**_Testimony_ for the Hearing on**
**The Role of Tax Incentives in Energy Policy**
**Committee on Finance**
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**By**

**Daniel M. Kammen**
**Professor of Energy and Society**
**Director, Renewable and Appropriate Energy Laboratory (RAEL)**
**Energy and Resources Group (ERG)**
**&**
**Professor of Nuclear Engineering**
**University of California, Berkeley**

## Introduction

Mr. Chairman and members of the Committee, thank you for this opportunity to appear before you today to provide testimony on the status of renewable energy and energy efficiency technologies. 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 policy for the formulation of a strong national energy strategy. This critical initiative is long overdue, as illustrated by the California energy crisis and the deficiencies that have been revealed in regional and national energy policy and planning. Additionally, as the threat of global climate change is becoming widely acknowledged in the U.S., there is finally a growing understanding that a responsible national energy policy includes a global climate change mitigation strategy that can be environmentally effective and economically advantageous.

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. It is critical to examine all energy options, and never before have so many technological solutions been available to address our energy needs. In the near term, some expansion of our fossil fuel, and particularly natural gas, supply is warranted to keep pace with rising demand. However, these measures should be balanced with measures to develop longer-term and cleaner energy solutions for the future. In general, while there are needs for new energy generation and infrastructure, energy efficiency and conservation represent our best short-term options, and even a natural gas-based strategy is not adequate in the long term to prevent the build up of unacceptably high $CO_2$ levels. The U.S.

spent over $600 billion on energy last year, with U.S. oil imports climbing to $120 billion, or nearly $440 of imported oil for every American. These amounts would have been far higher if not for past investments in energy efficiency research and development (R&D) and deployment programs. We have made great strides with energy efficiency in this country, and substantial accomplishments with renewable energy as well. Renewable energy systems, notably solar, wind, and biomass -- are poised to play a major role in the energy economy and environmental quality of the nation, but that potential demands greater examination and commitment to implementation. This is why I am particularly pleased, Mr. Chairman, that you are holding this hearing today.

In the last decade, the case for renewable energy has become an economic and environmental 'win-win' proposition. 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[2]. 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 the 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 modular and quick to install and bring on-line. In fact, some farmers, notably 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: help reduce energy costs; dramatically shave peak-power demands; produce a healthier living environment; and increase our energy supply while managing our energy demand.

California's energy crisis has raised fundamental questions about regional and national energy strategies. Rising demand suggests the need for new energy supplies, and certainly some new energy capacity is needed. However, there is a wide range of options for achieving supply and demand balance, and some of these options have not been given adequate attention. In general, the lack of past state and federal leadership has meant that we have seen too few incentives for renewable energy development, energy conservation, and efficiency measures, and too little attention to appropriate power plant siting issues and transmission and distribution bottlenecks. As a nation we are ignoring the importance of maintaining leadership in key technological and industrial areas, many of which are related to the energy sector.[3] This includes keeping pace with Japan and Germany in the production of solar photovoltaic systems, catching up with Denmark in wind and cogeneration system deployment, and with Japan, Germany, and Canada in the development of fuel cell systems. The development of these industries within the U.S. is vital to both our international competitiveness and commercial strength, and to our national security in providing for our own energy needs. Renewable and distributed energy systems and energy efficiency are areas experiencing tremendous market growth internationally. These systems combine the latest advances in energy conversion and storage, with improvements in computer and other advanced technologies, and are therefore natural areas for U. S. business interests and for U. S. strategic leadership. The U. S. must improve the financial and political climate for clean energy systems in order to reassert our leadership in this vital area.

## Energy Policy and Financial 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 that 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, 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.

## Energy Policy and Financial Recommendations (continued)

**• 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).

**• 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) in the house.

### 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 being the looming threat of climate change and a needed reduction in our greenhouse gas (GHG) emissions. It is now clear that any effort to maintain atmospheric levels of $CO_2$ below even doubled pre-industrial levels[4] cannot be met with an oil and coal-dominated global economy, barring radical and uncertain 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 results 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, however, and policy leadership that rewards 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 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.

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 also included[5].

*Leveling 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, the relatively low environmental costs of renewables would aid them in competing with conventional technologies, but many of these environmental costs are "externalities" that are not priced in the market. 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.

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 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.[6]

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. 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 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**

Historically, our nation's energy efficiency programs have been a resounding success. Last year, DOE documented the results of twenty of its most successful energy efficiency and renewable energy technologies and initiatives over the past two decades.[7] These technologies and activities have already saved the nation 5.5 quadrillion BTUs of energy, equivalent to the amount of energy needed to heat every household in the U.S. for about a year. The cost to taxpayers for these 20 activities was $712 million, less than 3 percent of the energy bill savings so far. In fact, the energy bill savings from these 20 projects alone is over three times the amount of money appropriated by the Congress for all DOE energy efficiency and renewable energy programs during the 1990s, demonstrating that spending taxpayers money on energy efficiency R&D and deployment is a very sound investment.

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 published by the Energy Information Administration (EIA), the American Council for an Energy Efficient Economy (ACEEE) estimates that total primary energy use per capita in the U.S. in 2000 was almost identical to that in 1973. Over the same period, economic output per capita increased 74 percent. Also, 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 the rest is due to structural changes and fuel switching. 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. Between 1996 and 2000, GDP increased 19 percent while primary energy use increased just 5 percent. Today's energy problems would be dramatically worse if energy use had also increased by 19 percent during 1996-2000.[8]

In 1997 the President's Committee of Advisors on Science and Technology (PCAST), a panel that consisted mainly of distinguished academics and private sector executives and upon which I served, conducted a detailed review of DOE's energy efficiency R&D programs. Based on this review the PCAST committee concluded that, "R&D investments in energy efficiency are the most cost-effective way to simultaneously reduce the risks of climate change, oil import interruption, and local air pollution, and to improve the productivity of the economy." PCAST further recommended that the DOE energy efficiency budget should be doubled between FY1998 and FY2003, and estimated that this investment could produce a 40:1 return for the nation including reductions in fuel costs of $15—30 billion by 2005 and $30—45 billion by 2010.[9]

Despite these successes, however, the U.S. wastes approximately 24 quadrillion BTUs in the production of electricity annually -- 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,* cost effective end-use technologies might reduce electricity consumption by ~1,000 billion kWh by 2020, which would almost entirely offset business-as-usual projected growth in electricity use.[10] This level of savings is more than Japan now uses for its entire economy.

