JOSEPH W. COTCHETT (36324;jcotchett@cpmlegal.com)
PHILIP L. GREGORY (95217; pgregory@cpmlegal.com)
PAUL N. MCCLOSKEY (24541; pmccloskey@cpmlegal.com
COTCHETT, PITRE & McCARTHY, LLP
San Francisco Airport Office Center
840 Malcolm Road
Burlingame, CA 94010
Tel: (650) 697-6000
Fax: (650) 697-0577

JULIA A. OLSON (192642; jaoearth@aol.com)
WILD EARTH ADVOCATES
2985 Adams St.
Eugene, OR 97405
Tel: (541) 344-7066
Fax: (541) 344-7061

THOMAS J. BEERS (Mt. State Bar #95, *pro hac vice*
blo@montana.com)
BEERS LAW OFFICES
234 E. Pine
P.O. Box 7968
Missoula, MT 59807-7968
Telephone: (406) 728-4888
Facsimile: (406) 728-8445

Attorneys for Plaintiffs

UNITED STATES DISTRICT COURT

NORTHERN DISTRICT OF CALIFORNIA

ALEC L., et al., Plaintiffs, vs. LISA P. JACKSON, et al. Defendants.	Case No. C11-02203 EMC **DECLARATION OF ARJUN MAKHIJANI, PH.D., IN SUPPORT OF PLAINTIFFS' MOTION FOR PRELIMINARY INJUNCTION** Date: November 21, 2011 Time: 2:00 p.m. Place: Courtroom 5, 17th Floor

I, Arjun Makhijani, Ph.D., declare as follows:

1. I am president of the Institute for Energy and Environmental Research, a non-profit institute located in Takoma Park, Maryland. I am over 21 years of age. In this declaration, which I authored, I provide facts and analysis about the technical and economic feasibility of achieving an efficient and fully renewable energy system in the United States by 2050 or even somewhat before that.

Summary

2. This declaration is based in large measure on my book, *Carbon-Free and Nuclear-Free: A Roadmap for U.S. Energy Policy*, as well as on research that I have done since that time up to the time of preparing this declaration. My main conclusions are:

a. Carbon dioxide (CO_2) emissions from fossil fuel use are responsible for almost 80 percent of U.S. greenhouse gas emissions. It is necessary to eliminate these emissions, or nearly so, to protect the climate; it is also highly desirable, since that will produce many other collateral benefits for society such as reduced air pollution and respiratory diseases, reduced casualties in the military for transporting and using petroleum, and reduced conflict over Middle Eastern oil resources. Fortunately, with the right policies, it is also technically and economically feasible to transition to an energy system that is fully renewable or nearly so (more than 90 percent renewable) by 2050 and to do so at reasonable cost. This means that CO_2 emissions from energy use can be reduced at an exponential rate of about 6 percent per year. A workable solution and a roadmap to get there is detailed in my book, *Carbon-Free and Nuclear-Free; A Roadmap for U.S. Energy Policy*, first published in 2007. My research since that time has led me to conclude that a faster rate of reduction of energy-related CO_2 emissions and an earlier achievement of a 90 percent (or better) renewable energy system, by about 2040 is feasible with determined and sound public policy.

b. Energy efficiency is central to a sound energy policy and to a transition to non-fossil fuel energy sources in a reasonable time (30 to 40 years). A reduction of the energy footprint of about 50 percent for existing buildings and 70 percent for new building energy footprints through the proper use of efficiency technologies is economically feasible and reasonable.

c. Current military investments and technological developments demonstrate the feasibility of an economical transition to displacing well over 50 percent of petroleum use by 2025 by increases in efficiency and a partial transition to electric vehicles and plug-in hybrids. That is, a rate of reduction of CO_2 emissions of more than 6 percent per year can be achieved in the vehicular transportation sector. A far faster rate is set to be achieved in some parts of the defense sector. But the commercial market will require a suitable set of carbon and efficiency policies and targets to ensure successful reductions in time and to achieve the greatest benefits at lowest cost.

d. The technical feasibility of replacing jet fuel in commercial and military aircraft with biofuels has been established. Algal biofuels are the most productive per unit of land and can bring many other benefits, since they do not require fresh water for feedstock production and can even be cultivated in wastewater as an ancillary service provided in wastewater treatment. The technological and economic developments of the last three years, the U.S. military's push to reduce costs and casualties associated with petroleum fuel, and the European goals for reducing CO_2 emissions from aircraft starting in 2012 are among the main driving forces of rapid change. Companies are planning large increases in biofuel production, including from algae, in the next two to three years; large oil companies are also investing in or purchasing companies that are in the biofuels business. The main missing element is a U.S. policy for reducing carbon emissions from commercial aircraft.

e. The industrial sector possesses much more fuel flexibility than the aircraft sector. There is no inherent barrier technically since biofuels and/or hydrogen from renewable sources can directly substitute for fossil fuels in almost all energy intensive industrial uses. Further, electricity in industry, like that in other sectors, can be derived completely or almost completely from renewable sources. What is needed from the federal government is a steadily declining cap on carbon emissions from large industrial sources, which would provide the maximum flexibility to industry to phase out the use of fossil fuels.

f. The United States possesses far greater wind and solar energy resources than could be used under any foreseeable scenario for the long term. The cost of wind-generated electricity in the best areas is already at the low end of fossil fuel (coal or natural gas) generated electricity; solar energy costs are headed in the same direction. Just as in the case of using plug-in hybrids and replacing petroleum fuels with algal and other biofuels, the Department of Defense is investing greatly, both to reduce costs and casualties, in going to renewable electricity. Moreover, when efficiency is combined with renewable electricity, the total bills for electricity should be about the same, since the lower costs for efficiency and the higher cost per kilowatt hour for generation will balance each other out.

g. The federal government will not have to bear significant costs to effect this transition. Its main responsibilities are to put its own house in order in regards to efficiency and renewable energy and to put in place a set of policies that will provide the framework for a transition for the U.S. economy as a whole. On the contrary, there will be a significant benefit in terms of reduced military expenditures and casualties that have been incurred in the quest for security of foreign oil supplies.

h. The transition to a renewable energy system can be accomplished with the typical fraction of Gross Domestic Product devoted to energy (about 8 percent) in the United States.

i. There will be immense overall direct and indirect benefits, though some sections of the country and population, such as coal mining areas, would be adversely affected. This is no more than the kind of difficulty normally experienced by the economy in any major transition, such as from a rural to urban economy or from whale oil and horses to petroleum, electricity, tractors, and cars.

j. The hardship can be mitigated by appropriate public policies, such as a carbon tax whose proceeds can be used to offset any regressive income impacts, create employment in the affected areas, encourage new energy infrastructure in the affected areas, and so on.

k. There are immense direct and indirect public benefits in transitioning to an efficient renewable energy system in terms of reduced incidence of diseases such as asthma, freeing up of most of the supplies of water that are now used for thermal electricity generation (and hence reduced conflict over water), reduced air, water, and soil pollution that accompanies fossil fuel production, processing and use, and greatly improved prospects of avoiding the worst consequences of climate change.

l. The main policies needed to make a transition are:

- A renewable portfolio standard for electricity that ramps up to 90 or 95 percent by 2050 at the latest with an option to increase the speed of phase out to 2040.
- A carbon tax whose proceeds are refunded to lower income groups and used to offset damage in areas and populations that would otherwise be negatively affected. Some of the funds would also be used for research and development of new efficiency and renewable energy technologies.
- A carbon-neutral federal government by 2030 that would create a market for renewable energy and reduce government expenditures on fuels and electricity in the medium and long term.
- Building, appliance, and vehicle efficiency standards, including all motor vehicles, ships, and aircraft.
- CO_2 emission targets per mile travelled for the transportation sector.
- A steadily declining cap on emissions from large, energy intensive industries to 10 percent or less of 1990 emissions by 2050.

A. Statement of qualifications (CV attached)

3. I have extensive experience (over 40 years) in the technical and policy aspects of the energy issue. I am principal author of the first study of energy efficiency ever done of the U.S. economy (1971). More recently, I authored *Carbon-Free and Nuclear-Free: A Roadmap for U.S. Energy Policy* (2007). I was part of the Ford Foundation Energy Policy Project team led by S. David Freeman that produced an efficiency-centered report (*A Time to Choose: America's Energy Future* (1974)) that became the foundation of President Carter's energy policy. I am a co-author of *Investment Planning in the Energy Sector* (1976), which is an econometric model of the relationship between electricity demand, rates, and levels of investment, prepared for the U.S. government's Energy Research and Development Administration. I am also author or co-author

of numerous other reports and articles on energy issues.

4. I have been a consultant on energy issues to a wide variety of groups including utilities (Tennessee Valley Authority and the Lower Colorado River Authority), the Federation of Rocky Mountain States, the Lawrence Berkeley National Laboratory, the Edison Electric Institute, and several agencies of the United Nations, including the United Nations Environment Programme, the United Nations Center on Transnational Corporations, the Food and Agriculture Organization of the United Nations, the United Nations Development Programme, the International Labour Office of the United Nations, and the Economic and Social Commission for Asia and the Pacific. Some of these consulting assignments were done in a personal capacity and others, the ones since 1987, have been through the Institute for Energy and Environmental Research.

5. I have a Ph.D. from the Department of Electrical Engineering and Computer Sciences of the University of California at Berkeley (1972), where I specialized in the application of plasma physics controlled nuclear fusion. I have an M.S. from the Electrical Engineering Department of Washington State University (1967) and a Bachelor of Engineering (Electrical) degree from University of Bombay in India (1965).

6. In 2007, I was elected a Fellow of the American Physical Society, an honor accorded to at most one-half of one percent of the Society's members, for my "*tireless efforts to provide the public with accurate and understandable information on energy and environmental issues.*" I am also a member of the Institute for Electrical and Electronic Engineers and its Power & Engineering Society, the Health Physics Society, and the American Association for the Advancement of Science. S. David Freeman, the former Chairman of the Tennessee Valley Authority and former CEO of several other publicly-owned utilities, has said of *Carbon-Free and Nuclear-Free: A Roadmap for U.S. Energy Policy*:

> My advice in these turbulent energy times is: when Arjun talks numbers, policymakers should listen. He has a stellar technical track record….I have no doubt that, with determination and guts, we can achieve a renewable energy

economy. Arjun has laid out a thoughtful and practical approach to get us there.[1]

B. Introduction and purpose

7. Fossil fuels are central to the functioning of the U.S. economy, accounting for about five-sixths of the total energy used in 2009[2] and almost four-fifths of U.S. greenhouse gas emissions in terms of carbon dioxide (CO_2) equivalent.[3] Hence, reducing U.S. greenhouse gas emissions by 80 percent or more will require eliminating the vast majority of CO_2 emissions from fossil fuel use. It may be difficult to reach that level of verifiable reductions in other greenhouse gas emissions from some other sectors such as land use and aspects of agriculture such as dairy farming; therefore, it is sensible policy to aim for reductions in fossil fuel-related CO_2 emissions of well over 80 percent.

8. The purpose of this declaration is to provide evidence that it is technically and economically feasible to accomplish a near-total elimination of fossil fuels (about 90 percent or greater reduction compared to 2009[4]) by the middle of this century. This means a steady compounded reduction of CO_2 emissions from fossil fuels at a rate of about 6 per percent per year until the year 2050. A somewhat faster phaseout of fossil fuels in about 30 years may be possible and could be made likely if policies were determined enough. This implies a reduction of fossil-fuel related CO_2 emissions at about 8 percent per year. [5]

9. Economic feasibility is defined directly, in terms of expenditures on the services that

---

[1] See Foreword by S. David Freeman, in Makhijani 2010 CFNF p. xi.

[2] All historical energy data are from the Department of Energy's Energy Information Administration website, www.eia.gov, unless otherwise stated. Data are often summarized on the "Energy Kids" page which is used here as much as possible, given that the declaration is prepared for youth. These are the same data as in other parts of the website, except they are better summarized.

[3] EPA 2011 GHG Table ES-2

[4] A 90 percent reduction of fossil fuel-related CO_2 emissions relative to 1990 is equal to about a 91 percent reduction relative to 2009. 1990 emissions were 4.738 billion metric tons and 2009 emissions were 5.209 billion metric tons. (EPA GHG 2011 Table ES-2)

[5] A steady decline at 6 percent per year over 40 years would be represented by the exponential expression that uses a continuous compounding rate: $e^{(-0.06*40)} = 0.09$. Hence, the emissions at the end of 40 years would be 9 percent of 2010 emissions, for a 91 percent reduction in fossil-fuel related CO2 emissions. At 8 percent per year, the same reduction of 91 percent can be achieved in 30 years.

energy provides, such as lighting, heating, air conditioning, electricity for appliances, such as refrigerators, and devices, such as computers, etc. These expenditures for energy services will not be excessive compared to historical norms and, given appropriate policies, they should be lower than during crisis periods (when they tend to be more than 10 percent of GDP). I will use 8 percent of GDP as a reference value. This was the fraction of expenditures on energy in the three years just prior to the start of the energy crisis in 1973.[6] I address expenditures on energy supply as well as expenditures needed to make the economy more energy efficient than the gradual, underlying increases that have been occurring over nearly four decades.

10. I investigated these issues in detail in my book *Carbon-Free and Nuclear-Free: A Roadmap for U.S. Energy Policy*.[7] The main conclusion was that a fully renewable, efficient energy system was technically and economically feasible by about 2050, based on available and tested technologies and on systems that were economical then or could be projected to be economical by about 2020, given appropriate public policies regarding carbon emissions. The development of technologies and policies in some parts of the United States and elsewhere (most notably in parts of Europe) since the publication of *Carbon-Free and Nuclear-Free* indicates that achieving a fully renewable energy sector in about 30 years is feasible.

11. This declaration draws upon the roadmap detailed in *Carbon-Free and Nuclear-Free*, and supplements it with additional research done since that time as well as new information about technological developments since late 2007.

12. I will also address some aspects of public good that would be achieved directly and indirectly for the people, environment, and security of the United States by transitioning rapidly to an essentially fully renewable and efficient energy system. However, I will leave out climate related benefits and avoided damage, because I understand that that is being covered in other declarations that are being prepared. For purposes of this declaration, I define a fully renewable

[6] Makhijani 2010 CFNF Figure 8-1 (p. 158)
[7] Makhijani 2010 CFNF

energy system as one that gets more than 90 percent of its energy supply from renewable sources such as wind, solar, and geothermal energy. CO_2 emissions due to energy use would also decline by 90 percent or more.[8]

13. Finally, I will consider areas where a transition to a fully renewable energy economy might produce hardship for some job types (such as coal mining and petroleum exploration and production) while producing benefits in other areas, such as renewable energy production, energy efficiency backfitting of existing buildings in the residential and commercial sector, etc. Specifically, I will point out that no significant change in the economic structure is without both benefits to some groups and places and costs to others. It is a question of balance. Indeed, "creative destruction" is understood to be a normal part of technological innovation, economic growth, and productivity improvement.[9] It is the process by which modern society moved from rural to urban areas, from whale oil and other animal fats to petroleum for lighting, from horses to tractors, or mainframe computers with punch cards to laptops. A transition to an efficient renewable energy system would be no different. Moreover, it is very important to note that the negative impacts can be mitigated by sound public policy.

C. Energy Efficiency

14. Energy efficiency is central to a sound energy policy and to a transition to non-fossil fuel energy sources in a reasonable time (30 to 40 years). This is because current energy use is very inefficient. For instance, just one percent of the energy liberated by burning coal or by nuclear fission appears as visible light in an incandescent bulb. Two-thirds is waste heat at the power plant. Of the electricity that reaches the home, about 97 percent is infrared radiation, rather than visible light and just about 3 percent is visible light. Similarly, vehicular transportation using automobiles is just about 1 percent efficient, though the mechanical efficiency is 15 percent or so. Most of the mechanical power is used to move the weight of the car, not the people in it. In other

---

[8] Ten percent of U.S. energy-related CO_2 emissions in 2009 would amount to just under 10 quadrillion Btu of natural gas use, or about 40 percent of 2010 natural gas consumption, assuming no other energy-related fossil fuel use.
[9] The concept was developed by the famed economist Joseph Schumpeter in *Capitalism, Socialism and Democracy*. (Schumpeter 1962 pp. 81-86)

words, the system is inefficient both because the system engine loses most of the energy in gasoline one way or another (waste heat, friction at the tires, etc.) and also because the weight of the vehicle that is moved is much larger than the people who are the real “payload” – the objective after all is not to move a steel hulk, but the people.

15. In this declaration, I will illustrate the importance of efficiency in two large energy use areas:

- Building electricity use (which accounts for about three-fourths of electricity use, including electricity use by appliances in buildings).
- Automobiles used for personal transport.

