THE RENEWABLE DEAL; ASPECT TWO, PLANK ONE: ENERGY
CHAPTER ONE

RENEWABLE ENERGY POTENTIAL:
WIND, HELICAL TURBINE, SOLAR, BIOFUEL, & CO-GENERATION
-A Means of Achieving National Energy and Climate Security-

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(updated 17 Dec 08)

Ivan Illich argued in his 1974 book *Energy and Equity* that inequality increases along with the energy flow through a society. However, meta-analysis of available research shows no correlation between happiness or well-being and energy consumption per capita after basic survival needs are met. I submit that Illich's thesis is true if the sources of energy are centralized, capital-intensive, and under management by a corporate economic elite representing passive investors who own the capital means of production. If the sources of energy flow in a society are decentralized and under management by members of many local communities, and are inexpensive enough to be acquired and owned by individuals, small businesses, and local communities within municipal power authorities, then total energy flow and social and economic inequality should be decoupled.

Chapter 1: Zero-Net-Carbon Renewable Energy System Feasibility

Introduction

Globally, an additional 20 terawatts of energy will be needed by 2050 to meet the demands of billions of people if they move from "low-impact" to "high-impact" lifestyles. Producing just 1 terawatt (1 million megawatts) would require 1,000 large electric power plants of 1,000 megawatts capacity each. As illustrated in detail below, a combination of improved energy efficiency and generation of power from existing, proven, renewable, non-polluting sources is competent to satisfy this energy demand.

Vaclav Smil argues in his books that the minimum energy requirement for a civilized lifestyle is a net 2 kilowatts per person. Currently, each U.S. citizen uses a net 9 kilowatts. Two kilowatts apiece for 9 billion people would require world energy production increase 30 percent above that achieved in 2000.

The U.S. DOE Energy Information Administration reports that in 2003, total U.S. energy demand was about 98 quads, of which 84 quads were supplied from fossil fuel sources. [One quad = 1 quadrillion British Thermal Units (Btu) = 1.06 exajoules ($1x10^{18}$ joules)]

In 1987, the World Commission on Environment and Development, Our Common Future, found that "Properly managed, efficiency measures could allow industrial nations to stabilize their primary energy consumption by the turn of the century." This referred to the year 2000, not 2100.

Bill McKibben writes: “Energy has become, in short order, the central environmental question, the central foreign policy question, and the central economic question.”

Apollo’s Fire (Island Press, 2007) was written by Representative Jay Inslee (D-WA) and Bracken Hendricks with a forward by Bill Clinton. The book advocates making renewable energy our moon shot and building a new economy around it. The authors say our real bugaboo in doing it is not research, money, or special interests, but fear. Lisa Margonelli writes that, “If we want a green alternative to black gold, we’ll need to ‘greendy’ the U.S. economy - encouraging the greedy and virtuous alike to create the best fuels.”

Zero-Carbon Renewable Energy Production Capacity Assessments (Using current Best Available Technology)

Section 1: 2006 National Policy Conference Forecast: Renewable Energy Can Be Fifty Percent of Total U.S. Energy Supply by 2025

According to the U.S. Energy Information Administration, the U.S. generated more than 55 Mwh of renewable energy in 2005, or about 1.5 percent of total U.S. energy production.

On November 30, 2006, 450 renewable energy policy, financial, and technology leaders attending the 5th national policy conference, “Renewable Energy in America: Phase II Market Forecasts and Policy Requirements” in Washington, D.C., announced their collective future deliverable renewable energy capacity to be 550 to 700 gigawatts by the year 2025. This assessment was an evaluative response to the “25x25" policy goal of producing 25 percent of U.S. energy from renewable sources by the year 2025. The industry panel projection of an achievable capacity ranging from a low of 550 gigawatts represents a 50 percent overshoot of the “25x25" policy goal by 2025 as the worst-case scenario. In other words, using off-the-shelf and late-stage developing renewable energy technologies, the U.S. can certainly generate 25 percent, and possibly as much as 40 percent of all its energy needs from renewables by 2025 if the investment is made to install this generating capacity. Conference presentations may be accessed at <www.acore.org/programs/06policy.php>.

Section 2: 2004 Pacala and Socolow: Greenhouse Gas Emissions Can Be Stabilized Now with “Silver Buckshot” Portfolio

Princton’s Dr. Stephen Pacala and colleage Dr. Robert Socolow demonstrated in a 2004 *Science* article that it is possible to stabilize greenhouse gas emissions now with what they called “silver buckshot:” a portfolio of existing technologies such as solar and wind energy, along with reduced deforestation and increased energy efficiency. To compare options, Pacala and Socolow created a common unit called a “stabilization wedge” which represents 25 billion tons of greenhouse gas emissions avoided over 50 years.