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[11]. Many of these changes can be accomplished at *negative cost*, while others can be realized for only a few cents/kWh, far less than the cost delivered by new power plants.

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.

**Policy Options for Renewable Energy and Energy Efficiency Technology Development**

I firmly believe that the ultimate solutions to meeting our nation's energy needs must be based on private sector investment, bolstered by well-targeted government support such as tax incentives for emerging energy technologies and R&D. This must be coupled with policies that *open* markets to new generating capacity, rather than through federal subsidies for programs to increase energy supply using already mature technologies. This latter strategy would only generate near-term and incremental paybacks, while doing little to promote energy security or advance social and environmental goals. Instead, we now have the opportunity to build a sustainable 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 and tax incentives to reward actions that further the public good. With these thoughts in mind, I present several options that address both the short-term need to increase energy supply and the long-term goal to have 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. With energy now a clear national priority, funding for the U.S. Department of Energy'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 resulted in important commitments, particularly in the life sciences, to double R&D funding over the next 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[12]. If the U.S. expects to be a world leader in this emerging industry, as it is in the biomedical and high-tech sectors, significant investments in renewable energy and energy efficiency are both essential and profitable.

Federal funding and leadership for renewable energy and energy efficiency projects has resulted in a small number of notable successes, such as the *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 the Energy Star Buildings Program and saved more than 21 billion kWh of energy in 1999 or $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. 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. 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 (See table below). 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. 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[13], 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 stimulus for 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<br>*Alternative Fuels Credit* | 21.84 | 24% | 1,048<br>*(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)

*Renewables*

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). As evidenced by the number of bills introduced the extension and expansion of the PTC has been garnering strong and consistent support in Congress with many of the strongest proponents on this committee. The wind credit has proven to be successful in encouraging strong growth of U.S. wind energy in the last few years, with a 30 percent increase in 1998 and 40 percent increase in 1999, and approximately 2,000 MW of wind energy under development or proposed for completion before the end of 2001 (a 40 percent increase), when the federal wind energy PTC is scheduled to expire. While the U.S. was once the world leader in installed wind energy capacity we have since dropped to second place behind Germany, which now has twice the U.S. installed capacity[14]. In addition, the major wind turbine manufactures are now all in Europe. Clearly we need to continue our support for wind energy and extend these benefits, which create jobs, help our environment and increase our fuel security, to the other renewables thereby leveling the playing field and further diversifying our renewable resources.

I also support a minimum of a 15% investment tax credit for residential solar electric and water heating systems. In this case, an investment credit is preferable to a production credit due to the relatively high cost of smaller scale solar technologies at this time. 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. These are used in commercial and farm applications and are relatively costly compared to large wind turbines (500 kW and up). This proposal is included in the Bingaman-Daschle (S. 596) bill.

*Energy Efficiency*

Many new energy-efficient technologies have been commercialized in recent years or are nearing commercialization. But these technologies may never be manufactured on a large scale or widely used due to their initial high cost, market uncertainty, and lack of consumer awareness. Tax incentives can help manufactures justify mass marketing and help buyers and manufactures offset the relatively high first cost premium for new technologies, thereby building market share and reducing costs through economies of scale. Tax incentives should be offered for a variety of innovative energy-efficient technologies such as highly efficient homes, commercial buildings, and appliances. A key element in designing the credits is for only high efficiency products to be eligible. If eligibility is set too low then the cost to the Treasury will be high and incremental energy savings low since the incentives will have paid for sales that happen anyway. For this reason these tax credits should have limited duration and be reduced in value over time since once these new technologies become widely available and produced on a significant scale costs should decline. In this manner the credits help innovative technologies get established in the marketplace rather than becoming a permanent subsidy.

A number of tax bills to encourage high efficiency technologies have recently been introduced. These include:

- $50-100 for highly efficient clothes washers and refrigerators, the two highest energy consumers in households, is included in bills by Senators Lincoln, Allard and Grassley (S. 686) as well as Murkowski-Lott (S. 389) and Bingaman-Daschle (S. 596) and Representative Nussle (H.R. 1316).
- $2,000 for highly efficient new homes, introduced by Senator Bob Smith (S. 207) as well as Murkowski-Lott (S. 389) and Bingman-Daschle (S. 596) energy bills.
- 20 percent investment tax credit with a cap for innovative building technologies such as furnaces, stationary fuel cells, gas-fired pumps, and electric heat pump water heaters is in Bingman-Daschle (S. 596) energy bill with parts introduced by Representative Nancy Johnson (H.R. 1275).

- $2.25 per square foot tax deduction for investments in commercial buildings that achieve a 50 percent of greater reduction in heating and cooling costs compared to buildings meeting current model codes. This is included in legislation by Senator Bob Smith (S. 207) and Representative Cummingham (H.R. 778).

