Part II
Employment Impacts

Opponents of strong environmental measures have time and again presented the argument that such policies would spell economic doom. Time and again, however, they have been shown to be wrong. On the contrary, three key truths are emerging:

- Economic activity and employment depend in fundamental ways on avoiding continued resource depletion and safeguarding ecosystems and ecological services.
- If action on urgent environmental problems, especially countering climate change, is not taken, many jobs could be lost to resource depletion, biodiversity loss, increasing disasters, and other disruptions.
- On the other hand, environmental policies not only protect existing jobs against these threats, but also stimulate new businesses and job creation.

The following sections of this report assess the numbers of green jobs that have already been created and are likely to be created in coming years, in six economic sectors: alternative (renewable) energy, the building sector (including appliances and office equipment), transportation, basic industry and materials recycling, food and agriculture, and forestry.

It is worth pausing for a moment to briefly consider the likely employment repercussions of not taking action. In agriculture, animal husbandry, forestry, and fisheries, jobs and livelihoods may be lost as a result of increasing drought, desertification, and climate change. Employment in the tourism industry is feeling the impacts as glaciers recede and ski areas lack snow, or as resorts in warmer zones of the planet are affected by shortages of water or the spread of contagious diseases. Jobs in the insurance sector may be endangered as companies are hard hit by rising claims—although on the other hand, there is also a rising need for experts in risk assessment and damage evaluation. Businesses and employment will suffer in the face of more-frequent and powerful storms and flooding, as buildings, production equipment, and infrastructure are damaged or destroyed. Pandemics linked to the spread of infectious diseases in a warming world could affect labor productivity. Jobs in the energy industry will be affected by countervailing trends, as warmer winters reduce the need for heating, yet hotter summers increase demand for cooling.[130]

Ideally, prevention is far preferable to remedial efforts. However, especially with regard to climate change, this is no longer an option. Scientists and environmentalists have long warned that the world needs to take action to mitigate climate change. Yet political deadlock has delayed timely and adequate responses to the point where mitigation alone is clearly insufficient. Adaptation to the consequences of climate change has become an equally pressing need.

Adaptive efforts could in coming years and decades become a major source of employment. The National Adaptation Programs of Action submitted by several (mostly African) governments to the United Nations Framework Convention on Climate Change (UNFCCC) highlight priority projects. Among others, they include protective measures against rising sea levels and storm surges, reforestation, enhancing the resilience of infrastructure and industries, information dissemination to better prepare vulnerable communities against climate disasters, flood-shelter construction,

water provision to coastal communities affected by salt water intrusion, and research into more hardy, drought-resistant and saline-tolerant crops.[131]

Community participation is critical to ensure that proposed measures are appropriate and contribute to improving livelihoods and incomes. So is the provision of adequate funding. With such funding, climate adaptation can become a source of millions of jobs and protect many millions of endangered livelihoods.

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Construction of a wind engine by workers. Germany.

1. Energy Supply Alternatives

This section analyzes the economic and employment prospects of alternative sources of energy to the dominant fossil fuel sources—oil, natural gas, and coal. Some governments and others have proposed an expansion of nuclear power as part of the solution. For the purposes of this report, nuclear power is not considered an environmentally acceptable alternative to fossil fuels, given unresolved safety, health, and environmental issues with regard to the operations of power plants and the dangerous, long-lived waste products that result. Being capital-intensive, the nuclear energy industry is also not a major employer, and is thus similarly ill-suited as a solution to the world's employment challenges. Trends in nuclear energy's development—influenced by issues such as safety and cost—contradict rosy assessments. Although it is still growing somewhat, world nuclear generating capacity has slowed down dramatically beginning in 1990 (capacity additions in the 16 years since 1990 are equivalent only to earlier additions in 1986–90).[132]

Advocates for the coal industry have similarly argued that new technologies may give this heavily polluting energy source a new lease on life. "Clean coal" is a frequently used term for efforts to reduce the carbon emissions associated with coal use. But it is a misleading name. From mining to burning coal to produce electricity, this is still an industry with calamitous environmental and health impacts. Coal mining—especially where companies blast away entire mountaintops in order to lay bare deposits of coal—is unalterably environmentally destructive. For many workers, coal mining remains a dangerous and unhealthy occupation.[133]

Still, heavy reliance on coal appears to be an unavoidable reality for a number of years. Not only are there already many coal-fired power plants in operation worldwide, but expansion is particularly rapid in China and to a lesser extent in India and the United States.[134] Representing heavy investments sunk into them, coal-fired power plants constructed today will likely be around for several decades. Thus, any climate-mitigation strategy will have to consider ways of minimizing or neutralizing carbon emissions from already existing coal plants. Carbon capture and sequestration (CCS) might be of help in this regard, though many questions remain concerning feasibility and cost. And an inherent danger of a sequestration strategy is that instead of being a pragmatic measure for dealing with carbon emissions from existing plants, it may well tempt governments, businesses, and labor unions toward an even greater commitment to coal, even though CCS is unlikely to create many jobs. This temptation is reinforced by the fact that captured CO_2, if injected into oil and gas wells, can be used to squeeze more of these resources out of the ground.

With regard to both nuclear power and coal, continued heavy investments may draw critical resources (R&D, investment capital, as well as scientists, engineers, and technicians) away from the pursuit of alternatives such as renewable energy and greater energy efficiency. A Greenpeace report notes that in its 2009 budget request, the U.S. government seeks a 26 percent increase in CCS-related programs to $624 million even as it is asking for a 27 percent cut in renewable energy and efficiency budgets to $146 million.[135] An indication of how expensive CCS projects are likely to be was provided when the U.S. government terminated its participation in the much-touted FutureGen "clean coal"/CSS public-private venture in January 2008, principally due to cost

overruns. All told, in 2007 at least 11 CCS projects were scrapped in countries including Canada, Norway, and the United Kingdom.[136]

Given troubling environmental, waste, health, and cost issues with regard to nuclear power and coal, this section focuses on a range of renewable energy sources—wind-generated electricity, solar photovoltaics (PV), solar thermal energy, biomass, geothermal energy, and hydroelectricity. It should be noted that not all fuels derived from biomass necessarily offer meaningful carbon emission advantages over fossil fuels, and some may even impose new environmental costs. A careful distinction within the biofuels sector is thus advisable. A similar word of caution is in order with regard to hydroelectricity: large-sale dams impose huge environmental costs and displace millions of people. They cannot therefore be considered an acceptable alternative. Some reports make a distinction between small- and large-scale hydro projects, but others do not.

Geothermal power.

Moving away from the current heavy reliance on fossil fuels will without doubt have negative job implications in the oil, gas, and coal industries. The section therefore first, and very briefly, addresses employment levels and trends in these industries. In a later section, the report also addresses the issue of transition assistance to workers affected by a future move away from fossil fuels.

The section then considers employment in the emerging renewables industries on the basis of available surveys, studies, and projections. It does so first by having an across-the-board look, examining evidence of currently existing jobs as well as assessing the future job-creation potential. Subsequently, the section addresses each of the major renewables sources in their own right: wind-generated electricity, solar PV, solar thermal, biofuels, geothermal, and small hydropower, with evidence from countries around the world.

In the face of rapidly growing demand for energy, an alternative supply strategy will need to combine alternative sources of supply with greater efficiency. The potential for efficiency gains in buildings, transportation, and selected industries will be addressed in subsequent sections of Part II.

Employment Trends In Extractive Industries

Extractive industries—the fossil fuel sector and other mining industries—do not employ many people. In fact, growing mechanization translates into fewer and fewer jobs with each passing year in most countries, irrespective of environmental efforts.[137] (See Table II.1-1.)

Table II.1-1. Mining Employment in Selected Countries, 1996–2006

Country	1996	2006	Change
	(thousands)		(percent)
China*	9,020	5,580	-38
Romania	241	120	-50
Ukraine**	4,390	4,037	-7
Slovakia	34	16	-52
South Africa†	603	398	-34
United States††	569	687	+21
United Kingdom§	107	103	-4
Malaysia‡	35	27	-22

Note: Includes coal and metals mining and oil and gas extraction jobs.
**Data are for the years between 1996 and 2002. **Data are for 2001 and 2006. †Data are for 2000 and 2006. ††Employment has peaked three times in 1998, 2001 and 2004. §Data are for 1997 and 2005. ‡Data are for 1996 and 2000.*
Source: See Endnote 137 for this section.

