Renewable Energy
Is Capable of Meeting Our Energy Needs

Despite having public support and advantages over other energy sources, renewable technologies have been repeatedly characterized as unable to meet our energy needs. People have been presented only a choice between conventional fossil fuels and nuclear power. This, however, is a false choice. Renewable energy can reliably generate as much energy as conventional fuels, and can do so without producing carbon emissions or radioactive waste.

Renewable energy – which includes solar, wind, advanced hydro, certain types of biomass and geothermal energy[1] – has the potential to replace conventional fossil fuels and nuclear power. While non-hydro renewables presently provide just 2.3% of electricity in the U.S., *it is technically and economically feasible for a diverse mix of existing renewable technologies to completely meet our energy needs.* In fact, as much as 20% of U.S. electricity could immediately come from non-hydro renewable energy sources without any negative effects to the stability or reliability of the electrical grid. Over the longer term, improvements to the grid can be made, and renewable technologies could supply increasingly higher percentages. Examining possible implementation and growth rates for different technologies, a 2004 report from the European Renewable Energy Council concluded that renewable energy could meet baseload power needs,[2] and in fact, could provide 50% of the world's primary energy by 2040.[3] Similar studies from Shell Oil have explored scenarios in which one third to one half of the world's energy can come from renewables by 2050.[4]

Importantly, renewable energy technologies produce virtually no greenhouse gas emissions and can effectively address climate change. If unchecked, the disruption of the earth's atmosphere poses the greatest threat to humankind in our lifetimes. Continuing to fill the atmosphere with greenhouse gases will melt the ice sheets, raise sea levels, bring extreme weather patterns, disrupt food production, and destroy whole ecosystems. Hundreds of millions of people may be left without food, shelter or clean water, causing political and social upheaval. According to a study by Japan's Ministry for the Environment, renewable energy combined with efficiency measures could reduce greenhouse gas emissions to a level consistent with goals of global climate stabilization – a 70% reduction by 2050.[5] With minimal initial capital costs and short deployment times, renewable technologies could address global climate change more quickly than nuclear power, and without the production of radioactive waste or other significant types of pollution.

How much renewable energy is there?

In the near to medium term, the combination of wind, solar, advanced hydro, and some biomass and geothermal energy could completely meet U.S. electricity needs.[6] *According to a recent National Renewable Energy Laboratory (NREL) analysis, the entire U.S. electricity demand could technically be met by renewable energy resources by 2020[7]. In the longer term, the potential of domestic renewable resources is more than 85 times current U.S. energy use.[8]*

Wind Energy

Researchers at Stanford University recently evaluated the potential of wind power globally. After analyzing more than 8,000 wind-speed measurements, the researchers concluded that wind at specific locations could generate more than enough energy to meet world demands.[9] Of the sites measured, over 13% had mean annual wind speeds strong enough for economic power generation (speeds greater than 6.9 meters per second at 80 meters). These candidate sites are found in every region of the world, both inland and offshore. The researchers concluded that global wind could have generated about 72 terawatts (TW) in 2000. *This is equivalent to 208 trillion kilowatt hours (kWh)—about one and a half times current annual world energy use.*

Wind Turbine, Maryland Energy Agency

Evaluating the wind potential of the U.S., the Pacific Northwest Laboratory – a Department of Energy (DOE) national laboratory based in Washington state – has estimated that land-based wind across the contiguous United States is capable of producing almost one and a half times current U.S. annual electricity use.[10] According to a recent analysis by DOE, there is also an additional 900 GW of power from offshore wind within 50 miles of the U.S. coastline. This is equivalent to at least 2.6 trillion kWh/yr – almost 70% of current U.S. electricity use.[11]

To produce this much energy, no significant developments in wind technology would be needed. Modern turbines are rugged horizontal-axis three-bladed designs that are turned into the wind by computer-controlled motors. The power capacity of these turbines has increased dramatically in the last twenty years, from 24 kW in 1981 to 1.5MW in 2006.[12] The turbines have been developed to function at high speeds, high efficiency, and with low stress, which all contribute to good reliability. Research on new lightweight composite materials, advanced control systems, and methods for addressing the additional variables involved in offshore sites will only improve the effectiveness of these designs.[13] Counter-rotating horizontal axis turbine designs, which capture a wider range of wind speeds, and vertical axis turbines, which have the potential to generate 4-10 megawatts (MW) per turbine, are also expected to become common in the next five to ten years. The most significant issue facing wind turbines will be the need for appropriate siting and community approval.