Buildings

16. Buildings account for roughly 75 percent of electricity consumption in the United States.[10] This consumption is driven by space heating and cooling, lighting, as well as a variety of other uses including refrigeration, televisions, and computers, and in many homes cooking and water heating as well.[11]

17. Standards for appliances and buildings are probably the most effective means for achieving building energy efficiency. This has been shown in specific cases, with refrigerators being the most dramatic and illustrative. Standards are also the best way to overcome the split incentive in buildings whereby builders and landlords have little incentive to invest in energy efficiency, even when it is economical, because they do not pay the utility bills.[12] Figure 1 shows the cost of efficiency measures for residential appliances in the form of a supply curve – that is, it shows the amount of reduction in electricity use by using more efficient appliances that can be achieved in specific parts of the residential electricity sector at a particular price per kilowatt-

[10] BEDB 2010 Table 1.1.9: Buildings Share of U.S. Electricity Consumption (Percent). March 2011.
[11] BEDB 2010 Table 1.1.4: 2008 U.S. Buildings Energy End-Use Splits, by Fuel Type (Quadrillion Btu)
[12] Standards may not be the most suitable means to achieve efficiency in all cases, as is likely the case with heavy industry, which is accustomed to watching its energy bills and responds to price signals. However, some equipment such as small motors used widely in industry may be suitably improved through a standard setting process.

hour. These estimates were published in a 2008 report on energy efficiency prepared by the American Physical Society.[13] For instance, an efficient color TV costs more compared to a typical market model having the same features, but it consumes less electricity. The added capital cost of the efficient TV when computed as a cost of the saved electricity over the life of the TV is about 0.8 cents per kilowatt-hour.[14] A standard TV would use more electricity, which would have to be purchased at a cost of 9.4 cents per kilowatt-hour. The width of the bar indicates how much electricity could be saved per year if there were efficiency standards, thereby ensuring that all color TVs conformed to the more efficient standard eventually (by 2030 in Figure 1).

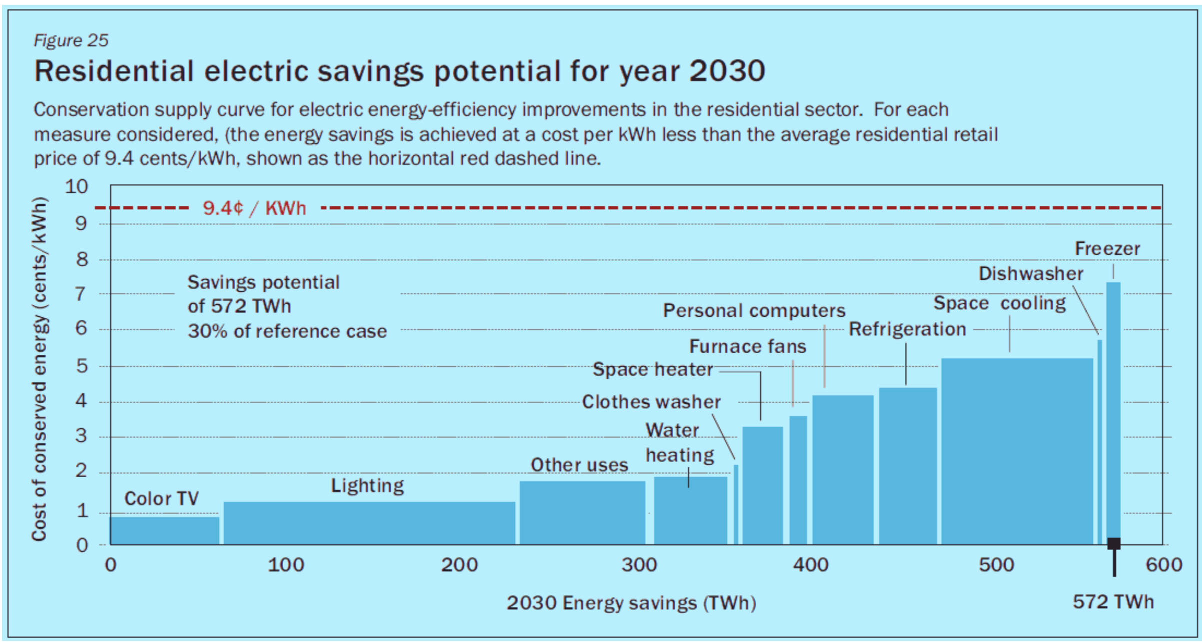

Figure 1: Residential Electric Savings Potential for Year 2030
Source: APS 2008 Figure 25 (p.76). Used with permission from the American Physical Society's report: *"Energy Future, Think Efficiency"* (2008)

18. The 2008 APS study, *Energy Future, Think Efficiency,* found that about 30 percent of residential electricity use can be eliminated through economic efficiency measures by 2030.[15] Note that there are essentially no governmental costs in this approach other than the minimal costs of evaluating and setting standards. And the government would save money since it would

[13] APS 2008 p. 76
[14] The cost energy saved is a calculated as the present value of all savings over the life of the appliance, using a discount rate of 7 percent. The savings in end-use categories may represent a mix of efficient technologies. Values are in constant 2007 dollars. APS 2008, p. 75.
[15] APS 2008 p. 76

also purchase more efficient appliances. The higher cost of the appliance is paid by the consumer, who also reaps the far larger benefit of lower electricity bills. Of course this requires that standards be carefully and reasonably set with economics and technical feasibility in mind.

19. Table 1 shows the details measure by measure, and how they all add up when they are combined. The table is prepared from Figure 1 above. For instance, Figure 1 shows that the added capital cost of an efficient television, translated into a per kilowatt-hour electricity cost, would be 0.8 cents per kWh (the height of the TV bar in Figure 1) and that the total national savings by the year 2030 would be 60 TWh (the width of the TV bar in Figure 1). Similarly, the cost per kWh for efficient furnace fans in a home with forced air heating is 3.5 cents per kWh, and the national savings would be 15 TWh. The last column shows the total incremental cost in 2030 of purchasing the more efficient appliances. It is not the total cost of the appliances but just the increase in cost compared to typical appliances that would be sold in the absence of efficiency standards.

Table 1: Residential Electric Savings Potential due to Efficient Appliances in the Year 2030

Item	Savings in 2030, TWh	Cost, cents/kWh	Total Cost in 2030, million $
TV	60	0.8	480
Lighting	170	1.2	2,040
Other	70	1.8	1,260
Water heating	50	2.0	1,000
Clothes washer	5	2.2	110
Space heater	35	3.2	1,120
Furnace fans	15	3.5	525
Personal computers	25	4.1	1,025
Refrigeration	30	4.3	1,290
Space cooling	100	5.2	5,200
Dishwasher	5	5.7	285
Freezer	7	7.4	518
Totals (average per kWh)	**572**	**2.6**	**$14,853**

Source: Based on APS 2008 (see Figure 1 above).

20. Note that the average cost of all the measures put together is just over one-fourth of the price of purchasing residential electricity. This means that a broader package of measures, installed together would still make economic sense, though some of the measures individually may not. To put the above figure of $14.9 billion (rounded) total investment in appliance efficiency in perspective, the annual expenditures on residential electricity in the United States in 2009 were $157 billion.[16] The net annual savings in 2030 would be about $39 billion (6.8 cents savings per kWh and 572 TWh = 572 billion kWh saved).

21. The history of the efficiency of three common household appliances illustrates the importance that standards can have; this history is shown in Figure 2. Refrigerator standards, which represent the most dramatic example, reinforced market-based trends that were occurring in the first part of the 1970s; the combination resulted in efficiency improvements by a factor of four in about 30 years. Smaller but also significant improvements also occurred in the other two cases.

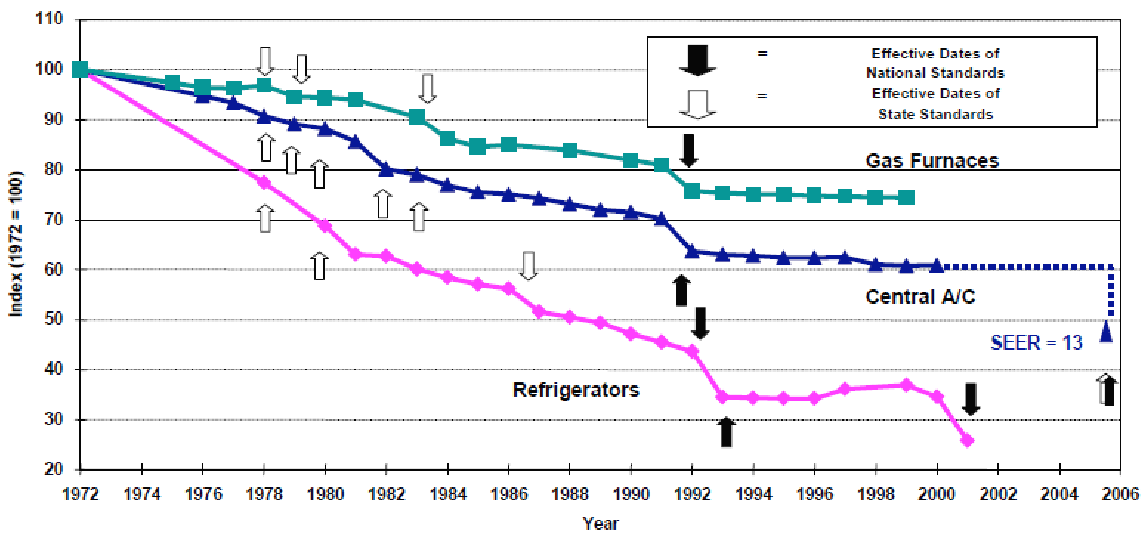

Figure 2: Impact of Standards on Efficiency of Three Appliances
Source: Rosenfeld 2008 Slide 7, which was adapted from S. Nadel, ACEEE, in ECEEE 2003 Summer Study, www.eceee.org

[16] EIA 2011 Electric Power (Electric Power Annual 2009 - Data Tables, on the Web at http://www.eia.gov/cneaf/electricity/epa/epa_sprdshts.html. See table "1990 - 2009 Revenue from Retail Sales of Electricity by State by Sector by Provider (EIA-861).")

22. A closer look at the history of refrigerators provides a clear illustration of the multiple positive effects that standards can achieve. Even as electricity use per refrigerator fell by a factor of four, the size increased by one-fourth, and the average price (in constant dollars) declined by almost a factor of 3 since the early 1970s.

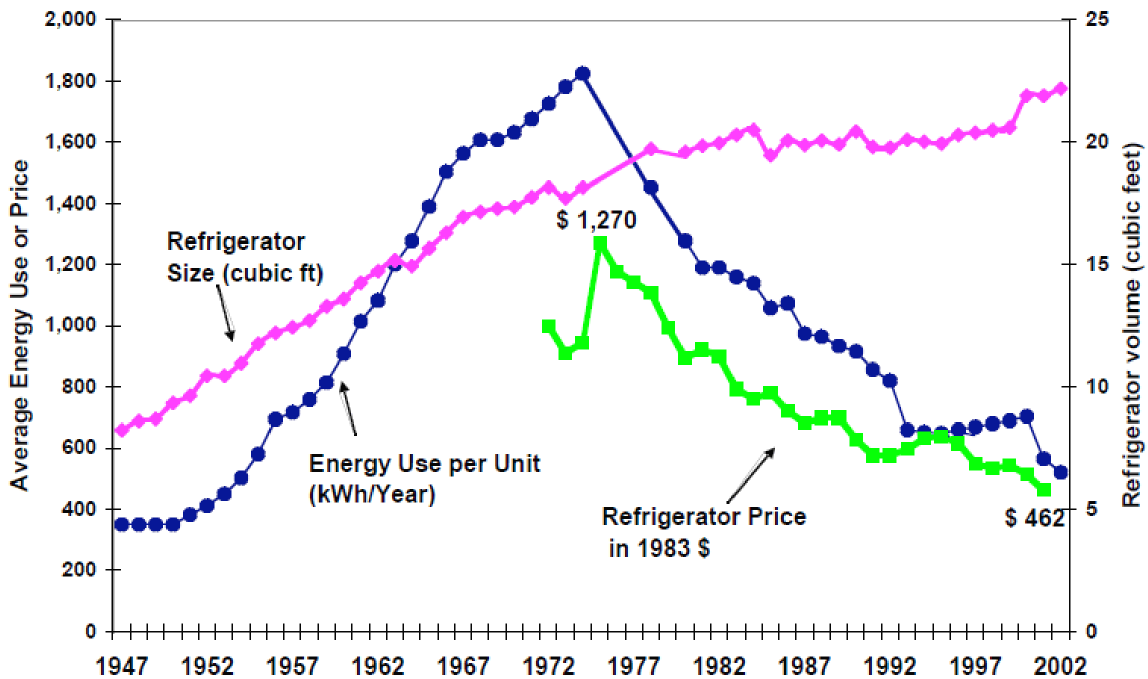

Figure 3: New United States Refrigerator Use v. Time and Retail Prices
Source: Rosenfeld 2008 Slide 8, with credit to David Goldstein

23. The 2008 APS report on energy efficiency cited the following reasons in support of the need for standards for appliances and buildings:[17]

> Minimum-efficiency standards are needed to overcome market failures that restrict the use of more efficient products. Among these failures are:
>
> - Third-party decision makers (e.g., landlords and builders) who purchase appliances but who do not pay the operating costs of the products they purchase;
> - Panic purchases that leave little time for consumers to become educated;
> - Inadequate and misleading information about the relative energy performance of products; and

[17] APS 2008 p .77-78

- High first costs for efficiency equipment due to small production quantities and the fact that manufacturers frequently combine efficiency features with extra non-energy features in expensive trade-up models.

24. Electrical appliance efficiency considerations do not include much of the household energy consumption, which is due to space and water heating using natural gas and petroleum fuel. Efficiency investments in the space heating area relate largely to the building envelope. As we will see below, an investment of several dollars per square foot is justified in making new homes (envelopes, heating and cooling systems, appliances), efficient enough to eliminate about 70 percent of the energy footprint of the house. Upgrading the efficiency of existing homes can yield efficiency improvements of about 50 percent.

25. Figure 4 shows the effect of increasing house size on central air-conditioning electricity use with (1) no efficiency changes, (2) with higher efficiency air-conditioners, and (3) with both high efficiency air-conditioners and building envelope efficiency increases achieved through building efficiency standards. New building air-conditioning electricity requirements can be reduced by about 70 percent by about 2014 relative to business-as-usual[18] if both new air conditioner standards and house envelope efficiency standards are put into place (the blue curve compared to the yellow curve in Figure 4).

[18] Defined as increasing house size without mandated efficiency standards.

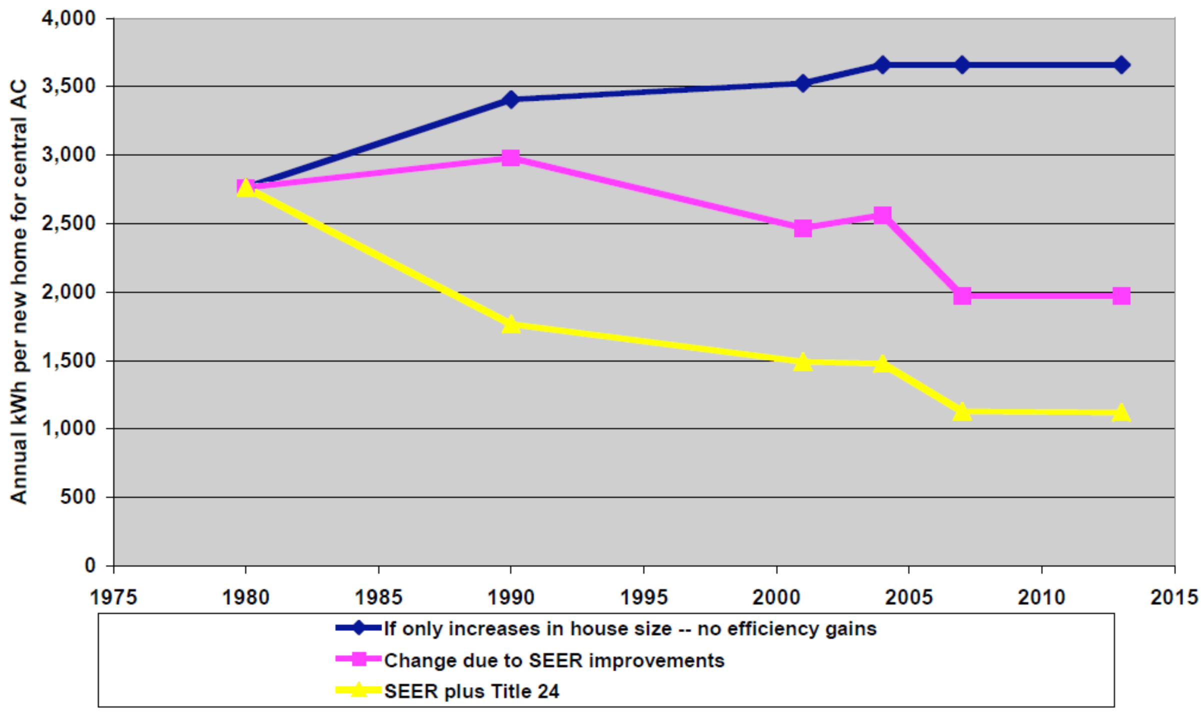

Figure 4: Air Conditioning Energy Use in Single Family Homes in PG&E: The effect of AC Standards (SEER or Seasonal Energy Efficiency Ratio) and Title 24 standards (California building standards)
Source: Rosenfeld 2008 Slide 11

26. Recent efforts in Congress to improve the efficiency of buildings have failed to produce actual legislation. The building standards in the Waxman-Markey legislation that failed in 2009 included a significant section on greater building energy efficiency, and set forth energy use targets for new buildings. If enacted, the Waxman-Markey efficiency targets would have encouraged a 50 percent reduction in energy use by 2014, relative to a comparable building constructed in compliance with the baseline code; an additional 5 percent reduction every 3 years would have been required beginning in 2017 for residential buildings and in 2018 for commercial buildings.[19] The legislation also established a goal of achieving net-zero energy commercial buildings.[20] These goals and targets are similar to Germany's passive houses.