The coal industry is increasingly characterized by bigger and fewer companies, larger equipment, and less and less need for labor. The effect has been a steady decline in the number of people employed in coal mining, which accounted for less than 1 percent of the global workforce in 2002.[138] In addition, global mining and quarrying have shown an average decline of more than 20 percent in 1995–2005.[139]

- In Europe, U.K. coal production has declined steeply, and employment evaporated from 229,000 in 1981 to about 5,500 miners today.[140] (Some 4,000 former miners have found jobs retrofitting homes to make them more energy-efficient, but about 100,000 remain long-term unemployed.[141]) And in Germany, productivity gains and rising coal imports translate into a projected decline in employment from 265,000 in 1991 to less than 80,000 by 2020.[142]

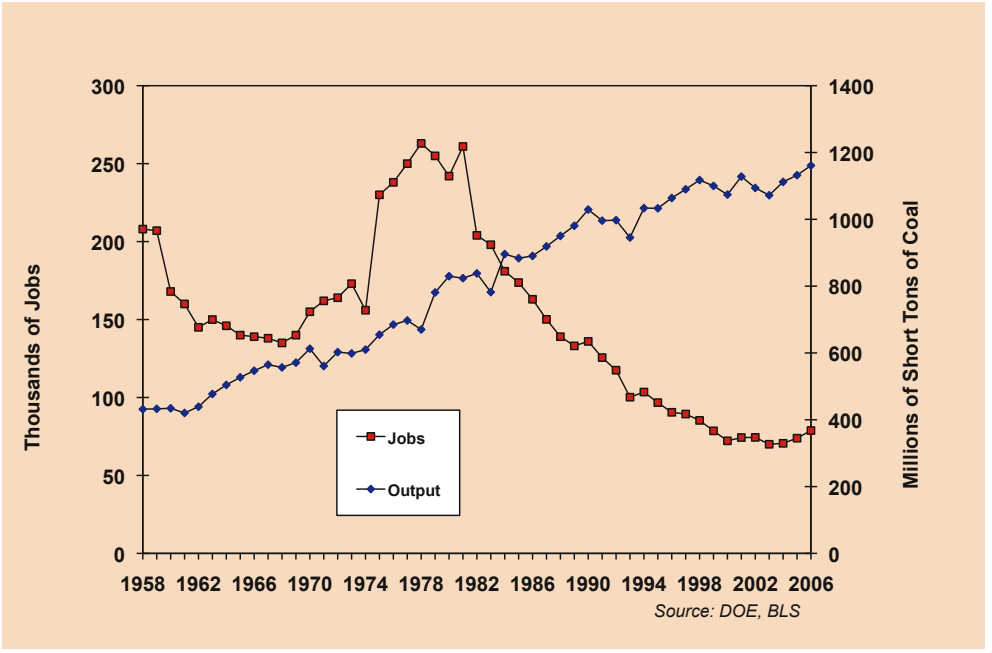
- China—the world's largest coal producer—cut some 870,000 jobs in the second half of the 1990s.[143] The growth of production has slowed in recent years, from 15 percent to 8 percent. Employment in China's quarrying and mining sectors has fallen steadily as well, with a total loss in jobs of 31 percent between 1997 and 2002.[144] But China continues to add huge capacities in coal-fired power plants—209,000 megawatts in 2006 and 2007 alone. Modern plants employ very few workers: one in southern China near the Vietnamese border needs just 270 workers for a 1,200 megawatt facility (compared with older plants that employ up to 1,000 people in a 50 or 100 megawatt facility).[145]

- In the United States, coal production rose by close to one-third during the past two decades, but mining employment was cut in half, to 79,000 in 2006. Production has shifted from more labor-intensive underground mines in the eastern United States to surface strip-mines in the West.[146] (See

Figure II.1-1) Although production is expected to continue to grow, employment is likely to decline by 23 percent through 2014 as more efficient techniques are used in extraction and processing, requiring less direct labor.[147]

- In South Africa, coal production grew by about 10 percent between 1999 and 2005, while total mining and quarrying employment declined from 603,000 to 398,000 jobs over the same period.[148]

Figure II.1-1. U.S. Coal Mining, Output and Jobs, 1958–2006



Similar trends dominate the refining and utility sectors. For example, almost 40 percent of U.S. oil-refining jobs disappeared between 1980 and 1999; another 8 percent decline occurred between 2001 and 2006.[149] In EU countries, more than 150,000 utility and gas industry jobs disappeared in the second half of the 1990s, and another 200,000 jobs—one in five—were projected to be lost by 2004.[150] By a different reckoning, the decrease in employment in Europe's electricity-generating sector is likely to have amounted to some 300,000 jobs since 1997. Market liberalization programs, privatization, and general technical progress (i.e., growing labor productivity) were the driving forces behind this development.[151]

Investment in Renewables

Growing awareness of the threat of climate change, rising prices for fossil fuels, and growing concerns over energy supply security are among the driving factors of increased interest in renewable energy sources. Global investment in renewable energy is exploding. Excluding

large-scale hydropower, it has grown from $10 billion in 1998 to $20 billion in 2003, $38 billion in 2005, more than $50 billion in 2006, and an estimated $66 billion in 2007.[152] UNEP's "Global Trends in Sustainable Energy Investment 2007" casts a somewhat wider net and puts investment in sustainable energy worldwide at $70.9 billion in 2006, with a forecast of $85 billion for 2007.[153] Although renewable energy still accounts for only 2 percent of worldwide installed power-generating capacity, it garnered 18 percent of all investment in power-generation facilities and equipment.[154]

OECD countries account for the bulk of global renewables investments (almost 82 percent in 2006, of which the European Union and the United States together had 74.1 percent), compared with 7.5 percent for China, 4.3 percent for India, 3.1 percent for Latin America, and 3.5 for all other developing countries.[155]

A variety of analysts project a continued surge in investments and sales in the coming decades. Based on a scenario developed by the European Renewable Energy Council (EREC), the German environment ministry projects that global capacities for electricity production from renewables will expand from 900 gigawatts (GW) in 2004 to 2,160 GW by 2020 and 4,070 GW by 2030, implying a rise in investments to $343 billion (€250 billion) in 2020 and $630 billion (€460 billion) in 2030.[156]

Clean Edge, a U.S.-based research and advocacy group, believes that global investment in renewables will reach more than $210 billion by 2016. Clean Edge and others forecast substantial further growth:

- Spending on wind power installations is expected to expand from $8 billion in 2003 and $17.9 billion in 2006 to $60.8 billion in 2016.
- Markets for the manufacturing and installation of solar PV modules and components will likely grow from $4.7 billion in 2003 and $15.6 billion in 2006 to $69.3 billion by 2016.
- The biofuels market reached $20.5 billion in 2006 and is projected to grow to more than $80 billion by 2016.
- The markets for fuel cells and distributed hydrogen might grow from $1.4 billion in 2006 to $15.6 billion over the next decade, according to Clean Edge; Roland Berger Strategy Consultants project a $103 billion (€75 billion) market for fuel cells by 2020.
- Geothermal power might become a $35 billion industry by 2020.
- Ocean wave power could become a $10 billion per year industry by 2012.[157]

Deutsche Bank pronounced government efforts to address climate change a "megatrend" investment opportunity. U.S. bank Morgan Stanley believes that global sales from clean energy sources like wind, solar, geothermal, and biofuels could grow to $505 billion by the year 2020, and to as much as $1 trillion by 2030. Under this scenario, Morgan Stanley thinks that solar PV could account for 11.2 percent of global electricity production in 2030 and wind for 9.6 percent, and that biofuels could account for 21 percent of transportation energy use (assuming, however, that overall demand levels are tempered via boosted fuel efficiency).[158]

A key characteristic of renewables trends in recent years is that even very optimistic projections of future growth have been met and surpassed. These are exciting developments in moving toward a more sustainable energy economy. It is interesting to note that wind power (measured in terms of cumulative installed capacity) is so far on a trajectory comparable to that of nuclear power in its initial expansion. World nuclear generating capacity rose from about 5 GW in 1965 to 71 GW in 1975. Wind capacity has expanded from 4.8 GW in 1995 to 74 GW in 2006.[159]

But there are also inherent dangers. As developments in the biofuels sector in particular suggest, a "boom time" atmosphere could potentially lead to undesirable side effects. Dramatic agricultural price increases and questionable land conversions (such as some palm oil plantations in Malaysia and Indonesia) raise the question of food-versus-fuel and global-versus-local CO_2 emissions. An overheated pace of development could lead to boom-bust cycles. And a "bandwagon" effect may bring the entry of companies, venture capital firms, and hedge funds that tend to be more attracted by profit margins than a long-term commitment to alternatives.

The Rise in Renewables Production Capacities

At present, renewables still account for relatively small shares of global fuel and electricity consumption. This means that the present high growth rates will need to be maintained for many years for alternatives to become a mainstay in the world energy economy. (This is an especially challenging task given that total consumption continues to expand: total world primary energy consumption grew 34 percent just between 1990 and 2006—oil use by 24 percent, natural gas by 44 percent, and coal by 36 percent. World demand for electricity has expanded especially fast: about 60 percent during the same period of time.[160])

To date, a small number of countries account for the bulk of renewables installations.[161] (See Table II.1-2.) In wind power, the top five countries represent 72 percent of global capacity; in grid-connected solar PV installations, the top two (Japan and Germany) account for 87 percent; in solar hot water, the top five control 91 percent (and China, the leader, alone accounts for 65 percent); in solar thermal electric installations, the United States alone has almost all the existing capacity; in fuel ethanol, the top two (United States and Brazil) produce 90 percent of global output; and in biodiesel, the top five represent 78 percent of production.[162]

Table II.1-2. Global Production Capacities for Renewable Sources of Energy, 2005 and 2006*

Energy Source	Capacity 2005	Capacity 2006	Leaders (Top 5 Countries)
Electricity Generating Capacity from Renewables *(Gigawatts)*			
Small Hydropower	66	71	China, Japan, United States, Italy, Brazil
Wind Power	59	74	Germany, Spain/United States, India, Denmark
Biomass Power	43	45	United States, Brazil, Philippines, Germany/ Sweden/Finland
Geothermal Power	9.3	9.5	United States, Philippines, Mexico, Indonesia/ Italy
Solar Photovoltaic (grid-connected)**	3.3	5.0	Germany, Japan, United States, Spain, Netherlands/Italy
Solar Thermal Electric Power	0.4	0.4	United States
Ocean (Tidal) Power	0.3	0.3	European Union
Total	182	204	
For comparison: Large Hydropower Total Electric Power Capacity	 750 4,100	 770 n.a.	*United States, China, Brazil, Canada, Japan/ Russia*
Heating Capacity from Renewables			
Solar Hot Water *(Gigawatts-thermal-GWth)*	88	102	China, Turkey, Japan, Germany, Israel
Biomass Heating *(GWth)*	n.a.	220	
Geothermal Heating *(GWth)*	25	28	
Fuels from Renewables†			
Ethanol *(Billion Liters)*	33	38	Brazil/United States, China, Spain/India
Biodiesel *(Billion Liters)*	3.9	6.0	Germany, France, Italy, United States, Czech Republic

**Cumulative production capacities.*
***An additional 0.3 and 2.7 GW of off-grid capacity was in place in 2005 and 2006, respectively.*
†Annual production.
Source: See Endnote 161 for this section.