Incentives of this magnitude would have a relatively modest direct impact on energy use and $CO_2$ emissions, saving on the order of 0.3 quadrillion BTU of energy and 5 million metric tons of carbon emissions per year by the end of the eligibility period. I favor stronger incentives, however, such as credits to help establish these innovative products in the marketplace and reduce the first cost premium so that these products are viable after the credits are phased out. In this case, the indirect impacts of the incentive could be many times greater than the direct impacts. Total energy savings could reach 1 quadrillion BTU by 2010 and 2 quadrillion BTU by 2015 if the credits are successfully implemented[15].

While tax measures send a clear signal of support to suppliers and consumers who purchase and manufacture innovative clean technologies, another important strategy for promoting energy efficiency is the implementation of building and equipment standards. 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 4 shows how federal standards dramatically increased the market share of highly efficient magnet ballasts used for lighting.

Standards remove inefficient products from the market but still leave consumers with a full range of products and features to choose among. 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 demand 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 5 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[16].

*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 we 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,[17][18] MIT,[19] OTA,[20] and Oak Ridge National Lab/ACEEE.[21] 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,[22] and to 30 mpg for light trucks for $800 to $1,400 per vehicle retail price increase.[23] 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) 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[24,25]. This standard is similar to the one proposed by Senators Jeffords and Lieberman in the 106$^{th}$ 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 by several groups of the effects of ramping up to the 20 percent RPS target in 2020 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 6. Electricity prices are projected to fall 13 percent between 1997 and 2020 under this RPS (see Figure 7)[26]. This increase in renewable energy usage would also reduce some of the projected rise in natural gas prices for all gas consumers, providing an added savings for households who heat with 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[27].

*5) Federal standards 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 uses 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% electrical efficiency, the addition of heat utilization can raise overall efficiency to 80%. 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[28] (See Figure 8). 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 10% 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% 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) in the house. 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.

*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 affecting electricity generation. 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; and 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 percent) 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 helps decrease the demand for fossil fuels resulting in price drops for natural gas as shown in Figure 12. This results in 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[30]. Consequently we can begin to deploy these technologies now and so reap the benefits all that much sooner[31].

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.[32] 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[33]. 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. This will cost-effectively enable us to meet goals of GHG emission reductions[34] 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)