27. The effect of building efficient homes as a common practice is illustrated by the growth of "passive" house construction in Germany. Such houses include a high degree of insulation,

[19] Waxman-Markey 2009. Specifically see H.R. 2454, 111th Cong. (2009-2010) Sec. 201, which includes Sec. 304(a)(1) of the of the Energy Conservation and Production Act as amended (July 7, 2009)
[20] Waxman-Markey 2009. Specifically see Sec. 201, which includes Sec. 304(a) of the of the Energy Conservation and Production Act as amended (July 7, 2009)

efficient windows, tight construction, with due attention to ventilation needs, heat gain from solar energy coming in through the windows and stored in the walls in the winter, and shade for windows in the summer to keep homes cool. They also use efficient appliances. They are called "passive" houses because most of the heating and cooling is provided not by energy consuming devices, such as heaters and air-conditioners but by the techniques of construction. Building standards that would mandate passive houses would greatly reduce energy use and thereby also reduce the amount of renewable (or any other) energy facilities that would be needed to keep the homes at normal levels of comfort and functionality. Measurement and cost data from German passive houses are useful in understanding the cost and level of efficiency possible with passive house-building techniques.

28. The German Passive House Institute published a report in 2001, translated into English in 2005, on the construction and energy measurements of the climate neutral passive house estate in Hannover-Kronsberg, Germany.[21] This report, a sponsored project of the European Commission, provides extensive detail into the construction elements of building passive houses, as well as detailed energy measurements. The estate is comprised of 32 terraced houses (row houses), which on average have a primary energy savings of almost 66 percent compared to typical new house in Germany.[22]

29. The costs of the Hannover-Kronsberg estate houses were also studied and compared to other similar houses in Germany. The report found that the total extra cost of the efficiency investments, including a solar thermal system for each house, resulted in an average 12.4 percent increase as compared to a similar house built to the German 1995 insulation ordinance.[23] Without the solar thermal system, the additional costs for a passive house would be 8 to 9 percent of the total investment costs.[24] The estate was constructed with four different home types with varying finished living space and room arrangements. Thus, the total construction costs per meter-

[21] Feist et al. 2005
[22] Feist et al. 2005 p. 6
[23] Feist et al. 2005 p. 42
[24] Feist et al. 2005 p. 42

squared of living area for this project ranged from 885.48 euros/m^2 (approximately $1,095) to 1,089.91 euros/m^2 (approximately $1,347).[25] In other words, the costs of these homes in 2010 dollars would be between about $1,400 and $1,724 per square meter, or about $130 to $150 per square foot. It must be remembered that these passive homes were built well before the more recent increase in interest and the large numbers of passive homes that have been built in Europe. Hence the cost increase relative to a standard home would not reflect the economies that would come with standardization should passive techniques become a common construction practice or even the standard practice (see below for further discussion).

30. Passive homes also exist in the U.S., though they are not as widespread as in Europe. One well-known example is a home built in Hanover, New Hampshire, in 1994 ("Hanover House").[26] This wood-framed, two-story, 1,887 square foot (175 m^2) house with an attached garage has 75 percent of its windows on the south side of the structure to maximize passive solar gain. This single element does not add any additional cost to the project, but incorporates an understanding of the efficient use of the sun for both lighting and heating. According to a detailed analysis of the cost and performance of the house, the total project cost of this house, which was a new construction, was $200,000 or $111/sq. ft., of which about $21/sq. ft could be attributed to custom features (cherry wood cabinetry for instance), the garage and the porch. The house itself, excluding the custom features cost about $90 per square foot and was completed in 1994. This amounts to about $137 per square foot in 2010 dollars, which is comparable to the passive house costs in Germany cited above. The cost of Hanover House also includes a 33 square meter solar hot water heater that provides almost all the space heating and hot water heating requirements. Separate metering of the supplemental electric heating required for these two functions showed an average heating electricity consumption of about 1,700 kWh per year, which would cost about $200. The rest of the electricity consumption was about 3,200 kWh or just under $400 per year,

[25] Feist et al. 2005 pp. 41-42. We assume the euro costs are in 2001 euros and escalate at 2.5 percent per year. Exchange rate conversions are made on a purchasing power parity basis. This allows for a more realistic comparison of costs between countries compared to spot market rates which fluctuate due to a number of factors not necessarily related to the local purchasing power of the currency.

[26] Hanover House 1998. Data in this paragraph are from this source, unless otherwise mentioned.

making the total energy costs about $600 per year in 2010 dollars. For comparison, in 2005, a single-family detached household expenditure on energy in the United States was $2,261 (in 2009 dollars).[27]

31. The reduction in energy costs for Hanover house type of passive construction and solar water heat is about $1,600 per year. Taking into account the fact that air conditioning was not needed in Hanover House (partly due to the way it is built and partly due to milder New Hampshire summers compared to, say, the southern United States), the annual average U.S. energy cost savings would be about $1,400 (since air conditioning energy use would be low in a house built like Hanover House). Over an assumed house life of 40 years, and a discount rate of 6 percent (a typical mortgage rate), the present value of the stream of savings is $21,000, or just over $11 per square foot. This is about 8 percent of the cost of the house (excluding custom features). Note that Hanover House also has very efficient appliances. The cost of the house includes appliance cost.

32. It is difficult at present to generalize cost estimates for passive houses in the United States since there is no significant industry, no large market for the materials, tools, certifications, etc. that go with the construction, verification and realization of the energy savings. As of the fall of 2010, there were only 13 certified passive houses in the United States, according to the *New York Times*, while 25,000 had been built in Europe. At present the additional cost for building a passive house in Germany is estimated at less than 5 percent, while it would be 10 to 15 percent in the United States.[28]

33. At a five percent marginal cost increase, a house that would cost $100 to $150 per square foot[29] to build would cost $5 to $7.50 per square foot more. The annual mortgage payment

---

[27] BEDB 2010 Table 2.3.11

[28] Zeller 2010. The numbers of houses built refer to certified houses on which measurements have been made to verify performance. See also the Frequently Asked Questions section of the Passive House Institute US at http://www.passivehouse.us/passiveHouse/FAQ.html.

[29] All building costs are exclusive of land costs.

increase would be 36 to 54 cents per square foot,[30] or about $720 to $1,090 per year for a 2,000 square foot single family house. The reduction in energy expenditures at 70 percent below the typical value of $2,261 would be over $1,560 per year. This calculation does not take into account the tax benefit of the mortgage interest deduction that would accrue on the added expenditure to build a passive house.

34. The main reason that passive houses are not the norm is that builders have no incentive to make their houses more expensive for items that are not major considerations for home buyers relative to comfort, aesthetics, convenience, safety, schools, and the like when purchasing a home. Building standards, like appliance standards, level the playing field for all builders. They also create a market for the specific goods and services that are needed to build the standard type of home. If passive construction features are required, for instance, via efficiency standards, the cost of the goods and services needed to build such homes would come down. This is beginning to occur in Germany and much of Europe, where estimated incremental costs are much lower than in the United States,[31] which has neither advanced federal building standards nor national carbon emission reduction mandates.

35. While generally more complex, it is possible to achieve significant efficiency improvements in existing buildings when such retrofits are carried out properly. As reported in a Florida Solar Energy Center study, measurements of retrofits in low-income housing in Florida, for instance, showed payback times of one to less than four years for most measures. The shortest payback of one year was associated with cleaning refrigerator coils. There were several other measures that were used such as efficient lighting (compact fluorescents) and low flow showers (which reduce both cold and hot water use). The simple (undiscounted) payback times were between 3.3 and 3.7 years.

36. As an experiment, one house was also provided with a solar hot water heater. This

[30] A six percent, 30 year mortgage is assumed.
[31] Zeller 2010.

resulted in the largest electricity savings: 1,960 kWh per year. It also had the longest simple payback time: 10.2 years, assuming an electricity rate of 8 cents per kWh and no inflation. However, since electricity costs have been rising and since a solar hot water heater has inflation proof, zero fuel costs, a realistic payback time frame would be shorter.

37. Such efficiency programs have additional benefits. The Florida study found a 500-watt decrease in the peak load of a house with a solar hot water heater, with reductions in load at most times except between 10 pm and 6 am. This benefits the utility and other consumers, since it lowers the overall cost of electricity generation. Ideally the reduction in peak load would be reflected in a lower electricity rate for the consumer installing the solar water heater; this would reduce payback time. Interestingly the study also found that the payback time for solar hot water heaters was about the same whether it was installed in a new home, or retrofit onto an existing home. This was not true for the other technologies, which generally had shorter payback times when installed as part of a new home construction.[32]

38. Measurements, though scarce, indicate a similar result in commercial building retrofits:[33]

> In determining what efficiency gains are possible with current and emerging technologies, it is useful to start by looking at what is happening under current standard practices. Contractors focused on energy upgrades to existing residential buildings achieve energy efficiency improvements ranging from 15 to 35 percent by installing better and more efficient insulation, windows (in some instances) and lights; by eliminating infiltration and duct leakage; by upgrading furnaces, boilers and air conditioners; by replacing the power supplies that waste electricity when their devised are in standby or low-power mode; and by replacing old appliances with newer, more efficient ones.

39. Table 2 shows a breakout of various commercial building energy retrofit projects. It is important to note that while there are additional costs associated with making investments in

[32] Makhijani 2010 CFNF pp. 81-82
[33] APS 2008 p. 60

energy efficiency, it does not always equate into a higher overall project cost per square foot than would have otherwise been required to remodel the property according to local building code standards. Additionally, the implementation of efficiency standards would have the added benefit of standardizing the various equipment and technology, which is currently more expensive because they are not used in all building and remodeling projects. **The bottom line: the energy footprint of existing commercial buildings can be economically reduced by about 50 percent.**

Table 2: Recent Commercial Retrofit Projects in the United States

	Empire State Building[a]	3 Retail Franchises (numbers are models, not actuals)[b]			Quality Bicycle Products[c]
		#1	#2	#3	
Location	New York, NY	Florida	Nevada	New York	Bloomington, MN
Building Type	Skyscraper	Retail	Retail	Retail	Warehouse/Office
Building Size (sq. ft.)	2,700,000	43,000	98,000	52,000	37,549 (office) and 90,735 (warehouse)
Incremental capital cost for efficiency improvements	$13.2 million	$301,000	$490,000	$520,000	$750,000
Total cost of project	$550 million	$473,000	$588,000	$1,092,000	Approx. $9,365,700*
Previous or standard energy use for building type (kBtu/square foot/pre-retrofit)	88	36-79			119.9**
Post-retrofit energy use (60 kBtu/square foot)	60	10-43			42.4
Annual energy savings (expected)	38%	72%	44%	48%	Approx. 65%
Annual energy cost savings	$4.4 million	$50,000	$78,000	$80,000	$75,000

(a) Source: http://retrofitdepot.org/Content/Files/ESBCaseStudy.pdf (RMI 2010)
(b) Source: http://retrofitdepot.org/Content/Files/RetailCaseStudy.pdf (RMI 2011). Pre- and post-retrofit energy use are presented as ranges in the data.
(c) Source: Link at http://www.mn2030.umn.edu/presentations.html, to 4-LHB: Case Study Metrics (Minnesota 2009)

* *based on a reported project cost of $73 per square foot. Note that a typical building of similar type has an average cost of $79 per square foot – more than the energy efficient case.*

*** Minnesota SB 2030 benchmark value*

40. Given that efficient appliances and buildings are economically justifiable, even apart from pollution and climate considerations, why are buildings not already built to such standards? One of the principal reasons is known as the "spilt incentive."[34] Builders do not pay the energy bills; owners or renters do. The builder has an incentive to minimize first cost, to install showy features that will enhance curb appeal and create an urge to buy. In the case of renters, the builders are twice removed from the bills, because even the building owners typically do not pay the energy bills; the renters do. The first cost and financing of improvements that could cost thousands or tens of thousands of dollars are also barriers. Hence, policy mechanisms such as appliance and building standards and rules for efficiency at the time of sale of existing buildings need to be considered.

41. The lack of standards and the disincentives faced by builders who would build efficient homes has led to a situation where there is not a robust supply chain of the necessary technologies and manufacturers. This would change with stringent efficiency standards on a federal level. At present, passive buildings are more expensive in the United States than they need be; a principal cause is a lack of appropriately stringent building standards.

Automobiles

42. The average fuel economy of passenger vehicles in the United States in 2009 was 23.8 miles per gallon for cars and 17.4 miles per gallon for light trucks (including SUVs), while the fuel economy standards for new passenger vehicles in 2010 were 27.5 and 23.5 miles per gallon respectively.[35] The official efficiency target for new vehicles in the year 2016 is 34.1 miles per gallon (including cars and SUVs). By comparison, the target for new vehicles in the European Union (EU standard) for the year 2015 is about 48 miles per gallon.[36] The CO_2 emissions according to the EU will be 130 grams per kilometer (about 210 grams per mile), compared to

---

[34] This is the first bullet on p. 11 above in the list of causes in the APS 2008 study.
[35] BTS 2011Table 4-23: Average Fuel Efficiency of U.S. Light Duty Vehicles
[36] ICCT 2011 Slide 4. This has been used as the basic reference for mileage standards for convenience. Values are approximate and were read off from the charts. The rest of this paragraph draws data from various slides in this source.

about 156 grams per kilometer (250 grams per mile) that the U.S. seeks to achieve by 2016.[37] The EU projects achieving a new car standard of 65 miles per gallon by 2020, or 95 grams per kilometer, presuming continued use of petroleum fuels (i.e., presuming very low penetration of plug-in hybrids and electric vehicles in the year 2020). The U.S. had been debating a much more lax efficiency standard of between 43 and 56 miles per gallon by 2025 and eventually adopted a standard of 54.5 miles per gallon, including cars and SUVs, by 2025 in July 2011.[38] If the United States adopted the EU standard by 2025, it would achieve a reduction in CO_2 emissions of about 6 percent per year between 2010 and 2025 for new vehicles.

43. Of course, plug-in hybrid electric-gasoline vehicles and even all-electric vehicles have already been commercially introduced. While the initial models of cars are more expensive overall than gasoline cars, they are well within striking range, even if lower maintenance costs (no oil changes for electric cars and fewer oil changes for plug-in hybrids, lower tire and brake wear, etc.) are ignored. The luxury all-electric Tesla 4-door sedan, due to be marketed in 2012 and as yet far from a mass production car, will cost $57,400.[39] It goes zero to 60 miles per hour in 5.6 seconds, comparable to the highest performance sedans, which range in price from $35,000 to $60,000 or more. It will have a stated range of 160 miles.

44. A typical present efficiency for an all-electric car is about 4 miles per kWh; the annual fuel cost would be $450.[40] Luxury gasoline sedans typically get 20 miles per gallon; the annual fuel cost would be $3,000. The present value of 10 years of fuel cost savings at a 7 percent discount rate is almost $17,910, making the effective first cost of the Tesla comparable to the

---

[37] ICCT 2011 Slide 1

[38] *New York Times,* at http://topics.nytimes.com/top/reference/timestopics/subjects/f/fuel_efficiency/index.html, July 29, 2011

[39] This price does not include the $7,500 federal tax credit. The price after than credit is expected to be $49,900. (Tesla 2011 (http://www.teslamotors.com/models/faq))

[40] We assume usage of 15,000 miles per year in all cases, unless otherwise mentioned. We use a fuel cost of $4 per gallon for gasoline and 12 cents per kWh for electricity, both slightly higher than U.S. averages at the time of this writing (about $3.50 and 10 cents respectively). Of course, the risk that gasoline could go significantly higher than $4 is non-trivial to significant within the next ten years. The efficiency of 4 miles per kWh is at about 60 miles per hour. It is higher at lower speeds. For details on the Tesla, including price and efficiency, see the chart at http://www.teslamotors.com/goelectric/efficiency.

lower end of gasoline-fuelled luxury sedans.[41]

45. At 160 miles, the range of the Tesla, of course, is not comparable to gasoline or diesel cars. A 300-mile range version will also be available at an estimated cost of $77,400. Given the present value of lower fuel cost of $17,910, the high-end Tesla, comparable in range to a gasoline sedan, would be comparable in cost to the higher end of luxury sedans.