This does not mean that alternative forms of energy have limited appeal, but it is an indication of how far ahead the global leaders currently are relative to the rest of the world. As with installed capacity, manufacturing of renewable energy equipment, facilities, and components is also relatively concentrated in a number of countries—many of the same that are leaders in installations. For the time being, most of the associated jobs are therefore being created in a limited number of countries. Countries like China and India are rapidly ratcheting up their involvement in renewables. (Over the last three years, investment in sustainable energy in India has jumped 160 percent, and it has soared 2,033 percent in China, to $6.1 billion.[163]) But to ensure timely

diffusion of renewables technologies and related job skills to additional countries, there is a need for policies and mechanisms to accelerate these processes.

Renewables' Employment Potential

This section of the report first considers job findings and estimates across the board for renewables before analyzing individual sources—wind, solar, biofuels—in more detail.

Europe's Potential

The European Union has been in the forefront of renewables development, setting ambitious targets. In coming decades, this policy can be expected to create large numbers of new jobs. A modeling exercise supported by the EU found that under current policies, there would be about 950,000 direct and indirect full-time jobs by 2010 and 1.4 million by 2020. These are "net" numbers—taking into account potential job losses in conventional energy and relating to renewables support mechanisms, which may result in lower spending elsewhere in the economy. Under an "Advanced Renewable Strategy," there could be 1.7 million net jobs by 2010 and 2.5 million by 2020. These results are actually quite conservative in the sense that they cover employment just within the smaller EU-15 (i.e., before expansion), and exclude jobs supported by renewables exports to other countries. About 60–70 percent of the jobs would be in renewables industries (primarily biofuels and biomass processing and wind power), the remainder in agriculture. An analysis by skill level indicates that skilled jobs account for about a third of net employment growth.[164]

Germany—a recognized leader in renewables development—is one of very few countries that have undertaken a detailed effort to quantify the jobs supported by this sector. The country's share of the world market for renewables production equipment and components was 17 percent in 2004.[165] In 2006, more than 70 percent of German-manufactured wind power plants in 2006 were exported.[166] Roughly every third wind turbine and solar PV cell in the world is German-made.[167]

Some 20,000 companies—many of them small and mid-size—can be found in the renewables sector, half of them in solar energy, about 5,000 in biomass, 3,500 in wind power, and 500 in the geothermal field.[168]According to detailed studies commissioned by the German environment ministry (BMU), Germany had 166,000 jobs related to renewables in 2004 and an estimated 260,000 in 2006.[169] (See Table II.1-3.) The ministry expects the share of renewables in primary energy use to grow from 4.6 percent in 2005 to 13.9 percent in 2020, requiring cumulative investments of €130 billion during the 15-year span.[170] This may bring employment in the renewables sector to roughly 400,000 jobs.[171] Roland Berger business consultants project that Germany may have 400,000 to 500,000 people employed in renewables by 2020 and 710,000 by 2030.[172]

*Table II.1-3. Employment in the Germany's Renewables Sector, 1998, 2004, and 2006**

	1998	2004	2006	Expected Growth, 2006–2010** (percent)
Wind power	16,600	63,900	82,100	6.8
Solar energy	5,400	25,100	40,200†	49
Hydropower	8,600	9,500	9,400	n.a.
Geothermal energy	1,600	1,800	4,200	74
Biomass	25,400	56,800	95,400	37
Services	10,000	n.a.	n.a.	n.a.
Subtotal	**66,600**	**157,100**	**231,300††**	**n.a.**
Research, public information, export and other marketing promotion, administration	n.a.	3,400	4,300	n.a.
Expansion of production capacities for renewable energy equipment	n.a.	5,800	23,500	n.a.
Total	**66,600**	**166,300**	**259,100**	**n.a.**

**Data include direct and indirect jobs, based on an input-output analysis. The data for the three years presented are not strictly comparable, as the underlying data collection for these estimates varies.*
***According to a poll of businesses.*
†26,900 jobs in solar PV and 13,300 in solar thermal.
††Of this figure, 139,300 jobs were in manufacturing and installations (including export sales), 41,800 in operations and maintenance, and another 50,200 in supplies of biofuels.
Source: See Endnote 169 for this section.

Other projections are similarly marked by optimism. In April 2007, the Bundesverband Erneuerbare Energien (BEE, German Federal Association for Renewable Energy) announced that it expected that some 15,000 jobs might be added in 2007 alone, and an additional 60,000 jobs by 2010.[173] Solarportal24 states that Germany's renewables sector may see its turnover grow by 17 percent in 2007, reaching $44 billion (€32 billion). This figure includes domestic investments of $16 billion (€11.7 billion), sales of $16.4 billion (€12 billion), and $11.3 billion (€8.2 billion) in export sales. By 2010, the sector hopes to see its total sales grow to $62 billion (€45.3 billion), propelled primarily by exports. An estimated 45,000 new jobs would likely be created in the process.[174]

Germany's renewables industry has been dominated by small- and medium-sized enterprises, but is now undergoing a phase of consolidation. A survey prepared with financial support from the IG Metall trade union found that although the renewable energy industry offers a rich range of job perspectives and career paths, it is also marked by high performance demands and long hours of overtime—a result of surging markets and shortages of skilled workers. While employee participation in corporate decision making among firms in the industry's supplier chain is well established, it is still less pronounced in the renewable sector itself, especially in the solar industry. About 40 percent of companies had active works councils, with a higher share among larger and older companies. But some companies have opposed the establishment of works councils or

union organizing among employees. The study notes that the booming solar industry in eastern Germany goes hand in hand with low-wage strategies. Firms in the renewables sector tend to prefer setting wage levels and work hours at the company level rather than via industry-wide collective bargaining (the exception being suppliers of wind energy companies).[175]

Spain has also seen considerable expansion of its renewables industry in recent years. An assessment conducted by Instituto Sindical de Trabajo, Ambiente y Salud (ISTAS) and the union federation Comisiones Obreras found that almost one out of three enterprises in the sector was created after 2000. Two-thirds of companies expanded their staff within the last five years.[176]

Based on an extensive survey, the study concluded that more than 1,000 enterprises in Spain's renewables industry employ 89,000 workers directly (see Table II.1-4.), and another estimated 99,000 indirectly, for a total of 188,000.[177] Employment has been growing steadily since the 1990s. The study also offers the following important findings:

- Half of the 1,000 companies operate exclusively in the renewables sector; the other half engage in business activities beyond renewables in the fields of manufacturing, engineering, installation, plumbing, air conditioning, and heating.
- Renewables firms are spread evenly throughout different regions of Spain, though with some concentration in already industrialized regions, including Madrid, Catalonia, Valencia, Basque country, and Andalusia.
- The renewables industry appears to offer greater job security (in terms of a higher share of long-term contracts) than is the case in the Spanish economy in general. However, among sub-contractors the share of temporary jobs may be higher. There is high demand for a professional workforce with higher education achievements.

Table II.1-4. Employment in Spain's Renewables Industry, 2007

Industry Segment	Direct Jobs
Wind power	32,906
Solar photovoltaics	26,449
Solar thermal (heat)	8,174
Solar thermal (electricity)	968
Biomass	4,948
Biofuel	2,419
Biogas	2,982
Small hydropower	6,661
Other (hydrogen, geothermal)	3,494
Grand Total	89,001

Source: See Endnote 177 for this section.

China

By dint of its population size and rapid economic growth, China's impact on global energy consumption looms large. To date, the country is heavily reliant on coal. But this strategy has brought about massive air pollution, threatening human health in China's cities, and is contributing a massive volume of carbon emissions. Both Chinese firms and subsidiaries of foreign companies are now quickly expanding a range of renewables. Rapidly expanding its presence in the renewables sector, China is poised to pass the current world solar and wind manufacturing leaders, perhaps as soon as within the next three years. It is already the dominant force in solar hot water and small hydropower.[178]

There are no systematic surveys or other firm statistics indicating the number of people employed in the renewables sector. However, the Energy Research Institute and the Chinese Renewable Energy Industries Association, both based in Beijing, have assembled some rough estimates. Their numbers indicate that close to a million people in China are currently employed in the wind, solar PV, solar thermal, and biomass industries. Close to two-thirds of the jobs are in the solar thermal industry.[179] (See Table II.1-5.)

