Beyond Nuclear Report

Renewable Energy & Efficiency: the real climate change solutions

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"[A Global Solar] Fund could easily be raised by cutting subsidies for fossil fuels and nuclear energy, to install solar photovoltaic equipment around the planet, thereby driving down the price and creating a mass market for a clean fuel technology." Mikhail Gorbachev, former Soviet President on the 20th anniversary of the Chernobyl nuclear power explosion

"…Yucca Mountain would be the world's first solar and wind powered atomic waste dump. This begs the question: couldn't renewable energy be used to generate electricity in the first place, so that nuclear power can be phased out and no more high-level nuclear waste generated?" anonymous submitted as comments to a Department of Energy Supplemental environmental impact statement, 2001.

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INTRODUCTION

To curb the threat of climate change, humanity must change the way it produces and uses energy. Renewable energies including wind, solar, geothermal and certain forms of biomass can completely replace both fossil fuel and nuclear power. According to a 2007 study, "a reliable U.S. electricity sector with zero carbon dioxide emissions can be achieved without the use of nuclear power or fossil fuels."[1] Not only would this reduce or eliminate net production of certain greenhouse gases like carbon dioxide[2], it would ensure energy independence at the individual, national, international and corporate level by bringing more options to consumers and introducing a level of democracy into the energy industry not possible with the use of fossil and nuclear fuels and the energy structures these technologies require.

Given the enormous potential of renewable energy sources to replace both nuclear and fossil fuels, society must adjust the supporting systems, many of which are in disrepair, to be compatible with renewable energy generation. One of the main concerns is the intermittency of wind and solar energy. However, there are sufficient and innovative technologies already in place that, if used judiciously, can effectively resolve this challenge.[3] In fact, the German government has shown that national economies can overcome issues of intermittency and base load to run entirely on renewables.[4] As of July 2009, non-hydro renewables were at 4.24 percent of electrical output in the US, already surpassing the Senate energy bill target of three percent by 2013.[5] If society is to crawl out of the fossil and nuclear trap, it must establish efficient energy use, and transmission, storage and production of energy at or near the site of use. Efficient appliances, distributed and/or "smart grid" and sufficient storage systems are not only renewable-friendly technologies, but encourage a stable and responsive energy supply; one less inviting of and susceptible to disruptions from accidents or terrorist attack.

RENEWABLE ENERGY SOURCES

"If it exists, it must be possible" Steven J. Strong, Solar Design Associates

Wind energy technology is ancient, dating back as early as the first sail boats. The first wind mills were developed to grind grains and pump water circa 500-900 CE in Persia. The windmill was continually modified for centuries in Europe becoming the electrical motor of the pre-industrial West. Although the first windmill to generate electricity was in the late nineteenth century,[6] "[t]he United States, generally, has embraced centralized production and distribution of electricity, such as the famous rural electrification program of the 1930s." [7] Ranchers and farmers were forced to topple their wind turbines in order to have transmission lines installed from a centralized grid to their properties.[8] This government mandate tied the United States to a central grid system (rather than allowing for a distributed grid) which solidified the electric company monopolies and their entrenched disdain for renewables—a policy position which still plagues this country.

Solar power has been around at least since ancient Greece, which established the first recorded application of passive solar architecture to allow the sun to warm interior spaces and heat hot water for bathing.[9] Solar cell technology dates back to 1839 when physicist Antoine-Cesar Becquerel (Henri, for whom the unit of radiation was named, was his grandson) discovered that "shining light on an electrode submerged in a conductive solution would create an electric current."[10] At the 1878 Paris World's Fair solar energy was used to boil water to power a printing press.[11] At the height of the industrial revolution a group of engineers, worried that fossil fuel would run out eventually, decided to search for a less finite form of energy. They settled on solar and developed an impressive array of techniques to capture and convert energy from the sun to produce the steam that powered the machines of the day. [12]

> In fact, just before World War I, they had outlined all of the solar thermal conversion methods now being considered. Unfortunately, despite their technical successes and innovative designs, their work was largely forgotten for the next 50 years in the rush to develop fossil fuels…Now, a century later, history is repeating itself.[13]

WIND

"The free benefit of the wind ought not be denied to any man."[14] –Herbert of Bury, circa 1180

As of September 2008, the United States had nearly 21,000 megawatts (MW) of installed wind power capacity providing electricity to the equivalent of 5.3 million homes. One megawatt of wind power produces enough electricity to serve 250 to 300 homes.[15] Worldwide, on- and offshore wind generates enough electric power to satisfy the residential needs of more than 150 million people with an installed capacity of over 100,000 megawatts.[16] In absolute terms, this may be a tiny piece of the market, but cars were an equally small market at the turn of the twentieth century. Prospects for continued expansion are good[17] with a projected total of 600 gigawatts (GW) global installed wind base by 2020.[18] By 2050, wind power could provide thirty percent of the world's energy needs.[19]

Net generation from wind sources in the United States increased by nearly thirty-five percent from 2008 to 2009[20] surpassing Germany for that year, injecting over nine billion dollars into the economy and accounting for nearly thirty percent of new power producing capacity.[21] Germany remains the frontrunner in total installed wind power capacity with 22,200 megawatts to date.[22]

> Unlike conventional energy sources, electricity generation from wind does not release greenhouse gases associated with global warming. Wind also offers long-term energy security, since it is inexhaustible, widely distributed, and free. If [a] 27 percent annual growth rate of installed wind power capacity is maintained, total capacity in 2020 will hit 2 million megawatts. With aggressive economic incentives, it could reach 3 million megawatts by that date.[23]

In order to reach full potential, wind power needs fair access to current transmission lines and redesign and redevelopment of new transmission lines.[24]

Land-based Wind Energy

Land-based wind energy could supply almost thirty percent of electricity in the United States –on a par with the European Union's predictions for Europe-by 2030.[25] Total US wind resources are actually greater, with North Dakota resources alone theoretically capable of meeting more than one quarter of US electricity demand. Following North Dakota in order of wind resources are Texas, Kansas, South Dakota and Montana.[26] However, wind use should not be limited to just those states with the greatest potential since many states offer enough wind power to be useful in a sustainable energy future by providing locally generated energy which would cut down on transmission losses and make wind power even more affordable.