46. This example is not meant to be a discourse on luxury automobiles, but an illustration that indicates that commercialization of electric vehicles in the next decade or so is very likely. Very new technologies that serve existing functions often enter the market through the high end of the market. For instance, large screen flat panel displays for televisions were introduced as high-end devices at costs of thousands of dollars. The first one to be marketed at Sears, with a 42-inch screen, in 1997, just 14 years ago, was reportedly $14,999.[42] Today a 50-inch plasma screen TV can be had for just $550.[43]

47. Of course, we don't expect a cost decline of 25 to 30 times for electric cars; nor is such a cost decline needed. The cost of lithium ion batteries, the best storage medium today for cars with an electric-only range of more than a mile or two, is about $700 to $1,000 per kWh.[44] At $300 per kWh the overall cost of an all-electric car (first cost plus fuel cost) would be comparable to a typical gasoline-fueled car. Given that the economies of scale in battery manufacturing and technical refinements of the batteries are at their early stages, commercialization of all-electric vehicles or at least plug-in hybrids with a high fraction of the range being electric could be expected in ten or at most fifteen years with appropriate vehicle efficiency standards and suitable government fleet purchasing policies.

---

[41] A 7 percent real discount rate is recommended by the Office of Management and Budget for private investments. If we use a social discount rate of 3 percent, the present value of the fuel savings would be even higher, about $21,750.

[42] See Wikipedia 2011 at http://en.wikipedia.org/wiki/Plasma_display, viewed on 4 August 2011.

[43] Sears 2011 at http://www.sears.com/shc/s/c_10153_12605_Computers+%26+Electronics_Televisions. Viewed on 6 July 2011. See the Zenith model.

[44] GM-Volt.com 2010. Battery cost dropping to $350 per kWh is already foreseen by some.

48. Such a course is being given a great boost by a recent policy adopted by the Obama administration on the performance of the federal vehicle fleet (including cars, vans, SUVs, and trucks) and being implemented by the Department of Defense (DOD). In June 2011, the Pentagon solicited information from vendors regarding large-scale conversion of its fleet of vehicles to plug-in electrics. The synopsis is as follows:

> The Department of Defense (DOD) requests an expression of interest from prospective entities (e.g., PEV manufacturers, PEV battery manufacturers, financing firms, energy management companies, joint ventures) capable of developing and executing cost-competitive strategies for a large-scale effort to integrate PEV's into DOD's non-tactical ground fleet. DOD is interested in understanding the potential for achieving total cost of ownership parity between PEV's and comparable internal combustion vehicles (ICE's) located on military installations within the Continental United States (CONUS) by leveraging high-volume procurement opportunities, "right-sizing" PEV batteries to specific duty cycles, use of PEV's for ancillary services, and use of alternative financing methods. This RFI specifically focuses on full-size (i.e., sub-compact sedans or larger, including light, medium, and heavy duty trucks) PEV's that are capable of reaching highway speeds (50+ mph) for an extended period of time. Please submit any questions or additional information you would like included in a solicitation, should this project proceed. [45]

49. The DOD not only solicited information about electric vehicles of all types, but also about the value of ancillary services, such as services to the electric grid and the residual value of batteries after they have lost enough storage capacity to degrade the range significantly but still retain enough capacity to be of value, for instance, for solar or wind energy storage.[46] Ancillary services to the grid could include load balancing by demand dispatch, which would result in earnings for the vehicle owner and reduce the cost of integrating intermittent wind and solar

[45] DOD 2011 p. 1
[46] DOD 2011 pp. 5-6

energy into the grid. Specifically, and as a simple example, the batteries in cars could be charged when excess supply of wind and solar is available on the grid. In case of low renewable supply, car charging could be interrupted for a fraction of an hour to a few hours to maintain grid reliability. In actual practice, ancillary grid services would be operated in a more sophisticated mode, in which there would be tiers of services and prices. The technical modes of such operation, which would be part of a "smart grid" (in which consumers and utilities exchange supply and demand information), are already being worked out. For instance, the May/June 2010 issue of the *IEEE Power & Energy Magazine*, of the Institute of Electrical and Electronic Engineers, was entirely devoted to smart grids, the integration of renewables, and similar topics.[47]

50. Of course, the two principal advantages of going to electric vehicles are that it would be possible to completely or nearly completely eliminate fossil fuels from the land-based transportation sector and that it would greatly simplify the integration into the electricity grid of intermittent renewable resources, notably solar and wind energy, for all purposes.

51. Assuming that electric vehicles of all sizes are commercialized by 2020, it would be possible to almost completely eliminate petroleum from the transportation sector by about 2040. The remaining issue for transportation would then be the CO_2 emissions from coal and natural gas-fired electricity generation remaining at that time and the rate at which coal could be phased out and natural gas mostly phased out.

52. For instance, a grid with natural gas combined cycle power plants supplying 20 percent of the electricity (approximately the proportion as today), and the rest of the sources being CO_2-free, the CO_2 emissions for passenger vehicles would be about 20 grams per mile, or about 5 percent of present-day average emissions per mile. For details of the electricity transition to a nearly 100 percent renewable grid (less than 10 percent of today's CO_2 emissions per kWh), see Section F. Electricity, below.

[47] Brooks et al. 2010

53. Existing gasoline and vehicles including buses and trucks can be converted to plug-in hybrid mode. This can greatly increase efficiency, reduce fuel use, and diminish pollution at a rate faster than the 6 percent per year discussed here. The organization that first converted commercial Toyota Prius cars to plug-in hybrids in 2004 when the industry was dismissive of the concept, CalCars,[48] is now promoting the conversion of existing vehicles to plug-in hybrid. The impact of such conversions for school buses, in-city trucks, and other vehicles with defined patterns of driving was evaluated recently in an article in *IEEE Power & Energy Magazine*, the professional journal of the Power & Energy Society of the Institute of Electronic and Electrical Engineers.[49] For instance, a diesel school bus operating 90 miles a day, 225 days per year typically consumes 3,375 gallons of diesel per year. A plug-in conversion would reduce diesel use and emissions by an estimated 72 percent while increasing electricity use by 13,500 kWh per year (which could come from renewable sources). The reduction in diesel use comes both from both electric operating mode (for half the miles) and operating in hybrid mode with regenerative braking when using diesel fuel. Each school bus would save about 34,000 gallons over its 14-year life. Hence, if 100,000 buses, or about 20 percent of the total in the United States, were converted, the lifetime savings for these buses would be 3.4 billion gallons. Net CO_2 emissions with present day electricity sector average emissions would be about 25,000 metric tons over 14 years. Simple payback time is estimated at only 3 to 5 years, if high volume production is achieved.[50] Taxis, vans, in-city delivery vehicles, city buses, and short haul trucks could all be converted in this way. This is because such vehicles could typically be charged more than once daily, minimizing the battery capacity needed to achieve a large fraction of all-electric miles.

54. Electric vehicles are not the only route by which continued annual reductions in CO_2 emissions at annual rates of 6 percent or more beyond 2025 can be achieved in the vehicle sector. As is well-recognized, solar and wind energy can be converted to hydrogen in a large variety of ways, some of which are in the demonstration stage and are semi-commercial and others of which are still very much in the research stage. Hydrogen can be used directly as a fuel in the same

[48] For a history of CalCars, see http://www.calcars.org/about.html. (CalCars 2011)
[49] Emadi 2011
[50] Emadi 2011 p. 28

engines that gasoline is used. Or it can be used in fuel cells, which generate electricity, which would power the vehicle. The latter approach is still rather expensive, since it involves fuel cells and adds a large cost element relative to use of hydrogen in internal combustion engines. So I will explore the use of hydrogen in internal combustion engines, which does not require any fundamental changes in vehicular technology, though it would require a partially new infrastructure for refueling.

55. I will use a 30-mile-per-gallon vehicle and a $4 per gallon cost of gasoline (or about 13 cents per mile fuel cost) as the point of comparison. A kilogram of hydrogen (about 2.2 pounds) has about the same heating value as a gallon of gasoline (actually a little higher). Trials indicate that a hydrogen-fuelled internal combustion engine could be up to 25 percent more efficient than the same engine using gasoline, without optimization of the engine for hydrogen use.[51] Hence, taking the higher efficiency of hydrogen into account, $4 per gallon of gasoline is approximately equivalent to $5 per kilogram of hydrogen, when computed on the basis of the same fuel cost per mile.

56. The production of hydrogen from wind and solar energy is still in the pilot project stage. A partnership between the National Renewable Energy Laboratory and Xcel Energy, an electric utility, used wind and solar energy to produce hydrogen and test its use in a car (a fuel-cell Mercedes Benz A-Class), a fuel-cell bus, and a Ford shuttle bus with an internal combustion engine.[52] The project estimated that the indicated costs of hydrogen from a large-scale wind energy system with modest improvements in power electronics produces about a 7 percent cost reduction from $6.25 to $5.83 per kilogram using electrolysis of water as the hydrogen production technology. The goal of the Department of Energy for this program is a hydrogen cost of $2 per kilogram by 2017.[53] This would be more than competitive with gasoline. As noted, it would require hydrogen storage on board the car, instead of gasoline (which is also flammable) and fueling infrastructure, as would electric vehicles.

[51] Makhijani 2010 CFNF p. 114
[52] NREL 2010 Slides, Slide 27
[53] NREL 2010

57. In sum, reductions in CO_2 emissions from the petroleum-dominated transportation sector of 6 percent or more per year (on a continuously compounded basis) are quite feasible; more than that, the technological developments of the last two or three years indicate that the technologies that were still at an early experimental stage then are now maturing to a demonstration and early commercialization stage. There is now enough information to reliably estimate that the needed rate of CO_2 emission reductions (and a reduction of petroleum use and imports) can be accomplished. The main problem is that present policy is rather piecemeal and vehicle efficiency standards in the United States continue to lag behind what is feasible and behind the European Union.

58. The same technology that can improve efficiency and reduce CO_2 emissions can also be used in trucks, including military trucks. In fact, the U.S. Navy plans a 50 percent reduction in petroleum use for its vehicles in just four years, by 2015, according to a June 2011 Navy press release:

> PORT HUENEME, Calif. (NNS) — Navy engineers in San Diego and Bangor, Wash., began testing diesel powered hybrid vehicle technology June 15, for possible deployment to Navy and Marine Corps bases worldwide.
>
> The program kicked off with the delivery of two vehicles to the Naval Facilities Engineering Command Southwest Coastal Integrated Product Team (IPT) in San Diego, May 12. A second pair of trucks will be pressed into service with the recycling team in Bangor, Wash., this month.
>
> The Navy has commissioned a total of four test vehicles – two diesel hybrids and two conventionally powered trucks – that will be compared side by side for six months at Bangor and the California site. Each location will receive a single hybrid to be tested against a similar, non-hybrid model. Both sites will operate the trucks under normal conditions, and the results will be compared at the end of the test period to determine potential fuel savings for the Fleet.

"The testing in this phase will be compared to earlier baseline tests to determine how well the hybrids match up in the real world against their conventional counterparts," said Capt. Paz B. Gomez, Naval Facilities Engineering Service Center commanding officer. "This has the potential to save millions of dollars for the fleet and taxpayers, enabling the Navy to move closer to achieving the SECNAV's energy goals of 50 percent reduction in petroleum used in naval vehicles by 2015."

….

Test data will be released to other Department of Defense components and federal government organizations by 2012, and the technology may eventually benefit warfighters in all theaters.[54]

59. This proposal for rapid adoption of hybrid technology by the military is partly driven by the high cost of petroleum delivery to the field, both in terms of money and casualties[55] (see Section F. Electricity, below). However, it also shows the rapidly approaching maturity of the technology for all applications including trucks. Finally, the scale of the military market for hybrids will likely transform the market for large vehicles, including commercial trucks much more rapidly than has been foreseen.

60. When all these developments are put together, the potential for an economical transition to displacing well over 50 percent of the petroleum use by 2025 by increases in efficiency and some transition to electric vehicles is clear. This translates into a rate of reduction of CO_2 emissions of more than 6 percent per year. A far faster rate is set to be achieved in some parts of the defense sector. But the commercial market will require a suitable set of carbon and efficiency policies and targets to ensure successful reductions in time and to achieve the greatest benefits at lowest cost because the fuel cost in the commercial vehicular market is far lower than that faced by the Department of Defense field operations.

---

[54] U.S. Navy 2011. Emphasis added.

[55] Tiron 2009. In the most difficult circumstances, the cost of fuel delivered to forward areas can be as high as $400 per gallon (as of 2009), or roughly 100 times the retail price in the United States. See also NPR 2011.

D. Aircraft

61. Aviation is recognized as one of the more difficult sectors to achieve a large reduction in CO_2 emissions. This is because at present, electrically-powered commercial aircraft of the type used for large-scale and long-distance passenger transport appear to be too far off to make an impact on CO_2 emissions at the rate required. Hence, the simplest route that would allow for solar and wind energy use does not appear to be open for aircraft in the near future with foreseeable technology. It must be noted though that this could change, since experimental aircraft using a combination of fuel cells and batteries[56] as well as aircraft powered by solar cells[57] have been tested in recent years.

62. Two routes for renewable fuel in aircraft are possible. One would be to use hydrogen in existing jet engines. This would involve modification of existing aircraft for storing liquid hydrogen rather than jet fuel. Passenger planes have been modified to use liquid hydrogen and liquid methane fuel and flown in demonstration flights. The various aspects of this technology, which should be developed, are discussed in *Carbon Free and Nuclear Free*.[58] I am not providing further details here because, to my knowledge, no large-scale development effort for using hydrogen as the main aircraft fuel is underway anywhere in the world.

63. The more likely route to substantial reduction of petroleum replacement by renewable fuels is to develop a biofuel that would be a drop-in replacement or close to a drop-in replacement for jet fuel. This would mean that the entire existing aircraft and fuelling infrastructure could be carried over to renewable biofuels. It is well recognized by now, that not all biofuels are created equal when it comes to the matter of greenhouse gas emissions. The analysis in *Carbon-Free and Nuclear-Free* indicated that biofuels from crops had too many defects from the point of view of high indirect greenhouse gas emissions (such as nitrous oxide from fertilizer use). The approach that would be the most workable, advocated in that book, was the use of aquatic weeds, and

---

[56] Boeing 2008

[57] AFP 2011. The solar-power aircraft has even flown through the night on solar energy stored in its batteries.

[58] Makhijani 2010 CFNF pp. 86-88

particularly algae, including microalgae, for liquid and gaseous biofuel production.[59]

64. Microalgae were at the margins of the biofuels debate in 2007, when I finished writing *Carbon-Free and Nuclear-Free*. However, as the problems with converting food to fuel, such as corn to ethanol, have become clearer, attention has been turned to other biofuel feedstocks, including microalgae. Dozens of companies have been working on the problem.

65. I will describe some of the most important developments that indicate that aircraft fuel could be replaced economically by fuel derived from algae, which are the most productive source of biomass. While a high yield corn field has an efficiency of solar energy capture of just ¼ percent, microalgae can capture up to about 5 percent of the incident solar energy. Moreover, they can be grown in wastewater and brackish water. If grown in wastewater, no fertilizer inputs would be needed.[60]

66. A number of developments in the past two to three years indicate that algal biofuels will likely be commercialized in the next few years. For instance, a Boeing 737 commercial jetliner using 50 percent algal biofuel in one engine was tested by Continental Airlines in January 2009; a number of safety tests were included:

> In Texas, Continental Airlines successfully demonstrated the use of algae as an aviation fuel yesterday in a two-hour test flight at George Bush International Airport in Houston. The flight was the first test of biofuels by a North American airline; the first to utilize algae as a biofuel feedstock; and the first biofuels test flight in a two-engine jet.
>
> The Boeing 737, powered by CFM engines, operated with a 50 percent biofuel blend in the right side engine during the two hour test program, which included a full power take off, a climb to 25,000 feet including a fuel pump switch-off, a cruise at 37,000 feet; deceleration/acceleration, descent, engine restart without starter; engine restart with

[59] Makhijani 2010 CFNF pp. 45-52

[60] For a discussion and comparative merits of biomass sources see Makhijani 2010 CFNF pp. 45-62 (Sections C to G of Chapter 3). Additional references can be found in the endnotes of these sections.

starter, approach and go around, and landing. Preliminary data showed that the engines performed as predicted, and the test flight was completed without a hitch.[61]

67. The Boeing 737 jetliner is one of the most popular planes for commercial airlines – hundreds of airlines fly thousands of them. For instance, it is the only model of aircraft flown by Southwest Airlines, one the largest airlines in the United States; it operates 548 of them.[62]

68. Enough algal biofuel has been produced and tested by now that standards have been created for drop-in biofuels used in jet aircraft. This provides a sound and definitive technical basis for biofuel producers using a variety of feedstock, including algae, to meet demand so that there would not be a question about marketability. In other words, if biofuels meet these standards and meet the price requirements, a market is assured. There are no technical or safety barriers to commercial airlines using 50 percent biofuel from algae in place of jet fuel derived from petroleum.