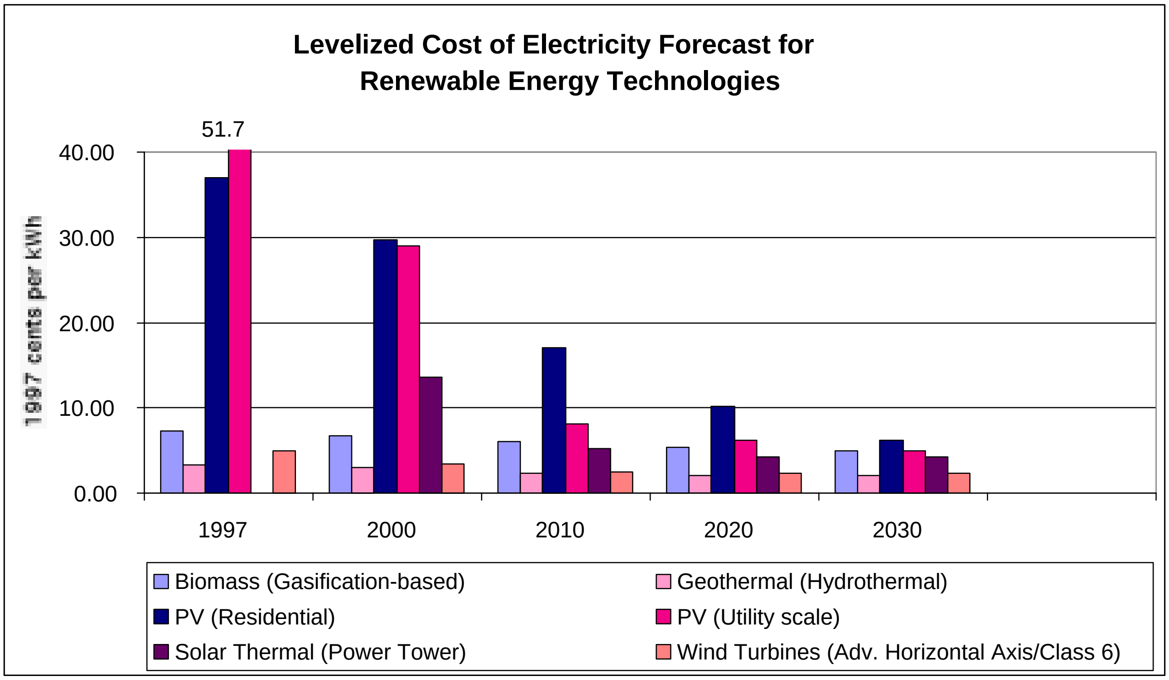
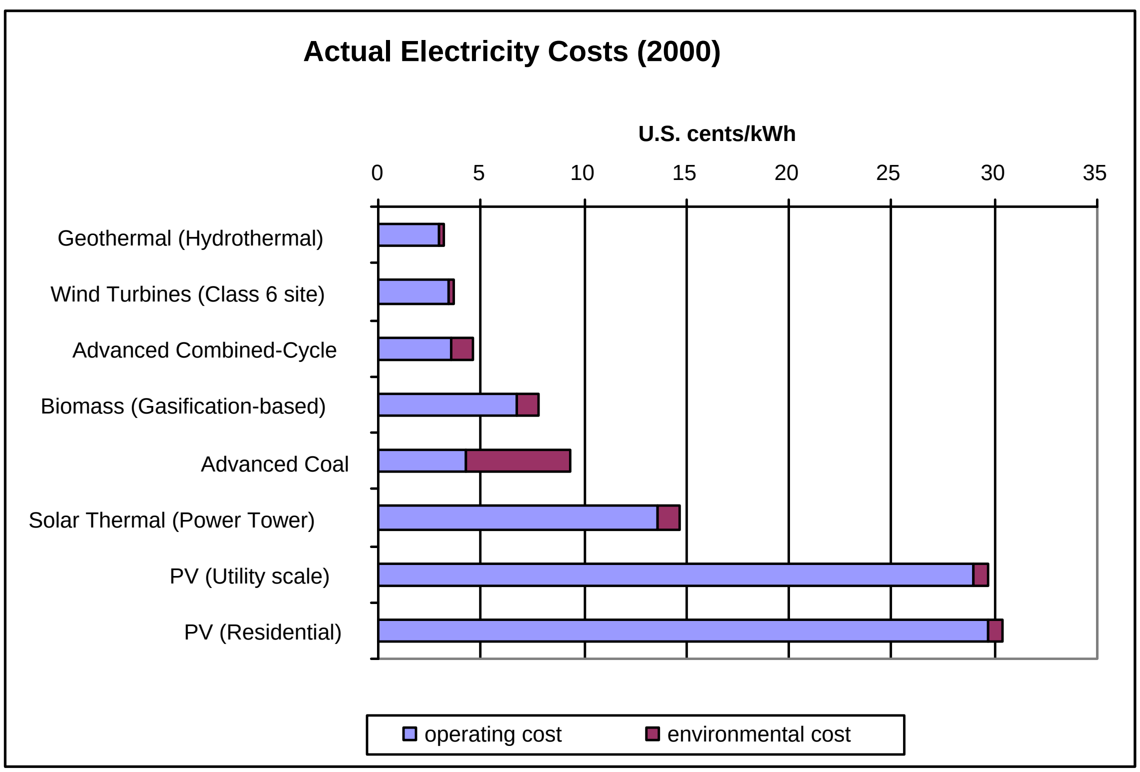
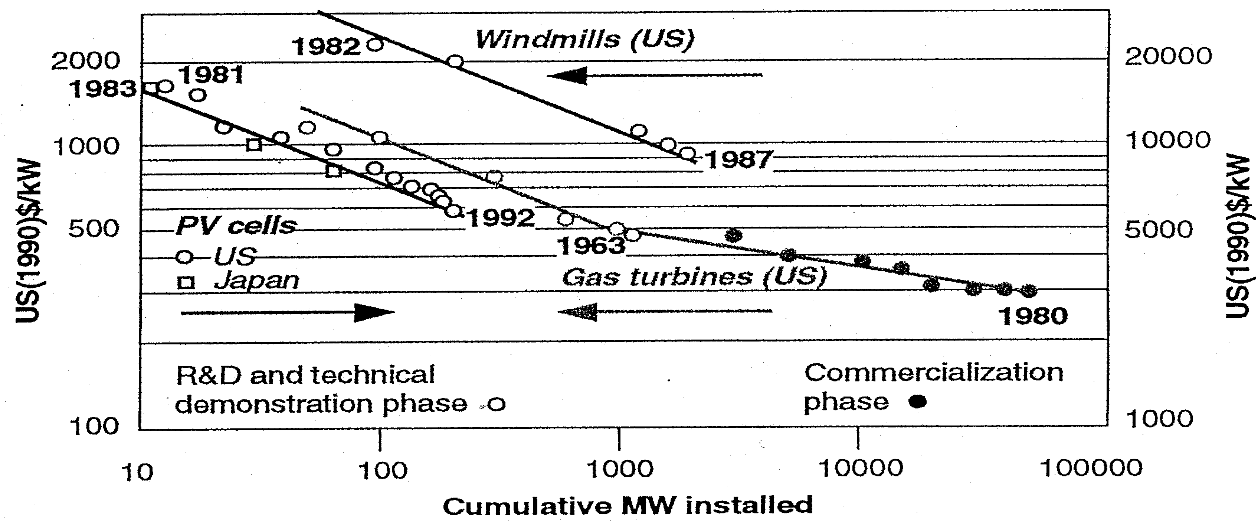



