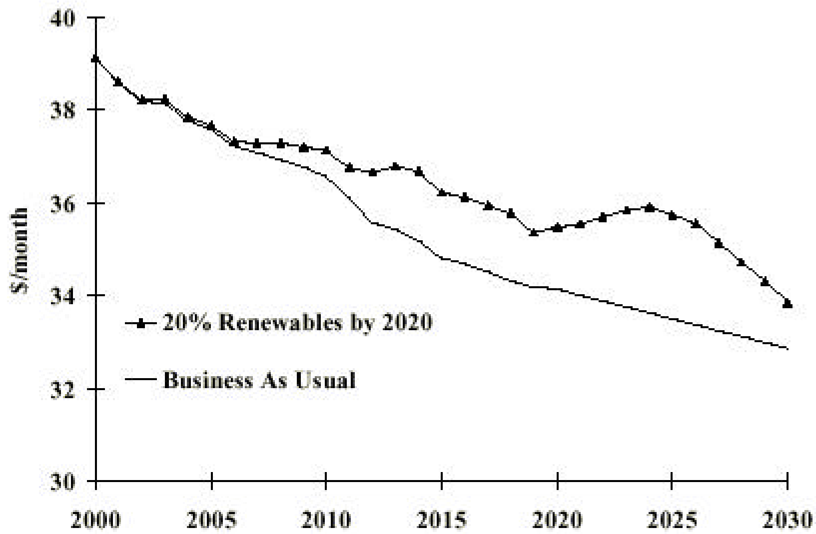


Figure 6. CHP growth potential within several sectors of the economy (ACEEE).

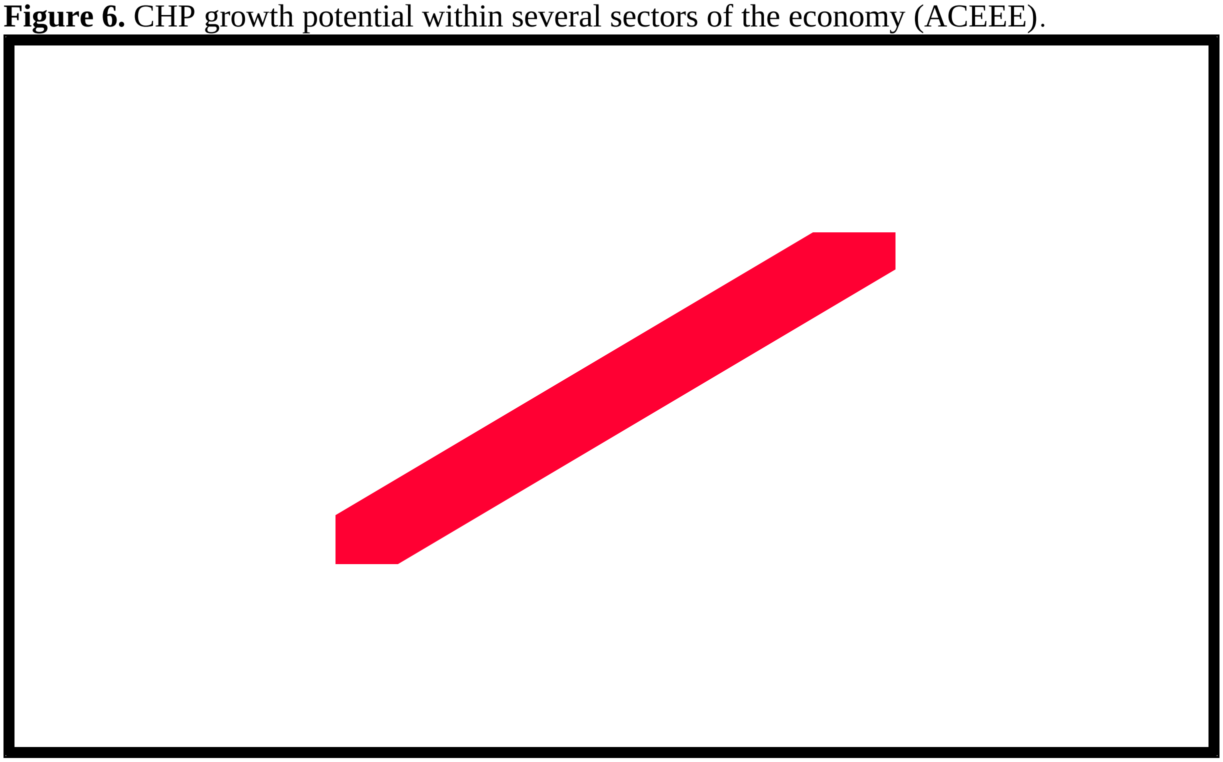


Figure 7. Market Share of efficient magnetic ballasts for lighting (Interlaboratory Working Group, 2000)