69. Specifically, ASTM International, which develops standards for fuels and materials, approved a revision of its jet fuel specification that allows up to 50 percent use of biofuels in jet fuel. According to the ASTM press release of July 1, 2011:

> Renewable fuels can now be blended with conventional commercial and military jet (or gas turbine) fuel through requirements in the newly issued edition of ASTM D7566-11, Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons. The revised standard was approved July 1, 2011.
>
> Through the new provisions included in ASTM D7566, up to 50 percent bioderived synthetic blending components can be added to conventional jet fuel. These renewable fuel components, called hydroprocessed esters and fatty acids (HEFA), are identical to hydrocarbons found in jet fuel, but come from vegetable

---

[61] Biofuels Digest 2009
[62] Southwest 2011

oil-containing feedstocks such as algae, camelina or jatropha, or from animal fats called tallow. The standard already has criteria for fuel produced from coal, natural gas or biomass using Fischer-Tropsch synthesis.[63]

70. A 50/50 algal biofuel and jet fuel mix was successfully tested in a Navy helicopter in June 2011.[64] The Navy has also successfully tested a 50/50 biofuel mix using camelina biofuel in its supersonic jet, the F/A 18.[65]

71. No differences in safety or performance were reported in these tests of 50/50 bio-jet-fuel and petroleum-based jet fuel compared to 100 percent petroleum-based jet fuel. The U.S. Navy plans to replace 50 percent of its petroleum use overall – in ships, aircraft, and land vehicles by 2020. It is planning to order 336 million gallons (8 million barrels) of biofuel a year by that date.[66]

72. The conversion to 100 percent biofuels for aircraft now appears to be mainly a supply and price issue though additional testing and safety certification for 100 percent jet biofuel use remain to be done.[67] The military's cost of fuels in money and lives is high; therefore, it is likely to be the biggest short-term market.

73. Jet biofuel is not yet in commercial production, but production is increasing rapidly, in part due to European regulations on CO_2 emissions from aircraft. The recent ASTM certification of biofuel for use in commercial jets has spurred a global introductory offer of 1 billion gallons of jet biofuel at a price of $2.97 per gallon or, in the alternative, a variable price between $2.50 and $3.50 per gallon keyed to jet fuel from petroleum.[68] While this may implicitly contain an allowance for a carbon price (since CO_2 allowances are traded in Europe), it is noteworthy that it

[63] ASTM International 2011
[64] Solazyme 2011
[65] U.S. Navy 2010
[66] Biofuels Digest 2010
[67] Aircraft have already been flown with 100 percent biofuel. See for instance, Mahony 2010.
[68] BioJet 2011

is a large-scale offer that is competitive with current prices of jet fuel made from petroleum. For instance, a recent spot market price for the latter from the Energy Information Administration was $3.02 per gallon on July 8, 2011.[69]

74. Since no infrastructure change in delivery or consumption will be required for drop-in jet biofuels, a carbon cap on aircraft emissions is feasible and practical; it would lead to a rapid transition to biofuels in the aviation sector. Preference can be given to biofuels with low indirect CO_2 emissions by appropriate policies for evaluating lifecycle CO_2 emissions for fuel production.

75. In sum, the technical feasibility of replacing jet fuel in commercial and military aircraft with biofuels has been firmly established. Algal biofuels are the most productive per unit of land and can bring many other benefits, since they do not require fresh water for feedstock production and can even be cultivated in wastewater as an ancillary service provided in wastewater treatment. The technological and economic developments of the last three years, coupled specially with the military's push to reduce costs and casualties associated with petroleum fuel and the European goals for reducing CO_2 emissions from aircraft starting in 2012 are among the main driving forces of rapid change. Companies are planning large increases in biofuel production, including from algae, in the next two to three years and large oil companies are also investing in or purchasing companies that are in the biofuels business.[70]

76. However, U.S. airline companies are fighting European regulations for CO_2 emission reductions from aircraft.[71] Instead of the U.S. government fulfilling its responsibilities to future generations regarding climate, the missing element again is a U.S. policy for reducing carbon emissions from commercial aircraft; as noted, the Department of Defense has one for military aircraft, even if its main rationales are security and cost rather than climate protection.

---

[69] EIA 2011-07-07
[70] Bloomberg 2011
[71] New York Times 2011

E. Industry

77. The main fuels directly used in industry are oil and natural gas, plus whatever energy sources are used to supply the electricity needed for operating the facilities.

78. The kinds of considerations that apply to liquid fuels for aircraft, discussed above, also apply to industry, though a wider variety of fuels is used in industry. In a way, the safety, performance, and technical requirements for commercial aircraft are extremely demanding and if those can be met from a variety of biofuel feedstocks including algae, which have the most impact of reducing CO_2 emissions, they can also be used in industry.

79. The industrial sector possesses much more fuel flexibility than the aircraft sector. For instance, solar concentrators could be used to preheat water for making process steam, which is needed for many industrial processes; this would reduce the use of natural gas. In some areas, solar could replace natural gas altogether for making steam. Liquid or gaseous biofuels could be used as feedstocks for plastics. For instance, methane derived from biomass is a direct substitute for natural gas. Hydrogen for industrial purposes is at present made using natural gas as a feedstock; it could be made using electrolysis of water and wind (or solar) energy. Similarly, ammonia as an industrial chemical or a fertilizer feedstock is made mainly using natural gas as a feedstock and to a lesser extent naptha, a petroleum distillate, and in some places, even coal. The feedstock is first used to make hydrogen, which is then combined with nitrogen to make ammonia. The fossil fuel feedstocks for ammonia could be replaced by hydrogen made by electrolysis of water and wind-generated electricity, eliminating the carbon altogether and one of the main sources of CO_2 emissions attributable to the agricultural sector.

80. As noted above, the present cost estimated for large-scale hydrogen production from wind energy and electrolysis is about $6 per kilogram. The Department of Energy's goal is to reduce this to $2, which would make it cheaper than hydrogen made from natural gas. This is a worthy goal and should be pursued; but it is even more necessary to have a declining cap on carbon emissions from large industrial sources, which would provide the maximum flexibility to industry

to phase out the use of fossil fuels. There is no inherent barrier technically since biofuels and/or hydrogen from renewable sources can directly substitute for fossil fuels in almost all energy intensive industrial uses. Further, electricity in industry, like that in other sectors, can be derived completely or almost completely from renewable sources.

F. Electricity

81. Electricity generation accounts for about 40 percent of U.S. energy consumption and about the same proportion of fossil-fuel-related CO_2 emissions. Almost half of the energy used for electricity generation is coal; this is by far the main use of coal in the United States. Figure 5 shows the proportion of electricity generation from various sources in 2009. The "other" item includes miscellaneous sources such as biomass, geothermal, and a very small amount of solar electricity; it also takes into account the net energy required for pumped storage in hydropower reservoirs. Pumped hydropower plants are used for managing electricity peaks and can also be used for storage of renewable energy.

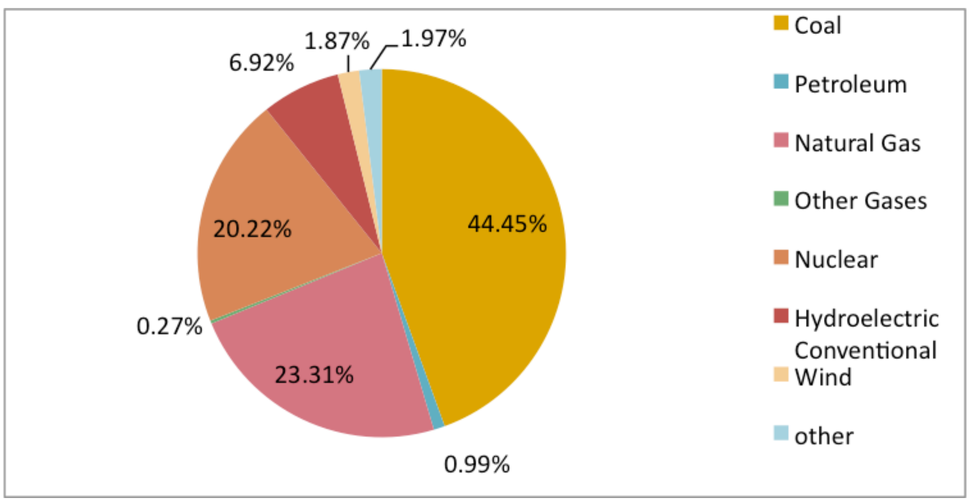

Figure 5: Energy sources for U.S. electricity generation, 2009. Source: EIA.[72]

82. Since about half the electricity can be economically saved with efficiency measures not requiring any change of lifestyle, we have estimated in *Carbon-Free and Nuclear-Free* that economic growth as well as electric vehicles could be accommodated over the coming decades

[72] EIA 2011 Electric Power (Electric Power Annual 2009 - Data Tables, on the web at http://www.eia.gov/cneaf/electricity/epa/epa_sprdshts.html. See the table "1990-2009 Net Generation by State.")

with about the same amount of electricity generation as at present – 4 trillion kilowatt-hours per year.

83. Note that the business-as-usual trend in electricity growth has been for the ratio of electricity growth per unit of GDP growth to decline from about 2 to 1 before the start of the energy crisis in 1973 to about 1 to 1 in the two decades after that to between 0.5 and 0.6 to 1 in the past decade (apart from the effects of the recession). Essentially, per capita electricity growth has been flat. Increasing efficiency by appliance and building standards as described in Section B above would turn the current trend from per capita constant electricity to overall constant electricity use.[73] Moreover, the United States has ample renewable resources to accommodate any foreseeable electricity growth rate.

84. It is now recognized that achievement of an overall 80 percent reduction in greenhouse gas emissions would be greatly facilitated by a near total elimination of fossil fuels from the electricity sector. This is because present evaluations indicate that it will be less expensive to achieve almost complete elimination of CO_2 emissions in the electricity sector than to try to achieve 80 percent reductions spread equally across various greenhouse gas emission sectors. For instance, the official German Advisory Council, which has devised a fully renewable electricity sector scenario for Germany – well before the start of the Fukushima accident on March 11, 2011 – stated the economic rationale as follows:

> Electricity generation is a key area of Germany's energy and climate policies in view of the fact that this sector currently accounts for roughly 40 percent of national carbon emissions (UBA 2010). However, ***it is also a sector where carbon emissions could be reduced at a relatively low cost – which means that reducing overall greenhouse gases by only 80 percent by 2050 will necessitate implementation of a completely carbon neutral electricity supply in Germany.***[74]

[73] Details are discussed in Chapter 5 of Makhijani 2010 CFNF.
[74] German Advisory Council 2010 p. 6. Emphasis (italics and bold) added.

85. I examined the technical and economic feasibility of a fully renewable electricity sector in various contexts in the past few years, with *Carbon-Free and Nuclear-Free* laying out the first technical and cost framework in 2007. Since then, IEER has examined the electricity sector in Utah with actual utility data and actual renewable energy resource data. This study was completed in 2010 and showed that a renewable electricity sector could meet the same reliability criteria as the present system. The technical and economic analysis for a similar study for Minnesota is nearly complete. In addition, other institutions have completed carbon-free energy reports in recent years.

86. There are two technical issues associated with a renewable electricity sector (apart from efficiency considerations, which we have discussed above):

a) Are the available renewable resources large enough to meet present and foreseeable electricity demand?
b) How will the intermittency issues associated with wind and solar energy be addressed, if these are to play a major role?

I address these in turn.

1. Availability of Renewable Energy Resources

87. The United States possesses far greater wind and solar energy resources than could be used under any foreseeable scenario for the long term. The wind energy resource, including only excellent and outstanding areas and excluding areas that are not likely to have large wind turbines installed (such as urban areas, national parks, and wilderness areas), is about 47 trillion kilowatt-hours per year, which is *more than eleven times the total present U.S. electricity generation from all sources*. It is also much more than the energy equivalent of the entire oil production of all the members of the Organization of Petroleum Exporting Countries (OPEC) put together.[75] Of this,

[75] OPEC oil production in recent years has been about 30 million barrels per day (OPEC 2011, Graph 3.7) or about 11 billion barrels per year. This amounts to about 64 quadrillion Btu of energy. At 3,413 Btu per kWh, 47 trillion kWh equals 160 quadrillion Btu. When due consideration is given to the fact that electricity is much more thermodynamically valuable (in terms of the second law of thermodynamics), wind generated electricity can provide

two-thirds of this – over 31 trillion kilowatt-hours – consists of wind resources in the very best category with a capacity factor of 40 percent or more.[76] In this category of sites, wind generation cost would be just 6 to 7 cents per kWh. This is cheaper than or, at most, at the low end of a new coal-fired power plant (excluding considerations of storage and intermittency – see below) even at zero carbon cost.

88. The solar resource is even larger. As for centralized solar resources, about 14,000 square miles of the State of Nevada (less than 13 percent of its area) could supply the entire electricity generation of the United States. Such a heavily centralized approach would have some disadvantages (such as security vulnerabilities); the calculation is provided here to illustrate the large size of the resource. Actually, solar photovoltaics can be installed on residential and commercial rooftops, over parking lots and roadways, and on the rooftops of public buildings, such as schools and colleges. These have sufficient area to supply most of the electricity requirements of the United States. Figure 2 shows a parking lot installation at a naval base in San Diego. This single installation would be sufficient to supply about 150 to 200 very efficient homes of 1,500 to 2,000 square feet with all of their electricity requirements (depending on climate and on whether they had air-conditioning or not).

---

between three and ten times the energy services of all of OPEC's oil production, depending on the application.

[76] These are estimates of the National Renewable Energy Laboratory of wind resources at a 100-meter hub height. The 47 trillion kWh estimate is for sites with 30 percent of higher capacity factor, the 31 trillion kWh figure is for sites with a capacity factor of 40 percent or more. (DOE Wind Power 2011)

Figure 6: 750 kilowatt installation at a naval base in San Diego
Source: DOE/NREL. Credit: SunPower Corporation

89. While the cost of wind energy in excellent and outstanding locations is already about the same or lower than new coal plants,, solar-generated electricity still has some way to go in this regard. Solar photovoltaic (PV) costs have come down rapidly in the past few years, especially with regards to the costs of manufacturing the solar panels. Thin-film solar panel manufacture now costs less than one dollar per watt. The completed installation, of course, requires other components, such as inverters, grid connection equipment, the structure that holds the panels, and labor for installation.

90. Current unsubsidized costs are in the range of about $3 or $3.50 per watt at the low end[77] to $6 or $7 per watt at the high end, depending on the scale of the installation, the location, and other factors. The higher costs are typical of small-scale installations and the lowest costs are for central-station plants. The latter, however, need transmission lines to get the power to consumers as well as dedicated land, while the former typically require neither. However, centralized plants

[77] Inferred from the San Antonio bidding for 400 megawatts of solar PV, described below.

have the advantage that they can be located in the areas with the most sun for the greatest part of the year; this makes the maximum use of the installed capacity.

91. Large central-station solar PV plants can produce electricity today at a cost of about 15 cents per kilowatt-hour.[78] Intermediate scale plants in sunny areas on commercial and industrial rooftops of a few megawatts scale per installation would cost about 20 cents per kWh, but without a need for transmission lines.

92. Solar PV is now at the beginning stages of becoming an established industry. Technological refinement is still occurring very rapidly and the scale of manufacturing of solar panels and the raw materials needed (silicon for most PV) is now approaching levels where economies of scale are reducing costs. The rapid evolution of the technology is also expected to reduce costs. However, given the technological flux, the large-scale manufacture of the machinery to make solar cells and solar PV raw materials is likely to take a few more years.

93. It is the express goal of the United States government, through its Department of Energy (DOE), to reduce the costs of solar electricity so that it is comparable to that from fossil fuels without carbon costs. This goal is explicitly stated on the website of the Office of Energy Efficiency and Renewable Energy of the DOE:

> The DOE SunShot Initiative is a collaborative national initiative to make solar energy technologies cost-competitive with other forms of energy by reducing the cost of solar energy systems by about 75% before 2020. Reducing the total installed cost for utility-scale solar electricity to roughly 6 cents per kilowatt hour without subsidies will result in rapid, large-scale adoption of solar electricity across the United States. Reaching this goal will re-establish American

---

[78] CPS Energy, the municipal utility of the city of San Antonio, Texas, will purchase 400 megawatts of solar PV in 2012 and is evaluating bids. The reported cost to CPS will be about 10.5 cents per kWh. (Hamilton 2011) However, the developer will get a 30 percent federal investment tax credit (DSIRE 2011). This indicates an unsubsidized cost for this very large-scale procurement of about 15 cents per kWh. In addition, San Antonio is requiring industrial development benefits as part of the bid. This means that bidders would offer, for instance, to locate manufacturing facilities in the area, creating more jobs than implied by the solar installation alone.

technological leadership, improve the nation's energy security, and strengthen U.S. economic competitiveness in the global clean energy race.[79]

94. Six cents per kWh is lower than or comparable to the cheapest electricity from new coal-fired power plants without carbon capture and storage. Further, since solar plants are much more modular than coal and can be built much faster, the financial risk is much lower even without taking carbon cost risks into account. It is difficult to estimate at present whether a cost as low as 6 cents per kWh will be achieved by 2020, though it is an excellent target. But a cost of 8 to 10 cents per kWh would make solar energy competitive with wind and far more economical than coal with carbon sequestration and new nuclear power plants.[80]

95. Since wind energy costs in the best areas are already at the low end of fossil fuel costs and solar energy costs are headed that way (not taking storage into account), and since the resources are plentiful, the only issue remaining is how intermittency is to be addressed and what the associated costs will be.