Wind power costs are about seven cents per kilowatt hour (kWh) currently. Wind has decreased in cost significantly over the last thirty years to a level competitive with conventional power sources like natural gas. These conventional sources still receive hefty subsidies; therefore to remain competitive, wind depends on economic incentives. If full carbon emissions costs were considered for natural gas and coal, wind would be the cheapest electricity source.[27]

Offshore Wind Energy

Wind turbines constructed offshore have several appealing qualities. While intermittency is still an issue, it is much less pronounced because wind blows steadier and faster over water than on land due to lack of tall obstructions. Heavier populations live on or near coastlines, so transmission is more efficient because less energy is lost during delivery.[28] In fact, enough off-shore wind resources exist near the coastal states that their development will produce power that is cost-competitive with some coal-fired plants.[29] The wind becomes even stronger further out over the water and the "visual pollution" a minority of wind opponents complain about is greatly lessened. [30]

Until now, wind developers have been limited to water shallower than sixty-five feet because foundation supports were prohibitively expensive. But several companies are developing floating turbine systems to be able to build further out and "open up a resource of immense scale"[31]. Demonstration projects are planned or under construction off the coasts of Italy and Massachusetts.[32] In June, 2009, the US Department of Interior awarded five leases for offshore wind development on the Outer Continental Shelf off the New Jersey and Delaware coasts.[33] The total estimated potential capacity off the entire coast of the US is 908 gigawatts. This includes exclusion zones to allow for restrictions and consideration of resources, avian, marine and other habitat as well as shipping routes. As a comparison, total U.S. electrical generation capacity for all fossil, nuclear and renewable generation is 914 gigawatts.[34] According to Ken Salazar, US Secretary of the Interior, the United States could replace most if not all coal fire power plants if wind power off the East Coast were fully developed.[35]

Currently offshore installed wind capacity accounts for 1,170 megawatts worldwide [36] with another 11,455 megawatts planned by 2010.[37] Denmark has the most offshore installed wind followed by the UK, Sweden, the Netherlands and Finland. Germany is poised to make this top five and the UK is advocating for 33,000 megawatts of offshore British wind power by 2020, enough to meet the electrical needs of every home in Britain.[38] The US has 54,000MW planned by 2030. Ten states, including Ohio, Michigan, and several Atlantic states, have enough offshore potential to provide 100 percent of their energy needs. The US Atlantic region alone has about 330 Gigawatts which exceeds the total energy use of this region.[39] By 2015, nine Gigawatts of offshore wind power capacity will be built in the United Kingdom, overtaking nuclear installed capacity.[40]

Shallow offshore wind costs range from eight to fifteen cents per kilowatt hour, roughly twice the cost of onshore wind.[41] The larger the turbine and the farther out it is placed, the more the cost will decrease. Off the East Coast in the United States, wind costs ten cents per kilowatt-hour making it competitive with other conventional energy sources. [42] Offshore wind planned for Galveston, Texas should cost 6.5 cents per kilowatt hour retail in 2010 when the wind farm is planned to go online.[43] By 2014 offshore wind could decrease to five cents per kilowatt-hour.[44]

SOLAR ENERGY

There are several forms of solar energy including electricity production, cooking and solar heating. Use of solar thermal and solar electric has the best chance of decreasing worldwide use of pollution producing technology. Electricity is produced directly from captured sun energy by use of solar panels. This is known as Solar Photovoltaic technology or PV.[45] Solar Thermal heating used to heat water replaces, in whole or in part, systems based on fossil fuels which produce greenhouse gases. Solar power systems can be at the dwelling and neighborhood level, or can be constructed in plants which can produce larger amounts of energy which must be stored and transported on a greater scale.

Solar Photovoltaic

Solar panels for electricity production have historically been made from polysilicon although other materials are now being incorporated into the process for greater efficiency in production of the cells and the electricity, leading to lower costs[46]. Sun hits the panels, which can be either solo or arranged in a group called an array; the more panels, the more electricity production. As the sun hits, the electrons in the silicon are knocked into a heightened state of energy that can be converted and used to power appliances, lights, power a battery or anything that runs on conventional electric power. These panels can be integrated into roofing tiles, window panes, even a building wall.[47]

Grid connected solar PV has been one of the world's fastest growing technologies since the early 2000s.[48] Worldwide, grid connected solar PV capacity was 5000 megawatts at the start of 2007.[49] In 2008 solar PV installed capacity reached 15,200 megawatts worldwide, with Germany having 5337 total megawatts, while Spain installed 2670 megawatts in 2008 alone. [50]

According to a report by Navigant Consulting, the United States could have installed solar electricity capacity of 711 gigawatts by 2010; and by 2025 we could have seen this rise to 1,037 gigawatts. The study discounted thirty-five percent of commercial rooftops and seventy-eight percent of residential roof area as not conducive to solar electricity production due to bad placement, structural integrity etc.[51] If we add solar panels to current rooftops *and* parking lots and solar energy could provide most of the US electricity supply[52] if the political will were present to make it happen. To put all of these energy capacity numbers into context, the US currently has a little less than 1000 GW installed capacity and wastes a large part of the energy this capacity generates.[53]

Solar electric costs will decrease more than forty percent in the next three years as the panel manufacturing process is streamlined and simplified, especially with China's entry into the production market as the world's third largest solar cell producer.[54,55] Currently, solar PV averages eight to fifteen cents per kilowatt hour in a high-yield area like Arizona (the lower figure accounts for avoided greenhouse gas production, job creation, and protection from fuel cost increases)[56] but with technical improvements, five to eight cents per kilowatt hour is not improbable within the next few years.[57] Currently, the average cost of solar electric is twenty cents per kilowatt hour.[58]

Solar Thermal Energy

Solar thermal energy uses plates, mirrors or other heat collecting and reflecting surfaces to heat air, water or other liquids, and in some cases, food.[59] This captured heat can make hot water directly[60] or be converted into electricity,[61] now with less energy loss due to longer-term storage using molten salts.[62] Installing a solar thermal water heater could reduce a single home's emission of greenhouse gases by one to two tons per year. Cost of a residential system is usually recovered in seven to ten years depending on local water heating costs. These systems require very little maintenance.[63]

Large-scale solar thermal costs about thirteen cents per kilowatt-hour for electricity generation[64], but this cost should decrease significantly if solar thermal plants are grouped together, to generate at least 600 megawatts. This would reduce the cost to eleven cents per kilowatt-hour. By building the plants closer to consumers and combining generation with storage technology, solar thermal could cost ten cents per kilowatt-hour making it competitive with natural gas.[65] With further technical development electricity generation costs could be as low as six cents per kilowatt-hour by 2020.[66]

Development of molten salt heat storage means that solar thermal power can generate electricity almost around the clock, during nighttime or rainy days,[67] nearly doubling the hours of production. Molten salt is a mixture of sodium and potassium nitrate, otherwise know as fertilizer. [68] In the US, 3100 megawatts of solar thermal power are planned by 2012 including facilities in Florida, Arizona, Nevada and California. Worldwide capacity is expected to increase by fourteen times, reaching 6400 megawatts a few years from now.[69]

Solar thermal heat technology can also be used to directly benefit developing nations for cooking food, desalinating water and disinfecting. All of these solar technologies use direct sunlight and heat, concentrated through or by plastics or reflective metals. Using solar to cook, pasteurize and dry foods saves costs and avoids the health risks of other types of fuel such as wood or coal. Disinfection and solar still desalination reduces health risks of water-borne illnesses and makes these technologies readily available at lower cost to the areas that need them.[70]

BIOFUELS

Biofuels can either come from material grown for the specific purpose of creating energy or from waste or other secondary sources. Most biofuels come from photosynthetic plants which capture carbon and then release it when used, creating a carbon-neutral or even carbon negative system. Biofuels can be used to generate electricity, but also hold promise for replacement of vehicular fossil fuel, reducing our reliance on foreign fuel, our carbon emissions, and other pollution.[71]

Use of some plant material is more controversial than others. Use of food crops such as corn, wheat and seeds is already being blamed for food supply shortages and rising food prices in some areas of the world. According to the BBC, rising food prices could be putting 100 million people at risk.[72] While it is difficult to identify precisely what responsibility, if any, biofuels bear in world food crises, there are non-food biofuel sources which many experts claim could be used instead. Many of these sources have other advantages over food crop use in addition to not competing with a hungry, heavily populated world.