**Figure 2**. Actual electricity costs in year 2000




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

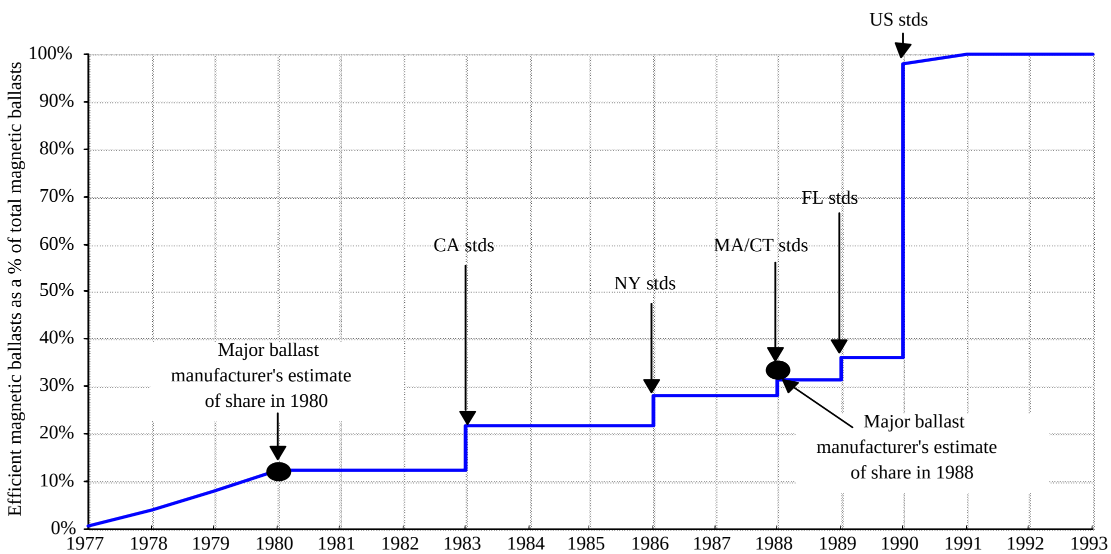


**Figure 5.** Television standby power consumption (Source: K. Rosen, LBNL, May 1999)

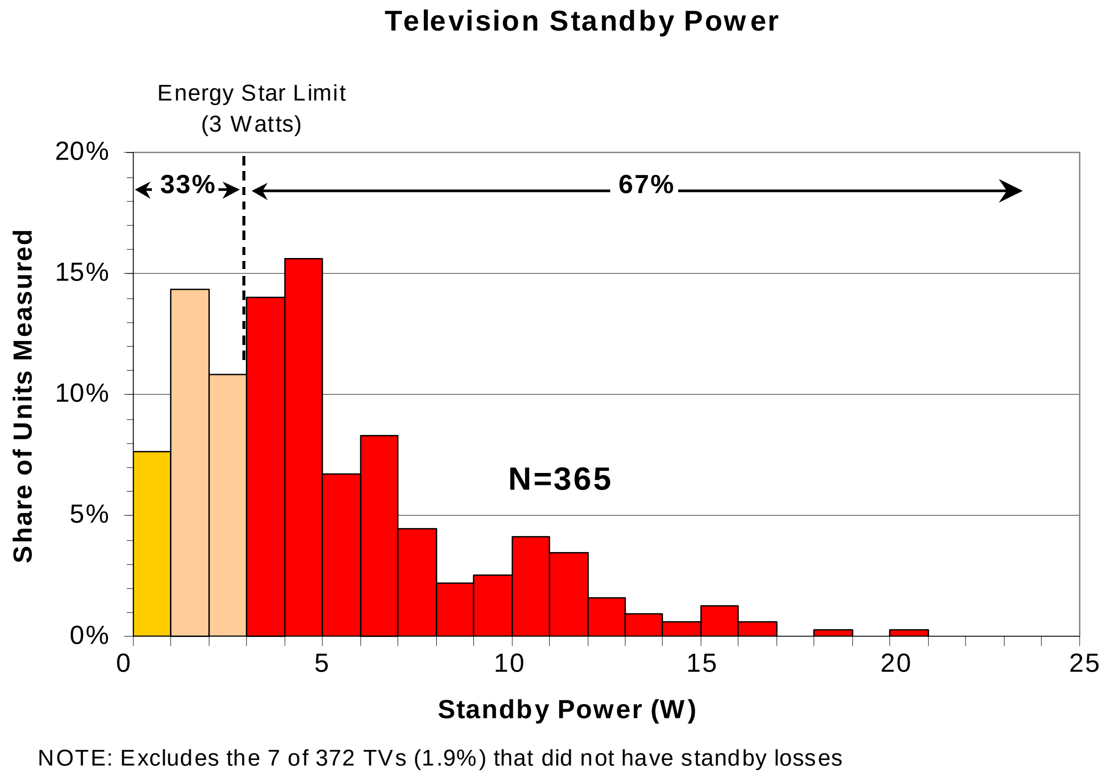



**Figure 6.** Renewable energy generation in the U.S. by region for a RPS with a 20 percent target in 2020 (Clemmer, 1999)