Table II.1-5. Employment in China's Renewables Sector, 2007

	Wind power	Solar PV	Solar thermal	Biomass	Total
Generation	6,000	2,000	—	1,000	9,000
Manufacturing	15,000	38,000	400,000	15,000	468,000
Service	1,200	15,000	200,000	250,000	466,200
Total	**22,200**	**55,000**	**600,000**	**266,000**	**943,200**
Output Value*	25	50	40	10	125

**Output value expressed in billion yuan (1 billion yuan = $135 million).*
Source: See Endnote 179 for this section.

U.S. Assessments

A variety of studies assessing the employment potential of renewables industries have been undertaken in the United States, both on the national and state levels. For example, here are selected findings of some of the more recent reports:

- A January 2008 study by the Blue-Green Alliance (a joint effort by the Sierra Club and the United Steelworkers union) showed that a strong investment program in renewable energy could create 820,000 jobs.[180]
- A 2004 report by the Apollo Alliance estimated that a 10-year federal investment of $36 billion in biofuels and other renewables could add close to 420,000 jobs.[181]
- A 2002 study by the California Public Interest Research Group (CALPIRG) Charitable Trust suggested that current demand in California would support 5,900 megawatts (MW) of additional renewable

energy capacity by 2010 which, combined with the current 3,163 MW, would allow the state to generate up to 20 percent of its electricity needs from renewable sources by 2017. It would create 28,000 person-years of work in construction jobs and an additional 3,000 permanent operations and maintenance jobs producing 120,000 person-years of employment over a 30-year period.[182]

- A 2003 study by the Environment California Research and Policy Center determined that California's Renewable Portfolio Standard (requiring 20 percent of electricity to come from renewable sources) could create a total of some 200,000 person-years of employment, at an average annual salary of $40,000. More than a third of these jobs would be supported by export sales.[183]

- According to the Solar Initiative of New York, the development of solar electricity in the state to the tune of 2,000 MW by 2017 can support 3,000 direct installation or maintenance jobs and more than 10,000 manufacturing and integration jobs.[184]

- A 2007 analysis by the Union of Concerned Scientists (UCS) found that establishment of a national Renewable Electricity Standard—requiring 20 percent of demand to be met by renewables by 2020—would create 185,000 jobs.[185]

There is broad agreement among these studies that alternative energy creates more jobs than conventional sources do—in other words, a switch from oil, gas, or coal produces a net gain in employment.[186]

A 2007 study carried out by Roger Bezdek for the American Solar Energy Society (ASES) assesses renewables employment on a far broader and systematic basis. It finds that the U.S. renewables sector had $39 billion in revenues in 2006 and employed close to 200,000 people directly and another 246,000 indirectly.[187] (See Table II.1-6.) Assessing future prospects under three scenarios, the report says that by 2030, some 1.3 million direct and indirect jobs could be created under a "business-as-usual" scenario, 3.1 million under a moderate scenario that leads to a 15 percent share of renewables in electricity generation, and 7.9 million under an advanced scenario (nearly 30 percent of electricity generated from renewables). The latter would require strong national policies, including targets, standards, and invigorated R&D.[188]

The ASES numbers are encouraging; however, they are somewhat overstated. For instance, all hydropower is included, even though large dams are now broadly acknowledged as highly destructive. Biomass accounts for 70 percent of the jobs figures, but at least some of the biofuels operations—turning corn crops into fuel in particular—are highly problematic from an environmental point of view (see the discussion later in this report). This does not invalidate the ASES figures, although somewhat of a downward adjustment would appear to be in order. Subtracting the ethanol job figures, for instance, would leave about 290,000 jobs.

Table II.1-6. Employment in the U.S. Renewables Sector, 2006

Industry Segment	Direct Jobs	Direct and Indirect Jobs
Wind power	16,000	36,800
Solar photovoltaics	6,800	15,700
Solar thermal	800	1,900
Hydroelectric Power	8,000	19,000
Geothermal	9,000	21,000
Ethanol	67,000	154,000
Biodiesel	2,750	6,300
Biomass power	66,000	152,000
Fuel cells	4,800	11,100
Hydrogen	4,000	9,200
Total, Private Industry	185,150	427,000
Federal Government	800	1,850
DOE Laboratories	3,600	8,300
State and Local Government	2,500	5,750
Total, Government	6,900	15,870
Trade and Professional Associations, NGOs	1,500	3,450
Grand Total	**193,550**	**446,320**

Source: See Endnote 187 for this section.

Making Sense of the Findings

One problem with the array of existing studies is that they employ a wide range of methodologies, assumptions, and reporting formats, which makes a direct comparison of their job findings—or any aggregation and extrapolation—very difficult or impossible. Some reports posit that a certain percentage of future energy demand will be met by renewables; others assume a given amount of investment in renewables. The percentages, investment totals, and target dates are often different as well. Some studies focus only on a particular segment of the renewables sector, or on the prospects of a particular state or region, whereas others cast a wider net. Moreover, some reports are based on analytical models that focus on direct employment impacts and are likely to under-report total job impacts. Others are based on complex input-output models, which provide a more complete picture by including direct, indirect (i.e., supplier), and induced jobs.[189]

In a 2004 assessment of various studies, Daniel Kammen, Kamal Kapadia, and Matthias Fripp of the University of California highlight another critical issue concerning the different capacity factors of conventional versus renewable industries. They point out that "one megawatt of installed coal capacity does not produce the same amount of electricity as one megawatt of installed solar panels." A coal-fired power plant may operate 80 percent of the time (shut down the rest of the time for maintenance). In comparison, a solar PV facility may generate electricity perhaps only about 20 percent of time—when there is sufficient sunshine. Thus, to produce the same amount of electricity as a coal plant, a solar PV facility would have to have five times the peak capacity. Comparing employment effects per actual output, as opposed to nominal capacity, would mean adjusting the number of manufacturing, construction, and installation jobs accordingly. In presenting jobs per megawatt of capacity figures, some studies make this distinction but others do not, leading to great variations in findings.[190]

Reviewing findings of about a dozen studies in the United States and Europe and taking into account the methodological issues presented above, Kammen, Kapadia and Fripp conclude that in comparison with fossil fuel power plants, renewable energy generates more jobs per average megawatt of power manufactured and installed (see Table II.1-7), per unit of energy produced, and per dollar of investment.[191]The picture is more mixed with regard to jobs created in operations and maintenance and in fuel processing. Coal and natural gas-fired plants require more people to run than relatively low-maintenance wind turbines. Solar PV systems, on the other hand, are more labor intensive. With biomass plants, it depends on the way biomass collection is organized.[192]

Table II.1-7. Estimated Employment per Megawatt, Renewable and Fossil Fuel Power Plants

	Average Employment over Life of Facility (Jobs per megawatt of average capacity)		
	Manufacturing, Construction, Installation	Operations & Maintenance/ Fuel Processing	Total
Solar PV	5.76–6.21	1.20–4.80	6.96–11.01
Wind power	0.43–2.51	0.27	0.70–2.78
Biomass	0.40	0.38–2.44	0.78–2.84
Coal-fired	0.27	0.74	1.01
Natural gas-fired	0.25	0.70	0.95

Note: Based on findings from a range of studies published in 2001–04. Assumed capacity factor is 21 percent for solar PV, 35 percent for wind, 80 percent for coal, and 85 percent for biomass and natural gas.
Source: See Endnote 191 for this section.

Based on figures summarized in Table II.1-7, Kammen et al. calculate that deriving 20 percent of U.S. electricity supply by 2020 from renewables could generate between 164,000 and 188,000 jobs (depending on the specific mix of different renewables). Providing this 20-percent share of electricity with coal and gas plants would support a mere 86,000 jobs. Renewables therefore promise a clear net employment gain.[193] Still, the authors point out that the distinct occupational profiles (most employment in coal and gas-fired power plants is in fuel processing and operations and maintenance, whereas most renewables employment is in manufacturing and construction) imply a substantial employment shift, and thus implies a need for transition measures to assist those affected.[194]

Job-per-megawatt rates are of course anything but static: over time, as economies of scale increase and renewables technologies mature, the number of jobs relative to installed capacity will decrease. And the capacity factor of solar PV and wind turbines will vary as well. For instance, offshore wind turbines, with more favorable wind conditions, are expected to achieve a higher factor than onshore installations. In sunny, southern locations, solar panels will be able to produce electricity during longer stretches of time than in northern locations. And as technological advances permit electricity generation even in limited sunlight, this too will increase capacity factors, albeit slowly. These advances will vary greatly from location to location, and from country to country.

Following this general look at existing and potential jobs in the renewables sector, we will now consider developments and prospects in individual areas—principally wind, solar, and biofuels—in greater detail.

