Renewable Energy—A Pathway to Green Jobs?

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Summary

In the United States, growing awareness of greenhouse gas (GHG) emissions and the possible implications for global climate change have combined with recent high energy prices and economic uncertainty to rekindle interest in renewable energy. Renewable energy technologies generate electricity from resources such as the sun, wind, or biomass, with essentially no net GHG emissions. President Obama has declared a goal for the United States to become the world's leading exporter of renewable energy technologies, setting out policy objectives for the development of related "green jobs".

Green jobs have often been defined to include (at a minimum) jobs that result directly from renewables for generating electricity and powering vehicles as well as jobs that result directly from achieving greater energy efficiency. Studies of green job creation in the renewable energy industry vary greatly as a result of differences in definitions, assumptions, and methodologies, with the resulting analyses producing wide-ranging estimates of the number of green jobs. Complicating the estimation of the number of green jobs is the absence of an authoritative data source. The North American Industry Classification System disaggregates firms into the categories of hydro, fossil fuel, nuclear and "other" sources. Renewables are part of the "other" category. The Bureau of Labor Statistics has requested funding for FY2010 to develop data on the number of green jobs and their characteristics (e.g., wages, training requirements) by industry and occupation.

Most of the future growth in green jobs is generally envisioned as coming from the growth in deployment of renewable energy technologies. Renewable energy deployment programs from state governments have had a great influence on the existing deployment levels of renewable energy technologies and resultant jobs. Historically, the federal investment in renewable energy technologies in the United States has not been about creating jobs, but was focused on developing the technologies to a point where they are ready for commercialization. The timeframe under consideration is thus important in any discussion of the potential for renewable energy technologies to create jobs, for the technologies are at different stages in their development cycles. It is also important to recognize that as a specific renewable energy technology becomes more efficient, the number of jobs per Megawatt of output is likely to decrease.

A key to maximizing green jobs growth in the United States from renewable energy is the domestic design and manufacture of equipment and components. Given the growing international competition for renewable energy markets and green jobs, policy mechanisms and incentives may be necessary to encourage manufacturers to locate production in the United States. Companies must be capable of competing in the domestic market for renewable energy first and foremost, as the potential growth of U.S. renewable markets already has attracted significant international participation. A renewable energy industry capable of serving the export market may create many more jobs than an industry which only serves domestic needs.

Few doubt the potential of renewable energy to help address climate change concerns; the question is whether the desired benefits merit the investment. But developing the next generation of renewable energy technologies and building an internationally competitive industry may require a significant and sustained national investment. Without it, the majority of the solar panels, wind turbines, and components providing the clean energy of tomorrow may continue to be designed and built by workers overseas.

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In the United States, growing awareness of greenhouse gas (GHG) emissions and the possible implications for global climate change have combined with recent high energy prices and economic uncertainty to rekindle interest in renewable energy. Fossil fuels have long met the needs of economic growth, which has been a primary driver of energy demand worldwide. But with half of electric power in the United States currently generated from coal, electric power generation is responsible for 40% of domestic carbon dioxide emissions (the primary anthropogenic GHG), and over one-third of all U.S.GHG emissions.[1] The prospect of federal climate change mitigation policies is seen as spurring the growth of renewable energy in the near future. Renewable energy technologies generate electricity from resources such as the sun, wind, or biomass, with essentially no net GHG emissions.

Approximately 567,000 people are employed in the utilities sector in the United States.[2] With renewable energy technologies accounting for about 10 percent of total U.S. energy production,[3] jobs in renewable energy currently represent a small part of this overall workforce. President Obama has declared a goal for the United States to become the world's leading exporter of renewable energy technologies, setting out policy objectives for the development of related "green jobs"[4] and the investment of $150 billion over 10 years in energy research and development (R&D) for the next generation of energy technologies.[5] The American Recovery and Reinvestment Act of 2009 (ARRA, P.L. 111-5) included more than $60 billion for clean energy investments, including $6.3 billion for state and local efforts in renewable energy and energy efficiency, and $500 million for jobs training to help prepare workers for careers in energy efficiency and renewable energy.

Other drivers are also pushing the growth of renewable energy and energy efficiency. Renewable energy technologies can provide clean electricity to help meet regional air quality standards. Goals of energy independence and energy security can also be advanced if trends in fuel efficiency continue and automotive vehicles become significantly powered by electricity from renewable sources. Additionally, as part of corporate social responsibility, many corporations are embracing sustainability[6] as a core principle and consider "green," renewable energy goals as part

[1] Nancy Spring, *CO_2: Climate Change Legislation* , Electric Light & Power, March 2008, http://uaelp.pennnet.com/display_article/324458/34/ARTCL/none/none/1/C02:-Climate-Change-Legislation-/.

[2] The Utilities sector comprises establishments engaged in the provision of the following utility services: electric power, natural gas, steam supply, water supply, and sewage removal. U.S. Department of Labor, Bureau of Labor Statistics, *Industries at a Glance, NAICS 22*, July 2009, http://www.bls.gov/iag/tgs/iag22.htm.

[3] Energy Information Administration, *Primary Energy Production by Source*, Monthly Energy Review, August 2009, p. 5, http://www.eia.doe.gov/emeu/mer/pdf/pages/sec1_5.pdf.

[4] Most discussions today associate green jobs with renewable energy (i.e., the manufacture of wind turbines and solar panels, or building wind farms and solar parks) and energy efficiency (i.e., retrofitting existing homes and buildings with new energy-efficient windows, or constructing energy-efficient and environmentally-friendly office space).

[5] *Obama Administration's Plan for Energy: An Overview*, The White House, http://www.whitehouse.gov/issues/energy_and_environment/.

[6] The United Nations World Commission on Environment and Development's 1987 report, *Our Common Future,* defines sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs."

of the same concept. Industrial processes and supply-chain operations are being examined and redesigned to key on low carbon emission, environmentally-friendly solutions as part of the corporation's perceived overall responsibility to its customers and the communities impacted by its operations. If such changes are adopted across the economy and incorporated into business norms, green, sustainable practices will then become standard for business operations.

This report will examine the current debate on green jobs, looking at the different renewable energy technologies to provide a context for the discussion of the potential for green jobs and issues associated with maximizing growth in the renewable electricity sector.

Green Jobs Studies

Current policy discussions of shifting the nation toward greater use of renewable sources of energy production almost inevitably have included the subject of green jobs. Although there is no consensus on the term's meaning, it often has been defined to include at a minimum jobs that result directly from increasing reliance on renewables for generating electricity and powering vehicles as well as jobs that result directly from achieving greater energy efficiency. Less often, green jobs have been defined to also include employment that results directly from reducing and mitigating pollution and from conserving natural resources (e.g., water).[7] To this direct employment (i.e., direct jobs), indirect and induced employment are sometimes added as well.[8]

A variety of researchers, usually with the financial support of advocacy groups, have operationalized the diverse definitions of green jobs in order to estimate the number of green jobs at present or at some time in the future. The estimates are based on varying assumptions about, for example, the percentage of U.S. electricity that will be generated by different combinations of renewable resources in the coming decades or the level of public and private sector investments in various renewable energy sources. Less often, the job estimates are based on firm-specific information about the number of persons who are currently employed producing green goods (e.g., solar panels) or providing green services (e.g., energy audits). As a consequence of differences in definitions, assumptions, and methodologies, analysts have produced widely divergent estimates of current and prospective green jobs.

Complicating the estimation of the number of green jobs is the absence of an authoritative data source. Federal statistical agencies, such as the Bureau of Economic Analysis and the Bureau of Labor Statistics (BLS), categorize the data they collect according to the North American Industry Classification System (NAICS). In the case of the utility industry, for example, NAICS disaggregates firms into the categories of hydro, fossil fuel, nuclear and "other" sources. NAICS does not disaggregate the "other" category into those that use renewable sources of electricity production such as wind, solar and biomass. Because renewables are part of the "other" category, no government series provides data on their output and employment. Analysts consequently have developed ways to address the data deficiency, although their methods usually are not clearly

[7] Sustainable Economies Consulting, *Green Jobs in North Carolina - 2008 Assessment*, June 2008, http://sustainable-economies.com/nc_green_jobs_2008.pdf.

[8] An example of jobs resulting directly from the use of a renewable energy source, namely, wind, are the assemblers, installers, and maintainers of wind turbines. An example of jobs resulting indirectly from green economic activities are miners who excavate ore, mill workers who turn it into steel and metal workers who shape the steel into components of a wind turbine. An example of induced jobs are cashiers at grocery stores and ticket takers at movie theatres where workers in direct and indirect jobs spend their earnings.

articulated. For its part, the government agency responsible for labor force statistics, BLS, has requested funding for FY2010 to develop data on the number of green jobs and their characteristics (e.g., wages, training requirements) by industry and occupation.[9] Industry statistics are expected to be available in FY2011.