Section 3: 2007 American Solar Energy Society Report

The Phase II conference forecasts are consistent with the American Solar Energy Society's projection that renewable energy can more than offset the 1.1 to 1.3 billion tons of carbon emissions required per year by 2030 in order to limit the effects of solar warming. The ASES's report can be accessed at <**Error! Hyperlink reference not valid.** The report is entitled *Tackling Climate Change in the U.S.: Potential Carbon Emissions Reductions from Energy Efficiency and Renewable Energy by 2030*.

Terawatt Hours and Percentage of Grid Energy by Renewable Source
Carbon Dioxide Reduction in Tons and for Each Terawatt of Renewable Production

Technology	Terawatt Hours Total 2030	% Grid Energy 2030	CO_2 Reduction Million T/Yr	-Tons CO_2 per terawatt produced
Concentrating Solar Power	301	7.0	63	209,302
Photovoltaic Solar Power	298	7.0	63	211,409
Wind	860	20.0	181	21,046
Biomass	355	8.3	75	211,268
Geothermal	394	9.2	83	244,188
Energy Efficiency			688	
TOTAL	2,208	51.3	1,211	210,598 avg

Of the total 1,211 million tons of CO_2 reduction per year from the ASES 2030 energy scenario, 465 million tons or 43 percent are from renewable energy production technologies displacing CO_2-emitting energy production sources, and 688 million tons or 57 percent is from energy efficiency (obtaining the same work from less energy consumed) displacing CO_2-emitting energy sources. Among renewable energy sources, wind accounts for about a third of CO_2 displacement and all other sources account for 11 to 16 percent each.

The study did not include any electrical storage for solar or wind energy sources. Current concentrating solar plants under construction include hot salt storage of thermal energy to generate steam for around-the-clock electrical generation, thus making concentrating solar facilities base rather than intermittent-load energy sources.

The study did not include offshore wind or open-water and ocean water generating technologies already installed and in use in other countries but not being pursued in the U.S. at the time the analysis was done.

Section 4: 2007 European Renewable Energy Council Study

Greenpeace and the European Renewable Energy Council commissioned a study by German Aerospace: *Energy Revolution: A Blueprint for Solving Global Warming*. The study concludes that 80 percent of the world's energy can be produced from renewable sources with currently available energy technology, resulting in a 50 percent reduction of carbon dioxide emissions globally and a 72 percent reduction in the United States.

Section 5: 2007 Institute for Energy and Environmental Research Study: A zero-carbon dioxide U.S. economy can be achieved in 50 years without nuclear power

In August 2007 the Institute for Energy and Environmental Research (IEER) published their executive summary of a study to be published as a book in October, 2007, as a special issue of *Science and Democratic Action*, Volume 15(1) <www.ieer.org/sdafiles/15-1.pdf>. The central finding of *Carbon-Free and Nuclear-Free: A Roadmap for U.S. Energy Policy* is "...that a zero-CO_2 U.S. economy can be achieved within the next thirty to fifty years without the use of nuclear power and without acquiring carbon credits from other countries. In other words, actual physical emissions of CO_2 from the energy sector can be eliminated with technologies that are now available or foreseeable. This can be done at reasonable cost while creating a much more secure energy supply than at present. Net U.S. oil imports can be eliminated in about 25 years. All three insecurities - severe climate disruption, oil supply and price insecurity, and nuclear proliferation via commercial nuclear energy - will thereby be addressed. In addition, there will be large ancillary health benefits from the elimination of most regional and local air pollution, such as high ozone and particulate levels in cities, which is due to fossil fuel combustion."

IEER observes that reducing U.S. CO_2 emissions by 80 percent from 2000 levels by 2050 would still leave U.S. emissions at about 2.8 metric tons per person. If other nations were able to increase their CO_2 emissions per person to match this 80-percent-reduced U.S. level, the total world CO_2 emissions would be roughly the same as in 2000. Thus, "A U.S. goal of zero-CO_2, defined as being a few percent on either side of zero relative to 2000, is both necessary and prudent for the protection of global climate. It is also achievable at reasonable cost."

The IEER report contains two novel sections which make it a working "blueprint" for achieving a zero-CO_2 economy without nuclear power. The first is a set of twelve policy recommendations for the U.S., and the second is a detailed description of all the energy production and storage elements of the national zero-CO_2 energy grid and how much each would contribute towards meeting total U.S. energy needs.

The "clean dozen" recommendations are:

1. Enact a physical limit of CO_2 emissions for all large users of fossil fuels (a "hard cap") that steadily declines to zero prior to 2060, with the time schedule being assessed periodically for tightening according to climate, technological, and economic developments. The cap should be set at the level of some year prior to 2007 so that early implementers of CO_2 reductions benefit from the setting of the cap. Emission allowances would be sold by the U.S. government for use in the U.S. only. There would

be no free allowances, no offsets and no international sale or purchase of CO_2 allowances. The estimated government revenues of $30-50 billion a year would be used for demonstration projects, research and development, and worker and community transition. IEER defines “large user” as one who uses more than 100 billion Btu per annum; this would cover about two-thirds of total U.S. fossil fuel use.