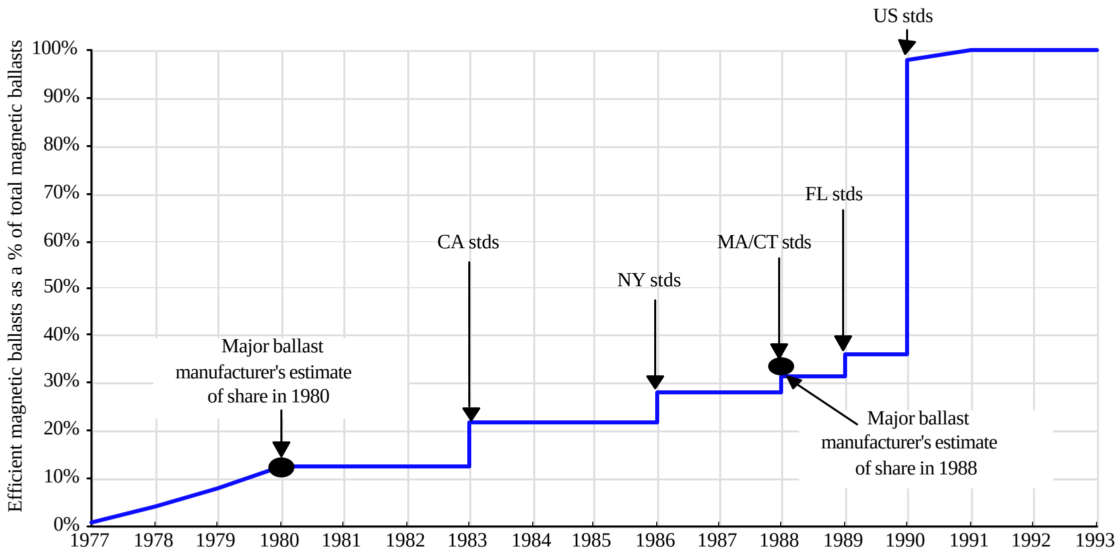


Figure 8. Standby power consumption for a selection of 365 televisios (Source: K. Rosen, LBNL, May 1999)