2. Intermittency and Smart Grid Considerations

96. One of the most important considerations regarding intermittency is that the level of investment and management needed is directly dependent on the proportion of solar and wind in the system and how complementary the patterns of solar and wind supply are to the patterns of demand. Very little additional investment or management is needed if penetration level is a few percent or less of total electricity generation, as it is on average in the United States today. Total wind and solar electricity generation is about 3 percent of the total at present, with almost all of it coming from wind.

[79] EERE 2011 SunShot: http://www1.eere.energy.gov/solar/sunshot/, viewed on 8 July 2011.
[80] It is difficult to make estimates of unsubsidized costs for nuclear power plants because Wall Street refuses to finance them and also because they cannot be insured without a government cap on liability. Ignoring the insurance problem, costs on an open market financing basis can be approximately estimated. They were 12 to 22 cents per kWh prior to the March 2011 Fukushima Daiichi disaster in Japan. Costs of coal with carbon capture are similar to new nuclear plants. See Makhijani 2010 eUtah for a detailed discussion and references. Coal with CCS costs are based on the 2010 report of the U.S. government's Interagency Task Force. (Interagency Task Force 2010) The costs of new nuclear power plants are likely to rise due to additional safety requirements after Fukushima.

97. When wind and solar reach five to ten percent of capacity, as is the case in Texas, accurate forecasting of the resource several hours or one day ahead and planning to fill any gaps with generation resources like hydropower and natural gas turbines are needed. These resources and capabilities are already available. Wind energy is almost 20 percent total generation in Denmark and its grid is a conventional one. It maintains the reliability of its grid largely by import and export of electricity. Denmark does not have a significant amount of storage in hydropower reservoirs, for instance. In effect, it uses other European countries capacity, notably Norwegian hydropower resources, for providing de facto storage.[81]

98. In the United States, considerable hydropower resources are available, including pumped hydropower storage resources expressly designed for storing energy when excess cheap electricity is available and generating it when supply is short at peak times. The existing U.S. pumped storage capacity is 21,000 megawatts, expressly built to store energy and manage peaks.[82] Compressed air energy storage (CAES) is also commercial and costs about 3 cents per kilowatt-hour when used on a large scale to support wind and solar energy.[83] Many other storage systems are in the research, development, or pilot testing stages. A liquid air energy storage system of significant size (300 kilowatts and 2.5 megawatt-hours) commenced pilot-scale operation in 2011 in Britain.[84] A commercial scale version is scheduled for 2013.[85] This system has the advantage relative to compressed air energy storage in that an underground cavern is not required. The liquid air (or nitrogen) is stored in insulated tanks.

99. The United States has hundreds of thousands of megawatts of natural gas fired capacity to support a transition to a high percentage of renewables. Most or all of this capacity could be retired in the last stages of transition to a nearly 100 percent renewable electricity sector.

---

[81] Energinet 2011, Energinet 2010, and Energinet 2009 p. 12
[82] ORNL et al. 2010 p. 2.
[83] Makhijani 2010 eUtah. Compressed air energy storage (CAES) has been used commercially for decades on a large scale with coal-fired power plants in two locations: Germany and Alabama. Compressed natural gas storage in caverns and aquifers is also a standard technology.
[84] Highview 2011a and Engineer 2011
[85] Highview 2011b

100. Existing hydropower resources (which supply about 6 percent of U.S. electricity generation) as well as geothermal resources can also supply dispatchable renewable electricity. Modest amounts of new geothermal and hydropower resources are available that could be regionally important in supporting high penetrations of wind and solar (as for instance geothermal in Utah and hydropower in Minnesota). These technologies have been established for some time.

101. One of the main tools to overcome intermittency is the smart grid. Today, essentially the only communication between consumers and producers or producing devices is via the on-off switches of the consuming devices.[86] The need for smart grids to improve reliability, security, economy, and management of intermittent renewable sources of energy is widely recognized. This is also an area where technology is developing rapidly. The need is due to the foreseen rapid increase of solar and wind generation capacity, notably the latter, as well as state mandates for renewable energy. Most notably, California's Renewables Portfolio Standard (RPS) mandates 33 percent renewable electricity generation by 2020.[87] Meeting this standard will mean that utilities will have to develop storage plans as well as smart grid plans.

102. A smart grid is basically a communications network in parallel with the electrical power grid. The information in the communication network drives much of the grid. For example, dishwashers and clothes washers could be set to operate when there is surplus energy available (wind is blowing and the sun is shining). The defrost cycle in frost-free refrigerators and freezers could be operated in the same way. Of course, this means that appliances would have to be able to receive such signals. Plug-in hybrids and electric vehicles would be charged in the times of plenty; they could also supply power back to the grid, since their batteries store electricity. In fact, the installed power in all motor vehicles is much greater than the installed generating capacity. And personal vehicles are parked roughly 95 percent of the time, making them available, in principle, for connection to the grid.

---

[86] Air conditioner cycling programs and industrial interruptible supply are the main, though very limited, exceptions.
[87] California Energy Commission 2011

103. Vehicle-to-grid technology—the hardware, software, and communications systems—that would accomplish such tasks have begun to be tested. The standardization of the communications protocols has been taken up by electrical engineers, grid operators, and government. Manufacturers have begun to make and market smart appliances. Smarter programmable thermostats could respond continuously and not just in an on-off mode, which is typically the case at present. For example, today a utility pays a customer (who signs up for the program) for the right to turn off the compressor (the main energy consuming device) on a central air-conditioner for all or part of an hour for several hours during summer peaks in demand.[88] In contrast, a smart grid approach would allow each customer to specify the range of indoor temperature in which they are comfortable and the utility could manage the power supply accordingly. This increases choice and comfort for the customer and flexibility and reliability for the utility. The greater the flexibility the customer provides the utility, the lower the cost of electricity for that customer. The modeling capabilities that would enable millions of local solar PV generating stations to operate seamlessly with local storage, intermediate level generation, and large scale generation are being developed.

104. Among the most important features of the smart grid system is that consumers at all levels from individual homes to large industries will have real-time information about prices, about the state of their own appliances and space conditioning systems, about the state of the generation in the system from their own solar devices to the entire system. Consumers are already able to install software to control lighting in their homes from their smart phones.

105. Basically, smart grids can be conceptualized as extending the Internet to operate with the electrical system and empowering consumers at all levels to manage their electricity systems and making available the option to utilities of more closely matching loads (with the agreement of customers and for a payment) with available renewable energy supply than they could do today.

[88] For example, Pepco 2010 describes the air conditioner cycling program run by a utility in the Washington metropolitan area.

106. The importance of governmental initiation of basic climate protection rules as a spur to investment, jobs, innovation, and environmental protection can be seen in operation in California where large utilities are putting in place plans to develop and implement smart grids in the coming years. For instance, the plan of Pacific Gas & Electric is worth quoting at length because it estimates that customers will have both more reliable and more economical service, while integrating solar and wind energy in the coming decade:

> Pacific Gas and Electric Company's (PG&E) Smart Grid Deployment Plan is not just a plan, it represents a *fundamental change* to the way PG&E uses technology to serve its customers and operate its business. Compliant with California Senate Bill (SB) 17 and the decisions and policies of the California Public Utilities Commission (CPUC or Commission) implementing SB 17, PG&E's Smart Grid Deployment Plan represents a disciplined and integrated approach to using new monitoring and control technology to support PG&E's mission of providing safe, reliable, responsive and environmentally sustainable service to its customers.
>
> PG&E developed this plan with a clear focus on what our customers need and value as well as California public policy. PG&E's customers will see many benefits from the Smart Grid in the coming years, including the ability to lower energy bills by controlling energy use. Today, through SmartMeter™ technology, customers already can view energy use hourly and daily online to help understand how and when they use energy.
>
> In the future, pricing signals will help customers save money by shifting their energy use to times of the day when energy prices are lower. Customers will also enjoy increased reliability of service, including faster outage detection and restoration, as well as greater convenience from faster response to service requests.
>
> The Smart Grid will integrate wind and solar supplies to give customers more clean and renewable energy. The Smart Grid will also support more widespread

customer adoption of rooftop solar as well as "smart charging" programs that encourage the use of zero-emission electric vehicles while helping protect the safety and reliability of the energy grid.[89]

107. Specifically PG&E, while underscoring uncertainties in a rapidly moving field, estimates that the benefits will exceed the costs, though some of the benefits,[90] such as a 10 to 20 percent improvement in reliability are difficult to estimate precisely at the present time.

108. Two other points should be noted. First, just as in the case of using plug-in hybrids and replacing petroleum fuels with algal and other biofuels, the Department of Defense has an immense stake, both to reduce costs and casualties, in transitioning to renewable electricity sources. Specifically, it is exploring solar panels as a substitute for diesel generators in the field. As another example, flexible, roll up solar panels are reducing the requirements for battery storage, thereby reducing the weight of the batteries soldiers have to carry.[91]

109. Second, when efficiency is combined with renewable energy, the total bills for electricity should be about the same, since the lower costs for efficiency and the higher cost per kilowatt hour for generation will balance each other out, approximately. This was shown above in the example of the reduction of the energy footprint of a house through passive design.

110. Overall, the development of technology, including electric and plug-in vehicles and the smart grid, has been more rapid than estimated when the research for *Carbon-Free and Nuclear-Free* was completed in 2007. For instance, the technology for converting hybrid cars to plug-in hybrids existed but the means to convert gasoline and diesel vehicles to plug-in hybrids were only beginning to be developed. Unlike the present, there were no production plug-in hybrids or electric vehicles being made by large automobile manufacturers. Passive house design and stringent building standards were at the margins of discussion. Now they are part of the

[89] PG&E 2011 p. 2
[90] PG&E 2011 p. 7
[91] Johnson 2011

mainstream discussion; there are even goals and legal requirements in some places. Measurements of energy use in existing and new buildings of various types have demonstrated the economic viability of efficient appliances and buildings. The necessity of a smart grid is recognized by utilities.

111. Overall, in my judgment, it should be possible with firm policies to nearly completely eliminate fossil fuel use from the electricity sector in the next 30 years. This would mean a reduction of about 8 percent per year in the use of fossil fuels with a corresponding decrease in CO_2 emissions from coal and natural gas-fired power plants.

112. The main obstacle to achieving rapid reduction in CO_2 emissions from the energy sector is neither technical nor economic; it is the lack of a clear government policy to drastically reduce CO_2 emissions to protect climate that is the main roadblock.[92]

G. The Balance of Costs and Benefits

113. As progress towards the California 33 percent Renewables Portfolio Standard is demonstrating, the main burden on government is not economic, but that of leadership to channel private investment resources for the public good. CO_2 reduction policies are needed to overcome market deficiencies such as the split incentives between builders and buyers of new homes. The lack of a price on carbon that allows CO_2 pollution to continue despite the public benefit it would bring without increasing the overall expenditures on energy services as a fraction of GDP.

114. It is true that large corporations, including fossil fuel companies and automobile companies, and many builders would resist stringent standards as increasing government "interference" in the marketplace, and increasing costs of doing business. But these arguments are not well-founded in research and analysis; rather they are mainly manifestations of narrow, short-term self-interest and ideological arguments against regulation. Auto makers resisted

[92] In this context, it is noteworthy that 62 percent of new solar PV orders are from California (Solarbuzz 2011). This is attributable to California's 33% Renewables Portfolio Standard by 2020.

pollution controls, seat belts, and air bags as well. But despite their protests, auto sales continued to climb, the quality of automobiles continued to improve, the deaths and injuries not only per vehicle but overall continued to decline, and the air in cities like Los Angeles went from heavily polluted most of the time to being much cleaner despite the larger number of vehicles.

115. I have shown above by many examples, including most dramatically in the case of refrigerators, that standards reduce electricity use and expenditures. In some cases this occurs even as the price of the appliance declines. This is because the standards were reasonable and achievable.

116. Besides the direct benefits, the indirect public benefits of phasing out fossil fuels will be immense. The twentieth century is littered with conflicts over oil and the present century has not begun in a very promising way.

117. For instance, Alan Greenspan, the former Chairman of the Federal Reserve wrote:

> [W]hatever their publicized angst over Saddam Hussein's "weapons of mass destruction," American and British authorities were also concerned about violence in the area that harbors a resource indispensable for the functioning of the world economy.
>
> I am saddened that it is politically inconvenient to acknowledge what everyone knows: the Iraq war is largely about oil.[93]

118. Former Secretary of State Henry Kissinger said much the same thing in the *Washington Post*:

> American forces…are in Iraq not as a favor to its government or as a reward for its conduct. They are there as an expression of the American national interest to prevent the Iranian combination of imperialism and fundamentalist ideology from

[93] Greenspan 2007 p. 463

> dominating a region on which the energy supplies of the industrial democracies depend.[94]

119. The direct cost of the Iraq war has been estimated to be about $800 billion.[95] The indirect costs in terms of treatment of injured veterans, lost lives, disrupted families, and lost productivity are likely even greater.

120. This is not just a recent phenomenon. For instance, a military doctrine was explicitly put in place by President Carter when the main U.S. ally in the Persian Gulf region, the Shah of Iran, was overthrown during the Iranian revolution, which led to the formation of an Islamic government in that country. In his State of the Union address in January 1980, which occurred during the crisis when Americans were held hostage in Iran, President Carter said:

> Three basic developments have helped to shape our challenges: the steady growth and increased projection of Soviet military power beyond its own borders; the overwhelming dependence of the Western democracies on oil supplies from the Middle East; and the press of social and religious and economic and political change in the many nations of the developing world, exemplified by the revolution in Iran.
>
> …
>
> The region which is now threatened by Soviet troops in Afghanistan is of great strategic importance: It contains more than two thirds of the world's exportable oil. The Soviet effort to dominate Afghanistan has brought Soviet military forces to within 300 miles of the Indian Ocean and close to the Straits of Hormuz, a waterway through which most of the world's oil must flow. The Soviet Union is now attempting to consolidate a strategic position, therefore, that poses a grave threat to the free movement of Middle East oil.

---

[94] Kissinger 2007

[95] National Priorities Project 2011 ($790 billion) and CRS 2011 Table 1 ($805.5 billion)

This situation demands careful thought, steady nerves, and resolute action, not only for this year but for many years to come. It demands collective efforts to meet this new threat to security in the Persian Gulf and in Southwest Asia. It demands the participation of all those who rely on oil from the Middle East and who are concerned with global peace and stability. And it demands consultation and close cooperation with countries in the area which might be threatened.

Meeting this challenge will take national will, diplomatic and political wisdom, economic sacrifice, and, of course, military capability. We must call on the best that is in us to preserve the security of this crucial region.

Let our position be absolutely clear: **An attempt by any outside force to gain control of the Persian Gulf region will be regarded as an assault on the vital interests of the United States of America, and such an assault will be repelled by any means necessary, including military force.**[96]

121. It is clear that the Cold War and the wars for oil were intertwined until the Soviet Union collapsed. The wars for oil have continued. And, as the above quote from President Carter shows, Afghanistan became part of that combustible Cold War-oil mix for the United States in 1979.

122. It began with World War I. Senator Bérenger of France put it rather dramatically in 1918, when speaking of the role of oil in World War I. Oil was, he said,

the blood of victory… Germany had boasted too much of its superiority in iron and coal, but it had not taken sufficient account of our superiority of oil…. As oil had been the

---

[96] Carter 1980. Emphasis added. The conflict over Iran between the U.S. and the Soviet Union was already close to a boil just after World War II, when the United States gave a firm notice to the Soviets to withdraw from Iran. At the time, only the United States had nuclear weapons. The Soviets withdrew. (Alexander and Nanes 1980 pp 145 to 188, especially from March to December 1946. For example, March 5, 1946, letter of U.S. Secretary of State to the Chargé in the Soviet Union (Kennan) – to deliver to the Soviet Foreign Affairs Minister (Molotov) (pp. 162-163))

blood of war, so it would be the blood of the peace. At this hour, at the beginning of the peace, our civilian populations, our industries, our commerce, our farmers are all calling for more oil, always more oil, for more gasoline, always more gasoline. *More oil, ever more oil!*[97]

123. However, France had no significant domestic oil resources. "More oil" therefore had an aspect of both imperialism and war from the time it became central to the operation of military machines. As the French Senator Revol put it:

> After World War I, the ruling establishment understood that in order to guarantee the independence and development of France, acquiring and controlling foreign underground resources was essential…[98]

124. The U.S. was an exporter of oil until shortly after World War II. The costs of dependence on oil imports, in an increasing degree, were seen early on by the Paley Commission appointed by President Truman, which warned, most presciently, of security problems related to Middle Eastern oil in the 1970s.[99] The crisis began in 1973. The oil wars and other oil-related security problems continue.