Compared with wind, solar, and biofuels, geothermal energy, and small hydropower (typically defined as projects up to 10 MW capacity) appear more limited in their potential globally, although they do play an important role in some countries. Small hydropower is particularly important in China, and geothermal power mostly in the Philippines, Indonesia, Japan, and the United States (California), but employment figures seem unavailable. The European small hydropower sector currently has been stagnant; employment (in construction and operating dams, and at turbine manufacturing companies) runs to about 20,000 people, a number that might grow to 28,000 jobs by 2020.[195] (A report on Spain claims more than 6,600 jobs in small hydropower, and more than 3,000 in geothermal.[196])

Wind Power

Global wind power capacity reached 94,100 megawatts (MW) by the end of 2007, up 27 percent from the previous year and 20 times as much as in 1995. (By April 2008, capacity topped 100,000 MW.) Germany has close to 24 percent of the world's installed capacity at 22,247 MW. The United States is now in second place (16,818 MW) followed by Spain (15,145 MW), India (8,000 MW), and China (6,050 MW). Given China's surge, the Chinese Renewable Energy Industry Association predicts that the country's wind capacity could reach 50,000 MW by 2015. More than 70 nations—from Australia to Zimbabwe—now tap the wind to produce electricity.[197]

In Europe, the market leaders are now being joined by a second wave of countries, including Austria, France, Italy, the Netherlands, Portugal, and the United Kingdom. In Asia, efforts are gathering momentum in Japan, South Korea, and Taiwan. Latin America has only seen limited development to date (Argentina's hopes to create 15,000 jobs during this decade have not been realized, for instance).[198] But the implementation of renewable energy laws and programs in a number of countries should trigger a change, and Brazil and Mexico are gaining momentum. The African continent accounts for less than half a percent of globally installed wind power generating capacity, even though it has good wind potential. Most development to date has taken place in Egypt, with the support of European government aid agencies, and Morocco is also getting some traction.[199]

Total turnover in the international wind market in 2006 was estimated at more than $18 billion (€13 billion).[200] Investments in new wind power generating equipment exceeded $20 billion in

2006 and may surpass $60 billion by 2016. The Global Wind Energy Council (GWEC) forecasts that wind capacity worldwide could reach 135,000 megawatts by 2010 and exceed 1 million MW by 2020.[201]

Employment data by industry publications vary. According to the GWEC, there were some 150,000 wind energy jobs worldwide in 2005.[202] It appears that this includes only direct jobs. Annual surveys conducted by the World Wind Energy Association (WWEA) in Bonn, Germany, concluded there were 235,000 jobs in 2005 and more than 300,000 by the end of 2006. This number includes direct and indirect employment, as well as associated fields such as technical and financial services, and marketing.[203]

© Joerg Boethling / Still Pictures
German Indian joint venture Enercon India Ltd. factory in Daman, India. Employees at factory producing rotor blades from synthetic fibre and epoxid resin for wind turbines.

Global Leaders

Europe dominates the wind power sector both in manufacturing and installations. European wind turbine manufacturers controlled about 90 percent of worldwide wind turbine sales in 1997; they still have an 80 percent market share today.[204] Although having lost market share in recent years, Denmark's Vestas remains the leading manufacturer, with 27 percent of the global market in 2006.[205] Other leading turbine manufacturers are based in Germany, Spain, the United States, and India.[206] The leading four companies controlled 73 percent of the world market in 2006.[207] With regard to installations, the European continent accounts for 66 percent of current global wind power capacity. In Denmark (20 percent), Spain (8 percent), and Germany (7 percent), wind provides a substantial share of total electricity use.[208]

Germany appears to have the most wind energy jobs. The Bundesverband Windenergie (Federal Wind Energy Association) says the number of jobs has climbed from just 1,100 in 1991 to about 70,000 in 2006.[209] As noted earlier, a study commissioned by the German environment ministry

estimated the number at about 82,000 people in 2006. And wind power compares favorably in its job-creating capacity with coal- and nuclear-generated electricity.[210]

Denmark has also long been a leader in wind development. But policy support has grown unsteady in recent years, and the number of new installations in the country has been minimal (just 30 MW of capacity was added in 2005 and 2006, whereas Germany added 4,000 MW during that time, India 3,270 MW, and China 1,850 MW). Danish employment, which grew from less than 10,000 jobs in 1996 to about 21,000 in 2002, has since stagnated at that level.[211] Denmark has been bypassed by Spain, which employs 33,000 to 35,000 people in the wind power sector.[212]

Germany and Denmark are testament to the fact that you don't have to have the best wind resources in order to become a leader in the technology to harvest energy from the wind. (Although the United Kingdom, for instance, has more favorable wind conditions than Germany, wind policy has lagged behind, and according to the U.K. government and the British Wind Energy Association, in 2005 there were only about 4,000 jobs in the sector.[213]) While jobs in turbine installations, operations, and maintenance will increasingly be created in the countries with the most favorable wind conditions, employment in manufacturing the turbines and components is not necessarily tied to these locations; rather, it will occur in those countries that provide the best support for continued wind technology development.

Domestic Content

As the environmental and economic benefits of wind power become more obvious, other countries will themselves want to undertake efforts to build a domestic wind power manufacturing base and to secure associated employment. This will be far easier for countries that already have a strong scientific and industrial base.

Currently, the United States still imports most of its turbines and blades from Europe.[214] But a 2004 study by the Renewable Energy Policy Project (REPP) in Washington, D.C., identified some 90 U.S. companies that already manufacture wind turbine components. And according to REPP, the U.S. industrial base would support a commitment to a major wind power expansion: more than 16,000 companies have the technical potential to enter the wind turbine market. The REPP study suggested that the development of 50,000 MW of capacity—about five times today's level—would likely create the full-time equivalent of 215,000 job-years of employment—some 150,000 in manufacturing, 35,000 in installation, and 30,000 in operations and maintenance.[215]

The U.S. Department of Energy's "Wind Powering America" program has set a goal of producing 5 percent of U.S. electricity from wind by 2020. DOE believes that achieving this goal would add $60 billion in capital investment in rural America, provide $1.2 billion in new income for farmers and rural landowners, and create 80,000 new jobs by that year.[216]

In its bid to build a domestic industry, Brazil has required a domestic content of 60 percent for wind equipment and construction. However, government policy has for a number of reasons failed so far to trigger the desired investment in additional manufacturing plants.[217] Brazil has now lifted the domestic content requirement.[218]

India's Suzlon is one of the world's leading wind turbine manufacturers. It has strong international operations and in early 2007 took over a leading German wind company, REpower.[219] Suzlon currently employs more than 13,000 people directly—about 10,000 in India, with the remainder in China, Belgium, and the United States.[220] India's domestic manufacturing of wind turbine components—and thus employment—is gaining strength. Some of its companies derive more than 80 percent of their components from Indian suppliers. Spare parts production and turbine maintenance are helping generate much-needed income and employment. More than half of all Indian wind installations are in the southern state of Tamil Nadu, but Maharashtra, Gujarat, Rajasthan, and Andhra Pradesh are slowly catching up.[221] Most of the turbines produced in India are currently exported, and several of the country's manufacturers are expanding their capacity to meet growing demand abroad and at home.[222]

© Joerg Boethling / Still Pictures
Wind power turbines are part of the landscape in rural India.

Foreign companies—principally Denmark's Vestas, Spain's Gamesa, and U.S. manufacturer GE—have controlled about two-thirds of China's wind turbine market in recent years.[223] But the Chinese government has encouraged the establishment of a domestic turbine manufacturing industry by requiring that 70 percent of components must be made in China and by imposing graduated import duties (3 percent for parts, 8 percent for assembled components, and 17 percent for fully assembled turbines).[224] China's four domestic turbine manufacturers, led by Goldwind, produced 29 percent of the turbines installed in the country in 2005 and 33 percent in 2006.[225] (The 2007 China Wind Power Report, however, mentions a somewhat higher domestic share—25 percent in 2004, 30 percent in 2006, and 41 percent for 2006.[226]) And the country has more than 40 other domestic firms involved in the development of turbine prototypes.[227]

A number of Chinese companies are planning a major expansion of production, seeking to leapfrog to large turbines. But quality remains a challenge; few have so far fully acquired the expertise to produce precise and reliable blades, gearboxes, and other critical parts. Although foreign products may cost more, money and time lost to breakdowns and necessary repairs erode the price difference.[228] China's wind turbine industry still confronts shortages of both experienced wind engineers and a range of components.[229]

In all countries, there are important considerations with regard to internal regional economic balance, and specifically providing economic opportunities for less-advanced regions. In order to access project sites in many provinces in Spain, for example, prospective developers are required to first commit to establishing a manufacturing base in the prospective region. This ensures job creation near areas that are rich in wind energy, such as the otherwise relatively poor province of Navarra.[230] In northern Germany, the structurally weak coastal areas have benefited from wind development. In the United States, reinvigorating the industrial "rustbelt" and providing additional income for rural communities are important considerations. Wind development could be a much-needed antidote to the loss of manufacturing jobs.[231] (See Box II.1-1.)

Box II.1-1. From Rustbelt to Windbelt

The American Wind Energy Association (AWEA) notes in its "Wind Power Outlook 2007": "New contracts for wind energy components such as towers and gearboxes create jobs across the country, even in states that do not have a large wind resource. Many rustbelt communities that have been losing manufacturing jobs now see economic opportunity returning thanks to the high demand for wind turbines."

One example is Gamesa, a Spanish company, which decided to redevelop an abandoned 20-acre (8-hectare) U.S. Steel plant in Bucks County, Pennsylvania. Three state-of-the-art turbine factories now produce high-tech blades, nacelles, and towers, employing more than 300 skilled laborers in a formerly blighted area. In Clinton, Illinois, a long-vacant freight-car plant was reconfigured to produce towers for wind turbines by Texas-based manufacturer Trinity. In Oakley, Ohio, Cast-Fab, an old metal foundry, has been transformed to churn out iron hubs and castings for wind turbines. Wind turbine manufacturers and their suppliers have set up shop in half of the 50 states across the country. Close scrutiny is needed, however, with regard to the supply chain: foreign wind companies may well rely on their existing supply chains rather than build new ones that support local or regional job creation.

In rural areas, wind energy can bring much-needed investment and jobs to isolated communities. The U.S. National Renewable Energy Laboratory reports that investment in wind power offers greater economic benefits in the form of jobs, income, and tax revenues than a fossil fuel power station would. Farmers can reap a "second crop" by setting up turbines in their fields—garnering income that helps them preserve their livelihoods. AWEA observes that this has been beneficial for Sherman County in eastern Oregon, for example—otherwise a typical "one-crop" county. There, the Klondike Wind Farm brought clean power, royalty payments to landowners, a shored-up local tax base, and 80–100 construction jobs.