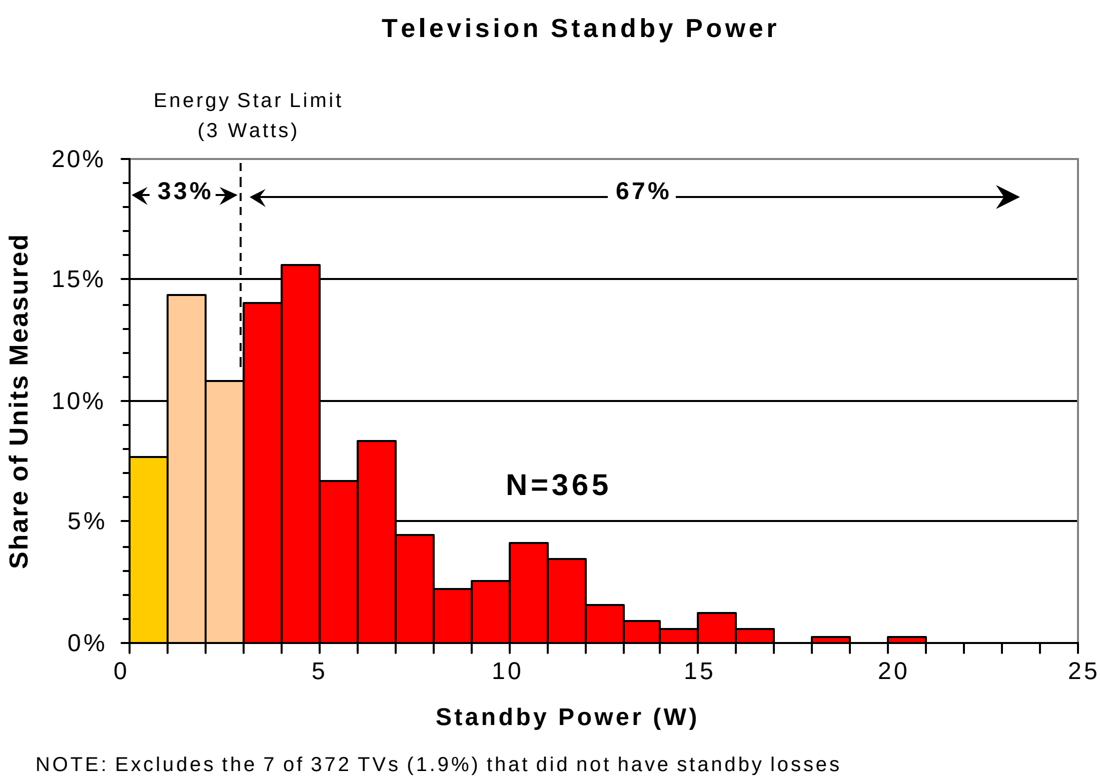


Figure 9. Electricity Deregulation under business as usual* (Clemmer, 2001)

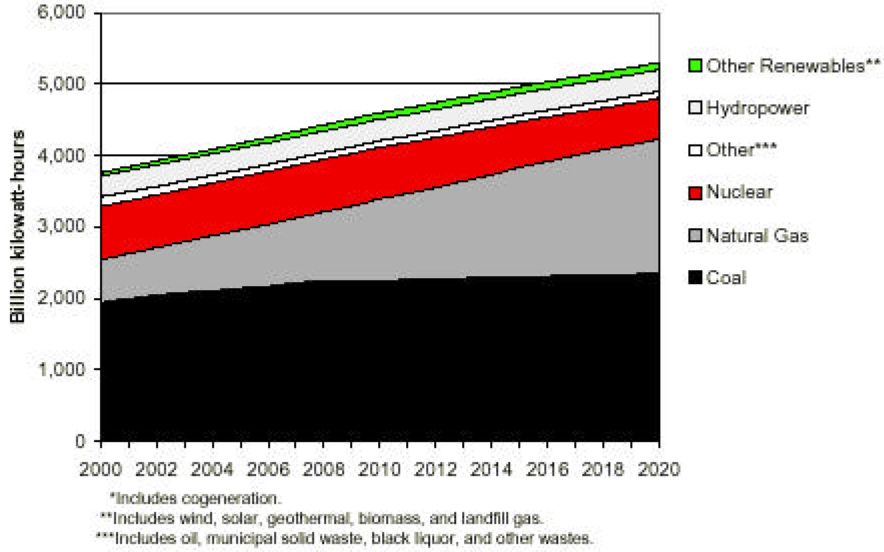


Figure 10. Energy generation with the implementation of various renewable energy and energy efficient policy options* (Clemmer, 2001)