125. Michael Klare, a scholar in strategic issues connected to resources, estimates the foreign troop deployments and wrote presciently in 2004 about the damage that resource-related wars were doing and would do to the U.S. economy:

> This deployment of American combat forces around the globe is going to place an enormous drain on our economic, military, and political resources. The bill – including the cost of keeping troops in Iraq and the Gulf, the Caspian basin, and Colombia, along with their supporting elements at home – will easily exceed $150 billion per year. Given

---

[97] As quoted in Yergin 1991 page 183. Translated from the French in Yergin, with the exception of "More oil, ever more oil." Emphasis added.

[98] Revol 1997-1998, Titre Premier, Ch. III Section I.B.1 (Une intervention constante de l'Etat). Translation by Annie Makhijani.

[99] Paley Commission 1952 v. III p. 10. The Commission also recommended pursuing solar energy in preference to nuclear energy. (Paley Commission 1952 v. IV, p. 220)

the enormity of the federal deficit and the attendant need to rein in government spending, we can sustain these expenditures only by pinching pennies at home – notably on domestic infrastructure and services, including, of course health care and education. And then there will be the vast sums we send abroad to pay for imported petroleum, an estimated $3.5 trillion between 2001 and 2025. With the American trade deficit already at precarious levels, spending on this scale will deliver a substantial blow to the American economy.[100]

126. Military expenditures on resource wars yield some negative returns: injured and dead military personnel, trade and federal deficits, high opportunity costs in terms of lower health and education levels. In contrast, the same expenditures invested in going from petroleum to electric vehicles powered with renewable energy would yield economic benefits in terms of jobs and lower fuel bills.

127. In addition, the indirect economic and health benefits would also be immense. While CO_2, the main greenhouse gas pollutant in the U.S. economy, causes damage via the losses attendant on severe climate disruption, other pollutants, such as unburned hydrocarbons, nitrogen oxides, sulfur dioxide, and particulates damage health directly and also by creating ozone pollution. Air pollution contributes to asthma, emphysema, and cardiovascular disease.

128. The EPA has estimated that the reduced death and illnesses from tightening air pollution (sulfur dioxide, nitrogen oxides, particulates, and ozone) standards would result in an almost $2 trillion annual benefit in the year 2020, with 85 percent of the benefits being from reduced "mortality associated with reductions in ambient particulate matter," while the costs would be about $65 billion.[101] The attribution of monetary value to reduced mortality is controversial and does not translate into the terms of the usual economic discourse, which is in terms of Gross Domestic Product. Yet the adverse health consequences of air pollution are well documented.

[100] Klare 2004 p. 182
[101] EPA 2011 Links and EPA 2011 Summary p. 3 (in 2006 dollars)

The EPA's analysis was reviewed in detail by its Science Advisory Board. Table 3 shows the final report's estimate of reduced adverse health outcomes.[102]

Table 3: Reductions in adverse health outcomes due to reductions in air pollution (in number of cases avoided, rounded)

Health Effect Reductions (PM 2.5 and Ozone Only)*	Pollutant(s)	Year 2010	Year 2020
PM2.5 Adult Mortality	PM	160,000	230,000
PM2.5 Infant Mortality	PM	230	280
Ozone Mortality	Ozone	4,300	7,100
Chronic Bronchitis	PM	54,000	75,000
Acute Bronchitis	PM	130,000	180,000
Acute Myocardial Infarction	PM	130,000	200,000
Asthma Exacerbation	PM	1,700,000	2,400,000
Hospital Admissions	PM, Ozone	86,000	135,000
Emergency Room Visits	PM, Ozone	86,000	120,000
Restricted Activity Days	PM, Ozone	84,000,000	110,000,000
School Loss Days	Ozone	3,200,000	5,400,000
Lost Work Days	PM	13,000,000	17,000,000

*Re PM 2.5: Particulate Matter 2.5 (or "fine particles") "refers to a mixture of aerosol particles which are less than or equal to 2.5 microns [millionths of a meter]." (EPA 2011 Summary footnote 2 (p. 3)
Source: EPA 2011 Summary Exhibit 8 (p. 14)

129. Most of the reductions in particulates would be due to restrictions of fossil fuel emissions. Reductions as a result of a ninety-plus percent reduction of fossil fuel use would be even more dramatic. As noted, these costs are not easily monetizable and the main controversies that surround the estimates are not about the health effects but about how a life is to be valued in monetary terms.[103]

130. There are communities and workers who would be adversely affected economically by the transition from fossil fuels to an efficient, renewable energy economy. But this transition will take place over about three or four decades, not overnight, so there will be time to adjust. The industrial age in the United States (and elsewhere) is full of major economic transitions that are much greater than going from oil pumped out of the ground to oil made from algae or from coal

[102] EPA 2011 Summary p. 14 and EPA 2011 Final p. 1-1
[103] Some monetary value is necessarily implied when a cost-benefit approach is used for decision-making.

mined and burned to generate electricity to solar and wind and geothermal energy. Tractors replaced horses as the main source of farm power within a few decades. People went from living mainly in rural areas and on farms to a majority living in urban areas and working in factories, also within the span of several decades. A transition from dimly lit homes and dark streets to most homes and shops lighted by electricity also happened within a few decades. The pony express and the stagecoach were replaced by the telegraph and the railroad. Each of these transitions had adverse consequences on some communities and people. But few would argue that they should therefore not have taken place.

131. Closer to our time, billions of people around the world are going from the most rudimentary technological existence to having cell phones, checking wheat and fish prices on the Internet from fields in rural India and from the landing spots of fishing boats. The value of making the transition from a world in which there are billions of people who do not have enough to eat to one in which the vast majority can have a decent existence, could be entirely or mostly negated by the consequences of severe climate disruption or the lung-choking pollution that is typical of cities in developing countries. Renewable energy, especially in the form of electricity, is a principal part of the answer for avoiding many of the most damaging negative consequences.

132. Finally, government can do much to stave off negative effects or to mitigate them substantially. For instance, much of the infrastructure, such as port facilities, and personnel skills, such as building complex structures out at sea, that are needed in the offshore oil industry can be used for an offshore wind energy industry. This is already beginning to occur in Scotland, which has for years had an offshore oil industry in the North Sea.[104] In Norway, Statoil, a major company that owns and develops oil and gas fields in the North Sea is developing advanced deep sea wind technology precisely because it has offshore expertise. According to the company's website:

[104] Scottish Development International 2011

The Hywind pilot is to be tested over a two-year period. It combines technology from both the wind power and oil and gas sectors, and draws on expertise gained from Statoil's long offshore experience.

The Hywind pilot – next generation wind technology

The Hywind concept combines known technologies in a completely new setting and opens up the possibility for capturing wind energy in deep-water environments.

…

The core expertise acquired by Statoil as a leading operator of offshore oil and gas fields has played a very important part in the development of the Hywind concept.

This expertise, combined with the group's financial strength and innovative ability, puts Statoil in a good position to develop this project.[105]

133. A transition from oil to wind can also happen in Houston or New Orleans; indeed, it could, with appropriate public policies, revive the maritime fortunes of cities like New Bedford, Massachusetts, once a great center of whaling and one of the richest cities in the world that subsequently lost its place in the sun.

134. As another example, wind turbine blade manufacturing as well as renewable energy installations can preferentially be set up in coal mining areas. Several coal mining areas, such as Wyoming and North Dakota, have excellent wind resources.

135. The main policies needed to make a transition are:

- A renewable portfolio standard for electricity that ramps up to 90 or 95 percent by 2050 at the latest with an option to increase the speed of phase out to 2040.

[105] Statoil 2009

- A carbon tax whose proceeds are refunded to lower income groups and used to offset damage in areas and populations that would otherwise be negatively affected. Some of the funds would also be used for research and development of new efficiency and renewable energy technologies.
- A carbon-neutral federal government by 2030 that would create a market for renewable energy and reduce government expenditures on fuels and electricity in the medium and long term.
- Progressively tighter building, appliance, and vehicle efficiency standards, including for motor vehicles, ships, and aircraft.
- Steadily declining CO_2 emission targets per mile travelled for the transportation sector.
- A steadily declining cap on emissions from large, energy intensive industries to 10 percent or less of 1990 emissions by 2050.

136. The direct positive economic effects of phasing out fossil fuels alone justify these policies. When the positive direct effects of investment in renewables and efficiency are taken together with the indirect benefits of stopping oil wars (with the concomitant casualties and deficits) and greatly reducing air and water and soil pollution (not to speak of ocean pollution), the case is extremely strong.

I certify under penalty of perjury that the facts presented above are true and correct to the best of my knowledge, and the analysis and opinions expressed in this declaration are based on my best professional judgment. Executed this 26 day of September 2011 at Takoma Park, Maryland.

Dr. Arjun Makhijani

H. References

AFP 2011	Agence France-Presse. "Swiss solar-powered aircraft lands in Brussels," *physorg.com*, May 13, 2011. On the Web at http://www.physorg.com/news/2011-05-swiss-solar-powered-aircraft-brussels.html.
Alexander and Nanes 1980	Yonah Alexander and Allan Nanes, eds. *The United States and Iran: A Documentary History.* Frederick, MD: University Publications of America, 1980.
APS 2008	American Physical Society. *Energy Future: This Efficiency: How America Can Look Within to Achieve Energy Security and Reduce Global Warming.* College Park, MD: APS, September 2008. Links on the web at http://www.aps.org/energyefficiencyreport to http://www.aps.org/energyefficiencyreport/report/aps-energyreport.pdf.
ASTM International 2011	"ASTM Aviation Fuel Standard Now Specifies Bioderived Components," *ASTM International News Releases*, Release #8908, July 1, 2011. http://www.astmnewsroom.org/default.aspx?pageid=2524.
BEDB 2010	United States. Department of Energy. *2010 Buildings Energy Data Book.* Washington, DC: DOE, Office of Energy Efficiency & Renewable Energy, March 2011. Links on the Web at http://buildingsdatabook.eren.doe.gov. • Table 1.1.4: 2008 U.S. Buildings Energy End-Use Splits, by Fuel Type (Quadrillion Btu), at http://buildingsdatabook.eren.doe.gov/docs/xls_pdf/1.1.4.pdf • Table 1.1.9: Buildings Share of U.S. Electricity Consumption (Percent), at http://buildingsdatabook.eren.doe.gov/docs/xls_pdf/1.1.9.pdf • Table 2.3.11: 2005 Energy Expenditures per Household, by Housing Type and Square Footage ($2009), at http://buildingsdatabook.eren.doe.gov/ChapterIntro2.aspx?2#3.
Biofuels Digest 2009	Jim Lane. "Continental Airlines tests aviation biofuel; first use of algae; first US biofuel test flight; first two-engine flight," BiofuelsDigest, January 8, 2009. On the Web at http://www.biofuelsdigest.com/blog2/2009/01/08/continental-airlines-tests-aviation-biofuel-first-use-of-algae-first-us-biofuel-test-flight-first-two-engine-flight/.
Biofuels Digest 2010	Jim Lane. "Military signals advanced biofuels demand: 336 million gallons by 2020," *Biofuels Digest*, December 16, 2010. On the Web at http://biofuelsdigest.com/bdigest/2010/12/16/military-advanced-biofuels-demand-336-million-gallons-by-2020-voices-from-the-bio-pacific-rim-summit.
BioJet 2011	"BioJet Supports Aviation Biofuel Approval with One Billion Gallon Availability," *BioJet Press Release*, Barbados and Santa Barbara, CA, July 6, 2011. On the Web at http://www.biojetcorp.com/reports/BioJet%201%20Billion%20Gallons%20V3.pdf. Labeled "Draft."
Bloomberg 2011	Louise Downing. "Airlines Prepare to Take Off on Fuel Made From Algae, Wood Chips," *Bloomberg*, July 6, 2011. On the Web http://www.bloomberg.com/news/2011-07-07/airlines-prepare-to-take-off-on-fuel-made-from-algae-wood-chips.html.
Boeing 2008	Tom Koehler. "A green machine: Boeing makes history with flights of Fuel Cell Demonstrator Airplane," *Boeing Frontiers*, May 2008, p. 44. On the Web at http://www.boeing.com/news/frontiers/archive/2008/may/ts_sf04.pdf.
Brooks et al. 2010	Alec Brooks, Ed Lu, Dan Reicher, Charles Spirakis and Bill Weihl. "Demand Dispatch: Using Real-Time Control of Demand to Help Balance Generation and Load," *IEEE Power & Energy Magazine* v.8, no.3 (May/June 2010) pp. 20-29. On the Web for members at http://www.ieee.org/organizations/pes/public/2010/may/index.html. The index to the issue is at http://www.ieee.org/organizations/pes/public/2010/may/index.html.

BTS 2011	United States. Department of Transportation. Bureau of Transporation Statistics. *National Transportation Statistics*. Washington, DC: DOT, Research and Innovative Technology Administration, BTS, 2011. Links on the Web at http://www.bts.gov/publications/national_transportation_statistics. • Table 4-23: Average Fuel Efficiency of U.S. Light Duty Vehicles, at http://www.bts.gov/publications/national_transportation_statistics/html/table_04_23.html. Updated July 2011.
CalCars 2011	California Cars Initiative. *About the CalCars Initiative*. [Palo Alto, CA]: CalCars, 2011. On the Web at http://www.calcars.org/about.html. Viewed July 14, 2011.
California Energy Commission 2011	California Energy Commission. *Renewables Portfolio Standards (RPS) Proceeding - Docket # 03-RPS-1078*. Sacramento, CEC, updated April 22, 2011. On the Web at http://www.energy.ca.gov/portfolio/index.html.
Carter 1980	Jimmy Carter. *State of the Union Address*, January 23, 1980, at http://millercenter.org/scripps/archive/speeches/detail/3404
CRS 2011	Amy Belasco. *The Cost of Iraq, Afghanistan, and Other Global War on Terror Operations Since 9/11*. (RL33110) Washington, DC: Congressional Research Service, March 29, 2011. On the Web at http://www.fas.org/sgp/crs/natsec/RL33110.pdf.
DOD 2011	United States. Department of Defense. *Plug-In Electric Vehicles: Request for Information*. [Washington, DC: DOD, June 16, 2011]. On the Web at https://www.fbo.gov/utils/view?id=151691ba8ffac2c907e03a2818141688, from link at https://www.fbo.gov/index?s=opportunity&mode=form&id=97189ca3098a25e113fccdb3120393c5&tab=core&_cview=0. Responses due July 18, 2011. Solicitation number: JB06162011.
DOE Wind Power 2011.	United States. Department of Energy. Office of Energy Efficiency and Renewable Energy. Wind & Water Power Program. *80-Meter Wind Maps and Wind Resource Potential*. Washington, DC: DOE, EERE, last updated 5/2/2011. On the Web at http://www.windpoweringamerica.gov/wind_maps.asp, with links to spreadsheets: "Additional 80- and 100-Meter Wind Resource Potential Tables." IEER is using the one at http://www.windpoweringamerica.gov/docs/wind_potential.xlsx, produced by NREL and AWS Truepower.
DSIRE 2011	Database of State Incentives for Renewables & Efficiency. *Federal: Incentives/Policies for Renewables & Efficiency; Business Energy Investment Tax Credit (ITC)*. [Raleigh, NC]: DSIRE, last DSIRE Review: 06/15/2011. On the Web at http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F.
EERE 2011 SunShot	United States. Department of Energy. Office of Energy Efficiency and Renewable Energy. Solar Energy Technologies Program. *SunShot Initiative*. Washington, DC: DOE, EERE, last updated 6/29/2011. On the Web at http://www1.eere.energy.gov/solar/sunshot.
EIA 2011 Electric Power	United States. Department of Energy. Energy Information Administration. *Electric Power Annual 2009 - State Data Tables*. Washington, DC, EIA, Office of Independent Statistics & Analysis, Report Released: November 23, 2010, Report Revised: January 4, 2011. On the Web at http://www.eia.gov/cneaf/electricity/epa/epa_sprdshts.html, • 1990 - 2009 Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923) (Revised April 2011) at http://www.eia.gov/cneaf/electricity/epa/generation_state.xls. • 1990 - 2009 Revenue from Retail Sales of Electricity by State by Sector by Provider (EIA-861) (Revised April 2011) at http://www.eia.gov/cneaf/electricity/epa/revenue_state.xls.