2. Eliminate all subsidies and tax breaks for fossil fuels and nuclear power, including guarantees for nuclear waste disposal from new nuclear plants, loan guarantees, and subsidized insurance.
3. Elminate subsidies for biofuels from food crops.
4. Build demonstration plants for key supply technologies, including central station solar thermal with heat storage, large- and intermediate-scale solar photovoltaics, and CO_2 capture in microalgae for liquid fuel production.
5. Leverage federal, state and local purchasing power to create markets for critical advanced technologies, including plug-in hybrids.
6. Ban new coal-fired power plants that do not have carbon storage.
7. Enact at the federal level high efficiency standards for appliances.
8. Enact stringent building efficiency standards at the state and local levels, with federal incentives to adopt them.
9. Enact stringent efficiency standards for vehicles and make plug-in hybrids the standard U.S. government vehicle by 2015.
10. Put in place federal contracting procedures to reward early adoptors of CO_2 reductions.
11. Adopt rigorous research, development, and pilot plant construction programs for technologies that could accelerate the elimination of CO_2, such as direct solar hydrogen production (photosynthetic, photoelectrochemical, and other approaches), hot rock geothermal power, and integrated gasification combined cycle plants using biomass with a capacity to sequester the CO_2.
12. Establish a standing committee on Energy and Climate under the U.S. Environmental Protection Agency’s Science Advisory Board.

IEER notes that “The U.S. renewable energy resource base is vast and practically untapped. Available wind energy resources in 12 Midwestern and Rocky Mountain states equal about 2.5 times the entire electricity production of the United States. North Dakota, Texas, Kansas, South Dakota, Montana, and Nebraska each have wind energy potential greater than the electricity produced by all 103 U.S. nuclear power plants. Solar energy resources on just one percent of the area of the United States are about three times as large as wind energy, if production is focused in the high insolation areas in the Southwest and West.” Citing the U.S. Navy’s 750 kW installation on the roof over one of its parking lots in San Diego, IEER says “Just the parking lots and rooftops in the United States could provide most of the U.S. electricity supply [from photovoltaics].”

To deal with the problem of renewable energy intermittency, IEER first talks about integration of different forms of production (e.g., solar, wind, hydroelectric, geothermal, natural gas as standby), then about storage - which is where the IEER report gets creative relative to previous efforts. Surplus renewable energy production could be stored in (1) compressed air; (2) solar thermal energy storage; (3) nanotechnology-based lithium ion batteries now being produced commercially by Altairnano which can be deep discharged 10,000-15,000 times versus the 2,000 deep dischage capacity needed over the life of a plug-in hybrid. IEER proposes that hybrid cars be used as the electrical storage medium in a vehicle-to-grid system (V2G): parked cars would be connected to the grid and charged and discharged according to the state of requirements of the grid and the charge of the vehicle battery. Communications technology to accomplish this via wires or wireless means is already commercial.

Thus, standby power to deal with intermittency of renewable sources in the mature renewables-based, zero-CO_2 U.S. energy system would be supplied by stationary storage, the V2G system, combined cycle power plants fueled by biomass, thermal storage in central station solar thermal power plants, hydropower, and compressed air storage in the combined cycle power plants.

According to IEER's calculations, "Complete elimination of CO_2 could occur as early as 2040. Elimination of nuclear power could also occur in that time frame." Such early elimination is contingent on technological breakthroughs in solar hyrogen production and in rapid implementation of the V2G hybrid-car-based storage system. Otherwise, zero CO_2 emissions and elimination of nuclear power from the U.S. energy production system would take until 2060 to achieve.

Energy efficiency plays a major role in the IEER design. "The use of highly efficient design technologies and building design, generally available today, can greatly ease the transition to a zero-CO_2 economy and reduce its cost. A two percent annual increase in efficiency per unit of Gross Domestic Product relative to recent trends would result in a one percent decline in energy use per year, while providing three percent GDP annual growth. This is well within the capacity of available technological performance....For instance, residential and commercial buildings can be built with just one-third to one-tenth of the present-day average use per square foot with existing technology."

Instead of using food crops for biofuel production, "...biomass that has high efficiency solar energy capture (~ five percent), such as microalgae gorwn in a high-CO_2 environment, can form a large part of the energy supply both for electricity production and for providing liquid and gaseous fuels for transport and industry. Microalgae have been demonstrated to capture over 80 percent of the daytime CO_2 emissions from power plants and can be used to produce up to 10,000 gallons of liquid fuel per acre per year. Some aquatic plants, such as water hyacinths, have similar efficiency of solar energy capture and can be grown in wastewater as part of combined water treatment and energy production systems." Five percent solar capture is about ten times that of a corn plant, including both the grain and crop residues.