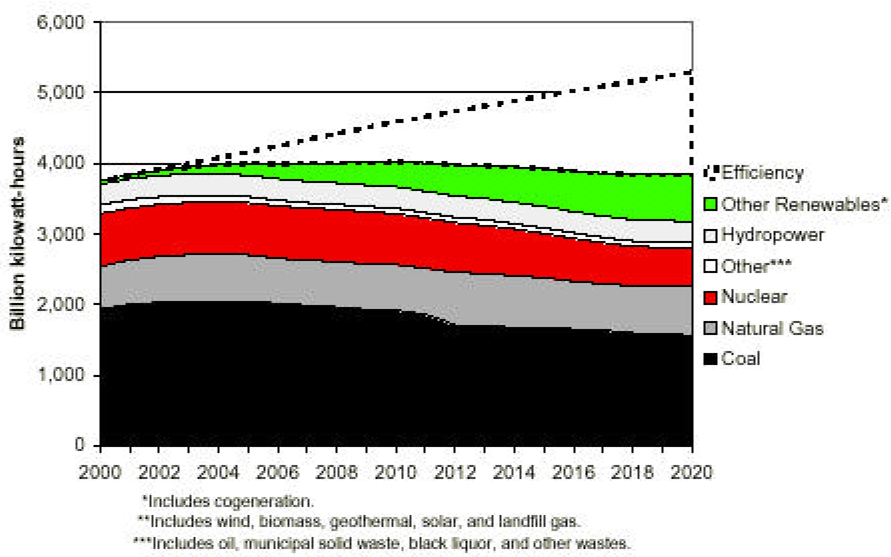


Figure 11. Power plant carbon dioxide emissions (Clemmer, 2001)

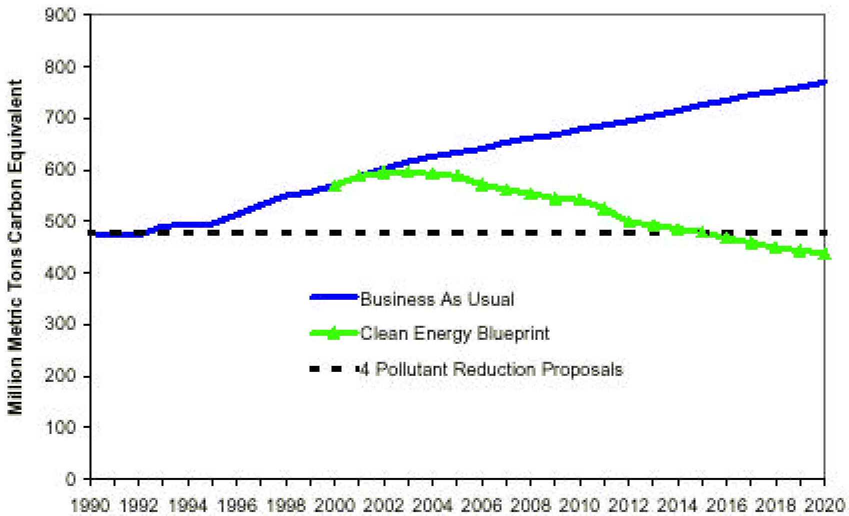
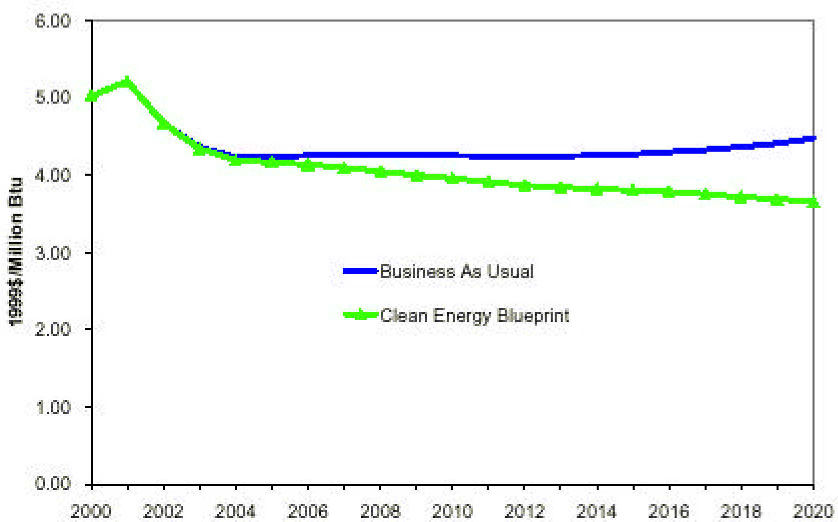


Figure 12. Natural gas prices (national average)* (Clemmer, 2001)



*In the AEO 2001 version of the National Energy Modeling System (NEMS), which was used for this analysis, the year 2000 is the first year of the forecast. Actual natural gas prices in 2000 were significantly higher than shown in the figure.