According to the U.S. Government Accountability Office (GAO), wind power projects provided about $5 million in property tax revenues in 2002 to the school districts in Pecos County, Texas, one of the country's poorest counties. About 30 to 35 full-time permanent operations and maintenance jobs were created. Generally, however, areas with larger populations and a more diversified economic base can expect that more local employment will be created than in areas that are unable to meet certain occupational and skill requirements.

GAO found that while income to farmers from wind power represents only a very small fraction of total net farm income, some individual farmers and rural communities have benefited considerably. Wind lease payments may typically run from $2,000 to $5,000 per turbine per year and "generally assure farmers that they will have a relatively stable income from wind power generation for the life of the lease, which may exceed 20 years." Owning a wind turbine could double or triple the income from leasing, but may be less affordable because of upfront costs.

Source: See Endnote 231 for this section.

Future Prospects

Employment projections to 2020 for the EU-25 countries by the European Wind Energy Association (EWEA) run to 153,400 direct and indirect employees for manufacturing, 27,400 for installation, and 16,100 for maintenance—for a total of close to 200,000. These figures, however, do not include job effects of wind technology supplied to non-EU markets—which is hard to predict, but will in all likelihood be a substantial portion of European firms' wind business.[232]

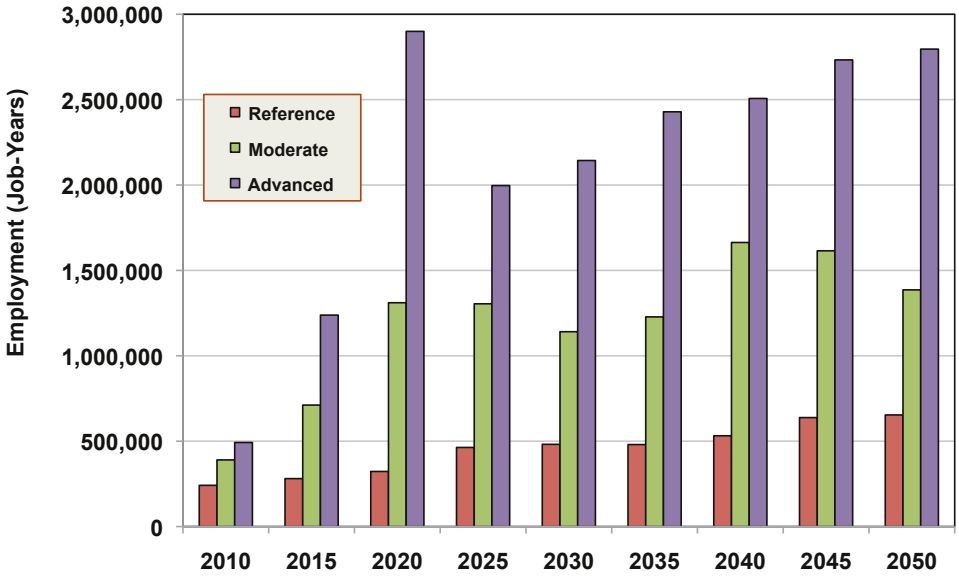
Global Wind Energy Outlook (GWEO), a study published in late 2006 by Greenpeace and the Global Wind Energy Council, outlines three scenarios for future worldwide wind energy development: a conservative "Reference" scenario based on 2004 projections by the International Energy Agency (IEA); a "Moderate" scenario that assumes that targets set for wind development by countries around the world are successfully implemented; and an "Advanced" scenario that posits more far-reaching policies in support of wind and in internalizing costs associated with traditional energy sources.

The capital costs of wind turbines have steadily fallen, but overall investment keeps growing strongly. Under its three scenarios, GWEO projects it to rise from under $16 billion (€12 billion) in 2005 to $40–153 billion (€29–112 billion) by 2050. (Under the Moderate and Advanced scenarios, annual investment actually peaks earlier, at slightly more than $100 billion (€75 billion) in 2040 and $193 billion (€141 billion) in 2020.) The study notes that while these figures may appear large, they need to be seen against the total investment in the global power industry. During the 1990s, annual investment was running at about $216–255 billion (€158–186 billion).[233]

Under the Reference scenario, cumulative capacity would grow from 59 gigawatts in 2005 to 577 GW in 2050, and production would expand from 124 Terawatt-hours (TWh) to 1,517 TWh. Under the Moderate scenario, these numbers rise to 1,557 GW capacity and 4,092 TWh output. And under the Advanced scenario, they would grow even more impressively to 3,010 GW and 7,911 Twh.[234]

The study assumes that for each megawatt of new capacity, 16 jobs will be created in turbine manufacture and supply of components. With rising economies of scale and optimized production processes, this is assumed to decline to 11 jobs per MW by 2030. (This is a global average; labor productivity in the European wind industry is higher, and will presumably remain higher, than that in countries that are just beginning to build their own industries.[235]) An additional five jobs per MW will be generated in wind farm development, installation, and indirect employment. And operations and maintenance will contribute 0.33 jobs for every megawatt of cumulative capacity. With these assumptions, the number of wind jobs is projected to grow to 481,000 in 2030 and 653,000 in 2050 under the Reference scenario; to 1.1 million and 1.4 million under the Moderate scenario; and to 2.1 million and 2.8 million under the Advanced scenario.[236](See Figure II.1-2.)

Figure II.1-2. Global Wind Power Employment Projections, 2010–2050



Source: Greenpeace and GWEC

Solar Photovoltaics

Between 2000 and 2005, the solar photovoltaics (PV) industry averaged annual growth rates of more than 40 percent—one of the fastest growing industries in the world.[237] Global sales revenues of $12 billion (€9 billion) in 2006 are projected to rise to $27.5 billion by 2012.[238] Investment in facilities to manufacture solar cells and modules is expected to total at least $5.5 billion (€4 billion) in 2007–2010, ensuring continued strong performance.[239]

Global production of PV cells rose to a record 3,733 MW in 2007—a more than 20-fold increase over 1998. Its output soaring, Europe has now overtaken Japan as the leading producer. Germany continues to dominate the installation market, with almost half the global market in 2007.[240] China and Taiwan dramatically increased their production, and China is now the second largest producer after Japan (but most of their output—90 percent in the case of China—is for export, principally to Germany and Spain). The U.S. share of global production and installations continues to fall.[241]

On the corporate side, the top 10 producers in 2006 accounted for roughly two-thirds of global production.[242] (See Table II.1-8.) Japanese and German companies are dominant, but in 2007 Germany's Q-Cells took over the number 1 spot from Japan's Sharp. China's Suntech Power has risen rapidly to become the fourth largest manufacturer.[243]

Table II.1-8. Share of Global PV Cell Production, by Geographical Area and Manufacturer, 2006

Global PV Cell Production			
Production by Country/Region		**Production by Manufacturer**	
	Share (percent)		**Share (percent)**
Japan	36.4	Sharp (Japan)	17.4
Germany	20.0	Q-Cells (Germany)	10.1
China	15.1	Kyocera (Japan)	7.2
United States	6.8	Suntech Power (China)	6.3
Taiwan	6.7	Sanyo (Japan)	6.2
Rest of Europe	8.2	Mitsubishi Electric (Japan)	4.4
India	1.4	Motech (Taiwan)	4.4
Rest of Asia	3.7	Schott Solar (Germany)	3.8
Australia	1.3	Solar World (Germany)	3.4
Middle East	0.3	BP Solar (Spain/UK)	3.4
		Top 10 combined	66.6
		Next 6 leading firms	12.3
		All Others	21.1

Source: See Endnote 242 for this section.

A "PV Roadmap" produced by the U.S. Solar Energy Industries Association (SEIA) sets a target of 9.6 GW of installed capacity by 2015, 200 GW by 2030, and 670 GW by 2050, up from 340 MW in 2004. This would dramatically accelerate the pace from SEIA's assumed "baseline" case of just 100 GW by 2050. The Roadmap suggests that employment could rise from 20,000 today to 62,000 by 2015, 260,000 by 2030, and 350,000 by 2050 (these projections are based on a jobs per MW rate that decreases at the same rate as costs are projected to decline). These numbers are far higher than the 95,000 jobs in 2050 under a business-as-usual development.[244]

A Renewable Energy Policy Project (REPP) assessment based on the U.S. PV Roadmap found that 80 percent of the jobs in 2015 would be in manufacturing, the remainder in construction and installation. According to REPP, the existing manufacturing base relevant to PV development (including sheet metal work, semiconductors, electronic equipment, and others) is substantial and widespread, with more than 10,000 U.S. companies in all 50 states. PV development can be a welcome antidote to the loss of manufacturing jobs in recent years.[245]

In China, development is particularly stormy. More than 15 major solar cell manufacturers were thought to employ over 20,000 people in 2006, though comparison with data in Table II.1-5 suggests this figure to be on the low side (and installation and maintenance add more jobs). Production and

employment look set to continue their steep rise. Solar PV cell production capacity jumped from 350 MW in 2005 to over 1,000 MW in 2006 and a projected 1,500 MW in 2007; planned additions might bring China's production capacity to as much as 4,000 MW by 2010. Actual production in 2006, at 370 MW, was far less than capacity, however.[246] Looking to the future, the China Solar PV Report 2007 projects that employment in China's PV industry could reach 100,000 by 2020 and perhaps as many as 5 million by 2050. These numbers are based on the assumption that total PV installed capacity might reach 1,000 GW (peak).[247]

Additional employment is found in the supply chain, including production of cells, modules, wafers, and silicon. A growing number of companies are joining at the lower end of the spectrum, which requires less investment and technical know-how. Relatively few companies are involved in wafers and silicon production. Several Chinese firms were expected to add production capacity totaling more than 4,000 tons during 2007 and 2008.[248] There are indications, however, that the breakneck speed with which silicon production is being pursued entails significant pollution dangers, rendering solar development less than green.[249] (See Box II.1-2.)