In addition, much of the empirical research has estimated only the numbers of green jobs. Estimation or discussion of the net impact on total U.S. employment generally is lacking. Net estimates take into account jobs throughout the economy eliminated or forgone in addition to those created to advance toward a low-carbon environmentally friendly economy. Similarly, the literature does not take into account factors, such as supply constraints (e.g., a tight labor market) and improvements in labor productivity (i.e., output per hour worked), that could affect attainment of estimated levels of green employment.

A review of several analyses of the number of green jobs associated specifically with the use of renewable energy sources is presented below. The distinctions between definitions, assumptions and methodologies of green job studies are addressed when possible.

(1) ***Management Information Services, Inc.*** (MISI) prepared the report ***Defining, Estimating, and Forecasting the Renewable Energy and Energy Efficiency Industries in the U.S. and in Colorado*** for the American Solar Energy Society.

The economic research firm developed the following definition of the renewable energy (RE) "industry":

> an employee working in one of the major RE technologies included in this report – wind, photovoltaics, solar thermal, hydroelectric power, geothermal, biomass (ethanol, biodiesel, and biomass power), and fuel cells and hydrogen. In addition, in this study, jobs in RE include persons involved in RE activities in the federal, state, and local governments, universities, trade and professional associations, NGOs, consultants, investment company analysts, etc.[10]

MISI estimated that there were 217,600 direct jobs in the domestic RE industry in 2007. The great majority (154,100 or 70%) were in the biomass segment, chiefly ethanol and biomass power. MISI further estimated the number of indirect and induced jobs supported by the RE industry to be more than twice the number of direct jobs. Although MISI included induced jobs, it acknowledged that some jobs are less green than others (e.g., "ancillary jobs created across the street from a factory producing solar collectors shortly after it opens, such as a doughnut shop, fast food restaurant, dry cleaner, etc. whose customers are primarily the workers at the renewable energy factory").[11] Based on this broad definition, the report states that there were a total of 503,500 (direct, indirect and induced) jobs in the RE industry in 2007.

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[9] Ten full-time equivalent employees would be added to BLS to help develop statistics on green jobs that build upon the Bureau's Quarterly Census of Employment and Wages as well as its Occupational Employment Statistics and Employment Projections programs. The BLS anticipates producing, beginning in FY2011, quarterly employment for establishments it determines engage in one or more green economic activities. In addition, statistics will become available on the concentration and characteristics of green occupations by industry.

[10] Management Information Services, Inc., *Defining, Estimating, and Forecasting the Renewable Energy and Energy Efficiency Industries in the U.S. and in Colorado*, The American Solar Energy Society, December 2008, pp. 6-7.

[11] Ibid., p. 8.

MISI took the analysis further by specifying, in vague terms, three scenarios for the future use of RE and projecting associated job creation. The base case is a "business as usual" scenario "based loosely on the EIA [Energy Information Administration] reference case."[12] The base case scenario yields a direct, indirect, and induced job total of 1.3 million in 2030. The moderate scenario, which assumes among other things an increase over the base case in government RE initiatives, produces a total of 2.8 million jobs in 2030. The advanced scenario "pushes the envelope" in terms of what might be economically and technologically feasible as a result of greatly heightened government support for RE through 2030.[13] Under the study's most ambitious assumption of RE utilization almost 20 years in the future, 7.3 million direct, indirect and induced jobs might be created.

The analysis does not estimate the impact of labor market conditions on achieving the job projections. If the unemployment rate is low in 2030, there might not be sufficient numbers of jobless workers to fill the projected RE positions. RE employment would either be less than forecast or the jobs would be filled largely by individuals working elsewhere in the economy. In the latter case, job growth in the RE industry would to some degree come at the expense of employment in other industries. The study also does not estimate the number of jobs that might be forgone or lost due to reduced production of energy from fossil fuel sources.

(2) The ***Renewable and Appropriate Energy Laboratory*** (RAEL) at the University of California-Berkeley prepared ***Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate?***

The researchers developed three scenarios which assume that a 20% Renewable Portfolio Standard (RPS) would be attained by 2020, and that electricity demand in 2020 would remain unchanged from 2002 (with gains in efficiency offsetting the usual 2%-3% annual increase in demand). The difference between the three scenarios is the proportions of the RPS composed of biomass (wood and waste) electricity, wind energy and photovoltaic (PV) solar.

Two additional scenarios were developed in which the 20% of electricity produced by renewables in the first three scenarios is instead produced by different mixes of fossil fuels. All five scenarios are shown in **Table 1**. RAEL concluded that substituting any one of the three renewable scenarios for either of the fossil fuel scenarios would create more direct and indirect jobs. The results also show that increasing use of renewables could result in a reduction of jobs in the fossil fuel industry. In acknowledgement of this point, the authors note that a study conducted by Tellus Institute and MRG Associates for the World Wide Fund for Nature projected a net loss of 23,900 jobs in coal mining and 61,400 jobs in oil and gas extraction by 2020 due to implementation of various clean energy policies.

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[12] Ibid., p. 26.

[13] Ibid., p. 36.

Table 1. Estimated Employment in 2020 of Five Electricity Generation Scenarios

Scenarios	Average Number of Jobs in Construction, Manufacturing and Installation	Average Number of Jobs in Operations and Maintenance and in Fuel Processing	Average Total Employment
20% renewable portfolio (85% biomass, 14% wind, 1% PV)	52,533	111,136	163,669
20% renewable portfolio (60% biomass, 37% wind, 3% PV)	85,008	91,436	176,444
20% renewable portfolio (40% biomass, 55% wind, 5% PV)	111,879	76,139	188,018
Fossil fuels replacing 20% renewables (50% coal, 50% natural gas)	22,711	63,657	86,369
Fossil fuels replacing 20% renewables (100% natural gas)	22,023	61,964	83,987

Source: Daniel M. Kammen, Kamal Kapadia, and Matthias Fripp, *Putting Renewables to Work*, RAEL Report, University of California-Berkeley, 2004.

Notes: Job estimates for PV, wind and biomass are the average of the high and low employment factors from Renewable Energy Policy Project, *The Work that Goes into Renewable Energy*, 2001; Greenpeace, *2 Million Jobs by 2020: Solar Generation*,2001; and Greenpeace and European Wind Energy Association and Greenpeace, *Wind Force12: A Blueprint to Achieve 12% of the World Electricity from Wind Power by 2020*, 2003.

There are several ways in which the RAEL and MISI studies differ. The primary difference is one of definition, which causes the job estimates of the RAEL analysis to be considerably lower than those of the MISI analysis. First, RAEL does not include induced employment which some do not regard as green jobs. Second, it excludes hydropower. And third, RAEL focuses on electricity generation alone. In addition, the timeframes of the two studies differ (i.e., 2020 RAEL vs. 2030 MISI), and no growth in demand is assumed by RAEL.

(3) ***Global Insight*** prepared ***Current and Potential Green Jobs in the U.S. Economy*** for the U.S. Conference of Mayors. The economic research firm estimated that there were 751,051 green (direct and indirect) jobs in 2006, with the largest number related to renewable power generation (127,246). A green job is defined as:

> any activity that generates electricity using renewable [including hydroelectric] or nuclear fuels, agriculture jobs supplying corn or soy for transportation fuel, manufacturing jobs producing goods used in renewable power generation, equipment dealers and wholesalers specializing in renewable energy or energy-efficiency products, construction and installation of energy and pollution management systems, government administration of environmental programs, and supporting jobs in the engineering, legal, research and consulting fields.[14]

[14] Global Insight, *Current and Potential Green Jobs in the U.S. Economy*, U.S. Conference of Mayors, October 2008, p. 5.

Global Insight next forecast the number of green jobs in the categories of renewable electricity generation, residential and commercial retrofitting, and renewable transportation fuels. The second category, retrofitting, is beyond the scope of this report and will not be discussed.

In terms of power generation, Global Insight relied on its Energy Group's forecast of a 30% increase in net electricity generation between 2008 and 2038. It assumed that 40% of net electricity generation in the United States during the 30-year period will come from five sources, with wind comprising 30%; solar, 20%; geothermal, 10%; biomass, 30%; and incremental hydropower, 10%.[15] The analysis used several factors to calculate direct green energy jobs in manufacturing and construction and in operations and maintenance. The factors come from research conducted by other parties, [16] which is also the case in the RAEL report. Unlike that study, the Global Insight analysis includes more sources of renewable energy and assumes that energy demand increases over time.