These include cellulosic sources such as food crop cast-offs, (stalks, peels, hulls and "woody" inedible left-overs) grasses and grass clippings. However, many of these crops should be carefully controlled because they can be quite invasive and rapidly overtake indigenous species.[73] Algae and other water plants are low-input, high yield biofuel sources and many biofuel proponents believe these sources hold the most promise [74,75] along with certain field grasses[76].

Grasses

Grasses may be one of the best biofuel sources, often yielding carbon negative energy, even with some fossil fuel use during production. Experts estimate grasses could produce nineteen percent of global energy needs while not adding greenhouse gases. Growing and harvesting other biofuel crops such as corn, which is also a food crop, are much more energy intensive.[77]

Algae

If predictions based on small-scale algae production are correct, algae-derived oil could replace all existing vehicle gasoline usage [78] by growing algae using an area about the size of Maryland and Delaware. By comparison, this area is one-seventh the area of corn harvested in the United States in 2000.[79] Certain types of smaller algae called microalgae (as opposed to seaweed) grow much faster than land crops and produce an oil yield that is seven to thirty times greater then the next best crop.[80] One type of green algae can be induced to create hydrogen instead of oxygen, making it a potential source of hydrogen for cars and other fuel users.[81] In addition to replacing auto fuel, algae can be harvested and burned in the same manner as other biofuel crops to produce heat and electricity.[82]

Algae production is currently high-yield and high cost—making commercial production less attractive, but research could bring the cost down to commercial viability in just a few years.[83] Additional increase in fossil oil costs could make algae biofuel cost competitive even more quickly.[84] The US National Renewable Energy Laboratory has an official program goal to produce biodiesel from microalgae costing one dollar per gallon.[85] Currently algae oil could be as little as $3.50 per gallon by sale of byproducts and use of waste heat.[86] Growing algae for fuel does not affect fresh water sources[87] as would other biofuel production since algae can be grown on marginal lands, like deserts, where the groundwater is salty.[88] Ironically, some research has found that carbon dioxide released from burning fossil fuels is just the resource needed to grow algae. Some experts recommend building algae ponds next to fossil fuel plants to help soak up pollution and to serve as an economic producer of this biofuel crop. [89]

Much of the research into fuel from algae is being conducted by the private sector in many countries including the Philippines, the US, New Zealand, and Germany. [90] The first test of algae jet fuel was conducted at the beginning of 2009 using a fifty-fifty blend of algae and regular jet fuel. The test was successful both in engine operation and fuel performance.[91] In September 2009, a plug-in hybrid Toyota Prius was driven across the United States from San Francisco to New York on algae fuel. The algae oil can be used in any petroleum-powered vehicle with no engine modification, is low-emission and renewable.[92]

Water Hyacinth

Water hyacinth is another abundant biofuel source which is also considered an invasive pest in many countries. [93,94] Native to South America, water hyacinth grows in swamps, ponds and other water bodies. It has been spread through much of the tropics and subtropics by human activity. As a highly invasive weed, it chokes out native aquatic species of fish and plants, polluting shorelines and providing breeding grounds for pests which carry malaria, schistosomiasis and other diseases. Its uncontrolled presence can cause severe environmental and socioeconomic destabilization. [95]

Water hyacinth has many positive uses, among them biogas production, which can be used for energy. Water hyacinth produces 1.5 times the amount of biogas of cow dung per gram volatile solid. Since acetic acid facilitates biogas production, this energy source is very viable for tropical nations which often have stores of acetic acid leftover from sugar cane refining; this allows local communities or villages to control energy resources. Many of these countries plagued by invasive hyacinth do not have the resources for control campaigns, so using the hyacinth for energy would serve two needs at once.[96]

GEOTHERMAL ENERGY

HOT DRY ROCK & ENHANCED GEOTHERMAL (HDR/EGS)

One to six miles below the earth's surface, the rocks are extremely hot. Water hits these rocks, and resurfaces with great heat and energy. When this occurs naturally, the water forms geysers such as those in California or Iceland.[97] When humans inject water intentionally into fractures or boreholes, it can be forced back up through another borehole, resurface and turn a turbine to generate electricity or furnish heat. The cooled water is then re-injected through the same boreholes and the process repeated.[98] Nicola Tesla mentions hot dry rock as an energy alternative to fossil fuel in two 1931 publications.[99]

Hot dry rock/enhanced geothermal produces base load (steady and constant) power,[100] making it ideally suited to pairing with other renewable energy sources which can have intermittency issues. Additionally, current HDR/EGS technology is scaleable and modular, unlike former geothermal technology,[101] making it a great candidate for a distributed grid. Commercial projects are in various phases in Japan, Europe,[102] Australia, Germany and the United States. In France, a 1.5 megawatt demonstration plant has been hooked to the grid. A plant in Basel, Switzerland had to shut down because the water injections caused a 3.4 magnitude earthquake. Since Basel is a known earthquake zone sitting atop a historically active fault, the solution is to avoid zones prone to earthquakes by predictive siting.[103] A decision whether or not to restart the plant will be made in 2011 or after, subsequent to necessary repair and risk analysis.[104] With this one exception, HDR/EGS has markedly lower negative environmental impacts compared to fossil fuels or nuclear power.[105] However, as with many forms of energy production or other development, geothermal must be sited carefully, avoiding sacred and cultural sites of first nations or other unwanted impacts on minority communities.