Figure 13. Typical household electricity bill (Clemmer, 2001)

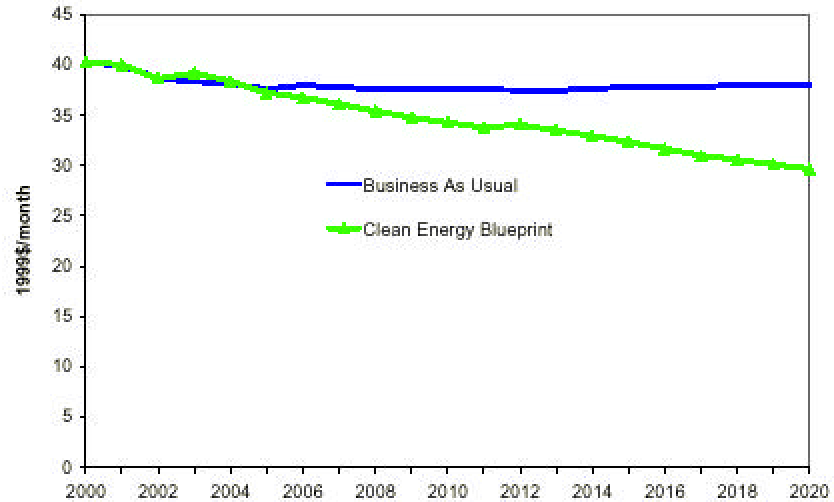
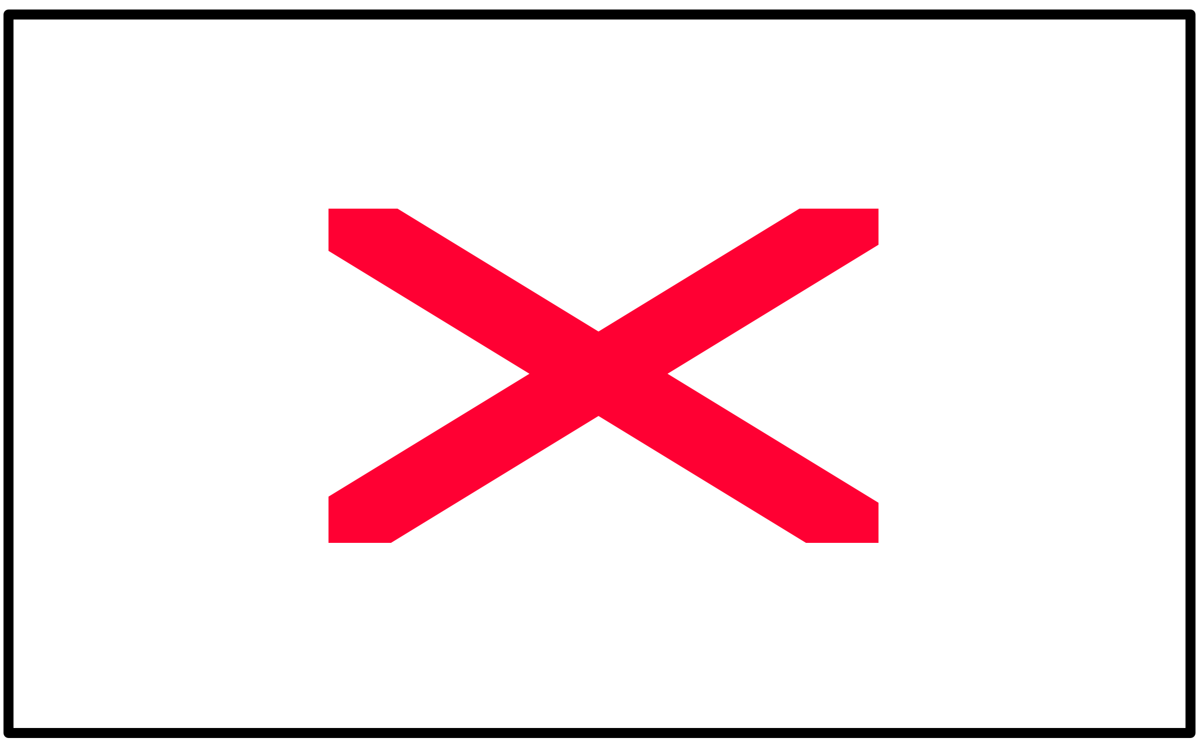


Figure 14. Potential carbon reductions from energy efficiency and renewable energy measures
Source: Energy Foundation, 2001.



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