The IEER list of supply and storage technologies and their probable implementation dates for the U.S. energy system is:

•	Solar PV - intermediate-scale	2010 to 2015
•	Solar PV - large-scale	2015 to 2020
•	Concentrating solar thermal power plants	2015 to 2020
•	Microalgae CO_2 capture and liquid fuel production	2015
•	Wind power - large-scale, land-based	Already being used
•	Solar PV - intermediate storage	~2020
•	Solar PV - intermediate scale with vehicle-to-grid	~2020 to 2025
•	Biomass IGCC	~2020
•	High solar energy capture aquatic biomass	~2020
•	Hot rock geothermal energy	2025?
•	Wave energy	2020 or 2025?
•	Photolytic hydrogen	2020 or 2025?
•	Photoelectro-chemical hydrogen	2020 or 2025?
•	Advanced batteries (nanotech lithium ion)	2015
•	Carbon sequestration	Unk: 15-20 years?
•	Ultracapacitors (commercial in certain apps now)	2015-2020?
•	Nanocapacitors (not developed yet - lab testing)	Unknown
•	Electrolytic hydrogen production (in certain apps now)	Unknown - infrastructure

As illustrated in sections of this paper below, several of these entries are incorrect on the conservative side. For example, wave energy is already being captured in commercial-scale installations of helical turbines in both Europe and Asia. Photolytic hydrogen panels are already developed and are going into commercial production in Europe. Thus, the implementation date should not have a question mark by it; these technologies can be implemented nationwide on the same timetable as established technologies such as microalgae CO_2 capture and liquid fuel production.

The next table in the IEER report consists of a list of demand side technologies such as plug-in hybrid vehicles and geothermal heat pumps, with the date IEER estimates they are deployable for large-scale use. Deployment of these demand-side technologies increases the efficiency of energy use, and thus represent components of the national conservation of energy strategy. The IEER report also provides an analysis of the costs of CO_2 abatement from various energy sources in terms of their cost per metric ton of CO_2 abated from pulverized coal-fired electricity generation.

IEER then demonstrates their “reasonable cost” hypothesis with the following table:

Item	IEER Scenario	Business-as-Usual
Electricity	$326	$442
Fuel	$150	$247
Sub-total energy cost	$476	$689
Added annual investment for efficiency	$205	$0
Total GDP-basis amount (rounded)	$681	$689

GDP in 2050	$40,000	$40,000
GDP fraction: energy services	1.70%	1.72%

All figures combine residential and commercial applications. Business-as-usual uses fuel and electricity prices from January 2006 of about $12 per million Btu and 9.6 cents per kWh. IEER prices are $20 per million Btu and 14 cents per kWh from its supply and storage technology system, powering the more efficient national system of deployed demand-side technologies. Note this is very conservative: the comparison assumes that energy from current fossil fuel and nuclear sources would cost the same per Btu and kWh in 2050 as they did in 2006!

Added efficiency estimates: existing residences = $20,000 per residence each time, assumed to occur in one of every three sales of existing buildings between 2010 and 2050; new = $10 per square foot to attain Leadership in Energy and Environmental Design (LEED) building certification standards. Also included is the cost of replacing appliances every 15 years with then-prevailing advanced appliances. Investments for solar thermal heating, combined heat and power, and geothermal heat pumps are added to the figures in proportion to the residential square footage using them. Commercial efficiency investment is estimated at $10 per square foot which is more than the amount needed to attain the highest LEED "platinum" standards due to additional investments for solar thermal heating, combined heat and power systems, and geothermal heat pumps being assumed.

GDP is calculated as consumption expenditures + investment + government spending on goods and services + exports - imports.

The IEER report contains two tables which show the source for delivered energy between 2005 and 2050 (natural gas, petroleum, coal, biofuels, solar thermal, electricity, and efficiency) in Quadrillions of Btu, and then the source of the electricity component in billions of kWh from coal, natural gas, oil, nuclear, hydropower, geothermal+wood waste+landfill gas, solid biomass, biomass-derived gas, geothermal hot rock, wind, solar PV central station and intermediate, solar PV small scale, solar thermal & other, and combined heat and power systems from 2005 to 2050. In the former table, natural gas, petroleum and coal all drop to zero by 2050; in 2050 efficiency accounts for about half of the delivered Btu, electricity for about 8 percent, solar thermal for about 3 percent, with the rest of delivered Btu shown as being from biofuels. In the latter table, coal, natural gas, oil, and nuclear all drop to zero by 2050; hydropower's kWh contribution is about constant, geothermal grows only slightly, while the rest of these sources expand to account for a total production of roughly 3750 billion kWh among them to meet a total national electricity demand projected at roughly 4300 billion kWh in 2050.

The Cleantech Venture Network reports that venture-capital investment in clean-technology companies jumped 78 percent to $2.9 billion in 2006 from 2005.