In terms of renewable transportation fuels, Global Insight used a forecast of total fuel production rising to 142,000 million gallons between 2008 and 2038. It assumed that 30% of the total gasoline and diesel consumed by passenger cars and light trucks in 2038 will come from alternative fuels. The analysis used separate factors to calculate direct jobs in manufacturing and construction needed to build additions to the ethanol and biodiesel infrastructure, and in agriculture to grow the feedstock and operate the facilities to turn it into fuel. The factors come from research conducted by the Renewable Fuels Association.[17]

According to this report, there might be 407,200 (direct and indirect) jobs in renewable electric power generation by 2018; 802,000 by 2028; and 1,236,800 by 2038.[18] In renewable transportation fuels, there might be 1,205,700 (direct and indirect) jobs by 2018; 1,437,700 by 2028; and 1,492,000 by 2038. Global Insight does not provide estimates of potentially slower job growth elsewhere in the economy due to competition for workers in future years or of jobs forgone due to the assumed percent increases in electricity generation and transportation fuels from renewables. Global Insight does caution that:

> It is important to recognize these forecast results depend heavily on our chosen scenarios. Altering any of the assumptions regarding the share of electricity to be generated from alternative resources, the extent of retrofitting, or the share of transportation fuels from renewable sources would obviously change the results.[19]

(4) In ***Study of the Effects on Employment of Public Aid to Renewable Energy Sources***, Gabriel Calzada of the ***King Juan Carlos University*** analyzed the net jobs impact of Spain's policy

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[15] Although nuclear power generation is included in the 2006 count of green jobs, it is not part of the projection scenario.

[16] The studies are *The Work that Goes into Renewable Energy*, by the Renewable Energy Policy Project, November 2001; *Geothermal Industry Employment: Survey Results and Analysis*, Geothermal Energy Association, September 2005; and *California Renewable Technology Market and Benefits Assessment*, Electric Power Research Institute, November 2001.

[17] John M. Urbanchuk, *Contribution of the Ethanol Industry to the Economy of the United States*, Renewable Fuels Association, February 2009, http://www.ethanolrfa.org/objects/documents/2187/2008_ethanol_economic_contribution.pdf.

[18] Global Insight forecast one indirect job for every two direct jobs for both renewable electricity generation and renewable transportation fuels.

[19] Global Insight, *Current and Potential Green Jobs in the U.S. Economy*, U.S. Conference of Mayors, October 2008, p. 17.

initiatives to increase its capacity to generate electricity by wind, mini-hydro, and PV solar power.

The study reportedly was conducted with support from the Institute for Energy Research.[20] It adopted the direct and indirect job creation estimates for Spain's three main renewable sources of electricity that MITRE, a research firm, previously had developed. Specifically, MITRE estimated that Spain's subsidies created 15,000 jobs in wind power, 4,700 jobs in mini-hydro and 14,500 jobs in PV solar between 2000 and 2008, for a total of 50,200 direct and indirect jobs. The researcher then calculated the total public subsidy that created these green jobs to be 28,671 million Euros, or an average government subsidy per worker added of 571,138 Euros.

> In order to know how many net jobs are destroyed by a green job program for each one that it is intended to create, we use two different methods: with the first, we compare the average amount of capital destruction (the subsidized part of the investment) necessary to create a green job against the average amount of capital that a job requires in the private sector; with the second, we compare the average annual productivity that the subsidy to each green job would have contributed to the economy had it not been consumed in such a way, with the average productivity of labor in the private sector that allows workers to remain employed.[21]

Both methods produced the same outcome, namely, an average of 2.2 jobs were not created elsewhere in Spain's economy for each subsidized job created.

This study takes a much different approach than other job creation analyses by estimating the number of jobs had Spain's government not subsidized the three renewable sources of electricity generation. In developing its estimate, the author relies on average measures of capital and productivity across the entire private sector of the economy – but the cost of job creation can differ substantially from economic activity to another. A better comparison might have been with measures of capital and productivity in other electricity-generating industries (e.g., fossil fuel).

(5) Robert Pollin, James Heintz and Heidi Garrett-Peltier of the ***Political Economy Research Institute*** at the University of Massachusetts prepared ***The Economic Benefits of Investing in Clean Energy*** with support from the Center for American Progress.

The study, which provides perhaps the clearest explanation of its assumptions and methodology, estimates the number of jobs per year that might be created as a result of spending and other provisions in the American Recovery and Reinvestment Act of 2009 and a version of the American Clean Energy and Security Act of 2009 which is being considered by Congress.

The analysts calculate that the two measures working together might yield $151 billion per year in new "clean-energy investments" made by the government and private firms, and generate a net annual increase of about 1.7 million direct, indirect and induced jobs. This net employment gain is composed of a gross increase economy-wide of approximately 2.5 million jobs and a gross loss of 795,000 jobs if the entire $151 billion annual investment in clean energy came at the expense of the fossil fuel industry. About one-fourth ($41 billion) of the total spending is estimated to occur in the following renewable energy areas: on-grid renewable electricity production and

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[20] George Will, "Tilting at Green Windmills," *The Washington Post*, June 25, 2009.

[21] Gabriel Calzada, *Study of the Effects on Employment of Public Aid to Renewable Energy Sources*, King Juan Carlos University, March 2009, p. 27.

transmission to residential, commercial, and industrial customers ($30 billion),[22] off-grid renewable electricity generated by solar panels on buildings ($3 billion);[23] off-grid nonelectric renewable energy production by geothermal pumps ($3 billion); and alternative motor fuels such as cellulosic biofuels ($5 billion).[24] Thus, the researchers estimate that the great majority of clean-energy investments prompted by the two pieces of legislation involve energy efficiency activities, which they defined as building retrofits, mass transit/freight rail, and smart grid.

The data in **Table 2** below underpin the analysts' conclusion that an expenditure on "clean energy sources" creates more jobs than an equivalent expenditure on fossil fuel energy sources. Estimates of jobs per $1 million of spending on renewable resources of energy production are shown in the bottom third of the table, and estimates for comparable spending on fossil fuel sources of energy production are shown in the top third. For example, the wind energy industry (as defined by the analysts) would generate 9.5 direct and indirect jobs per $1 million invested,[25] while $1 million invested in the oil and gas energy industry (as defined by the analysts) would generate 3.7 direct and indirect jobs.[26]

From the perspective of spending that provides the most "bang for the buck" – a major concern when government tries to mitigate the labor market impact of an economy in recession – the results of this analysis suggest that investment in renewable energy sources is superior to fossil fuel sources in terms of job creation. (Both the American Recovery and Reinvestment Act of 2009 and H.R. 2454, the American Clean Energy and Security Act of 2009, have been characterized by some as "jobs bills.") With an unemployment rate of 9.7% in August 2009 and forecasts that the rate will continue to rise through at least year-end and remain elevated for some time to come, the supply of labor is unlikely in the near-term to prevent reaching the analysts' estimate of green job creation. Once the labor market recovers from the recession, however, attainment of the annual job estimate could become increasingly untenable even if $151 billion per year continued to be invested in clean energy (including renewable) sources.

[22] The authors estimate, based on data from the Department of Energy's Energy Information Administration (EIA), that for retailers to supply from renewable sources 20% of total electricity in the coming decade an investment of $30 billion per year might be required.

[23] The analysts base their estimate that end-users will need to invest $3 billion annually over a 10-year period to increase their generation of electricity from renewable sources are based on EIA data.

[24] The researchers estimate that, if the market for ethanol from all sources is 20 billion gallons per year (*Energy Outlook 2009*), about $5 billion per year in additional investments would be required to "produce one-third of the quantity of ethanol from cellulosic sources by 2020." Robert Pollin, James Heintz, and Heidi Garrett-Peltier, *The Economic Benefits of Investing in Clean Energy*, Political Economy Research Institute, June 2009, p. 19.

[25] As noted in the introduction to this section, separate output and employment data are not available for electricity produced by wind and some other renewable resources (e.g., solar). In order to use an input-output model of the economy to estimate job creation, the authors developed definitions of these economic activities from industries uniquely identified in the North American Industry Classification System. For example, the authors defined wind-powered electricity as 26% construction industry; 12% plastic products, 12% fabricated metal, 37% machinery, 3% mechanical power transmission equipment and 3% electronic components manufacturing; and 7% scientific and technical services.

[26] Although fossil fuel electricity generation is uniquely identified in the North American Industry Classification, the authors note that oil-and-gas-powered energy production includes extractive, research, manufacturing and distribution activities. They accordingly defined oil-and-gas-powered energy as being 23% oil and gas extraction, 7% drilling oil and gas wells, 4% support activities for oil and gas extraction, 10% natural gas distribution, 45% petroleum refineries, 8% petroleum product manufacturing, and 3% pipeline transport.