Box II.1-2. Polysilicon: The Dangers of Stormy Solar Development

Polysilicon is critical to the production of solar PV panels. Given global shortages, soaring world market prices, as well as generous government grants and loans, production in China is now booming with close to two-dozen companies setting up factories. Capacity is expected to rise to 80,000 to 100,000 tons, more than doubling existing global capacities. But it appears that corners are being cut, as companies try to build factories in half the time it usually takes to set up a plant.

These plants produce a highly toxic byproduct, silicon tetrachloride—at least four tons for each ton of silicon produced. Unlike facilities elsewhere, it appears that Chinese firms have only inadequately or not at all invested in equipment to recycle this hazardous substance. Some are stockpiling it in drums. Others, like Luoyang Zhonggui High-Technology Co. (a key supplier to Suntech Power poised to become China's largest silicon producer), apparently are dumping it, rendering land infertile and exposing people in surrounding communities to dangerous concentrations of chlorine and hydrochloric acid.

One reason is to keep production costs low. Shi Jun, head of a polysilicon research firm in Shanghai, estimates that it would cost about $84,500 to produce a ton in an environmentally responsible manner. Many Chinese companies are currently producing the material at $21,000 to $56,000 a ton.

Source: See Endnote 249 for this section.

As China continues to rely strongly on cheap labor, it is likely that the added capacity will further boost the number of solar jobs in the country. However, a cheap labor strategy also implies that these jobs are not well paid and that working conditions may well be precarious—a sharp reminder that green jobs are not necessarily or automatically decent jobs. Renewables development in China and elsewhere needs to place much greater emphasis on workers' needs and rights.

The European Renewable Energy Council put global PV industry employment in 2005 at more than 70,000 people. It expects the industry will create 1.9 million full-time jobs globally by 2020.[250] Solar Generation IV, a joint study by European Photovoltaics Industry Association (EPIA) and

Greenpeace International, estimated existing jobs worldwide at roughly 74,000 in 2006. Some 48,000 of these jobs are in installation and more than 14,000 in manufacturing. The remainder are in research, wholesaling, and supply.[251]

However, in light of various national employment estimates reported in this section, these numbers appear to be quite conservative. As mentioned earlier, a German government-sponsored study estimated PV employment at 26,900 jobs in 2006. But in 2007, the Bundesverband Solarwirtschaft (German solar energy association) put employment even higher—at 35,000 people, surpassing the number of jobs in the country's nuclear industry.[252] Spain follows closely behind, with more than 26,000 jobs in 2007.[253] In China, rough estimates suggest some 55,000 current jobs, and in the United States, there may be some 15,000 to 20,000 jobs. By one estimate, Japan had 9,000 PV jobs in 2005.[254] However, given Japanese companies' leading role in this industry, it seems highly implausible that employment is lower than that in the United States. Japanese firms might be expected to employ a number of people roughly equal to that of German companies. Relying on that assumption, and combining estimates for leading PV manufacturing countries, global PV employment may now come to at least 170,000. This needs to be seen as a rough order-of-magnitude estimate (one problem is that some national estimates include direct jobs only, others indirect jobs as well).

As important as leadership in PV technology is, many jobs are also created in the installation and servicing of PV systems rather than in their manufacture.[255] The technology thus holds promise for economic development and employment in many locations. In Bangladesh, microloan programs have proven successful in introducing a large number of PV household systems in rural areas and creating associated employment.[256] (See Box II.1-3.) And in Kenya, a PV assembly project has even been initiated in Kibera, a notorious slum area of Nairobi.[257] (See Box II.1-4.)

© Grameen Shakti
Solar panel on a roof in Bangladesh. Grameen Shakti project.

Box II.1-3. Solar Entrepreneurs in Bangladesh

In Bangladesh, about 70 percent of the population, mostly in rural areas, does not have access to electricity. Improving their livelihoods requires alternatives to the grid. Grameen Shakti (GS), set up in 1996 as a not-for-profit company, has installed more than 100,000 solar home systems (up from 50,000 in 2005)—one of the fastest-growing solar PV programs in the world. By 2015, GS expects to have installed 1 million solar systems. In households with these systems, women no longer have to clean kerosene lamps every evening, and families are no longer exposed to dangerous indoor pollutants.

GS emerged out of the Grameen micro-lending experience. To make solar systems available to rural communities, it put together financial packages based on installment payments that lowered costs without providing subsidies. GS emphasizes community participation by training youth and women as certified technicians and in repair and maintenance. This offers local employment and generates community acceptance and goodwill. Twenty technology centers have been set up so far.

To date, some 660 women are installing, repairing, and maintaining solar systems, as well as producing accessories; in addition, more than 600 youth have been trained. Providing business education and access to credit will help scale up the program. And in coming years, GS is planning to train more than 5,000 women in repair and maintenance, as well as instruct close to 10,000 school children in renewable energy technologies. GS is aiming to create 100,000 jobs through renewable energy and related businesses. Solar systems are helping to launch new businesses such as community TV shops, solar-charged mobile phone centers, electronic repair shops, handicrafts, and others. Existing businesses can operate at extended hours, helping to increase turnover and employment.

GS introduced a micro-utility system to help the poorest households who cannot afford a complete solar home system. Local entrepreneurs share the power generated with neighbors, who help to pay for the system. Currently, more than 10,000 micro-utility systems are operating in rural areas. In many cases, biogas plants are also shared by multiple households.

Source: See Endnote 256 for this section.

Box II.1-4. Solar PV Assembly in Kibera, Nairobi

The Kibera Community Youth Program (KCYP) initiated a simple solar photovoltaic (PV) assembly project in Kibera, Nairobi, one of the largest slums in sub-Saharan Africa. The project provides young people with employment opportunities in assembling small and affordable solar panels. The panels power radios and charge mobile phones in Kibera, but use of the solar panels made there has also spread to all parts of Kenya. In neighboring countries, numerous groups have requested training to undertake similar projects. KCYP won a World Clean Energy Award in 2007 for its pioneering work.

Kenya has one of the largest and most dynamic solar markets in the developing world. Kenya has about 10 major solar PV import companies, and an estimated 1,000–2,000 solar (non-specialist) technicians. Since the mid-1980s, more than 200,000 systems have been sold in Kenya. Private households account for three-quarters of all solar equipment sales in the country. Product quality, however, has been uneven, with Chinese brands not performing as well as brands imported from France, Britain, and Croatia.

Source: See Endnote 257 for this section.

© KCYP
Kibera Community Youth Program. Nairobi, Kenya.

Future Prospects

A 2006 report by the EPIA and Greenpeace International projected possible PV employment by 2025 to be 80,000 to 100,000 jobs in Germany, 180,000 in the United States, 430,000 in China, and 92,000 in Japan (and 300,000 by 2030). A number of countries that currently do not play a major role in PVs may also see rapidly growing employment in coming years. The report projects a combined 60,000 jobs in 2015 in Australia, Brazil, India, and Thailand, and 250,000 to 330,000 in 2025.[258] Despite excellent potential, Australia in 2004 was estimated to have only 1,155 direct PV jobs and 2,310 indirect jobs. Adequate investments could substantially raise those numbers.[259] India, Malaysia, and South Korea are currently working to attract growing PV investment.[260]

Meanwhile, the 2007 EPIA/Greenpeace International report, Solar Generation IV, projects future worldwide developments via three scenarios: a conservative "Reference" scenario based on assumptions developed by the International Energy Agency; a "Moderate" scenario assuming continued but lower level of political support for PVs; and an "Advanced" scenario positing additional support and dynamic growth. The Advanced scenario leads to a cumulative global capacity of 1,272 GW by 2030, 1,802 TWh of electricity generation, and avoidance of 1.1 billion tons in annual CO_2 emissions. For the Moderate scenario, the figures are 728 GW, 1,027 TWh, and 616 million tons of CO_2. For the Reference scenario, they are a mere 87 GW, 142 TWh, and 77 million tons of CO_2.[261]

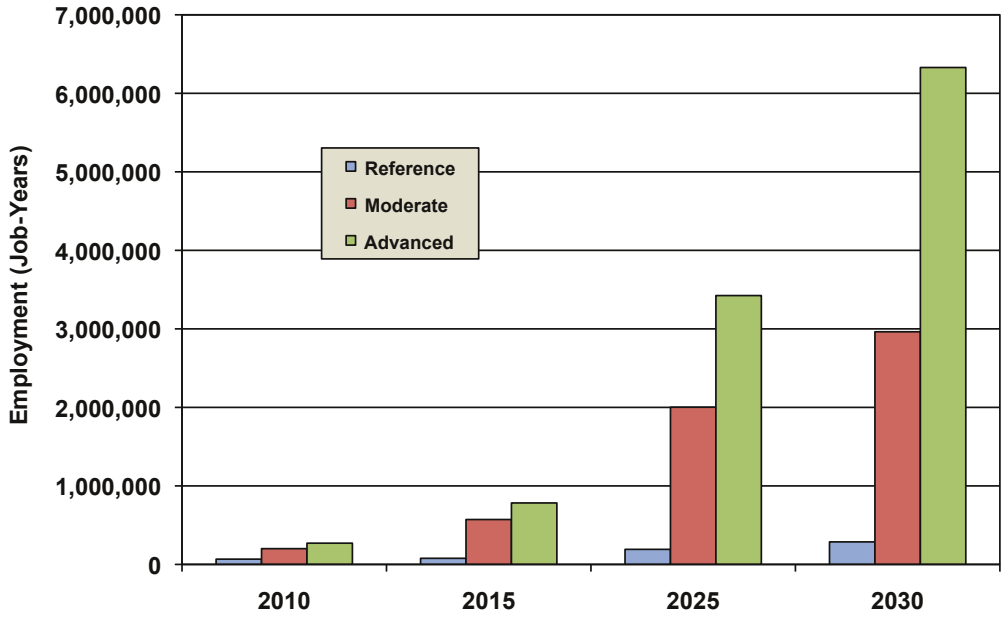
Solar Generation IV points out that much of the PV employment creation is at the point of installation (including retailers and service engineers), thus providing a boost to local economies. Based on industry data, the study assumes that a total of 50–53 jobs might be created per MW of installed capacity, with the following breakdown:

- Manufacturing: 10 jobs
- Installation: 33 jobs

- Wholesaling of systems: 3–4 jobs
- Indirect supply: 3–4 jobs
- Research: 1–2 jobs.