Section 6: The McKinsey and Company Report

The McKinsey and Company report, "Reducing U.S. Greenhouse Gas Emissions: How Much at

What Cost?" was released in December, 2007. McKinsey is a private investment analysis firm commissioned by a coalition of corporations and conservation groups including Royal Dutch Shell, Pacific Gas and Electric, the Natural Resources Defense Council, and Environmental Defense, to analyze the economic cost feasibility of attaining various levels of anthropogenic greenhouse gas abatement. McKinsey found it will only cost a few billion dollars net to achieve a 3.5-4 gigaton cut in U.S. greenhouse gas emissions by 2030. Overall mitigation costs under the most stringent cut scenario still averaged less than $50 per ton of greenhouse gas emission reduction. Eighty percent of the greenhouse gas abatement they describe in their financial models was achieved using technologies available today on a commercial scale; the other twenty percent was achieved using technologies in late-stage commercial development such as cellulostic alcohol and plug-in hybrid vehicles.

Under "The Central Conclusion of This Project," McKinsey states: "The United States could reduce greenhouse gas emissions in 2030 by 3.0 to 4.5 gigatons of CO_2e using tested approaches and high-potential emerging technologies. These reductions would involve pursing a wide array of abatement options available at marginal costs less than $50 per ton, with the average net cost to the economy being far lower if the nation can capture sizeable gains from energy efficiency."

If nothing is done, annual greenhouse gas emissions in the U.S. are projected to rise from 7.2 gigatons carbon dioxide equivalent (CO_2e) in 2005 to 9.7 gigatons in 2030, an increase of 35 percent. McKinsey used five government reference forecasts to derive this number; one the U.S. energy Information Administration's Annual Energy Outlook 2007, supplemented by four EPA and one Forest Service publication. These analyses exclude HCFCs on the assumption that they will be phased out per the Montreal Protocol. "Growth in emissions would be accompanied by a gradual decrease in the absorption of carbon by U.S. forests and agricultural lands. After rising for 50 years, carbon absorption is forecast to decline from 1.1 gigatons in 2005 to 1.0 gigatons in 2030."

The McKinsey report warns, "Without a forceful and coordinated set of actions, it is unlikely that even the most economically beneficial options would materialize at the magnitudes and costs estimated here."

In the section which breaks out "clusters of abatement potential," McKinsey clusters are: buildings and appliances, transportation, industry, carbon sinks, and power [generation].

- Improving energy efficiency in buildings and appliances can produce 710 (midrange) to 870 (high-range) megatons of abatement.

- Increasing fuel efficiency in vehicles and reducing the carbon-intensity of transportation fuels can produce between 340 and 660 megatons (same ranges) abatement. McKinsey notes that, "Though the savings from fuel efficiency may offset the incremental cost of the abatement option over a vehicle's 12- to 15-year lifecycle, these options require up-front investment by automakers and thus higher vehicle costs for consumers. Lower-carbon fuels, such as cellulostic biofuels, could abate 100 megatons to 370 megatons of emissions, though this potential is highly dependent on innovation rates and near-term commercialization of these technologies. Plug-in hybrid vehicles offer longer-term potential if vehicle cost/performance improves and the nation moves to a lower-carbon electricity supply."

- Pursuing various options across energy-intensive portions of the industrial sector can produce 620 to 770 megatons (mid and high range) abatement. "Despite offering direct bottom-line benefit, these options must compete for capital and, without clear incentives to control GHG emissions, may not receive funding."

- Expanding and enhancing carbon sinks can abate 440 megatons (mid-range) to 590 megatons (high-range). "Increasing forest stocks and improving soil management practices are relatively low-cost options."

- Reducing the carbon intensity of electric power production can abate 800 megatons (mid-range) to 1,570 megatons (high-range). "This potential derives from a shift toward renewable energy sources (primarily wind and solar), additional nuclear capacity, improved efficiency of power plants, and eventual use of carbon capture and storage (CSS) technologies on coal-fired electricity generation. Options in the power plant sector were among the most capital-intensive ones evaluated. These options also tend to have the longest lead times, given bottlenecks in permitting, materials and equipment manufacturing, and design, engineering, and construction."

McKinsey points out the theme of greater "energy productivity" that "pervades these clusters." "Improving energy efficiency in the buildings-and-appliances and industrial sectors, for example, could...offset some 85 percent of the projected incremental demand for energy by 2030, largely negating the need for the incremental coal-fired power plants assumed in the government reference case. Similarly, improved vehicle efficiency could roughly offset the added mobility-related emissions of a growing population, while providing net economic gains."

McKinsey advocates that a comprehensive greenhouse gas abatement program for the U.S. should proceed quickly, using a portfolio of strong, coordinated policies to capture GHG reductions efficiently across industry sectors and geographies, accelerating development of a low-carbon energy infrastructure. Among the portfolio of strong, coordinated policies McKinsey lists:

- Visible, sustained [market] signals to create greater certainty about the price of carbon and/or required emissions reductions; this will help encourage investment in options with long lead times and/or lifecycles

- A coordinated economy-wide abatement program or set of programs. Because abatement options are highly fragmented and widely distributed across sectors and geographies, any approach that does not simultaneously unleash a full range of abatement options risks missing proposed 2030 reduction targets and/or driving up total cost to the economy.