Table 2. Estimated Employment Effect of Investment in Select Energy Sources

(number of jobs per $1 million in output)

Energy Source	Direct Jobs[a]	Indirect Jobs[b]	Direct and Indirect Jobs	Direct, Indirect and Induced Jobs[c]
Fossil fuels				
Oil and natural gas	0.8	2.9	3.7	5.2
Coal	1.9	3.0	4.9	6.9
Energy efficiency				
Building retrofits	7.0	4.9	11.9	16.7
Mass transit/freight rail	11.0	4.9	15.9	22.3
Smart grid	4.3	4.6	8.9	12.5
Renewables				
Wind	4.6	4.9	9.5	13.3
Solar	5.4	4.4	9.8	13.7
Biomass	7.4	5.0	12.4	17.4

Source: Robert Pollin, James Heintz, and Heidi Garrett-Peltier, *The Economic Benefits of Investing in Clean Energy*, Political Economy Research Institute, June 2009.

Notes: The definitions of direct, indirect, and induced effects appear on p. 27 of the above-captioned report.

a. "Direct effects. The jobs created by retrofitting homes to make them more energy efficient, or building wind turbines."

b. "Indirect effects. The jobs associated with industries that supply intermediate goods for the building retrofits or wind turbines, such as lumber, steel, and transportation."

c. "Induced effects. The expansion of employment that results when people who are paid in the construction or steel industries spend the money they have earned from produce these immediate and intermediate goods for clean energy industries on other products in the economy."

(6) The ***Pew Charitable Trusts and Collaborative Economics***, a policy research firm, developed ***The Clean Energy Economy: Repowering Jobs, Businesses and Investments Across America***. Unlike the above-described analyses which largely were based on models of the U.S. economy, the authors of this report attempted to identify companies engaged in clean energy activities and the number of clean energy jobs at those individual businesses. Put very succinctly, the researchers used multiple sources of information to develop a database of "clean energy economy" firms in selected industry classification codes. Employment statistics for the individual companies in these industry codes came from the National Establishment Time Series (NETS) database, which is based on Dun & Bradstreet information covering the population of business establishments in the United States.[27]

> Our analysis is conservative relative to other studies because we count actual clean energy economy businesses and jobs rather than entire occupations (such as all jobs in mass transit, or all electricians). For example, our report counts the workers who manufacture hybrid cars

[27] Data users have ready access without confidentiality restrictions to NETS, unlike data of the U.S. Bureau of Labor Statistics and other government agencies. NETS is maintained by Walls & Associates, which licenses it to researchers.

> and buses, technicians who construct wind turbines, electricians who install solar panels on homes and engineers who research fuel cell technology, but it does not include all auto manufacturers, electricians, technicians and engineers. In addition, we focus exclusively on producers and suppliers in the clean energy economy. We do not count jobs that use these products and services—for example, jobs within utilities responsible for purchasing energy monitoring equipment or the mass transit operations that buy hybrid buses—because data limitations prevented the disaggregation of specific jobs within these types of companies.[28]

The researchers define the clean energy economy as (1) clean energy, (2) energy efficiency, (3) environmentally friendly production, (4) conservation and pollution mitigation, and (5) training and support. The five categories are further divided into 16 segments. In the case of clean energy, the segments are energy generation (e.g., wind, solar, geothermal, biomass, hydro, marine and tidal, hydrogen), energy transmission (e.g., power monitoring and metering services, smart grid), and energy storage (e.g., advanced batteries, fuel cells). Nuclear power is excluded "because of significant, ongoing questions about how and where to safely store its waste."[29]

In 2007, according to the Pew analysis, there were 770,385 jobs in the clean energy economy. The clean energy category of renewable sources of energy generation, transmission and storage accounted for 89,000 jobs or 11.6% of the total. About two-thirds of the jobs (501,551) were in the conservation and pollution mitigation category. Each of the remaining categories accounted for fewer jobs than clean energy: 73,000, energy efficiency (e.g., geothermal heating and cooling, smart lighting); 53,700, environmentally friendly production (e.g., biofuel, coal gasification, ethanol, hybrid vehicles, biodegradable products; and aquaculture); and 50,000, training and support (e.g., research in renewable sources of energy generation and in alternative fuels, emissions trading and offsets, and project financing). Some of the jobs in these three categories likely were included by other analysts in their renewable energy estimates. For example, the MISI analysis appears to define the RE industry to encompass related research and investment activities. The Pew report, in contrast, classifies such activities in its "training and support" rather than "clean energy" category.

In summary, the preceding studies of green job creation in the renewable energy industry vary greatly in a few key respects. As a result of differences in definitions, assumptions, and methodologies, the analyses produce wide-ranging estimates of the number of green jobs.

Renewable Energy Technologies and Green Jobs Growth

As previously noted, there is no universally-accepted definition of green jobs. The preceding studies of green jobs generally consider these to be jobs in energy efficiency activities and/or renewable energy. Improving the energy efficiency of current buildings and residences is seen as the easiest way to reduce GHG emissions, and is an area in which many workers could be employed for years to come in energy audit and retrofit activities.[30] But energy efficiency may see

[28] The Pew Charitable Trusts, *The Clean Energy Economy: Repowering Jobs, Businesses and Investments Across America*, June 2009, p. 10.

[29] Ibid., p. 12.

[30] Daniel Sosland, Derek Murrow, and Samuel Krasnow, *Energy Efficiency as Economic Stimulus*, Progressive Policy Institute, December 2008, http://www.ppionline.org/ndol/print.cfm?contentid=254849.

as much or more achieved from new construction standards than may be achieved from retrofits to today's existing buildings and housing.

Most of the future growth in green jobs is generally envisioned as coming from the growth in deployment of renewable energy technologies. A common misperception in the studies of green jobs seems to be that all renewable energy technologies have generally the same qualities, with regard to job creation potential. Little effort is made to differentiate between them.

However, renewable energy technologies are designed to harness renewable energy resources with very different physical characteristics, such as the wind and the sun. Different technologies have seen different levels of investment over the years based upon various evaluations of potential and economic readiness to serve current markets or applications. The timeframe under consideration is important in any discussion of the potential for renewable energy technologies to create jobs, for the technologies are at different stages in their development cycles and have attributes suited to different applications. Consequently, the costs of generating electricity varies with each renewable energy technology, and the potential for deployment often depends upon local incentives and the quality of the renewable resource. As such, renewable energy deployment programs from state governments have had a great influence on the current deployment levels of renewable energy technologies and resultant jobs.[31]

Historically, the federal investment in renewable energy technologies in the United States has not been about creating jobs, but instead simply focused on developing the technologies to a point where they are considered ready for commercialization. Even though renewable energy projects are currently being deployed, further development of the technologies is needed if these technologies are to meet the perceived future needs of the marketplace. Some of today's renewable energy technologies may in fact turn out to be "transitional" as advances in technology have and could further lead to new research directions. Innovation could be stimulated from within the industry or induced by developments ancillary to the industry, such as the development of the Smart Grid[32] or schemes to encourage Demand Response.[33] Further research, development, and deployment is likely necessary to develop a more robust renewable energy industry and potential spillover benefits[34] to the economy at large from the R&D spending.

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[31] State of Texas, Comptroller of Public Accounts, *Window on State Government: Overview of Renewable Energy*, http://www.cpa.state.tx.us/specialrpt/energy/renewable/index.php.

[32] Smart grid initiatives envision an advanced electricity generation, transmission, and distribution system which is capable of self-diagnosing and self-healing; incorporates numerous advanced technologies at all stages of the electricity supply chain; and focuses on efficiency, affordability and environmental quality. Massoud Amin, S. and Wollenberg, B.F., *Toward a Smart Grid: Power Delivery for the 21st Century*, Power and Energy Magazine, September 2006, http://www.todaysengineer.org/2008/Aug/smart_grid.asp.

[33] Changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized. Federal Energy Regulatory Commission, *A National Assessment of Demand Response Potential*, http://www.ferc.gov/industries/electric/indus-act/demand-response/dr-potential.asp.

[34] Economists and other social scientists have demonstrated that the R&D activities of private firms generate widespread benefits enjoyed by consumers and society at large. As a result, the overall economic value to society often exceeds the economic benefits enjoyed by innovating firms as a result of their research efforts. Adam Jaffe, *Economic Analysis Of Research Spillovers Implications For The Advanced Technology Program*, Brandeis University and the National Bureau of Economic Research, December 1996, http://www.atp.nist.gov/eao/gcr708.htm.

Enabling mechanisms for renewable energy technologies, such as those discussed to help with deployment (i.e., the feed-in tariff in Europe), were designed not so much to create jobs as they were to encourage the use of the new technologies. The U.S. government is now discussing how to invest in renewable energy technologies as a growth engine for future jobs. The investment may not result in large direct jobs creation in the short-term, but prepares for potential growth in the near future especially as climate change considerations may shift paradigms regarding electricity generation choices. This transition would likely require further domestic policies to develop the supporting infrastructure and supply chains to enable the success of new clean energy industries. Additionally, a transition to low carbon energy technologies may result in jobs being lost in other parts of the economy, but this may be considered part of the opportunity cost of making the decision.