Solar Energy

The amount of solar energy by any measure is also enormous. Every hour more energy strikes the surface of the Earth than is consumed globally in a year.[14] According to the DOE's Solar Energy Technologies Program, there is on average between 2.8 and 6.2 kilowatt-hours (kWh) of sunlight available per square meter (m^2) each day.[15] The exact amount of sunlight depends on the region and the season. In the United States, the annual average is 4.8 kWh/m^2 per day.[16]

One way of using this solar energy is to transform it directly into electricity.[17] Two types of photovoltaic technology that have been developed for this purpose are photovoltaic panels (PV) and photovoltaic concentrators. For PV panels, the efficiency – or ability of the photovoltaic cells to capture solar energy and convert it into electricity – ranges from 12 to 25%. The panels themselves have efficiencies slightly lower than the actual cells because of structure and wiring. Traditionally, the highest efficiencies have come from expensive, thick silicon panels. Recent work by several scientists, however, has led to the development of cheap, flexible thin film panels capable of at least 15% efficiency.[18] These panels have begun to be produced on a significant scale.[19]

As a result, with existing technology, PV could make a significant contribution to U.S. energy production. According to a recent Energy Foundation study, assuming 15% panel efficiency and a conservative estimate of at least 7854 million m^2 available residential and commercial rooftop space, *the U.S. could accommodate about 1 million MW of PV by 2025, which would generate approximately 1.9 trillion kWh per year – almost half of current U.S. electricity use.*[20] This does not include other distributed forms of PV electric generation, such as ground mounted PV, PV shingles, covered parking lots, windows, awnings, and sides of buildings. It also does not take into account additional improvements in panel efficiency. *According to a recent NREL analysis, the total long-term technical potential of PV in the U.S. is around 219 TW –which could provide over three times current world energy use*.

Photovoltaic concentrators – systems that reflect or focus light from a wide area onto a small photovoltaic panel – could also make a significant contribution to meeting U.S. energy needs. Solar concentrators move to track the sun, produce a more constant level of "peak energy" throughout the day, and operate at higher efficiencies than PV panels. Concentrators can also reduce costs by using less PV material per unit of energy generated (although they do require an inexpensive optical element and a support structure and tracker).[21] Concentrators could be well-suited for stabilizing the generation of wind farms and for installation along highways and transmission corridors.


40 KW Solar photovoltaic system on a commercial building in Pittsburgh, PA, Installation by Mountain Solar, Grass Valley, CA.

Advanced Hydro

Hydropower currently provides 10% of the electricity generation in U.S. and could be a significant source of renewable energy.[22] Large conventional dams, however, have caused serious environmental damage.[23] They will have to be retrofitted or taken down, while smaller systems with advanced turbine designs are set up (up to 25 MW). According to DOE, advanced systems can be applied at more than 80% of existing hydropower projects, and can also be built at small existing dams that have not been previously used to produce power.[24] Advanced hydro designs reduce the impact of turbines on fish, facilitate upstream fish migration, and mitigate sediment and water quality problems. River-run systems – which harness the power of moving water without dams or reservoirs - are also a small, low-impact alternative that could be developed where dams are removed or at new sites. Estimates of potential sustainable hydro resources from existing dams in the U.S. range from 77 to 82 gigawatts (GW). This includes 62 GW from retrofitted existing hydropower projects and 15-20 GW from fitting advanced systems onto other existing small dams.[25] *These hydropower sources could provide between 337 and 359 billion kWh per year, or 8.5 - 9 % of current U.S. electricity use.*