Total HDR/EGS resources are 140,000 times the US annual primary energy use and the extractable energy is sufficient to provide all of the world's current energy needs for several millennia.[106] As of August 2008, the on-line capacity of geothermal power in the United States was almost 3,000 megawatts with installations in Alaska, California, Hawaii, Idaho, Nevada, New Mexico and Utah. New geothermal activity could result in installed capacity of nearly 4,000 megawatts in the next few years in the states already listed and additional states such as Arizona, Wyoming and Washington.[107] With an investment of one billion dollars total over fifteen years, (a fraction of the cost of one 1,000 megawatt nuclear reactor) 100 gigawatts (that equals 100,000 megawatts) of electricity or more could be installed by 2050 for as low as 3.9 cents per kilowatt-hour depending on resource temperature and system efficiency.[108]

RENEWABLE ENERGY & EMPLOYMENT

Renewable energy, on average, would create four times more jobs per megawatt of installed capacity than natural gas and forty percent more than coal. Substantial numbers of jobs would be in manufacturing and construction trades.[109] Green collar jobs—blue collar jobs whose products and services directly improve the environment- are relatively high quality. According to a City of Berkeley analysis, these jobs are also more available to those who have lower level education, low income, or who were formerly incarcerated than traditional blue collar employment. Within this green collar job category are energy, water and green building employment opportunities including energy and conservation systems installations, energy retrofits, construction and demolition. The jobs include both entry level and more difficult work, allowing room for advancement and offering competitive, above minimum wage salaries, and health and retirement plans. [110] In the United States alone, 1.3 million "direct impact" jobs could be created by a ten-year investment of $150 billion in the renewable energy sectors (electricity and motor fuel). Direct impact jobs result from an increase in demand for the industry in question. They do not include tangential jobs such as retail stores or other support work. [111] Wind power alone created 35,000 jobs in the United States in 2008, most of which were in manufacturing.[112] Wind power gives more jobs, energy, and carbon reduction than nuclear.[113] A French study shows permanent employment in the nuclear industry will remain very limited in both the maintenance and operations sectors with person-years required by wind being two to five times higher than nuclear resulting in thousands more jobs.[114]

By contrast, a proposed "new" nuclear reactor would employ at most 700 permanent workers[115] and cost, by some estimates, as much as twelve billion dollars,[116] maybe more as cost predictions keep increasing. Therefore, an investment of less than two million dollars in an offshore wind farm creates one job, whereas it takes seventeen million dollars to create an equivalent job at a nuclear reactor.

While the coal and oil industries have had massive job losses—in the hundreds of thousands in the past decade, despite continuing subsidies—wind is now poised not only to compete in cost with coal and oil, but to provide more jobs per unit of cost than fossil energies. Although wind is a labor-intensive technology, it is competitive with other energy sources because it saves money in other ways such as lower requirements for materials and capital, no fuel and few disposal costs, and fewer costs to the environment. Wind jobs fit a variety of fields, including structural, electrical and mechanical engineering, meteorology, surveying, metal-working, supervising, computer operations, mechanical and technical. [117]

Many well-paying jobs in construction, maintenance and operation would be created from an overhaul of our electricity infrastructure such as transmission improvements to support a distributed grid. Energy efficiency creates jobs in installation, creation, operation and maintenance of new buildings systems and new manufacturing of efficient appliances. This represents a shift of investment from creation of energy to conserving energy. For every one million dollars invested in energy efficiency there are 21.5 jobs created as opposed to 11.5 jobs in new natural gas generation.[118]

DISTRIBUTED GENERATION

"…decentralized power democratizes energy: it delivers power to the people both literally and metaphorically." Jeremy Leggett, Solarcentury, UK

Distributed generation goes by several names: distributed energy, distributed grid and micropower. Distributed energy is defined as energy being generated by technologies that are placed at or near the point of use rather than placed at a central location where energy has to be transmitted to the user—the latter is the current prevalent system. Distributed grid technologies can be owned by the person making use of the energy or by utilities and a source can be as simple as an electric generator providing backup or a complex, wider-ranging and interconnected system of energy generators and management structures.[119]

One drawback of the current centralized grid system is that energy flows one way. A proper distributed grid welcomes a two-way flow of power—a comparable structure is personal computers that hook up to internet servers and sites, allowing a two-way exchange of information. The idea for a distributed grid is not new—it was Thomas Edison's first model for electricity generation with neighborhood steam plants providing heat and light for one square mile sectors.[120] This old idea is now seen as the wave of electricity's future. Kurt Yeager, president (1996-2004) of the Electric Power Research Institute (EPRI), the utilities' own privately funded think tank, called attempts to fix the current grid system "…trying to put Humpty Dumpty back together again."[121] Yeager claims the Bush II administration tried to extend the life of the existing grid to the detriment of grid innovations. Instead, he says we need smarter production, delivery and use of energy. [122]

Advantages

Distributed power generation is inherently modular, meaning power can be generated where and when it is needed, making this form of power generation mobile and much more flexible than a centralized system. These generators typically rely on natural gas or renewable energy making them less polluting and more suitable for on-site generation unlike a 1000 megawatt coal or nuclear plant.[123] Onsite generation lessens loss of power from transmission and distribution, allowing distributed power to be more efficient and less costly.[124,125] For businesses and consumers who need dependable, high-quality power to run sensitive digital equipment, the stability of onsite generation is particularly appealing. [126] Many Silicon Valley giants have underwritten construction of their own electricity generating systems since temporary failures can lead to huge economic loses. Hewlett-Packard estimated in 2001 that an outage of just fifteen minutes at one chip factory would cost the company thirty million dollars which would equal just one half of the plant's power budget for an entire year.[127]

Renewable energy: Where nuclear power goes when it needs on-site power

Renewable energy is reliable and modular enough that the DOE proposed using solar panels and windmills for running a ventilation system at the now canceled Yucca Mountain radioactive waste dump. This ventilation system would have been necessary to keep the radioactive waste from overheating and damaging or melting the surrounding rock and would be needed for centuries into the future. This would have made Yucca Mountain the world's first renewable powered atomic waste dump.[128]

In the State of South Australia has a very promising geothermal rock body. However, the Olympic Dam uranium mining operations were proposing to use the energy it might produce to power its expansion of the world's largest open pit uranium mine.[129] Open pit uranium mining blasts and drills away top layers of earth to expose veins of uranium ore that is then mined by blasting and excavation using loaders and dump trucks and a great deal of water.[130] Health effects from exposure to the dust and radiation can last many generations.[131]

Distributed energy systems are highly compatible with renewable energy such as wind, solar, biomass, fuel cells, and various battery storage systems as well as communication and control devices for efficient use and management of the system.[132] The intermittent nature of wind and solar energy could be a drawback with the old central grids, but with a distributed grid, the overall energy availability need not be subject to time of day or lack of sun since electricity would be supplied from multiple locations.[133] Distributed energy systems can meet base load, peak, backup and remote power needs in addition to heating and cooling. Distributed power provides grid stability and flexibility not available from centralized energy generation.[134]

A distributed grid system could also make use of the thousands of hybrid and all-electric car batteries available to meet energy storage and discharge needs while the cars are parked. The current installed power of conventional car and light truck engines is more than the US electrical power system, therefore, only a small portion of the cars need to be available at any one time to assure reliability of a future vehicle-to-grid or V2G system. At ten kW per vehicle, ten million vehicles would supply 100,000 megawatt capacity in standby power, the equivalent of one hundred large nuclear power reactors. By 2050, ten million hybrid or all electric vehicles would constitute only three percent of the vehicular fleet, making the V2G system feasible. Further, if parking-lot/rooftop solar systems are in place, the V2G could take advantage of this system's infrastructure. Google and Pacific Gas and Electric are collaborating in the first test of a V2G system at Google's Silicon Valley headquarters.[135]