Many of the studies concerning green jobs and renewable energy technologies provide estimates of employment reflecting the state of technology at a specific point in time. It is important to recognize that as a specific renewable energy technology becomes more efficient, the number of jobs per Megawatt (MW) of output is likely to decrease. The increase in efficiency may also be reflective of an increase in productivity of manufacturing processes. This has particular relevance if most jobs in renewable energy are likely to be in manufacturing and construction, as opposed to fossil energy in which most jobs relate to fuel processing and operations and maintenance activities.[35]

Outlook for Renewable Energy in the United States

Renewable energy resources may be defined as naturally replenishing (in that they are virtually inexhaustible) resources limited in the amount of energy that is available in a particular period of time.[36] This definition illustrates both the promise and the problems associated with renewable energy technologies which seek to produce electrical energy from renewable resources.[37] Many of today's renewable energy technologies were largely developed in the United States as the federal government explored ways to reduce our dependence on imported oil. Renewable electricity technologies are designed to harness very different renewable energy resources. Some of these renewable resources are fairly constant and predictable, while others can vary significantly according to location, and even time of the day or year. Estimates of market growth are provided to illustrate the potential size of future markets for a particular renewable energy technology.

The U.S. Department of Energy's (DOE's) Energy Information Administration (EIA) annually performs an analysis of trends to arrive at long-term projections of energy supply, demand, and the effect on energy prices. For 2009, the *Annual Energy Outlook* (AEO 2009) has a Reference Case which assumes that existing laws and regulations as of 2007 will be maintained through to 2030. This scenario expects a global economic recovery to begin in 2010, spurring demand for oil and corresponding increases in oil prices to $110 per barrel (2007 dollars) by 2015, increasing to

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35 Dan Kammen, Kamal Kapdia, and Matthias Fripp, *Putting Renewables to Work: How Many Jobs can the Clean Energy Industry Generate?*, University of California, Berkeley, January 2006, (RAEL 2006) http://rael.berkeley.edu/files/2004/Kammen-Renewable-Jobs-2004.pdf?src=.

36 U.S. Department of Energy, Energy Information Administration (EIA), http://www.eia.doe.gov/glossary/glossary_r.htm.

37 Renewable energy resources include solar energy, wind, biomass, geothermal energy, and hydropower captured from the movement or temperature differentials of water.

$130 per barrel in 2030. The AEO 2009 Reference Case therefore does not assume climate change legislation will be in effect for the period.[38]

This can be compared to EIA's case for a future in which GHG mitigation is required by legislation and calls this scenario the *LW110* case, modeling such a provision on S. 2191, the Lieberman-Warner Climate Security Act of 2007 introduced in the 110th Congress. EIA also has a scenario called *No GHG Concern* case which removes cost-of-capital adjustments for GHG-intensive technologies from the Reference Case. The AEO 2009 Reference Case shows all renewable energy sources accounting for approximately 8.5% of electricity generation in the base year of 2007.[39] Projecting forward to 2030, the Reference Case sees renewable electricity growing to 14% of total generation. Using the LW110 case, the analysis projects renewable energy sources accounting for 22% of all electricity generated.

EIA also has analyzed two additional scenarios specifically for changes in the cost of renewable energy technologies. In the case of High Renewable Energy Cost, capital costs, operating and maintenance costs, and performance levels for wind, solar, biomass, and geothermal resources are assumed to remain at 2009 levels through to 2030. In this case, it is assumed that dedicated energy crops do not become available. In its *Low Renewable Energy Cost* scenario, EIA assumes that levelized[40] costs of generating renewable energy will decline 25% below AEO 2009 Reference Case costs by 2030. Generally, this is realized through lower capital costs to construct the plants, and in the case of biomass, fuel supplies are assumed to be 25% less expensive compared to the Reference Case costs. Under the Low Renewable Energy Cost scenario analysis of AEO 2009, renewable electricity sources could account for as much as 22% of power generation for the (non-nuclear) electric power and end-use sectors by 2030.[41]

What these scenarios illustrate is that domestically, a relatively high rate of growth may be expected for renewable electricity overall even if no federal GHG mitigating legislation is enacted during the period to 2030, based on the conditions described.

Outlook for Renewable Energy Markets Overseas

According to EIA projections in its International Energy Outlook for 2009 (IEO2009), global renewable electricity generation could rise by an average 2.9% per year (from 2006 to 2030). If realized, that would mean that renewable electricity would make up 21% of global supply in 2030 as compared to 19% in 2006.[42] With oil prices expected to increase with an expected global economic recovery, renewables are projected to be fastest-growing source of electricity internationally. Wind and hydroelectric power are expected to represent much of the increase. Solar power can be cost-competitive in areas with especially high electricity prices or where government incentives are available. Government subsidies often provide the necessary support

[38] Ibid. p. 29.

[39] U.S. Department of Energy, Energy Information Administration (AEO 2009), *Annual Energy Outlook 2009*, Table 14 on p. 52, http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2009).pdf.

[40] The present value of the total cost of building and operating a facility over its life, as represented by equal annualized amounts.

[41] U.S. Department of Energy, Energy Information Administration (AEO 2009), *Annual Energy Outlook 2009*, Table D10 on p. 186, http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2009).pdf.

[42] EIA, *International Energy Outlook 2009*, http://www.eia.doe.gov/oiaf/ieo/highlights.html.

for building renewable generation facilities. Renewable sources also offer an opportunity for electrification of regions with unreliable or no centralized electricity services.

Renewable Energy Technology Status and Development Needs

A summary of the current status of current major renewable energy technologies follows, using figures for domestic estimated growth based on AEO 2009 projections. Some of the major perceived barriers the technologies must overcome in order achieve a greater share of the electricity generation market are presented. Capacity estimates are for the electric power sector, whose primary business is to sell electricity to the public. Estimates of net summer capacity in 2030 are from AEO 2009's *Low Price* scenario (which assumes technology improvements and other factors will continue a trend of declining prices for electricity from renewable energy technologies) unless otherwise stated.

Biomass

Biomass for electric power or biopower has a large potential and is arguably the most conventional of all renewable electricity technologies. Biomass is the largest source of renewable energy in the United States. Approximately 53% of all renewable energy comes from biomass, represented by biofuels, landfill gas, biogenic municipal solid waste, wood, wood-derived fuels and other biomass such as switchgrass and poplars. Agricultural wastes (such as corn stover) are another potential feedstock. With wood and biomass net summer capacity reported at 7 Gigawatts (GW) for 2007, DOE estimates that 41 GW of domestic biomass generation could be available by 2030.[43] Sustainable management of biomass resources, especially forests, will be critical to this future.

Biomass combustion is a relatively mature technology but it is not widely used and is generally not very efficient unless it is used in a combined heat and power application. As of 2003, there were approximately 66,000 direct jobs in the biomass power segment.[44] Large scale co-firing of biomass with coal is a higher efficiency, lower per unit cost application. Technologies for biomass gasification could result in higher efficiencies when used to produce synthesis gas or hydrogen for heat and/or power production. Demonstration and deployment of newer industrial gasification technologies is needed to scale-up plants and provide economical designs with high degrees of availability. Huge potential exists for the biomass category, as it is generally regarded as a carbon-neutral source of energy. Wood-burning stoves and solar water heaters are the most common applications of residential renewable energy. But improvements are needed to increase fuel efficiency and lower toxic air pollutants for wood stoves.

Liquid biofuels can readily be made from biomass using fermentation processes. Ethanol, the most widely produced biofuel today, is commonly blended with gasoline as a transportation fuel

[43] AEO 2009.

[44] R.L. Bain, W.P. Amos, and M. Downing, et al., *Highlights of Biopower Technical Assessment: State of the Industry and the Technology*, National Renewable Energy Laboratory, NREL/TP-510-33502, April 2003, http://www.chemicalvision2020.org/pdfs/biopower_techassessment.pdf.

thus reducing GHG and particulate emissions. Other biofuels with transportation potential are methanol and butanol, both of which can be made from renewable sources such as wood wastes, agricultural or municipal solid wastes. Methanol also has electric power production potential, and can be used to fuel combustion turbines to produce electricity, either directly or in its dehydrated form of DiMethyl Ether, a diesel substitute.