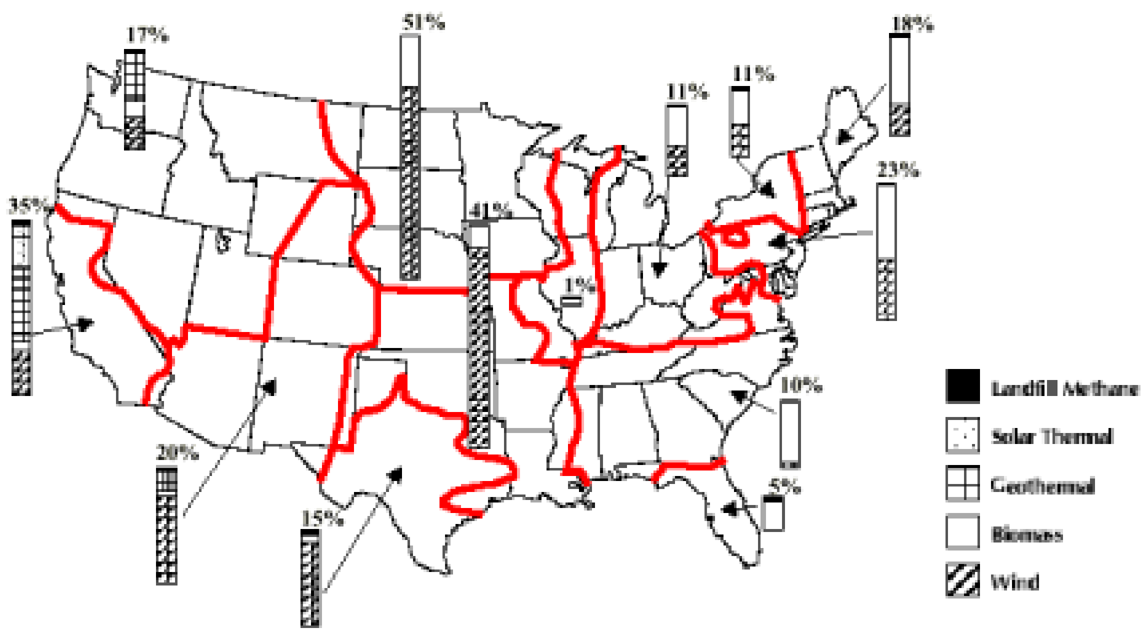


**Figure 7.** Average monthly electricity bill for typical nonelectric heating household (Clemmer, 1999)

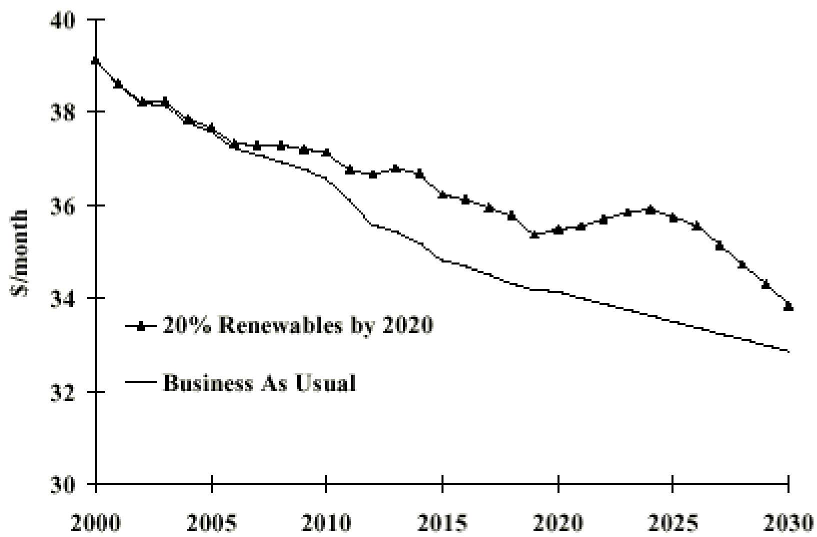



**Figure 8.** CHP growth potential within several sectors of the economy (ACEEE).

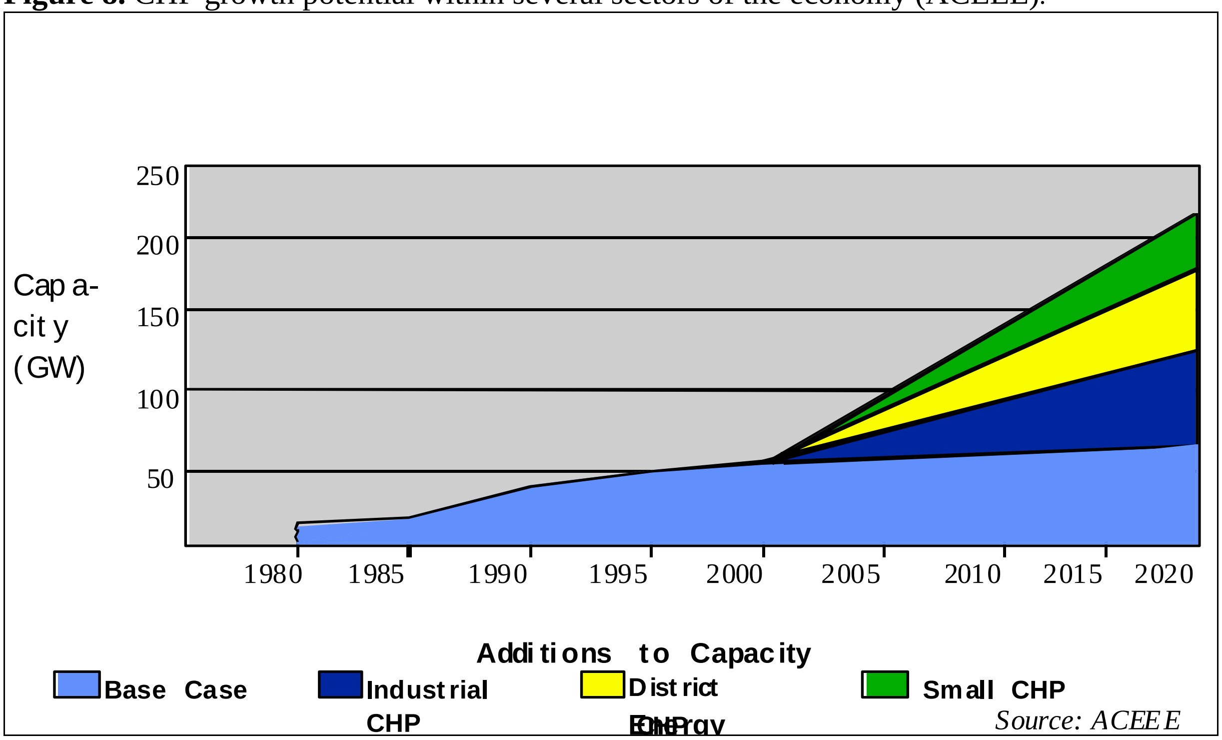


**Figure 9.** Electricity Deregulation under business as usual* (Clemmer, 2001)

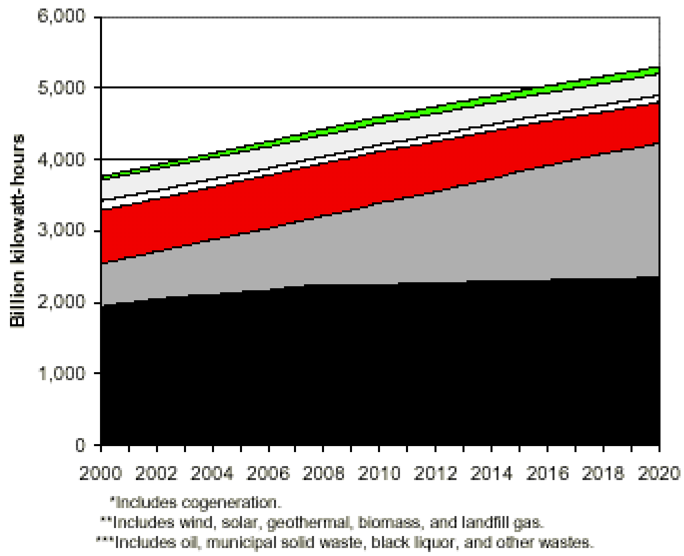



**Figure 10.** Energy generation with the implementation of various renewable energy and energy efficient policy options* (Clemmer, 2001)