- Exchange mechanisms (e.g., trading schemes, offsets, tax credits) to create fungibility across fragmented markets, create greater market transparency, and drive least-cost solutions.

The McKinsey report concludes: "This project evaluated the costs and potentials of more than 250 abatement options available in the U.S. We did not examine economy-wide effects associated with abating greenhouse gases, such as shifts in employment, impact on existing or new industries, or changes in the global competitiveness of U.S. businesses. The project did not attempt to assess the benefits to society from reducing global warming. The report also did not attempt to address other societal benefits from abatement efforts, such as improved public health from reducing atmospheric pollution or improving national energy security."

From other sources, I think the bulk of the evidence supports the expectation that shifting to a renewables-based, GHG-abating energy economy in the U.S. would create more and better-paying jobs than were lost, improve global competitiveness of U.S. businesses in an international economic environment which is scaling back GHG emissions, improve public health due to air and water quality improvements; and greatly improve national security and the national economy through shift from imported fossil fuel energy sources which have adverse effect on balance of trade deficits and are subject to disruption due to international political instability or hostility, to domestically-produced renewable sources which are not subject to foreign disruption and recycle dollars spent on them in the domestic economy.

Section 7: *Earth: The Sequel* - Transforming the World Energy Economy

A 2008 book, *Earth: The Sequel* by Environmental Defense Fund president Fred Krupp and author Miriam Horn, describes how the $6 trillion world energy economy is being - and can be - transformed. Among other initiatives, the book describes advances in electricity generation from ocean waves, production of biofuel from algae, adaptation of saturated steam turbine technology from the nuclear industry to solar concentrating electricity plants, and geothermal heating and cooling technologies.

Internet powerhouse Google is investing millions in solar, wind and geothermal technology with the aim of developing a gigawatt of renewable energy that is cheaper than coal-fired power generation is currently (without a carbon tax).

Section 8: Zero Carbon Britain Report

The Centre for Alternative Technology in the United Kingdom published its plan for how the U.K. can eliminate emissions from fossil fuels in 20 years (2027), half through adoption of efficiencies and half through renewable energy source utilization. The 105-page report is downloadable from <zerocarbonbritain.com> at no charge. The report was published in October, 2007. It utilizes a new conceptual analytic scheme called "contraction convergence" to improve on the implementation timetable of the IEER design, reviewed above. On the renewable energy side of its prescription, in 2027 45 percent of all electricity would be from wind turbines, 90 percent of which would be located offshore. On its heading, the Zero Carbon Britain website bears the name of Sir John Houghton, who was co-chair of the IPCC.

Section 9: Solving the Problem of Renewables Intermittency

Many of the Renewable Energy Sources Are Not Intermittent: using as our point of reference the fact that the DOE EIA places the duty capacity of coal-fired power plants as 87 percent: a given coal-fired power plant, which is considered a "base load" electricity resource, will be available to generate at its rated capacity 87 percent of the time and will be off-line 13 percent of the time.

The renewable energy source types detailed in the renewable deal that do not have a duty capacity lower than a coal-fired power plant include:

- geothermal electrical plants
- concentrating solar plants with hot salt thermal storage
- any "negawatt" or efficiency resource that offsets load demand on the grid
- most helical and other open-water turbine generating facilities
- biomass-fired generating facilities

The renewable energy source types detailed in the renewable deal that do have a duty capacity lower than a coal-fired power plant include:

- solar photovoltaic
- wind
- tidal turbine power generating plants that run twice a day with the tide

Bear in mind, as discussed in more detail below, that contemporary grid control centers which balance energy source against electrical load in a given block of the electrical grid can handle a mix of up to 80 percent non-intermittent to 20 percent intermittent electrical source. Thus, if we have 80 percent of a totally renewables-based U.S. electrical grid powered by renewables in the first non-intermittent category above and 20 percent from renewables in the second intermittent category, we don't have any problem to worry about and can go home to enjoy being snug and non-polluting.

Dealing With Renewable Energy Sources That Really Are Intermittent:

Contemporary electrical grid load distribution centers - particularly those in Europe - can routinely handle intermittent energy sources which constitute up to 20 percent of total grid source capacity, balancing a portfolio of base load and intermittent energy sources with fluctuating load on the grid. This is particularly easy if the intermittent energy source, e.g. photovoltaic solar electricity, ramps up in synchrony with consumer load, as does in fact occur in daytime versus at night. The problem for the grid load distribution controller is when an intermittent energy source such as wind peaks at a time of low use load, as may occur at night.

Under these latter conditions, the grid load distribution center must be able to either quickly throttle down input from another electricity source to balance electricity from the renewable, intermittent source and all other sources in the grid with load, or the grid load distribution center has to be able to put only part of the renewable source electricity into the grid and direct the rest to an off-line load, or both. The Danish load distribution centers have capacity to do the latter with electricity generated from the nation's vast off-shore wind farm source capacity.
Outside the grid load distribution centers, there are three solution pathways available in theory that would permit current intermittent renewable electricity generation sources to reduce their intermittency as "seen" from the perspective of the grid load distribution control center. These represent system design solutions to the fact that the sun does not always shine and the wind does not always blow in synchrony with changes in energy demand from the grid's loads - although both sources of energy are capable of producing, on a cumulative annual basis, far more quads of energy than are consumed in total by U.S. electricity loads.