Wind

Electricity produced from wind power is growing at a faster rate than natural gas, with a net summer capacity in 2007 of 16.23 GW.[45] This growth has caused a surge in employment with over 85,000 jobs reported by the American Wind Energy Association, of which about 8,000 jobs are construction-related.[46]

Most wind power projects today are onshore, but several coastal regions around the United States also have good quality offshore wind resources that may see development in the near future. Wind turbine sizes are increasing in generating capacity, with domestic turbines in 2007 averaging 1.6 MW in size.[47] When the wind is blowing at speeds which can be harnessed, electricity can be generated at prices nearly competitive with conventional fossil energy based generation. Most of today's wind turbines use a three-bladed windmill rotor design to generate electricity from the wind, but new turbine designs are being developed to generate power at lower wind speeds. Since the wind doesn't blow all the time and varies in strength, integration of large amounts of wind into an electricity grid has often been raised as an issue.[48] Backup generation in the form of natural gas combustion turbines has been the standby choice in some instances. Energy storage (using batteries or other means) is often suggested as a potential answer to deal with intermittency and load variability concerns. Since many of the best wind resource areas in the United States are far from population centers where the electricity generated will be used, the development of transmission facilities to carry power to population centers will likely be needed for wider development. Given these factors, DOE estimates domestic capacity from wind could reach 61 GW by 2030. Additionally, DOE projects as much as 20% of the nation's electrical supply could be provided by wind energy by 2030. This would require wind power capacity to reach 300 GW, or a growth of over 280 GW over the next 21 years. Achieving such a prodigious goal would mean addressing significant challenges in technology, manufacturing, employment, transmission and grid integration, markets, and siting strategies.[49]

[45] AEO 2009.

[46] American Wind Energy Association, *WIND ENERGY GROWS BY RECORD 8,300 MW IN 2008*, http://www.awea.org/newsroom/releases/wind_energy_growth2008_27Jan09.html.

[47] CRS Report RL34546, *Wind Power in the United States: Technology, Economic, and Policy Issues*, by (name reda cted).

[48] International Energy Agency, *Variability of Wind Power and Other Renewables: Management Options and Strategies*, Management Options and Strategies, 2005, http://www.iea.org/Textbase/Papers/2005/variability.pdf.

[49] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *20% Wind Power by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply*, December 2008, http://www1.eere.energy.gov/windandhydro/pdfs/42864.pdf.

Solar PV

Another renewable resource with enormous potential is sunlight. Solar photovoltaic power converts sunlight directly into electricity using photovoltaic (PV) cells which today are largely made from crystalline silicon. Research is underway to reduce the cost of PV cells using base materials other than silicon (such as cadmium telluride) and improved manufacturing techniques which may increase the efficiency of solar cells.[50] Recent advances in "thin-film" technology using cadmium telluride have resulted in module production costs dropping from $2,940 per kilowatt (kW) of capacity in 2004 to $1,120 per kW in 2007.[51] DOE estimates that there were 46 companies manufacturing PV modules and cells in the United States in 2007, with 6,170 person-years of direct employment (representing the equivalent of 6,170 full-time jobs).[52]

Solar PV is currently used in a number of off-grid applications where distributed energy resources are useful, and in peaking power applications to reduce power usage from the electric utility grid. Battery storage is important to off-grid usage to extend hours of usage past peak daylight. While Solar PV installations only represented 0.47 GW of capacity in 2007, DOE estimates generating capacity from solar PV could reach almost 18 GW by 2030 in the United States.[53]

Since the amount of electricity that can be produced from solar PV depends on the intensity of sunshine (and the angle at which PV panels face the sun), significant potential exists for applications in sunny regions. But the relative success of solar PV installations in Germany (with a capacity of 3,000 MW in 2007) prove the wider applicability of the technology in less than optimal climes.[54] Integration of PV cells and materials into building structures and designs for could be a major step for the technology.

The cost of electricity in the United States today from solar PV is relatively high at approximately 18 to 23 cents per kilowatt-hour (kWh) when compared to electricity from fossil energy sources. However, the costs of solar PV capacity have been decreasing. Increases in the efficiency of solar PV cells, combined with other technological advances, could result in solar PV prices of 5 to 10 cents per kWh by 2015[55] which is close to parity with fossil-fueled electricity.

Concentrating Solar Thermal

Concentrating solar thermal technologies use mirrors to concentrate sunlight and generate heat usually for steam production. This steam is then used to generate electricity or provide high-temperature hot water for industrial or other process uses such as heating and cooling. Fairly large areas of land are needed, plus access to water since it is used for steam generation and condenser cooling purposes. Some novel applications heat air directly to generate thermal gradients which

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50 Solar Today, *Game Changing Technology on the Horizon*, American Solar Energy Society, March 2009, http://www.solartoday-digital.org/solartoday/200903/?pg=27.

51 Desert Protective Council, *Educational Bulletin #08-3*, http://www.dpcinc.org/_new/images/EB/EB08-3.pdf.

52 U.S. Department of Energy, *Renewable Energy Annual 2007*, April 2009, http://www.eia.doe.gov/cneaf/solar.renewables/page/rea_data/rea.pdf. (REA 2007).

53 AEO 2009.

54 Australian Broadcasting Corporation, *Germany an unlikely hot spot for solar power*, August 2007, http://www.abc.net.au/news/stories/2007/08/01/1994041.htm.

55 Stanley R. Bull, *Renewable Energy: Status and Potential*, National Renewable Energy Laboratory, January 2009, (NREL 2009). http://www.drcog.org/documents/StanleyBullPresentation.pdf.

are harnessed to produce electricity. Solar thermal technologies are currently used for utility-scale power generation, but costs of 12 cents per kWh in the United States are higher than for fossil-fuel power generation. Advances in the designs and materials of absorbers, reflectors and heat transfer fluids in next-generation solar thermal systems could potentially reduce costs to 6 cents per kWh by 2015.[56] As of 2007, DOE estimates that employment in the U.S. solar thermal industry represented the equivalent of 686 manufacturing jobs.[57]

Improved energy storage schemes would benefit both conventional power generation and off-grid applications in particular. New utility-scale solar thermal facilities will likely be located mostly in the southwestern region of the United States, an area where water resources may be under stress.[58] As such, EIA projects slow growth in domestic power generation from solar thermal technologies from 0.53 GW capacity in 2007 to 0.86 GW by 2030.

Applications in residential and smaller industrial/commercial facilities are another area of potential solar thermal use. Solar hot water heaters are growing in use in the United States, with wide applications in parts of Europe and Asia. Additional R&D investment may be needed to increase energy conversion efficiencies and bring down energy costs if smaller solar thermal systems are to become mainstream choices domestically.

Geothermal

Steam or hot water extracted from geothermal reservoirs in the Earth's crust can be used to generate electricity, or to provide thermal energy for heating or thermal processes. EIA projects this hydrothermal capacity could reach 3 GW by 2030, up from 2.36 GW in 2007.[59] But geothermal energy may no longer depend upon the availability of suitable natural geothermal resources. Enhanced Geothermal Systems (EGS) are man-made geothermal reservoirs. By drilling into the Earth's crust and injecting water to create steam, EGS offers the potential to provide geothermal energy almost anywhere, not just in areas where steam or hot water occur naturally. EGS offers the possibility for large scale generation of clean energy. Improvements in drilling technology can lower costs, and better fluid flow can increase the amounts of power generated.

Ground Source Heat Pumps (GSHP) are used mostly in residential applications and take advantage of the differential of the ground compared to surface air temperatures. GSHP require a piping network to be buried underground to serve the customer's heating and cooling needs. Energy efficiency standards focused on home heating and cooling could lead to improved technologies and wider deployment in new construction. Direct employment in the geothermal heat pump sector as of 2007 represented the equivalent of 1,219 jobs.[60]

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[56] NREL 2009.

[57] REA 2007.

[58] CRS Report R40631, *Water Issues of Concentrating Solar Power (CSP) Electricity in the U.S. Southwest*, by (name r edacted) and (name redacted).

[59] AEO 2009.

[60] Energy Information Administration, *Geothermal Heat Pump Manufacturing Activities, 2007*, February 2009, http://www.eia.doe.gov/cneaf/solar.renewables/page/ghpsurvey/ghpssurvey.html.

Hydroelectric Power

Only 2,400 of the 80,000 dams in the United States produce electricity.[61] Building a new hydroelectric power plant is expensive, and construction uses much water and land. As such, with most of the better sites already developed, DOE does not expect much growth in large conventional hydroelectric capacity. But DOE has identified approximately another 5,677 sites with the potential to generate about 30 GW of power using small-scale hydroelectric technologies. Opportunities with small head and low flow applications may need further R&D to optimize the power generation potential. Most of the future employment opportunities in hydroelectric power are likely to come from small scale projects.

Hydrokinetic energy technologies generate power from the movement of water. Electricity can be generated from the flow of water in rivers, or additionally from the flow of released water at existing dams. Wave energy and tidal applications are just beginning demonstrations of the various technologies to tap the potential.

Micro- and pico-hydropower are options for power in "village scale" or distributed settings. Transmission lines from turbine to service application may be required. Battery storage may not be necessary, depending on the application. Micro-hydropower systems are less than 100 kW. Pico-hydropower systems are less than 5 kW.