Biomass
Biomass is the burning of organic matter – typically agricultural crops and grasses – to produce heat or electricity. Biomass, unlike solar and wind, does produce significant carbon dioxide emissions. These emissions, however, can be balanced out by planting new crops, which take up carbon dioxide as they grow. The carbon emission to carbon uptake ratio, the location of the two processes, and the effects on local soil and water quality, are important issues that must be considered in determining what forms of biomass are sustainable. For biomass to be a significant source of non-carbon emitting renewable energy, crops must be grown with little cultivation and fertilizer, transported only over short distances, and grown and harvested in a way that does not degrade the land. Grasses - such as switch grass and big blue stem - are low impact possibilities for biomass. *If produced and used correctly, biomass could contribute significantly to meeting U.S. energy needs. According to a recent NREL study, biomass could produce 17-28% of U.S. electricity by 2020.*[26]

WHAT ABOUT VARIABILITY AND INTERMITTENCY?

Despite the abilities of renewable technologies and the vastness of the resource, renewable energy is still often depicted as far too variable and inconsistent to meet our energy needs. This, however, is an incorrect picture. Advanced hydro and sustainable biomass are already capable of producing baseload power, and offshore wind has similar potential. For PV and land-based wind - although it is true that "the sun doesn't always shine and the wind doesn't always blow" - it is possible to harness these sources of energy in a way that substantially reduces the problems of intermittency and variability.

A recent analysis by the International Energy Agency (IEA) - an intergovernmental body of twenty-six countries committed to advancing security of energy supply, economic growth, and environmental sustainability- concluded that *intermittency is not a technical barrier to renewable energy*.[27] To deal with variability and intermittency,[28] IEA recommends distributed generation, links across geographic areas, a diverse mix of technologies harnessing different resources, and the continued development of storage technologies.

Significant advances along these lines have already been made. The first three measures alone can allow non-hydro renewable technologies to well exceed 20% of generating capacity by 2020 without impacting grid reliability or stability. In the longer term, storage remains the most significant issue. Presently, the best options for storage are hydroelectric pumped water and compressed air. Hydroelectric pumped storage moves water from lower to higher reservoirs when extra electricity is being produced, and releases it when that energy is needed. These systems are well-established, low in cost, up to 80% efficient, and have an enormous capacity for storage. Also, because energy is stored in times of excess generation, pumped storage systems do not compete with hydro generation.[29] Using advanced hydro technology, these systems can also have minimal environmental impact. Air compression systems work on a similar principle, compressing air and storing it in airtight underground caverns during times of less demand, and releasing it to run turbines when needed.[30] These technologies have undergone significant developments recently, being designed to store energy from wind farms. In the longer term, the development of extensive regional grids will increasingly stabilize geographically distributed generation, and the production of hydrogen will likely become an important energy storage mechanism.

ARE RENEWABLE TECHNOLOGIES MORE EXPENSIVE?

Despite all their advantages, renewable technologies are still often rejected as too costly. But this fails to take two very important factors into account. In the last fifty years, federal support for nuclear power and fossil fuels has far surpassed support for renewable technologies. This imbalance has resulted in unequal technology development and commercialization. In addition, while the costs of renewable technologies are decreasing substantially, the costs of nuclear power and conventional fuels continue to be underestimated.