Solution Path #1: Establish a superconducting electrical DC grid nationwide, with hydrogen used as the coolant traveling through the same pipelines that contain the DC busses, thus delivering the energy stored as hydrogen for combustion nationwide. This system, which has been engineered and costed out in a *Scientific American* article, assumes that the sun will be shining or the wind will be blowing somewhere in the U.S. at a given time sufficiently to generate power to meet grid load demands.

Solution Path #2: Establish storage of energy at solar or wind farm sites which can be used to power electric generation turbines when the primary energy source is absent. There appear to be three major schools of thought on how to accomplish this storage:

> **2.A**: Use surplus energy from the solar or wind farm to compress air into underground salt caverns, then release the air at night through a generating turbine, supplemented with combustion of natural gas or biomethane as needed.
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> **2.B.** Use surplus energy from the solar or wind farm to catalyze water into hydrogen. Store the hydrogen in tanks and burn it at night to drive a generating turbine. This idea was first advanced by former Oak Ridge director S. David Freeman in his book, *Winning Our Energy Independence*. He advocates using natural gas as a backup to locally-produced hydrogen.
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> This path was rendered far more feasible by the breakthrough discovery at Daniel Nocera's Massachusetts Institute of Technology laboratory, announced July 31, 2008, of new catalysts which, when placed in water, produce either hydrogen or oxygen at room temperature, from pH-neutral water, when a voltage is applied to the electrode from a renewable energy direct current source. <www.Sciencemag.org/cgi/content/abstract/1162018> Dr. Nocera anticipates that, within ten years, solar or wind electricity generators will be able to generate hydrogen and oxygen with these catalytic electrodes to store for fuel for hydrogen fuel cells to generate electricity when sun and wind production are absent.

Hydrolysis of water into oxygen and hydrogen requires two catalytic steps. The positively charge anode pulls electrons from the hydrogen atoms in water molecules. The protons remaining when hydrogen atoms lose their electrons float away from the oxygen molecules to which they are no longer bonded. The anode catalyst then captures the oxygen molecules and links them together into O_2. The hydrogen protons are attracted to the negatively charged cathode where they hook up with new electrons to make molecular hydrogen H_2. The difficulty has been with finding catalysts which will perform these functions at the anode and cathode; the anode is the largest problem. Platinum works well as the anode catalyst, but it is too expensive and rare to be used on a large industrial scale for hydrogen production. A number of metals and metal oxides will work as the anode catalyst, but only in high or low pH water solutions. Nocera's team reported in a 2004 *Journal of the American Chemical Society* that a cobalt-based catalyst would produce water from O_2, protons and electrons, which indicated it could do the reverse. Unfortunately, cobalt is water-soluble. Nocera and Ph.D. student Matthew Kanan went around this hurdle by starting with a stable electrode material, indium tin oxide, and putting the electrode in a solution spiked with cobalt (Co_2+) and potassium phosphate. When a positive charge was applied to the indium tin oxide electrode, apparently electrons were pulled from the Co_2+ turning it into Co_3+, which then paired up with negatively charged phosphate ions to form a rocklike cobalt phosphate crust on top of the indium tin oxide. The positively charged anode then pulls another electron from the Co_3+ in the film to form Co_4+, which then proceeds to grab electrons from hydrogen atoms in water and welds oxygen atoms together into O_2. In the process, the Co_4+ turns back into Co_2+ and dissolves in the water solution, and the cycle repeats.

The anode and cathode catalysts used by Nocera's team work in pH-neutral water and are indifferent to dissolved solids in the water. Nocera plans to determine if the catalysts will work in seawater. His team is working to engineer the easy-to-make anodes and cathodes to carry higher levels of current in order to accelerate the rate of hydrogen and oxygen gas production from each per unit of time.

2.C. For concentrating solar farms only, use the solar-heated high temperature oils to superheat salts in a storage tank through which the secondary water circuit is circulated, generating steam to drive generating turbines both when the sun is shining and when it is not. As described in the chapter on solar energy in this plank, concentrating solar plants are now under construction utilizing this heat storage technology which permit round-the-clock ("base load") electrical generation by them.

Solution Path #3: Build low-loss high voltage DC cable systems, which are already in use today, to distribute power from wind sites in many different places to load centers. Contemporary high voltage DC cable technology loses only ten percent of source energy to resistance in each thousand miles of distribution length. Linking wind generating facilities in different locations with each other and load centers lowers the intermittency of the wind generating resource system. If you have widely separated wind farms A, B, C, and D, each with

240 megawatts capacity and a duty capacity of 40 percent of installed generation capacity - which means in effect that the wind farm will generate electricity the 40 percent of the time the wind blows fast enough at the wind farm site to operate the turbines - then the probability 240 megawatts of wind-generated energy will be fed into the grid by one or more of the plants rises from 40 percent to whatever the probability is that the wind will be blowing at more than 8 m.p.h. at any one of the four sites on the high-voltage DC distribution network at a given time.