Distributed power is much more robust against terrorist attack or accident since power loss to the full grid is less likely and could be more easily recovered.[136,137] The electricity generated by a 1,000 megawatt nuclear reactor, which is already a recognized terrorist target,[138] would be much harder to replace, than the electricity from a solar or wind farm because of construction time and cost of nuclear. And while loss of power from a renewable energy facility of any size would be a problem, a successful attack on a nuclear reactor could devastate hundreds of square miles for generations due to catastrophic release of harmful radioactivity.[139]

Overall cost

The one current drawback is the overall cost of distributed systems.[140] In many ways, this added expense is a false market cost, since it is controlled by utility decision, not market forces. "Grid interconnection has been identified by industry groups as the most significant barrier to the installation of distributed generation technologies."[141]

Industry has assured that the grid interconnection needed for a distributed grid would be difficult because they have perceived distributed generation as a threat to safety and reliability of their electrical systems. According to the utilities, this threat arises from large numbers of generators being owned and operated by non-utilities, causing lack of standardization, communication and sharing. As a result, utilities have instituted conservative restrictions, ensuring that distributed generation will cost more.[142]

State, national and international efforts are underway to overcome these interconnection issues. The Institute of Electrical and Electronics Engineers (IEEE) has developed a series of national standards for systems testing, application, performance, operation, safety and maintenance, monitoring and information exchange. The Department of Energy has produced some guides for buying distributed generators and connecting them to the grid, one for larger organizations and one for homeowners and small businesses (see below for links).[143]

One major concern is the need for new transmission infrastructure to ensure electricity reliability in the United States. While some of this retooling would have to occur no matter what energy source was used because older lines are in need of repair, many new lines need to be constructed, especially from areas where renewable energy is created to areas that need the power. To illustrate: for new wind resources in Texas, over 2,300 miles of new bulk transmission was approved for construction to transport the power these resources would generate in the western part of the state to the eastern part. While the US is making progress by adding more transmission lines addition of renewable generation is currently set to outpace transmission availability by nearly two times. More investment is required to upgrade and add to this system.[144]

International Distributed Generation

Distributed power is already surging in both industrialized countries and regions without electricity, such as Kenya and Zimbabwe, offering power to rural communities and their entrepreneurs without costly grid extensions. Many of these areas are now using solar or other renewable energy instead of the high-carbon biomass like charcoal they would have used otherwise. Use of these high-carbon fuels affects the health of disproportionately women and children, causing half a million premature deaths each year and increasing incidents of bronchitis, lung cancer, pneumonia and heart disease at rates which rival chronic smokers[145]. Additionally, if the smart grid is applied in the developing world, where there is no grid to speak of in many cases, it could bring entire regions into the twenty-first century, revolutionizing energy production, distribution and use much like the cell phone revolutionized communication for these same areas. [146]

"Smart Grid"

Through use of computer microprocessor technology, a distributed grid will be more efficient at energy production, storage and use than current centralized energy systems causing the costs of the distributed grid to decrease significantly.[147,148] By using computerized control systems, distributed power can be "on demand" generating electricity as needed especially during peak times,[149] lowering the price of this peak power.[150] In this way, distributed power can support a centralized grid system if necessary.[151]

> In the background is the most powerful energy technology of all, the microprocessor. …Perhaps the most important message about the energy technology revolution is that, remarkable as each of the new devices is on its own, … appliances that sense and adjust to grid conditions, climate control systems that allow remote diagnosis and

control, wind turbines, solar cells, etc … their value is fully unleashed only when they are linked together in coherent systems. Information technology represents the connective tissue.[152]

This application of computer technology to a distributed energy grid is called a "smart" energy grid.[153] Smart grids, using technology such as real-time sensing control[154], can manage power from a variety of distributed sources. Importantly, renewable sources such as solar and wind, as well as people's individual power sources, will be able to feed the grid efficiently and when needed.[155] These smart grids will actively encourage renewable power while helping to prevent the type of blackouts that have plagued the United States in the last decades[156]. The two-way nature of the smart grid system will allow smaller energy producers, such as farmers and ranchers, to sell extra energy they could produce from renewable sources such as wind, back to the grid.[157]

Through funding from the American Reinvestment and Recovery Act, the Department of Energy will make available 4.5 billion dollars (of the $165 billion needed) in grants and loans for smart grid security and grid modernization that is overdue.[158] To help recoup the remaining costs, the Obama administration is allowing early adopters (utilities) of smart grid technology to charge consumers more.[159] Most Americans are willing to pay more for the advantages of smart grid, but it still may not be enough to cover the entire cost initially, so costs may have to be recovered over the long-term.[160] For each 100 billion dollars invested in the smart grid, utility bills will rise from three to five dollars per month.[161] Additionally, correcting current grid problems could save both business and individual consumers nearly 120 billion dollars a year—extra costs paid for current grid transmission disruptions and congestion.[162]

"Smart grid" case studies

Britain

The United Kingdom plans to draw thirty percent of its energy from alternative sources by 2020. The government is establishing a smart grid to handle this energy production and has undertaken a 4.7 million pound (a little over 9 million U.S. dollars) project to accomplish this.

The project aims to develop the equipment and software needed to build a grid computing network that could autonomously process the instrument data from thousands of energy sources, and allow the power industry to optimize the ebb and flow of electricity on their national grids.[163]

Britain will choose up to four cities to create mini-smart grids modeled on the Boulder, Colorado prototype and set aside the money to construct these grids from utility customer payments and investment in the grid systems will be spread out over the next five years.[164]

Colorado, USA

Boulder, Colorado is up-grading its electricity grid, spending up to 100 million dollars over the next two years to allow customers some new and flexible energy options with the first "smart grid" in the United States. Energy consumers can see real-time data on their energy use and make decisions based on these data—waiting for low energy use times to do laundry, for instance, or making sure their energy use stays within their monthly budget. Customers could even use their hybrid cars to power their houses during outages or peak energy demand time-making effective use of the car's battery storage technology. More importantly, these upgrades could remove the roadblocks to adoption of solar power so that people with their own solar generating systems could sell their surplus back to the grid. The energy company, Xcel, will have increased ability to prevent and track power outages and Boulder's goal of reducing greenhouse gas emissions would be met. In fact, twenty-five percent of the emission-reduction goal could be met within the first phase of this project[165] completed in August 2008[166].