Federal Subsidies
In the last fifty years, federal support for nuclear power and fossil fuels has been significant, while support for renewable technologies has been limited. According to a report by the Renewable Energy Policy Project (REPP), from 1947 through 1999, direct federal government subsidies totaled $115.07 billion for nuclear power and $5.49 billion for wind and solar.[31] If the most notable non direct budget subsidies–such as limitations on nuclear liability and renewable energy investment and tax credits–are added into these figures, the federal subsidies for the same period are $145.4 billion for nuclear power and $5.7 billion for wind and solar.[32] These numbers are consistent with the 1992 study by Charles Komanoff - an internationally known energy-economist and transport-economist - which puts subsidies to nuclear power at about $124 billion through 1990.[33]

The disparity in funding continues, and is well illustrated by recent appropriations and the Energy Policy Act of 2005. For instance, the annual budget for the National Renewable Energy Laboratory (NREL) – the country's primary research and development facility for renewable energy technologies – is just $174 million in fiscal year 2006.[34] This is $28 million less than fiscal year 2005, and is less than one grant to NuStart Energy – a consortium of energy companies looking to build new nuclear power plants in the U.S. – for the paperwork for one license application under DOE's Nuclear Power 2010 program.

Cost
Despite the vast discrepancy in federal support, wind power is competitive with nuclear power and fossil fuels at around $0.05-0.06 per kWh, and the price of solar PV has fallen to roughly $0.25-0.30 per kWh.[35] With recent advancements in thin film PV technology,[36] improved wind turbine performance, and greater economies of scale, it is expected that the costs of these technologies and others will continue to fall. For solar, this fall is expected to be particularly dramatic, as more panels are produced

and significantly less photovoltaic material is required per panel. The price of PV, for instance, has been shown to drop by 20% for each doubling of production volume.[37]

It is also important to include the costs of conventional technologies not presently accounted for in their cents per kWh. These externalized costs from fossil fuels include carbon emissions, air pollution, and land and water degradation from coal mining. For nuclear, they include the pollution from uranium mining, the safety and security risks posed by commercial reactors, risks from nuclear weapons proliferation, and the dangerous legacy of radioactive waste. Coal and uranium are also finite, while most renewable energy sources are unlimited in supply and free. If these effects are quantified and included in the price of conventional fuels, renewables are already far cheaper for society.[38]

POTENTIAL FOR EFFICIENCY

In addition to renewable technologies, using energy more efficiently is also an important part of moving to a clean energy future. Efficiency is the cheapest and easiest way to reduce electricity use and facilitate the transition to renewable technologies. In 1993, the U.S. federal government's Office of Technology Assessment (OTA) estimated that the U.S. could reduce its electricity use 20-45% by adopting currently available efficiency technologies. OTA similarly concluded in 1994 that the federal government – the nation's largest single energy consumer - could reduce the energy use at its facilities by at least 25% using commercially available, cost-effective efficiency measures.[39] These changes range from improvements in heating, ventilation, and air conditioning systems, to more efficient refrigerators and other appliances, advanced lighting systems, and increased building insulation. Since the early 1990's when these analyses were performed, other efficiency measures - such as LED lights - have become commercially available, and thus the energy reductions possible through efficiency today are likely to be even greater. For example, earth source heat pumps – which use the relatively constant temperature of the earth to provide heating and cooling – are also an effective efficiency measure. It is estimated that widespread use of these pumps could reduce energy used for heating and cooling by 30-60%.[40] [41]

WHERE DO WE GO FROM HERE?

Presently, there are many artificial regulatory barriers limiting the immediate growth of renewable energy technologies. If we are truly to move towards these technologies, adjustments to the way renewable energy is produced and sold, and the establishment of long-term purchase agreements between renewable energy producers, utilities, and large end-users are necessary. Change like this can be affected from the local and state level. In addition, cities and states can develop renewable portfolio standards (RPS) which mandate a certain percentage of energy generation come from renewable technologies, and states can also put in place financial incentives that encourage the development of renewable technologies.

For further detail and explanation of the technical terms used in this fact sheet, refer to glossary of terms at http://www.eia.doe.gov/cneaf/electricity/epav1/glossary.html

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[1] This analysis primarily focuses on wind, solar, and advanced hydro technologies. Geothermal heat pumps are also discussed under efficiency. These technologies are the fundamental and nearest term options for renewable energy. While there is potential for some sustainable biomass and other forms of geothermal energy, we have not focused on them here, because they are more problematic and not necessary to make the case for renewable energy. In the future, wave and tidal energy technologies are very likely to also be developed. At present, however, these technologies are still in the research and development phase, and only beginning commercialization. Impacts on aquatic ecosystems are also not well understood.