Focusing on Potential Markets for Jobs Growth

If green jobs from renewable energy technologies is a goal, then understanding the future needs and structures of markets for renewable electricity could help the development of a market focus, and provide a strategy for U.S companies to become a global provider of equipment for the next generation of renewable energy technologies. Serving these demands can potentially mean growth in domestic green jobs. While most studies of the potential for green jobs from renewable energy focus on growth in U.S. electricity markets, the developing world may present opportunities for the future. Evolving domestic energy policy concepts (such as the development of a Smart Grid or Demand Response programs) may have an impact on the physical infrastructure and development of services in energy markets internationally. The sections that follow describe some of the major trends which are likely to influence future renewable electricity markets.

Centralized vs. Distributed Electricity Generation

Most communities in the United States are served by a local electric utility which brings power to businesses and residences via electric transmission lines from steam-electric power generating facilities located miles away from large population centers. In fact, a network of power plants generally connects to a grid of transmission lines which then distribute electric power over smaller lines for customer use. These plants commonly burn coal or natural gas (i.e., fossil fuels) to generate electricity, and are usually operating twenty-four hours a day. Efficiency of operation (i.e., as ratio of fuel input to energy produced) has been achieved from large economies of scale,

[61] Oak Ridge National Laboratory, *Dams: Multiple Uses and Types*, http://www.ornl.gov/info/ornlreview/rev26-34/text/hydside1.html.

resulting in electrical power being generated fairly cheaply, but with a consequence of commensurately large GHG emissions. This central station concept allows for a number of power plants to serve multiple communities, providing reliable power, and allowing different generating options to be incorporated into networks including renewable electricity.

Some renewable electricity technologies are also capable of serving as base load capacity, notably geothermal, biomass, and hydroelectric facilities with impoundments. Wind power is considered intermittent because the wind doesn't blow all the time, and may not be predictable as a resource. Similarly, solar facilities are dependent on sunlight. Storage schemes may provide an answer for variability of power generation issues thus improving dispatchability, i.e., the capability to generate power to meet system loads. This could allow for more widespread use of renewable energy technologies for traditional electric utility-type operations. Energy storage capabilities could also be key to increasing distributed generation applications of renewable electricity technologies.

Distributed generation does not rely upon a grid or centralized power station for electricity, instead allowing electric power to be generated at or near the point of consumption (i.e., the customer or load). Wind and Solar PV are well-suited to distributed generation, serving as back-up or main power supplies for single customers or communities. Similarly, on-site generation is used by industrial facilities such as pulp and paper mills with biomass generation. Communities or consumers seeking back-up or independent power supplies using stand-alone generators or renewable electricity technologies may seek to take advantage of these opportunities.

Some renewable electricity technologies lend themselves to modular, scalable *energy* solutions which may be more favorable to distributed energy solutions. While traditional lead-acid batteries are usually thought of for today's electricity bulk storage systems, new energy storage technologies are on the horizon. For example, advanced battery and fuel cell technologies may be able to efficiently use hydrogen from dissociated water, thus employing distributed generation technologies like solar PV or wind power to generate hydrogen as well as power during peak hours of operation, and provide power for night-time use. Charging stations for electric vehicles may also be ideal applications for renewable electricity solutions.

Developed vs. Developing Economies: A Two-Tiered Energy Future?

In 2009, developing countries surpassed developed countries in total energy use for the first time, reaching a high of 51.2%.[62] EIA has estimated a growth rate for renewable electricity technologies in non-OECD[63] countries at 3.2% annually for the period 2006 to 2030, compared to 2.5% for OECD countries in the same period. Countries in the developed world may be moving towards building economies based on a low-carbon, technology-based energy future following legislative proposals for climate change mitigation. More robust versions of today's renewable electricity technologies could be the future, hybridized with other renewable technologies or possibly natural gas-powered fuel cells or generation. The evolution of a Smart Grid could enable

[62] Chris MacDonald, *Historic first: Emerging countries surpass developed nations in energy consumption*, June 2009, http://www.sustainable-development.com/economy/2009/06/A172/historic-first-emerging-countries-surpass-developed-nations-in-energy-consumption.html.

[63] Organization for Economic Cooperation and Development.

wider deployment of renewable energy technologies as part of a larger centralized network, or alternatively, it could provide for more distributed customer based applications interfaced with electric utility controllers allowing for Demand-Side Management options.[64]

In contrast, the cost and refinements of a smart grid future may not be necessary at this time for markets in the developing world. But that does not mean that these markets do not provide opportunities for U.S. firms. Many of today's existing renewable energy technologies may be adequate for many "village" or distributed applications. Grid-connected electricity systems in many developing countries may not be as reliable or robust as in the United States, providing an opportunity for U.S. manufacturers to provide modular renewable systems as "back-up" or alternative power systems in areas of high-electricity cost. Energy-efficient appliances specifically designed for renewable-powered village applications in developing countries is another possible area for U.S. manufacturers to focus on product development.

Renewable Energy and Climate Change Assistance

Developing countries are less likely to have the resources to afford technologies to help mitigate the potentially detrimental effects of climate change, therefore providing assistance for developing countries to deploy clean energy technologies has been discussed at international forums.[65] By understanding the needs and operational parameters of segments of these markets, or designing products to serve the specific needs of communities in developing countries, U.S. manufacturers could build products for markets in almost any country. Distributed generation schemes can bring renewable sources of electricity to off-grid communities (or communities underserved by a central grid) in developing countries. Such "village applications" could serve GHG reduction goals, enable access to equipment and services which could help improve the health of local populations, and further goals of good will. Electrification is often the first step to the development of modern services for many regions and an educational system providing access to centralized teaching and tools.

By providing options or simply giving assistance in the form of renewable electricity technologies, developed economies can help developing countries avoid GHG emissions from coal or other fossil fuel power generation technologies which may be easier to acquire. U.S. legislative proposals for climate change mitigation include provisions for use of *emissions allowances* to provide exactly such assistance.[66] In the short-term, U.S.-made products could be provided to communities in developing countries. A possible positive benefit of such assistance could be the development of "brand awareness," which may help to develop long-term customers interested in purchasing U.S. manufactured products.

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[64] Demand-Side Management refers to the planning, implementation, and monitoring of utility activities designed to encourage consumers to modify patterns of electricity usage, including the timing and level of electricity demand. It refers to only energy and load-shape modifying activities that are undertaken in response to utility-administered programs. It does not refer to energy and load-shaped changes arising from the normal operation of the marketplace or from government-mandated energy-efficiency standards. Demand-Side Management covers the complete range of load-shape objectives, including strategic conservation and load management, as well as strategic load growth. http://www.eia.doe.gov/glossary/glossary_d.htm.

[65] Delegates agreed on principles for financing a fund to help the poorest nations cope with the effects of climate change at the Conference of the Parties meeting of the *United Nations Framework Convention on Climate Change* in Poznan, Poland, in December 2008.

[66] H.R. 2454, Subtitle D, Sec. 441.

Developing an Industry, Not Just Jobs

Investment in renewable energy technologies in the United States until recently was not about creating jobs. Any employment in areas related to or growing out of renewable energy has often been considered as a spillover economic benefit of the original R&D investment rather than a specific focus. Helping technology ventures to become viable manufacturing companies capable of competing for the domestic clean energy market is another step. Supporting structures involving academic institutions and manufacturing supply chains may have to be developed to enable a larger, competitive, domestic renewable energy manufacturing capability.

Transitioning renewable energy companies into an industry capable of competing for global clean energy markets to build related green jobs in the United States over the longer-term may require coordinated policies and further government involvement. Companies must be capable of competing in the domestic market for renewable energy first and foremost, as the potential growth of U.S. renewable markets already has significant international participation. Success in building new manufacturing industries can often be traced to planned, cooperative approaches working with government entities. States and local communities have embraced these ideas for years as part of public-private partnerships in assisting technology to manufacturing ventures.

Globally Competitive Manufacturing Clusters

Many economists believe that complex industrial ecosystems, or *Clusters*, are the drivers of a growing economy.[67] Clusters can be defined as geographic concentrations of interconnected companies, specialized suppliers, service providers, and associated institutions in a particular field that are present in a nation or region.[68] Clusters arise because they increase the productivity with which companies can compete. They do this in three broad ways: first, by increasing the productivity of companies based in the area; second, by driving the direction and pace of innovation; and third, by stimulating the formation of new businesses within the cluster.[69] Achieving a critical mass with regard to the number of firms may be necessary for renewable electricity technology companies to develop the technological innovations enabling U.S. firms to be competitive in future markets. Competitive companies working with supplier industries and academic institutions in diverse geographic regions can aid the innovation cycle.