UPDATE: In September 2009, Xcel Energy announced it has completed construction and launched all remaining software to complete this project, making Boulder the world's first fully functional smart grid enabled city. Since launch, the system averted four potentially long-term outages by warning of transformers that were about to fail. This enabled transformer replacement without loss of power or significant disruption of service. [167]

A Bit About Base Load

"Base load" power is electrical power that runs reliably enough to meet customer electricity demand consistently for both time and amount. Current power sources such as coal, oil and nuclear, meet this demand collectively, not individually. This means that, to the extent that current electricity producers are reliable, it is because each individual producer can rely on the other producers to produce enough electricity to compensate should something go wrong, such as expected or unexpected outages. If electricity came from wind, solar and other renewable sources, base load would also be met collectively, where one producer compensates for another, echoing our current model. The argument that renewable sources are too intermittent to meet demand consistently without some sort of storage is fallacious.[168]

Examining downtime of nuclear and fossil fuel facilities shows that these sources *are* intermittent, with failure rates between ten and twelve percent.[169] In fact, modern solar and wind are more technically reliable with failure rates between one and two percent. While renewable sources are variable, this variability can be managed by proper choices in siting and operation. To cope with this large intermittency, utilities must install a fifteen to twenty percent reserve margin of producers spinning and ready for instant use. This cost should figure into comparisons of renewable and current power sources.[170]

Reliability is not dependent on base load production alone, however, but on power failures originating in the grid structures that are responsible for ninety-eight to ninety-nine percent of failures. Decentralizing the grid is stabilizing and favors onsite rather than remote producers, a scenario perfect for renewable producers. Having backup power for renewables such as wind, would raise windpower's cost by less than a half-cent per kWh and will require less storage backup than is already installed to accommodate intermittency of current power systems. This is a demonstrated, practical reality in Germany, Denmark, and Spain, each receiving large parts of their power from renewable energy without reliability problems:

> *The belief that solar and windpower can do little because of their variability is thus exactly backwards: these resources, properly used, can actually become major or even dominant ways to displace coal and provide stable, predictable, resilient, constant-price electricity.*[171]

Nuclear Power and Reliability

A broader assessment of reliability tends not to favor nuclear power. The US built 132 nuclear power facilities of the 253 ordered originally. The remaining facilities were cancelled after ordering. Of the 132 built, twenty-one percent were closed permanently and prematurely due to cost and reliability issues while an additional twenty-seven percent have failed at least once for a full year or more. Even while meeting ninety percent of their potential full-load full-time (capacity factor), nuclear power reactors must still shut down for approximately thirty-nine days during a seventeen-month operating cycle for maintenance and refueling.[172]

Shutdowns due to external threats also occur, causing outages for weeks and months, since reactors are unable to quickly restart after an emergency shutdown. Reactors in France, Sweden, Japan and the United States have had to shut down under threat from natural disasters such as earthquakes and drought which can often close many reactors simultaneously. In the 2003 Northeast blackout, nine operating US and Canadian reactors had to shut down because it was unsafe to run them on such an unstable grid. They were only able to restart after twelve days, and failed to provide electricity for the first three days of the blackout when they were most needed. During this time, their output was less then three percent of normal and their average capacity loss exceeded fifty percent.[173] When hurricane Katrina struck, all of the Gulf Coast reactors had to shut down as a safety precaution, worsening power outages over a much wider area.[174]

The report "Walking a Nuclear Tightrope" reports on fifty such shutdowns in the past several decades and the loss of their power - 1000 MW each- from the grid leaves a huge power hole.

STORAGE SYSTEMS

The current electricity system is built to provide on-demand energy: energy created for use immediately. If too much energy is produced, it remains unused and is wasted. Transmission and distribution systems are also built to accommodate the maximum amount of power needed, not the average used, resulting in frequent underuse of these resources.[175] Use of storage systems decouples energy production and end use, allowing energy where and when it is needed.[176] Energy storage systems can be integrated into distributed or centralized electricity grids to make renewable energy economically viable, serve as an electricity reserve in the case of national emergency, enable more efficient use of current energy production, and stabilize electricity markets, transmission and distribution.[177,178,179] By acting as both an energy sink and a power source, storage systems can function as a shock absorber for the grid making it less vulnerable to energy spikes and dips.[180]

Several expert sources agree that storage systems are key both to a distributed grid and renewable energy production.[181,182] While storage system production was discouraged by deregulation in the late 1990s, this trend is reversing, to the benefit of both energy producers and consumers.[183] Most distributed grid users self-provide over ninety percent of their energy needs, but provide fifty to seventy percent of their peak use. Therefore, onsite generation could provide or even replace base load power while peak power would often have to be purchased from a grid system. Energy storage would help cover this gap by ushering a seamless transition from on-grid to off-grid and back again and provide stability to an off-grid system.[184]

Thermal Energy Storage (TES)

TES has become a necessary component of concentrating solar power systems such as the Solar Two facility in California and the Andasol solar power plant in Spain. Heat is usually stored in a heat transfer fluid, like molten salt, which is later used to make steam at times when the sun is not shining.[185] In addition to molten salt, other fluids are now being developed and tested, such as aluminum nanofluids that can provide greater efficiencies because of increased heat storage and transfer capabilities.[186]

Flywheels

A flywheel can store excess energy by using it to accelerate a rotor to a high speed and storing it[187] for a short duration.[188] Flywheels can stand alone or be coupled with distributed grids and/or battery storage. This technology has the capability of providing rapid injections of energy or of handling deep or cyclic responses that might overwhelm a grid without storage capacity. Flywheels can recharge more quickly than batteries and are capable of tens of thousands of cycles rather than the 250-1000 recharges most current batteries can handle. Because they operate using mechanical rather than chemical storage, they can recharge many more times without suffering the chemical damage many batteries do. They have very low maintenance needs, are relatively small, and can power a wide range of equipment. High initial costs have hampered adoption of this technology but life-cycle costs are far lower than batteries, especially under harsh or demanding conditions.[189]

Batteries

Lead-acid batteries are the most ubiquitous and traditional battery technology. They are inexpensive, but short-lasting, with a life-span of about five years.[190] They are heavy and inefficient but can supply a large amount of power for short periods of time which is why they are used for starting cars. However, they are not versatile enough to continually charge and discharge which makes them inappropriate for renewable energy storage.[191]

Pioneered in the early 1960s by Ford Motor for its electric cars, the sodium-sulfur battery, although it is room-sized, is compact, long-lasting and efficient compared to other utility-sized batteries. This storage technology would make wind power a more reliable resource by compensating for its intermittency. Just as importantly, these batteries are distributable in neighborhoods, replacing diesel generators which need polluting fuel. Sodium-sulfur batteries have a fifteen-year life span. Japan has refined this battery technology for the electric grid and currently uses one to light about 155,000 homes. American Electric Power, a large US utility, is running a sodium-sulfur battery test case in Charleston, West Virginia where a thirty by fifteen foot battery is charged at night to provide power during peak times. This is the same pattern of storage and discharge which could be used to make wind power more reliable, useful, and efficient. Wind often blows more consistently at night when energy use is less, but could provide additional and needed power during peak day-time energy use. The battery costs about $2,000 per kW, about ten percent more than a new coal fired power plant, however, mass production is predicted to drive down this cost and the sodium-sulfur battery is expected to become widespread within a decade or so.[192]