[2] Baseload power means the basic average electricity usage of any time of day. EAI defines baseload power as "the minimum amount of electric power delivered or required over a given period of time at a steady rate."

[3] "Renewable Energy Scenario to 2040," European Council on Renewable Energy, May 2004.

[4] *Energy Needs, Choices, and Possibilities: Scenarios to 2050*, Global Business Environment, Shell International, 2001, p 6.

[5] "Reactor increase not needed to cut CO2 drastically," *Japan Times*, November 15, 2005. The Low Carbon Society Scenarios toward 2050 Program authored the study.

[6] According to the Energy Information Agency, total U.S. electricity use in 2004 was 3.953 trillion KWh. Total US energy use in 2003 was 28.7 trillion kWh (98.31 Quad BTU), while world energy use was 123.35 trillion KWh (420.98 Quad BTU), http://www.eia.doe.gov/emeu/aer/elect.html and http://www.eia.doe.gov/emeu/aer/pdf.gif.

[7] These numbers include the increase in electricity demand predicted by EIA with no reliance on energy efficiency measures. They do not, however, deal with questions of renewable technology intermittency reduction through integration or the economics of the renewable technologies.

[8] Brown, Elizabeth, "Near-Term Practical and Ultimate Technical Potential for Renewable Resources," Draft, NREL, January 2006, p.4.

[9] Archer, Christina L. and Mark Z. Jacobson, "Evaluation of global wind power," *Journal of Geophysical Research*, Vol. 110, June 30, 2005, http://www.stanford.edu/group/efmh/winds/2004jd005462.pdf.

[10] Elliot, D.L. and M.N. Schwartz, *Wind Energy Potential in the United States*, Pacific Northwest Laboratory, September 1993, http://www.nrel.gov/wind/wind_potential.html.

[11] *A Framework for Offshore Wind Energy Development in the United States*, DOE, Massachusetts Technology Collaborative, and GE, September 2005, http://www.masstech.org/renewableenergy/press/pr_9_30_05_wind.htm

[12] Yen-Nakafuji, Dora, "California Wind Resources," Draft Staff Paper, California Energy Commission, April 2005, p.7.

[13] European Union Energy Research Program, http://europa.eu.int/comm/research/energy/nn/nn_rt/nn_rt_wind/article_1103_en.htm

P[14] This calculation is based on estimated 510,067,420 kmP^{2P}for the Earth's surface area and an average figure of 6 kWh of sunlight per mP^{2P} per day.

[15] DOE Energy Efficiency and Renewable Energy, Solar Energy Technologies Program, "Solar FAQs – Photovoltaics – The Basics, Other Resources," HTUhttp://www.eere.energy.gov/solar/cfm/faqs/third_level.cfm/name=Photovoltaics/cat=The%20Basics#Q8UTH.

[16] Green Power Market Development Group, World Resources Institute, "Solar Photovoltaic Resources," http://www.thegreenpowergroup.org/solarphotovoltaic.php.

[17] Solar energy can also be used thermally for heating and for light in buildings.

[18] The thin-film technology developed by Dr. Vivian Alberts uses a compound semiconductor of copper, indium, gallium, selenium, and sulphide.

[19] "SA solar research eclipses rest of the world," IOL – Independent News and Media, February 11, 2006, http://www.int.iol.co.za/index.php?set_id=1&click_id=143&art_id=vn20060211110132138C184427.

[20] Chaudhari, Maya, Lisa Frantzis, Tom E Hoff, "PV Grid Connected Market Potential Under a Cost Breakthrough Scenario," September 2004, The Energy Foundation and Navigant Consulting, p. 33.