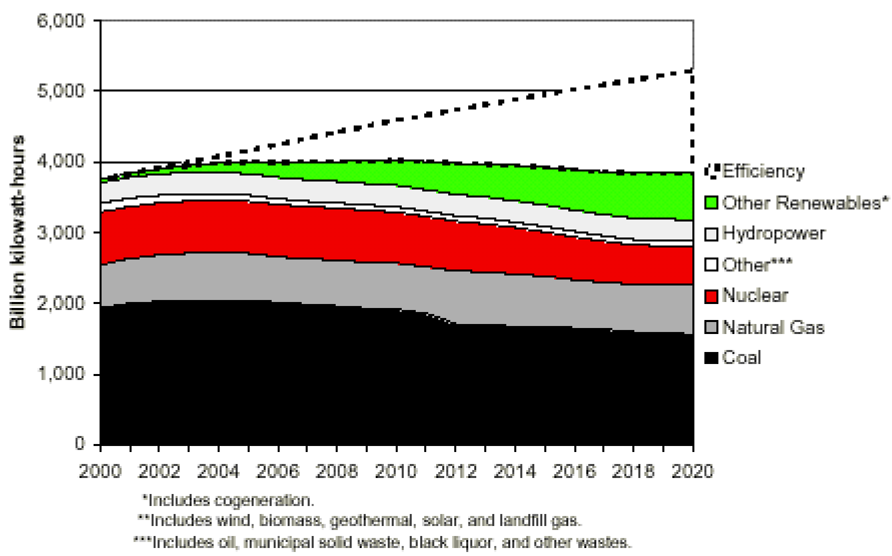


**Figure 11.** Power plant carbon dioxide emissions (Clemmer, 2001)

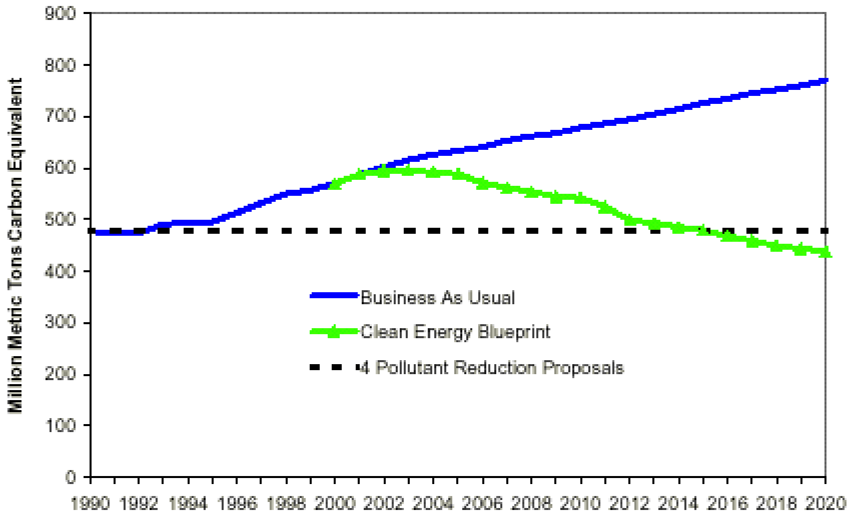
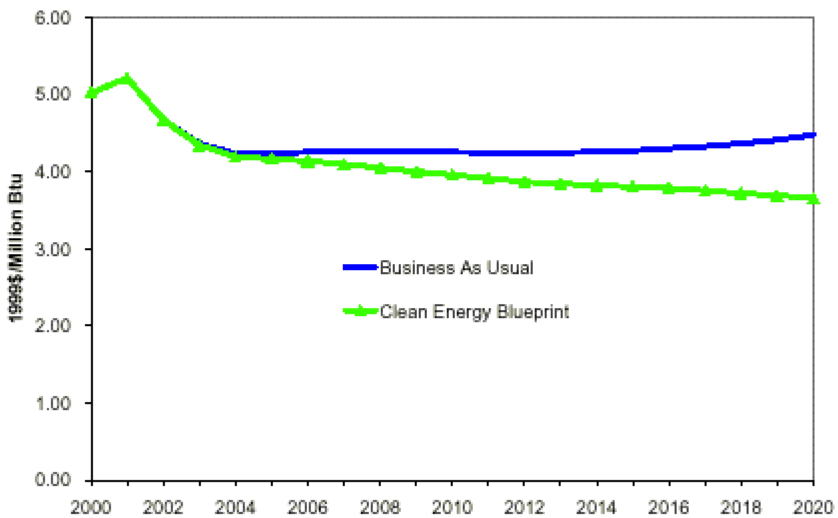
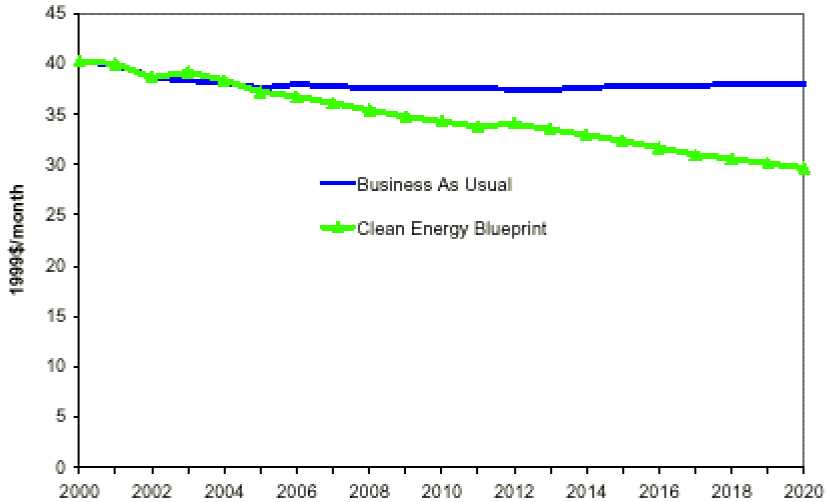