Additional battery types include nickel-metal-hydride (NiMH) and lithium-ion batteries. NiMH batteries have limited storage capacity and are expensive. They are smaller and lightweight which makes them a promising candidate for hybrid cars such as Toyota's Prius.[193] Lithium-ion batteries, currently used in cell phones, laptops and other portable electronics, are also considered candidate technology for plug-in hybrid electric vehicles (PHEV).[194] Lithium-ion batteries have several advantages including high storage capacity, high charging efficiency and the ability to carry thousands of charges and handle a wide range of charges and discharges. Hybrid cars running on lithium-ion batteries average 73.6 miles per gallon of gasoline.[195] The costs must come down if this technology will be viable for auto use from $1,000 per kilowatt hour to $200 per kilowatt hour. [196] With recent advances in nanotechnology, these batteries could be used on the utility scale. [197] Once mass production starts, it is also feasible that the costs will drop significantly reaching the $200 goal within the next decade.[198] If two percent of cars in America were PHEVs it would represent a charging load of forty gigawatts. This capacity could be used to address peak electricity loads if plugged into a distributed grid system at night to charge and discharge during the day while parked.[199]

Air compression

Surplus energy, produced during off-peak time, is used to compress air and store it in a large underground cavern. The compressed air would be extracted during times of peak energy need to help cover demand. Compressed air has been used with conventional energy sources such as coal, but can certainly be used for renewable energy, too, such as wind. When used in context of carbon releasing energy sources like natural gas or coal, air compression actually increases the greenhouse gas output while reducing energy costs by approximately 4.7 cents per kilowatt hour overall. However, when used for wind energy storage, because wind produces no greenhouse gas, air compression leads to reduction in emissions overall.[200] A group of Iowa utilities are using compressed air storage to capture energy from wind in an underground cavern and discharge it when needed during peak use time to power about 200,000 homes[201].

ENERGY EFFICIENCY

It is possible to cut climate emissions in the United States by half, relatively painlessly and almost immediately using existing technology. Not only will energy efficiency save energy consumers money, but it will make a switch to massive amounts of solar, wind and other renewables much more cost-effective. Since the 1970s some energy experts have argued that nuclear power and coal technologies were too inefficient because they were not localized. Amory Lovins has argued that "soft energy" is the most beneficial path: energy produced at the local level creating local jobs and using less energy to curb environmental damage from energy use.[202]

A major key to "soft energy" or distributed grid, is less energy use. The average home owner can reduce the energy bill by thirty percent by making the simplest energy efficiency improvements: weatherizing, unplugging electronic devices, setting computers to "sleep" when not in use, replacing incandescent bulbs with compact fluorescent bulbs, etc. Add bigger efficiency steps like solar hot water heaters, and the savings reach seventy-five percent by using techniques that cost less than production of the electricity in the first place.[203] According to a DOE national laboratory report, Americans used less energy overall in 2008 decreasing use from 101.5 quadrillion BTUs to 99.2. [204] A BTU is a measure of energy in thermal units. Energy efficiency is pollution free and far cheaper than current energy rates, at about two to three cents per avoided kilowatt hour.[205] In 2009 the Obama administration pledged over eleven billion dollars to energy efficiency programs for low income individuals and local and state governments with additional billions for federal buildings.[206] Energy efficiency consists of more than just compact fluorescent bulbs and turning off the lights. There are more sophisticated technologies on the horizon such as smart electronics and super-efficient appliances that sense and adjust to grid conditions and commercial climate control systems that allow remote diagnosis and control.[207]

Regulatory (dis)Incentives

Part of the difficulty in instituting energy efficiency is the lack of incentives, even the presence of disincentives, for utilities to support efficient energy use. Utilities are operating within a regulatory framework which rewards them for selling more energy. This framework makes no sense for people or for the planet. According to the International Energy Agency, "one dollar spent on efficiency improvements avoids two dollars of investment in electricity supply."[208] It is more expensive for a company to provide the energy to meet demand than it is to save that same energy. Therefore, not only do consumers save using efficient technology, utilities do as well. [209]

Negawatts

If free market principles were really operating in the energy industry, utilities would consider the demand side of their business, not just supply. Utilities would favor energy conservation because they can satisfy their customers while saving their businesses money by using less energy, a concept Amory Lovins calls Negawatts. Lovins says we need to decouple utility profits from amount of energy sold. This advantages transition to renewable energy and a distributed grid and provides a model to the rest of the world for wise energy use.[210]

RENEWABLES AND EFFICIENCY COMPARED TO NUCLEAR POWER

Many energy experts do not think nuclear power is necessary or recommended for energy production. Peter Darbee, Chairman and CEO of Pacific Gas & Electric, one of the nation's largest utilities, says: "I have concerns about the lack of consensus in California around nuclear power and therefore…I'd rather push on energy efficiency and renewables…"[211] S. David Freeman, a former Tennessee Valley Authority chairman, is appalled that TVA is seriously considering building more nuclear reactors: "the federal agency still has more than twenty billion dollars in debt on its books due largely to that previous nuclear push and Freeman worries ratepayers will be facing billions of dollars more…"[212]

Potential & Capacity

Worldwide, in both generating capacity and electrical output, low- or no-carbon sources (excluding large hydropower) have surpassed nuclear sources and this increase continues. In 2010, the International Atomic Energy Agency projects that nuclear power will add only 1/177th of the potential that low- or no-carbon sources will add.[213] "Renewables have a very large potential on a global scale. Even under restrictive solar power assumptions, the International Energy Agency's *World Energy Outlook 2004* (pp. 229–232) foresees a potential of approximately 30,000 TWh/y [TerraWatt hours per year] in 2030—roughly 2030 world demand."[214]

"About fifteen percent of total generation (not far short of the contribution of nuclear electricity today) can come from wind and solar without serious cost or technical difficulty with available technology…".[215] Despite huge federal subsidies, nuclear power only generates about nineteen percent of U.S. electricity at great cost. It only provides six percent of world total *energy* use. [216]

Total Costs

Dollars

Between 1947 and 1999 $150 billion in subsidies were divided between nuclear power and wind and solar. Nuclear power received over ninety-five percent of these subsidies while renewables (solar and wind) received the remainder.[217] While renewables are now receiving more subsidies, this basic subsidy imbalance has not changed. In 2005, Congress and President Bush granted the nuclear power industry over thirteen billion dollars in subsidies and tax breaks. In late 2007, it added another $20.5 billion in federal loan guarantees and was asking to receive over $100 billion more, thereby gobbling up the lion's share of "low carbon" energy subsidies.[218, 219] The Obama Administration has awarded $8.3 billion for new reactors already as part of a promised total of $54.5 billion for new reactors in their 2011 fiscal year budget.[220]