[21] *Concentrating Photovoltaic Technology*, NREL, http://www.nrel.gov/csp/concentrating_pv.html

[22] Energy Information Administration, "Existing Capacity by Energy Source," HTUhttp://www.eia.doe.gov/cneaf/electricity/epa/epat2p2.htmlUTH.

[23] Conventional dams have had serious impacts on rivers. Turbines have killed large numbers of fish swimming downstream and blocked others from migrating upstream to feed and reproduce. Water quality is also deteriorated, as the concentration of metals and sediment organic matter in the water increases after construction, and the dams themselves push oxygen into water below the turbines. Rivers above dams also tend to become slow and stratified, resulting in the build up of sediment that makes layers of the river unlivable for aquatic life. Dam construction has also flooded large swaths of land, often unbalancing local ecosystems, covering important farmland, and endangering various species.

[24] "Advanced Hydropower Technology," U. S. Department of Energy – Energy Efficiency and Renewable Energy Office – Wind and Hydropower Technologies Program, www1.eere.energy.gov/windandhydro/printable_versions/hydro_advtech.html

[25] National Renewable Energy Laboratory (NREL), Power Technology Energy Databook, April 2005.

[26] Brown, Elizabeth, p.4.

[27] Gul Timur and Till Stenzel, "Variability of Wind Power and Other Renewables: Management Options and Strategies," International Energy Agency (IEA), June 2005.

[28] Variability is the day to day, week to week fluctuations in the intensity of a renewable resource (the weather conditions). Intermittency is the natural cycle of the resources availability (i.e. sunlight only being present part of the day).

[29] *Technologies: Pumped Hydro Storage*, Electric Storage Association, http://www.electricitystorage.org/tech/technologies_technologies_pumpedhydro.htm

[30] "Compressed Air Energy Storage," U.S. Department of Energy – Energy Efficiency and Renewable Energy Office - Distributed Energy Program, http://www.eere.energy.gov/de/compressed_air.html

[31] Goldberg, Marshall, "Federal Energy Subsidies: Not All Technologies Are Created Equally," Research Report No. 11, Renewable Energy Policy Project, p. 7. Figures are in 1999 dollars, and subsidies are from their inception in 1947 through 1999.

[32] Goldberg, Marshall, "Federal Energy Subsidies: Not All Technologies Are Created Equally", Research Report No. 11, Renewable Energy Policy Project, p. 3, 7.

[33] Komanoff, Charles and Cora Roelofs, "Fiscal Fission: The Economic Failure of Nuclear Power," December 1992. Komanoff's estimate is adjusted here for the sake of comparison to 1999 dollars.

[34] FY2006 DOE Budget Request to Congress, http://www.mbe.doe.gov/budget/06budget/Content/Labandstate/labtable.pdf.

[35] *Managing Greenhouse Gas Emissions in California*, California Climate Change Center at UC Berkeley, January 2006, Chapter 4, p 11, http://calclimate.berkeley.edu/managing_GHGs_in_CA.html.

[36] The advancements in thin film PV use a fraction of the materials of mono or poly-silicon panels. By using an alloy of metals as opposed to silicon, the panels are cheaper both in material cost and manufacturing. Thin film PV has the additional advantage of being flexible and available for use in a wide range of spaces and applications.

[37] Farrell, Alexander, Daniel Kammen and Frank Ling, *Managing Greenhouse Gas Emissions in California*, The California Climate Change Center at UC Berkeley, January 2006, Chapter 4,. P. 10.

[38] Kammen, Daniel and Sergio Pacca, "Assessing the Costs of Electricity," Annual Review Environmental Resource, 2004.

[39] U.S. Congress, OfIce of Technology Assessment, ***Energy Eflciency in Federal Facilities: Update on Funding and Potential*** Savings, OTA-BP-ETI-125, March 1994.

[40] Department of Energy, EERE, *Consumer's Guide to Energy Efficiency and Renewable Energy - Selecting and Installing a Geothermal Heat Pump System*, http://www.eere.energy.gov/consumer/your_home/space_heating_cooling/index.cfm/mytopic=12670.

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