Section 10: The Problem of Portable Energy Storage

The lithium ion battery: Lithium ion batteries were proposed in the 1970s, developed in the 1980s, and first marketed by Sony in 1991. (By comparison, lead-acid batteries were invented in 1859.) Lithium ion batteries present enormous difficulties as the electrical energy storage medium for higher wattage applications such as motor vehicles.

First, lithium is a highly reactive element. Early batteries in computer laptops had to be recalled because of their propensity to heat up, catch fire, and explode. Lithium batteries do not "like" to be charged or discharged rapidly. If discharged below about 2.5 volts per cell, the battery can be damaged so it will not accept a full charge ever again. If charged above 4 volts per cell, the result is "thermal instability." Lithium ion batteries react badly to being fast charged, yet this is a necessary ability in a vehicle battery if one is to recapture braking energy as electrical regeneration.

Current lithium ion batteries being used in such vehicles as the Tesla electrical car use nanotechnology to form the charging surfaces within the lithium ion battery, lowering the amount of heat that is generated at a given rate of charge or discharge of the battery and thus making the battery stable for a wider range of vehicular charge and discharge currents.

Engineers are now working on battery management systems which couple electrochemical capacitors, otherwise known as "ultra capacitors," with lithium ion battery storage systems in vehicles. Ultra capacitors can be designed to receive extremely large currents, and they can be charged and discharged millions of times without deterioration. Capacitors hold a charge only as long as there is a potential across their positive and negative leads, so they cannot be used as an electrical storage medium. Designers are attempting to design vehicle power systems in which the ultra capacitors receive large currents from electrical regeneration or other fast charging, from which electricity is fed through the battery controller at a controlled rate into the lithium ion battery assembly for long-term storage. Conversely, a motor controller system could draw a charge into the ultra capacitors from the lithium ion battery system so that a burst of current could be fed to the vehicle motors, generating short-term torque far in excess of what the lithium ion batteries could power at their maximum rate of current delivery. Working prototypes of such systems have not been built, and present formidable cost and control system issues.

Although Toyota's electrical vehicle research effort is based on developing lithium ion battery technology, Honda's management concluded that lithium ion battery technology cannot be cost-effectively developed as the platform for electrical vehicle power in vehicles to be owned and operated by members of the public. Honda is instead focused on developing a commercially-viable fuel cell technology to power the electric motors on its electric vehicles.

Section 11: Why Build the Alternative Energy System Now?

Robert Kaufmann said in *WorldWatch* January/February 2006: "If the infrastructure for the alternative energy source is put in place before the peak arrives, the energy used to do so will have a relatively small impact on non-energy sectors. Conversely, if society waits until the peak, constructing the large infrastructure for the alternative fuel will siphon large amounts of energy from the non-energy sectors of the economy at the very time that the total supply and energy surplus from oil is shrinking. In short, society has to pay the costs for the transition. We can pay them now, while we have oil in the bank, or we can pay them later, when our oil bank account is emptying."

In a December 4, 2007 article in the U.K. *Guardian*, George Monbiot illustrated why much larger cuts in greenhouse gas emissions than had been discussed would be necessary to prevent global warming from exceeding 2 degrees Centigrade. He starts with the IPCC table that shows the world needs to cut total emissions of greenhouse gases to roughly 15 percent of the volume emitted in 2000 by the year 2050 to prevent warming exceeding 2 degrees Celsius. Monbiot looked up the global figure for carbon dioxide production in 2000 and divided it by the current population, resulting in a "baseline" figure of 3.58 tonnes of CO2 per person. An 85 percent cut if population remained constant results in a global output per person budget of 0.537 tonnes by 2050. The UK currently produces 9.6 tonnes and the US 23.6 tonnes per person. Reducing these figures to 0.537 tonnes by 2050 requires a 94.4 percent cut in the UK and a 97.7 percent cut in the US. If world population rises to 9 billion in 2050 as UN projections assert, the cuts needed to reach total emissions goals rise to 95.9 percent in the UK and 98.3 percent in the US. Monbiot then points out that 18 percent of global warming currently is accounted for by greenhouse gas emitted by "feedbacks" - warming accelerating natural release of greenhouse gases from forests, peat bogs, and the like. In order to compensate for these emissions which are not subject to human control, "to stabilise temperatures at 1.5 degrees above the pre-industrial level requires a global cut of 100%. The diplomats who started talks at Bali yesterday should be discussing the complete decarbonisation of the global economy." Monbiot goes on to demonstrate why this is not impossible, since you can run almost the entire energy system on renewable power that does not emit greenhouse gases.