Nuclear power currently costs about fourteen cents per kilowatt-hour and could increase to an average cost of seventeen cents for new reactors. In the first year of commercial operation a new reactor could cost as much as twenty-nine cents per kilowatt-hour[221] while wind costs four-six[222] cents and cogeneration (using waste heat from energy production) costs about one to two cents.[223] Even solar photovoltaic is projected by the US Department of Energy to cost the same or less than nuclear within five years' time, attaining a cost between five and ten cents per kilowatt hour.[224] Construction time[225] and cost[226] for most renewable energy production plants is minimal compared to that of nuclear power reactors. For solar PV, the output to repay the energy invested to make these facilities takes a few months to a few years, while wind payback takes under seven months.[227] While these cost differences should make renewable energies the obvious investment choice, they also point to the perilous nature of making the *wrong* choice—considering the immediacy and danger of climate change, society may very well have one chance at a solution. Nuclear power is clearly not the choice.

Land

Nuclear power is more land-use intensive than renewable energy consuming at least seven times the land required by wind for equal power generation. The nuclear power fuel cycle requires at least 14.5 square miles for each one GW reactor while wind is only .2 to 2 square miles. Wind uses less land, taking only the space for the wind turbine itself, while land around and between windmills can be used for raising crops or livestock or for other uses.[228] While there are legitimate concerns over bird deaths from windmills, bird deaths from this source are fewer than the fossil fuels it would eventually replace. Additionally, these wind facilities can be constructed and operated to diminish bird deaths, such as making wind turbines taller than bird flight routes. [229] Solar panel land use would be comparable with nuclear land use if all solar cells were placed directly on the ground, but currently, ninety percent are placed on structures that already take up land space such as rooftops and parking garages, therefore using NO additional land.[230] In fact, the National Renewable Energy Lab concludes that "Contrary to popular opinion, a world relying on PV [solar panels] would offer a landscape almost indistinguishable from the landscape we know today."[231]

Trade-offs

The nuclear industry is beginning to advocate for defunding renewable energy technologies, revealing their fear of a growing, popular and prospering sustainable energy industry. In Britain, two foreign energy giants, E.On and Electricite de France (EDF) are telling the government that they must choose between renewables and nuclear, calling for Britain to scale back its wind power targets. Further, the nuclear industry is claiming that Britain's twenty percent renewable energy target would be damaging to nuclear power expansion plans while it simultaneously asks for more government subsidies to construct more reactors. In truth, a subsidy for nuclear power will be a subsidy that continues as long as nuclear power is used since its costs keep rising, while subsidies to renewables can be temporary as evidenced by their falling costs.[232]

In addressing the climate crisis, we cannot afford to have all options remain on the table because not only is nuclear power more expensive, it is the slowest option to deploy and the most costly carbon dioxide abatement option per dollar spent.[233] "The cost of such 'options' doesn't complement but devours its rivals. It consumes money, time, and attention better devoted to the solutions that buy approximately two to twenty times more carbon reduction per dollar and approximately twenty to forty times more carbon reduction per year."[234] Switching from current energy sources, including nuclear, to renewable alternatives and efficiency is absolutely necessary to address the climate crisis. Keeping nuclear power on taxpayer-subsidized life support means diverting investment from the faster and cheaper choices of cogeneration, renewables and efficiency, to the slower and costlier nuclear choice.[235] This is, of course, in addition to the important safety, security, health and environmental advantages of efficiency and renewables over dirty fossil fuel and nuclear power.[236]

> For all these reasons, a portfolio of least-cost investments in efficient use and in decentralized generation will beat nuclear power in cost *and* speed *and* size by a large and rising margin. This isn't hypothetical; it's what today's market is proving decisively.[237]

THE DEMOCRACY OF "NEW" ENERGY

The advent of the distributed grid has been compared to the computer revolution. Once, all computers were hooked to a mainframe and had no processing power of their own-no autonomy. Now society has servers and computers with processing power of their own which can connect to each other or not, resulting in more independence, smaller computer size, more efficient use and lower cost. Likewise, distributed power can allow small businesses and individuals to run their own power systems, and make their own energy creation and use choices.[238]

"Smart" distributed grid technology will allow freedom from Enron-like market manipulation and better control of which energy sources are chosen and how and when they are used. Rather than continuing to pay for polluting sources like fossil and nuclear fuels, people can choose less-polluting energy efficiency and renewables. Through net-metering programs energy producers/consumers can put their excess energy back into the grid for use by someone else, and get paid for it.

Additional on-line Resources:

For more information on why nuclear power is not a solution to climate change, see www.beyondnuclear.org

For general information on sustainable energy sources, including a compilation of recent news stories and reports, see the Sustainable Energy Coalition website: http://www.sustainableenergycoalition.org/

For a more detailed wind power history, see Illustrated History of Wind Power Development. http://www.telosnet.com/wind/

For a wind Resource map of the United States see http://www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps.asp

For an interactive European map of solar potential see: http://re.jrc.ec.europa.eu/pvgis/

For a more detailed solar power history, see History of solar energy http://www.southface.org/solar/solar-roadmap/solar_how-to/history-of-solar.htm

For annual solar radiation in the US, see: http://upload.wikimedia.org/wikipedia/en/2/2c/Us_pv_annual_may2004.jpg

For information on solar utility PV go to: http://www.solarelectricpower.org/

The Solar Energy Industry Association is at: http://www.seia.org/

The American Solar Energy Society, a solar non-profit organization supporting increased use of solar technology, can be found at: http://www.ases.org/

Visit Solar Design Associates, a solar design firm founded in 1974: http://www.solardesign.com/

For more information on geothermal energy go to the Geothermal Energy Association: http://www.geo-energy.org/

To find tips on how to save energy see Efficiency First from Co-op America: http://www.coopamerica.org/pubs/caq/articles/summer2008/LevelOne.cfm

For more information on energy efficiency visit the American Council for an Energy Efficient Economy, ACE^3 website: http://www.aceee.org/

To view a distributed energy animation visit (you need flash player): http://www.nrel.gov/learning/flash/de_story.html

For guides on buying distributed generators and hooking them up to the grid please see: http://www.eere.energy.gov/de/installing.html

For advice on connecting your electricity production system to the electricity grid safely, see this Department of Energy page: http://www.eere.energy.gov/consumer/your_home/electricity/index.cfm/mytopic=10520

For more on *Carbon-Free and Nuclear-Free: A Roadmap for U.S. Energy Policy*, please go to www.ieer.org

For information on sustainable practices, visit Worldwatch: http://www.worldwatch.org/

Clean Edge researches and publishes reports on clean technologies. See: http://www.cleanedge.com/

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