The close manufacturer-supplier relationships in clusters help companies to learn about technological needs or developments. Clusters make opportunities for innovation more visible, and provide the capacity and the flexibility to act rapidly. Local suppliers and partners can and do get closely involved in the innovation process, thus ensuring a better match with customer requirements.[70] Clusters competing with other similar regional clusters can increase the industry's competence domestically. Clusters are particularly well-suited to connections between manufacturing and technology, especially as these are advantaged by research institutions, and

[67] Wharton School, University of Pennyslvania, *Rising Giants: Industrial Clusters Are Changing the Face of Chinese Manufacturing*, June 2009, http://knowledge.wharton.upenn.edu/article.cfm?articleid=2250.

[68] Harvard Business School, Institute for Strategy and Competitiveness, *Clusters and Cluster Development*, http://www.isc.hbs.edu/econ-clusters.htm.

[69] Michael E. Porter, *Clusters and the New Economics of Competition*, Harvard Business Review, December 1998, http://www.isc.hbs.edu/econ-clusters.htm.

[70] Ibid.

highlight the importance of a well-prepared workforce in enhancing productivity. If more green jobs is the goal, then these concepts may need to be applied to develop the renewable electricity industry. Cluster development could possibly trigger the type of innovation that can lead to the next generation of marketable renewable energy technologies resulting in opportunities for U.S. green jobs growth.

Market and Policy Challenges for Green Jobs Growth

Renewable energy resources have an unmatched potential for clean energy production, if the right technologies can be employed to harness them. U.S. national energy policy with goals for use of renewable electricity and greenhouse gas mitigation will add to efforts in the states to grow the markets for renewable energy technologies. While the growth in power generation pointed to by EIA projections speaks to the potential market for sales of equipment and systems to provide renewable energy and hence manufacturing-related green jobs, the question of where the systems and components will be designed and built is quite another issue.

International Competition

The attraction of growing markets for clean energy and technologies will likely mean increasing international competition for renewable energy technology product orders. Most of the developed economies and a number of developing countries have or are seeking to create their own renewable electricity technology manufacturing sectors, and U.S. companies are helping other countries to develop or increase these capabilities.[71] Additionally, slowing renewable energy markets in Europe have turned the attention of European companies to the U.S. market. In fact, with the growing requirements from individual state renewable energy standards (and a possible federal requirement) spurring the sales of equipment and many Gigawatt-hours of renewable electricity sales for years to come, new entrants into the market could come from a number of countries with renewable energy expertise.

Existing companies with prior experience serving renewable energy markets will likely have an advantage. European-based companies (or their subsidiaries) currently dominate the wind turbine business in the United States.[72] These companies have marketing and technical expertise honed from serving their home markets, and are setting up joint ventures with U.S. firms (which can benefit from the knowledge base of their overseas partner). In such a setting, a new entrant which is purely a U.S. enterprise likely has a competitive disadvantage.

Such limitations are amplified in instances where the entrant is effectively subsidized by a national government. For example, China is seeking to be a global leader in sales of renewable energy equipment, and in a bid to build market share, is allegedly selling solar panels in the United States at prices less than the cost of materials, assembly and shipping. [73] Chinese

[71] Tom Friedman, *Have a Nice Day*, New York Times, September 15, 2009, http://www.nytimes.com/2009/09/16/opinion/16friedman.html?_r=1&emc=eta1.

[72] Ryan Wiser and Mark Bolinger, *2008 Wind Technologies Market Report*, U.S. Department of Energy, July 2009, http://www1.eere.energy.gov/windandhydro/pdfs/46026.pdf.

[73] Keith Bradsher, "China Racing Ahead of U.S. in the Drive to Go Solar," *New York Times*, August 24, 2009. (continued...)

companies are embracing foreign direct investment as part of this strategy with plans to build U.S. assembly plants for solar panel sold in the United States to avoid protectionist legislation.[74]

Incentivizing Domestic Production

A key to maximizing U.S. green jobs growth from renewable energy is the domestic design and manufacturing of equipment and components. The more of these functions that take place in the United States, the greater the number of higher paying jobs that will likely be located here. Plants to assemble components built and designed elsewhere miss the opportunity for intellectual capacity development and learning that may result in advances in the technology. These advances may eventually result in competitive advantages throughout a supply chain or manufacturing cluster. A renewable energy industry capable of serving the export market may create many more jobs than an industry which only serves domestic needs since production would necessarily be at internationally competitive prices. This can be achieved all the easier if the domestic market has sufficient demand to bring renewables rapidly down the cost curve.[75]

Many factors and considerations may influence the decision of where to build a factory. For example, labor costs overseas can be a fraction of those in the United States.[76] If such overhead costs for manufacturing products can be reduced and reflected in the final price of a product, the resulting competitive advantage could result in increased sales. For other firms, having a technically competent, well-educated workforce may be a paramount consideration. This may ease the training process for workers with an unfamiliar product and help accelerate the process of getting plant operations online and functioning.

Given the growing international competition for renewable energy markets and green jobs, policy mechanisms and incentives may be necessary to encourage manufacturers to locate production of renewable energy products and components in the United States. Incentives are commonly used by countries (and states within countries) to give a competitive advantage to domestic manufacturers. Some of the more frequently used policy tools include financial and tax incentives, local content requirements, and quality certification requirements. Each of these policy tools can be designed to favor domestic manufacturers in varying degrees. The degree to which such incentives can be used depend to a certain extent on the size of the domestic market, a factor which may favor U.S. production.[77]

(...continued)

http://www.nytimes.com/2009/08/25/business/energy-environment/25solar.html?_r=1&em.

[74] Ibid.

[75] RAEL 2006.

[76] "Chinese wages are still less than $1 an hour, and factory workers in Vietnam earn as little as $50 a month for a 48-hour workweek, including Saturdays." Keith Bradsher, *Investors Seek Asian Options to Costly China*, New York Times, June 2008, http://www.nytimes.com/2008/06/18/business/worldbusiness/18invest.html?_r=1.

[77] Joanna Lewis and Ryan Wiser, *Fostering a Renewable Energy Technology Industry: An International Comparison of Wind Industry Policy Support Mechanisms*, Lawrence Berkeley National Laboratory, LBNL-59116, November 2005, http://eetd.lbl.gov/ea/EMS/reports/59116.pdf.

Technological Challenges, Opportunities, and Risks

Renewable electricity technologies face well-defined challenges in making the transition from niche to mainstream power generation choices. Given the raw potential of certain renewable energy resources and results from ongoing research, further R&D investment is expected to increase the efficiency and applicability of the technologies.[78] However, research efforts do not always prove successful, and competitors may be quicker to bring improvements to the market. Incremental improvements may benefit a mature product, but most renewable energy technologies are not at that stage. Real breakthroughs in efficiency and applicability would benefit especially solar and wind energy technologies. Such innovations may provide opportunities to differentiate products and lead to competitive advantages, if these are adequately financed and appropriately focused on customer and market needs.

Developing the technical manufacturing capabilities needed to build today's and future generations of renewable electricity technologies may require better educated, highly trained workers capable of operating sophisticated equipment and controlling sensitive processes. A lack of qualified workers was identified as a potential barrier to growth of the U.S. renewable energy industry and was addressed by the Energy Independence and Security Act of 2007, Title 10, with additional funds subsequently provided by ARRA for green workforce training.[79] The opportunity exists for governments and educational institutions to work together with industry to assure that workers are properly prepared in sufficient numbers to meet anticipated increases in demand for electricity production from renewable resources.

Green Jobs as a Sustained National Focus

Over the last few decades, government interest and funding of renewable energy R&D has trailed the peaks and valleys of fossil energy prices. Most of the U.S. energy research budget has been spent on fossil fuels and nuclear energy, the old mainstays of central station generation.[80] But whatever advances in fossil fuels R&D may bring, legislative proposals to mitigate climate change concerns propose to levy a price on carbon emissions which could add significant costs to any future use of fossil fuels.

Few doubt the potential of renewable energy to help address climate change concerns; the question is whether the desired benefits merit the investment. While green jobs also encompasses jobs in energy efficiency and powering vehicles, growth of green jobs is generally envisioned as coming from the future development and deployment of renewable energy technologies. Renewable energy technologies will likely be an increasing part of the U.S. energy future. But developing the next generation of renewable energy technologies and building an internationally competitive industry may require a significant and sustained national investment. Without it, the majority of the solar panels, wind turbines, and components providing the clean energy of tomorrow may continue to be designed and built by workers overseas.

[78] NREL 2009.

[79] CRS Report R40412, *Energy Provisions in the American Recovery and Reinvestment Act of 2009 (P.L. 111-5)*, coordinated by (name redacted).

[80] J. J. Dooley, *U.S. Federal Investments in Energy R&D: 1961-2008*, U.S. Department of Energy, October 2008, http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17952.pdf.

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