**Figure 12.** Natural gas prices (national average)* (Clemmer, 2001)




**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)

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1 The Renewable and Appropriate Energy Laboratory: URL http://socrates.berkeley.edu/~rael

2 Herzog, A.V., Lipman, T.E., and Kammen, D.M. (2001) ""Energy Resource Science and Technology Issues in Sustainable Development: Renewable Energy Sources," in, *OUR FRAGILE WORLD: Challenges and Opportunities for Sustainable Developmen*t, forerunner to the Encyclopedia of Life Support Systems (EOLSS), (UNESCO-EOLSS Secretariat, EOLSS Publishers Co. Ltd.).

3 Kammen, D. M. and Margolis, R. M. (1999) "Evidence of Under-Investment in Energy R&D Policy in the United States and the Impact of Federal Policy," *Energy Policy*, **27** pages 575 - 584.

4 IPCC (Intergovernmental Panel on Climate Change) (2001) *Climate Change 2001: The Scientific Basis*, January.

5 Swezey, B. G. and Wan, Y-H. (1996) "The True Cost of Renewables: An Analytic Response to the Coal Industry's Attack on Renewable Energy," National Renewable Energy Laboratory, U.S. Department of Energy, NREL/TP-462-20032.

6 Duke, R. D., and Kammen, D. M. (1999), "The economics of energy market transformation initiatives", *The Energy Journal*, **20**: 15 – 64.

7 Clean Energy Partnerships: A Decade of Success (2000) DOE/EE-0213. Washington, D.C.: Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy.

8 Nadal, S. and Geller, H. (2001) "Energy Efficiency Polices for a Strong America," American Council for an Energy-Efficient Economy (ACEEE), May (draft).

9 President's Committee of Advisors on Science and Technology (PCAST) (1997) *Federal Energy Research and Development for the Challenges of the Twenty-First Century,* Washington, D.C., Energy Research and Development Panel, November.

10 Interlaboratory Working Group (2000) *Scenarios for a Clean Energy Future* (Oak Ridge, TN; Oak Ridge National Laboratory and Berkeley, CA; Lawrence Berkeley National Laboratory), ORNL/CON-476 and LBNL-44029, November.

11 Nadal and Geller (2001) *op cit.*

12 Margolis, R. and Kammen, D. M. (1999) "Underinvestment: The energy technology and R&D policy challenge", *Science*, **285**, 690 - 692.

13 Established by the Windfall Profit Tax Act of 1980. Tax credit is $3 per barrel of oil equivalent produced, and phases out when the price of oil rises to $29.50 per barrel (1979 dollars)

14 American Wind Energy Association (2001) http://www.awea.org.

15 Nadal, S. and Geller, H. *op cit.*

16 Nadal, S. and Geller, H., *op cit.*

17 Mark, J. (1999) "Greener SUVs: A Blueprint for Cleaner, More Efficient Light Trucks," Union of Concerned Scientists, July.

[18] David J. Friedman, Jason Mark, Patricia Monahan, Carl Nash, and Clarence Ditlow (2001) *Drilling in Detroit: Tapping Automaker Ingenuity to Build Safe and Efficient Automobiles*, Union of Concerned Scientists, Cambridge, MA, June.
[19] Malcolm A. Weiss, John B. Heywood, Elisabeth M. Drake, Andreas Schafer, and Felix F. AuYeung (2000) "On the Road in 2020: A lifecycle analysis of new automobile technologies," Energy Laboratory, Massachusetts Institute of Technology, MIT EL 00-003, Cambridge, October.
[20] Office of Technology Assessment (1995) *Advanced Vehicle Technology: Visions of a Super-Efficient Family Car*, OTA-ETI-638, Office of Technology Assessment, U.S. Congress, Washington, D.C., September.
[21] David L. Greene and John Decicco (2000) "Engineering-Economic Analyses of Automotive Fuel Economy Potential In The United States," *Annual Rev. Energy Environ*. **25**: 477–536.
[22] Greene and DeCicco, 2000.
[23] Interlaboratory Working Group, 2000.
[24] Clemmer, S.L., Nogee, A., and Brower, M. (1999) "A Powerful Opportunity: Making Renewable Electricity the Standard," Union of Concerned Scientists, January.
[25] PCAST, *op cit.*
[26] Clemmer, S., Nogee, A, and Brower M. *op cit*.
[27] Rader, N. (2000) "Getting it Right and Wrong in the States," Windpower Monthly, PP. 42-47, April.
[28] Source: U.S. DOE-EIA and Onsite Sycom (include www address)
[29] Clemmer, S.L., Donovan, D., Nogee, A. (2001), *op c it.*
[30] CALPIRG Renewable Energy Report (2001), June.
[31] Kinzig and Kammen, *op cit.*
[32] Interlaboratory Working Group, 2000.
[33] Krause, F., DeCanio, S, and Baer, P. (2001) "Cutting Carbon Emissions at a Profit: Opportunities for the U.S.," (International Project for Sustainable Energy Paths: El Cerrito, CA), May.
[34] Baer, P., Harte, J., Haya, B., Herzog, A.V., Holdren, J., Hultman, N.E., Kammen, D.M., Norgaard, R.B., and Raymond, L. (2000) "Equity and Greenhouse Gas Responsibility," *Science*, **289**, page 2287.