EIA 2011 Web Site	United States. Department of Energy. Energy Information Administration. [*Web site*] www.eia.gov. Washington, DC, EIA, viewed July 2011. "Energy Kids" is at http://www.eia.gov/kids/.
EIA 2011-07-07	United States. Department of Energy. Energy Information Administration. *Petroleum & Other Liquids. Spot Prices*. Washington, DC, EIA, Office of Independent Statistics & Analysis, 7/7/2011. On the web at http://www.eia.gov/dnav/pet/pet_pri_spt_s1_d.htm, viewed on July 8, 2011.
Emadi 2011	Ali Emadi. "Transportation 2.0," *IEEE Power & Energy Magazine* v. 9, issue 4 (July-Aug. 2011) pp**.** 18-29. Link on the Web at http://ieeexplore.ieee.org/Xplore/login.jsp?url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel5%2F8014%2F5899003%2F05899015.pdf%3Farnumber%3D5899015&authDecision=-203. Index for issue is at http://www.ieee.org/organizations/pes/public/2011/jul/index.html.
Energinet.dk 2009	Energinet.dk. "Wind power to combat climate change: How to integrate wind energy into the power system," *Green Thinking in Denmark*, [2009]. On the Web at http://energinet.dk/SiteCollectionDocuments/Engelske%20dokumenter/Klimaogmiljo/Wind%20power%20magazine.pdf.
Energinet.dk 2010	Energinet.dk. *Electricity interconnections*. Fredericia, Denmark: energinet.dk, last updated on 14 September 2010. On the Web at http://energinet.dk/EN/ANLAEG-OG-PROJEKTER/Electricity-facilities/Sider/Electricity-interconnections.aspx.
Energinet.dk 2011	Energinet.dk. *Environmental key figures for electricity*. Fredericia, Denmark: energinet.dk, last updated on 1 June 2011. On the Web at http://energinet.dk/EN/KLIMA-OG-MILJOE/Sider/Environmental-key-figures-for-electricity.aspx.
Engineer 2011	"Compressors for world's first liquid air energy storage plant," *The Engineer*, 5 September 2011. On the Web at http://www.theengineer.co.uk/channels/process-engineering/compressors-for-world%E2%80%99s-first-liquid-air-energy-storage-plant/1009869.article#ixzz1XrOzLZHR. At head of title: Process Engineering.
EPA 2011 Final	United States. Environmental Protection Agency. *The Benefits and Costs of the Clean Air Act from 1990 to 2020: Final Report*. Rev. A. Washington, DC: EPA, Office of Air and Radiation, April 2011. On the Web at http://www.epa.gov/air/sect812/feb11/fullreport.pdf. Links to the summary report, etc., are at http://www.epa.gov/air/sect812/prospective2.html.
EPA 2011 GHG	United States. Environmental Protection Agency. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 - 2009*. (EPA 430-R-11-005) Washington, DC: EPA, April 15, 2011. On the Web at http://epa.gov/climatechange/emissions/downloads11/US-GHG-Inventory-2011-Complete_Report.pdf.
EPA 2011 Links	United States. Environmental Protection Agency. *Benefits and Costs of the Clean Air Act: Second Prospective Study - 1990 to 2020*. [Washington, DC: EPA, Office of Air and Radiation, March 2011]. On the Web at http://www.epa.gov/air/sect812/prospective2.html.
EPA 2011 Summary	United States. Environmental Protection Agency. *The Benefits and Costs of the Clean Air Act from 1990 to 2020: Summary Report*. Washington, DC: EPA, Office of Air and Radiation, March 2011. On the Web at http://www.epa.gov/air/sect812/feb11/summaryreport.pdf. Links to the full report, etc., are at http://www.epa.gov/air/sect812/prospective2.html.

Feist et al. 2005	Wolfgange Feist, Søren Peper, Oliver Kah, Matthias von Oesen. *Climate Neutral Passive House Estate in Hannover-Kronsberg: Construction and Measurement Results.* (PEP Project Information No. 1) Darmstadt, Germany: Passiv Haus Institut, 2001; English translation 2005. On the Web at http://www.passivhaustagung.de/zehnte/englisch/texte/PEP-Info1_Passive_Houses_Kronsberg.pdf.
German Advisory Council 2010	German Advisory Council on the Environment. *Climate-friendly, reliable, affordable: 100% renewable electricity supply by 2050: Statement.* (Nr. 15) Berlin: SRU [Sachverständigenrat für Umweltfragen], May 2010. On the Web at http://www.umweltrat.de/cln_135/SharedDocs/Downloads/EN/04_Statements/2010_05_Statement15_Renewablesby2050.html or http://www.umweltrat.de/SharedDocs/Downloads/EN/04_Statements/2010_05_Statement15_Renewablesby2050.pdf.
GM-Volt.com 2010	"Report Reveals Lithium-ion Battery Prices Already Dropping Steeper Than Expected," *GM-Volt: Chevy Bolt Electric Car Site*, posted March 9, 2010. On the Web at http://gm-volt.com/2010/03/09/report-reveals-lithium-ion-battery-prices-already-dropping-steeper-than-expected.
Greenspan 2007	Alan Greenspan. *The Age of Turbulence: Adventures in a New World*. New York: Penguin, 2007.
Hamilton 2011	Tracy Idell Hamilton. "CPS Energy ratchets up investment in solar: Utility notifies its bidders that project will be eight times larger," *San Antonio Express-News*, updated July 7, 2011. On the Web at http://www.mysanantonio.com/living_green_sa/article/CPS-Energy-ratchets-up-investment-in-solar-1455605.php.
Hanover House 1998	"New Hampshire House Pushes the Energy Performance Envelope," *Environmental Building News*, v.7., no. 2. (February 1998). On the web at http://www.buildinggreen.com/auth/article.cfm/1998/2/1/New-Hampshire-House-Pushes-the-Energy-Performance-Envelope.
Highview 2011a	Highview Power Storage. *Cryogenic Energy Storage (CES) – briefing note*. London: Highview, July 2011. On the Web at http://www.highview-power.com/wordpress/wp-content/uploads/2011/07/Highview-Power-Storage-Cryogenic-Energy-Storage-CES-Briefing-Note-21.07.2011.pdf.
Highview 2011b	Highview Power Storage. *Commercial Unit*. London: Highview, July 2011. On the Web at http://www.highview-power.com/wordpress/?page_id=295. Viewed on September 24, 2011.
ICCT 2011	International Council on Clean Transportation. *Global Comparison of Light-Duty Vehicle Fuel Economy/GHG Emissions Standards*. Washington, DC: ICCT, updated June 2011. On the Web www.theicct.org/info/data/ICCT_PVStd_June11.ppt.
Interagency Task Force 2010	Interagency Task Force on Carbon Capture and Storage. *Report of the Interagency Task Force on Carbon Capture and Storage*. [Washington, DC: U.S. Department of Energy and U.S. Environmental Protection Agency, and others], August 2010. On the Web at http://fossil.energy.gov/programs/sequestration/ccstf/CCSTaskForceReport2010.pdf. Links to related documents at http://fossil.energy.gov/programs/sequestration/ccs_task_force.html.
Johnson 2011	Keith Johnson. "Solar Updates Marines' Arsenal," *Wall Street Journal*, May 9, 2011. On the Web at http://online.wsj.com/article/SB10001424052748704810504576307563280615054.html.
Kissinger 2007	Henry A. Kissinger. "Stability in Iraq and Beyond," *Washington Post*, January 21, 2007, p. B7. Reprinted at http://www.henryakissinger.com/articles/wp012107.html.

Klare 2004	Michael T. Klare. *Blood and Oil: The Dangers and Consequences of America's Growing Petroleum Dependence.* New York: Metropolitan Books, 2004.
Mahony 2010	Melissa Mahony. "Plane Takes First Flight on 100% Biofuel," *SmartPlanet*, July 22, 2010. On the Web at http://www.smartplanet.com/blog/intelligent-energy/plane-takes-first-flight-on-100-biofuel/2035.
Makhijani 2010 CFNF	Arjun Makhijani. *Carbon-Free and Nuclear Free: A Roadmap for U.S. Energy Policy*. Takoma Park, MD: IEER Press, third printing 2010, incorporating minor corrections from the second printing of 2008. On the Web at http://www.ieer.org/carbonfree/CarbonFreeNuclearFree.pdf. Changes from original 2007 version outlined at http://www.ieer.org/errata.html#bks.
Makhijani 2010 eUtah	Arjun Makhijani. *eUtah: A Renewable Energy Roadmap*. Salt Lake City: HEAL Utah, December 2010. On the Web at http://www.ieer.org/reports/eUtah2010.pdf.
Minnesota 2009	Minnesota Sustainable Building 2030. *Case Study Metrics*. [Presented at June 15, 2009, SB 2030 Advisory Group Meeting]. Link on the Web at http://www.mn2030.umn.edu/presentations.html, to 4-LHB: Case Study Metrics. (file name: 4-LHB-Draft Presentation Revised.ppt)
National Priorities Project 2011	National Priorities Project. *Cost of War*. Northampton, MA: NPP, 2011. On the Web at http://costofwar.com/en/. Viewed on August 3, 2011.
New York Times 2011	James Kanter. "U.S. Airlines Challenge European Emissions Rule," *New York Times*, July 3, 2011. On the Web http://www.nytimes.com/2011/07/04/business/global/04emissions.html.
New York Times 2011 Fuel	"Fuel Efficiency (Gas Mileage)," *New York Times*, updated July 29, 2011, at http://topics.nytimes.com/top/reference/timestopics/subjects/f/fuel_efficiency/index.html.
NPR 2011	NPR Staff. "Among The Costs Of War: Billions A Year In A.C.?" *All Things Considered,* June 25, 2011. On the Web at http://www.npr.org/2011/06/25/137414737/among-the-costs-of-war-20b-in-air-conditioning.
NREL 2010	National Renewable Energy Laboratory. *NREL Improves System Efficiency and Increases Energy Transfer with Wind2H2 Project, Enabling Reduced Cost Electrolysis Production.* (Hydrogen and Fuel Cell Technical Highlights) (NREL/FS-5600-48435) Golden, CO: NREL, November 2010. On the Web at http://www.nrel.gov/hydrogen/pdfs/48435.pdf.
NREL 2010 Slides	Kevin Harrison, Robert Remick, Aaron Hoskin, Gregory Martin. *Hydrogen Production: Fundamentals and Case Study Summaries*. Presented at the World Hydrogen Energy Conference, Essen, Germany May 19, 2010. [Golden, CO]: National Renewable Energy Laboratory, May 2010. On the Web at http://www.nrel.gov/hydrogen/pdfs/48269.pdf.
OPEC 2011	Organization of the Petroleum Exporting Countries. *Annual Statistical Bulletin*. 2010/2011 Edition. Vienna: OPEC, 2011. On the Web at http://www.opec.org/opec_web/static_files_project/media/downloads/publications/ASB2010_2011.pdf.
ORNL et al. 2010	*Pumped Storage Hydropower*: *Summary Report on a Summit Meeting Convened by Oak Ridge National Laboratory, the National Hydropower Association, and the Hydropower Research Foundation, Washington, DC, September 20-21, 2010*. [Oak Ridge, TN: ORNL, 2010]. On the Web http://www.esd.ornl.gov/WindWaterPower/PSHSummit.pdf
Paley Commission 1952	The President's Materials Policy Commission (Paley Commission). *Resources for Freedom*. 5 volumes. Washington, DC: Govt. Print. Off., 1952.

Passive House 2011	Passive House Institute US. *FAQ*. Urbana, IL: PHIUS, 2011. On the Web at http://www.passivehouse.us/passiveHouse/FAQ.html. Viewed on August 4, 2011.
Pepco 2010	Pepco. *Pepco Energy Wise Rewards™ Program*. Washington, DC: Pepco, 2010. On the Web at https://energywiserewards.pepco.com/overview. Viewed on August 3, 2011.
PG&E 2011	Pacific Gas and Electric Company. *Smart Grid Deployment Plan 2011 - 2020: Smart Grid Technologies Order Instituting Rulemaking 08-12-009, California Public Utilities Commission*. Sacramento: PG&E, June 2011. On the Web at http://www.pge.com/includes/docs/pdfs/shared/edusafety/electric/SmartGridDeploymentPlan2011_06-30-11.pdf. "Appendix A"
Revol 1997-1998	Henri Revol. *Politique énergétique de la France*. (Rapport 439) [Paris]: Sénat, Commission d'Enquete, 1997-1998. On the Web at http://www.senat.fr/rap/l97-4391/l97-4391_mono.html. Viewed June 21, 2011.
RMI 2010	Rocky Mountain Institute. *Project Case Study: Empire State Building*. (RetroFit) [Snowmass, CO]: RMI, [2010?]. On the Web at http://retrofitdepot.org/Content/Files/ESBCaseStudy.pdf, Viewed July 2011.
RMI 2011	Rocky Mountain Institute. *Retail Chain Case Study*. (RetroFit) [Snowmass, CO]: RMI, [2011?]. On the Web at http://retrofitdepot.org/Content/Files/RetailCaseStudy.pdf. Viewed July 2011.
Rosenfeld 2008	Arthur H. Rosenfeld. *Energy Efficiency: The first and most profitable way to delay Climate Change: The Indus Entrepreneur*. Sacramento, California Energy Commission, July 21, 2008. On the Web at http://www.energy.ca.gov/2008publications/CEC-999-2008-017/CEC-999-2008-017.PDF.
Schumpeter 1962	Joseph A. Schumpeter. *Capitalism, Socialism and Democracy.* 3rd ed. New York: Harper Torchbooks, 1962. The third edition was first published in 1950. Some of the chapter on Creative Destruction is reprinted (1975 ed.) at http://transcriptions.english.ucsb.edu/archive/courses/liu/english25/materials/schumpeter.html.
Scottish Development International 2011	Scottish Development International. *Wind Energy in Scotland*. (SE/3142/Dec10) Glasgow: SDI, January 2011. On the Web at http://www.sdi.co.uk/~/media/SDI/Files/documents/energy/SDI%20Wind%20Energy%20in%20Scotland_Jan_2011.ashx. Date from URL. Link at http://www.sdi.co.uk/resources/brochures/energy/wind-energy-in-scotland-brochure.aspx.
Sears 2011	Sears. *Televisions from Sony, Samsung, Panasonic, and more at Sears.com*. [Hoffman Estates, IL]: Sears, [2011]. On the Web at http://www.sears.com/shc/s/c_10153_12605_Computers+%26+Electronics_Televisions. Viewed July 6, 2011
Solarbuzz 2011	Solarbuzz. *US Photovoltaic Project Pipeline Soars to 17 Gigawatts, Solarbuzz Reports*. San Francisco: Solarbuzz, July 6, 2011. On the Web at http://www.solarbuzz.com/our-research/recent-findings/us-photovoltaic-project-pipeline-soars-17-gigawatts-solarbuzz-reports.
Solazyme 2011	"Solazyme Announces Successful MH 60S Seahawk Helicopter Test Flight on a 50/50 Blend of Algal Derived Solajet HRJ-5® Jet Fuel," *Algae News*, June 20, 2011. On the Web at http://algaenews.com/?p=499.
Southwest 2011	Southwest Airlines. *Fact Sheet*. [Dallas, TX]: Southwest, May 1, 2011. On the Web at http://www.southwest.com/html/about-southwest/history/fact-sheet.html.

Statoil 2009	Statoil. *Hywind: Putting Wind Poser to the Test*. Stavanger, Norway, February 11, 2009. On the Web at http://www.statoil.com/en/TechnologyInnovation/NewEnergy/RenewablePowerProduction/Onshore/Pages/Karmoy.aspx.
Tesla 2011	Tesla Motors, Inc. [Web site] Palo Alto, CA, Tesla, 2011. On the Web at www.teslamotors.com. Viewed July 7, 2011. • http://www.teslamotors.com/models/faq • http://www.teslamotors.com/goelectric/efficiency
Tiron 2011	Roxana Tiron. "$400 per gallon gas to drive debate over cost of war in Afghanistan," *The Hill*, October 15, 2008. On the Web at http://thehill.com/homenews/administration/63407-400gallon-gas-another-cost-of-war-in-afghanistan.
U.S. Navy 2010	Liz Wright. *Navy Tests Biofuel-Powered 'Green Hornet'*. (Story Number: NNS100422-17) Washington, DC: Navy Office of Information, April, 22, 2010. On the Web at http://www.navy.mil/search/display.asp?story_id=52768.
U.S. Navy 2011	Darrell E. Waller. *Navy Tests "Green" Hybrid Diesel Trucks*. (Story Number: NNS110615-25) Port Hueneme, CA: Naval Facilities Engineering Command Public Affairs, June 15, 2011. On the Web at http://www.navy.mil/search/display.asp?story_id=61040.
Waxman-Markey 2009	Text of *H.R. 2454 [111th]: American Clean Energy and Security Act of 2009*. Links to PDF & text versions at http://www.govtrack.us/congress/billtext.xpd?bill=h111-2454.
Wikipedia 2011	"Plasma display," *Wikipedia, the free encyclopedia*, last updated June 29, 2011. On the Web at http://en.wikipedia.org/wiki/Plasma_display.
Yergin 1991	Daniel Yergin. *The Prize: The Epic Quest for Oil, Money, and Power*. New York: Simon & Schuster, 1991.
Zeller 2010	Tom Zeller. "Can We Build in a Brighter Shade of Green?" *New York Times*, September 25, 2010, at http://www.nytimes.com/2010/09/26/business/energy-environment/26smart.html?_r=1&scp=1&sq=passive%20houses&st=cse. At head of title: Beyond Fossil Fuels.