Especially in manufacturing, these numbers will decrease over time with greater automation.[262] EPIA and Greenpeace project that by 2030, 6.3 million, 3 million, and 287,000 jobs, respectively, could be created under the three scenarios.[263] (See Figure II.1-3.)

Figure II.1-3. Global Solar PV Employment Projections, 2010–2030



Source: EPIA and Greenpeace

Solar Thermal

China is the undisputed global leader in solar heating. Increasing its installed capacity from 35 million square meters in 2000 to 100 million square meters in 2006, it accounts for about two-thirds of the global total. More than 10 percent of all households in China use the sun to heat their water. With combined sales revenues of about $2.5 billion in 2005, more than 1,000 Chinese manufacturers employed more than 150,000 people.[264] In light of more recent estimates from the Chinese Renewable Energy Industries Association, however, it appears that this figure is either somewhat dated or otherwise incomplete. There appears to be even greater employment in installations and maintenance. Luo Zhentao, director of the Solar Thermal Energy Utilization Committee of the China Association of Rural Energy Industry, estimates that the solar water heating sector as a whole may employ as many as 600,000 people in China.[265] Clearly, these are rough estimates that require further substantiation via surveys and other efforts.

The Chinese government aims for 150 million square meters of solar water heating systems by 2010 and 300 million square meters by 2020. Some observers say China might reach 400 million square meters of installed capacity by 2020 and 800 million by 2030. Domestic production is expected to more than double, from 20 million square meters in 2006 to perhaps as much as 45 million square meters by 2020.[266]

With such developments, employment could grow substantially. China is likely to continue relying on its cheap labor, even though the currently fragmented field of manufacturers will presumably yield to fewer and larger producers with a degree of job consolidation and somewhat higher labor productivities. As mentioned earlier, this cheap labor strategy is problematic.

The Himin Group is the world's largest solar hot water manufacturer, with 50,000 employees worldwide. Himin produces principally for the domestic market, but the company has begun to target export markets. If Chinese manufacturers can master quality issues and sort out marketing and distribution questions, exports are likely to become a major aspect. Given the considerably lower cost of Chinese systems, European producers might suffer.[267]

Germany has some 19,000 people employed in this industry.[268] Within Europe, Germany leads solar thermal water heating development, accounting for 50 percent of the market in 2006—way ahead of Austria, Greece, France, and Italy.[269] Spain currently has about 9,000 jobs.[270] In 2006, the Italian solar thermal industry provided almost 2,000 full time (direct and indirect) jobs, with 3,000 jobs forecast for 2007 (assuming one full-time job per 70 kilowatts-thermal (100 square meters) installed).[271]

© T. Mohr / Still Pictures
Solar thermal collector. Font-Romeu, France.

According to the European Renewable Energy Council (EREC), employment in the European solar thermal sector currently exceeds 20,000 full-time jobs (a figure that appears highly conservative, given that the combined national estimates for Germany, Spain, and Italy alone would indicate employment of about 30,000). Given the industry's dynamic expansion, eventually—in a few decades—it might employ more than half a million people. EREC points out that nearly half the solar thermal jobs are in retail, installation, and maintenance: "These works are necessarily local, and create jobs mainly in small and medium sized enterprises, directly in the areas where the solar thermal market develops."[272]

A number of solar thermal concentrating plants are under construction or in the planning stage—typically in desert areas or other very hot locations—in Algeria, China, Egypt, Israel, Mexico, Morocco, South Africa, Spain, and the United States. Companies and their suppliers are preparing for a boom in this industry. Spanish companies seem well-placed: Abengoa and Acciona are building new plants in the U.S. states of Arizona and Nevada, respectively. Ausra, a U.S. subsidiary of Australian company Solar Heat and Power, is building a factory to make mirrors for solar thermal plants; the facility will double global capacity.[273]

Biofuels

Much of the emphasis in biomass in recent years has been on biofuels for transportation purposes. Biofuels can be produced from a variety of feedstocks—including corn, soybeans, sugar cane, palm oil, other plants, and agricultural wastes—utilizing a range of processes. A November 2007 New York Times article notes that rising world oil prices have created an incentive to examine an even broader range of methods. Both biological and chemical processes for turning corn stalks, wood chips and other logging wastes, straw, and garbage into fuel have recently attracted a flood of investment capital.[274]

World production of biofuels rose some 20 percent to an estimated 54 billion liters in 2007—accounting for 1.5 percent of the global supply of all liquid fuels. Fuel ethanol production—derived primarily from sugar or starch crops—rose to 46 billion liters, and biodiesel production—made from vegetable oils or animal fats—climbed to 8 billion liters. The United States and Brazil account for 95 percent of the world's ethanol production.[275] Germany dominates biodiesel output.[276] Brazil is so far the only country where biofuels currently account for a sizable portion of total transportation fuel use—just under 22 percent 2005.[277] In the United States, ethanol use in motor fuels grew to 6.9 billion gallons (26 billion liters) in 2007, equal to less than 5 percent of gasoline consumption.[278]

Although it was recently surpassed in output by the United States, Brazil has been a leader in ethanol development since the 1970s. In the 1990s, the government worked with farmers to help reduce sugarcane production costs and improve yields, and required a 20–25 percent ethanol share in all regular gasoline. Industry has reduced ethanol feedstock and production costs. Savings in avoided oil imports of nearly $50 billion since the 1970s exceed investments and subsidies almost by a factor of 10.[279]

Brazil currently accounts for about half of global ethanol exports. The country is planning to increase sugarcane production by 55 percent over the next six years, and much of the ethanol derived is destined for Europe and the United States. In Asia, Malaysia and Indonesia account for most of the world's palm-oil production. Although only a small share currently goes to transport fuels, the two countries aim to capture 20 percent of the European biofuel market by 2009. Other developing countries, including Tanzania and Mozambique, are similarly hoping to gain a slice of the expanding European market.[280]

Boon or Bane?

There is vigorous and contentious debate over the economic and environmental merits of biofuels, including the question of direct competition with food production. Currently, biofuels account for just 1 percent of the world's arable land, but the U.N. Food and Agriculture Organization (FAO) projects that this could increase to as much as 20 percent by 2050.[281] Following a rush by many governments, companies, and even nongovernmental organizations to embrace biofuels as a climate savior, a spate of more recent reports has begun to cast a more critical eye.

A report for the OECD Round Table on Sustainable Development cautions that, "the rush to energy crops threatens to cause food shortages and damage to biodiversity.[282] The 2007/2008 edition of the U.N. Development Programme's Human Development Report concludes that, "The expansion of plantation production has come at a high social and environmental price. Large areas of forest land traditionally used by indigenous people have been expropriated and logging companies have often used oil palm plantations as a justification for harvesting timber."[283]

A number of factors determine key outcomes such as cost, net energy and carbon balance (i.e., how the energy yield of biofuels compares with needed energy inputs), and other environmental impacts such as potential air and water pollution, deforestation, and threats to biodiversity. Among these factors are the type of land used (rainforests, woodlands, peat forests, crop-growing areas, savannahs, wetlands), choice of feedstock, type of agricultural operation (small-scale versus large monocrop plantations), and processing methods. Some feedstocks (such as sugar cane) require substantial amounts of water, while others (jatropha) take far less, and processing of energy crops may cause dangerous agrochemical runoff. Corn-based ethanol, the dominant biofuel in the United States, appears to be particularly problematic in light of its energy and carbon balance.

The complexity of circumstances produces a range of cost and benefits in pursuing biofuels projects. Environmental and human impacts also depend on such key factors as whether biofuels will be produced on large-scale plantations (that are likely to be industrialized monocultures) or smaller plots of land; whether these fuels are destined for local use or for export markets; how much influence local communities have vis-à-vis corporations and government agencies as well as how much of the income these communities can garner.

Backers of biofuels projects tend to argue that pitfalls can be minimized or avoided if the right kinds of technical and policy decisions are made. While this is undoubtedly true, there is a considerable danger that prudence will be set aside, for at least two reasons: panic and profit. One, as the world

faces a rising threat of potentially catastrophic climate change, there may well be overwhelming pressure to pursue biofuels (and other alternatives—suitable or not) at a grand scale, even if the interests of local communities have to be sacrificed in the process. Two, as the gold rush-like atmosphere of recent years' biofuels development suggests, the human needs, especially of the poor and marginalized, all too easily lose out to profit interests.

Environmental and human impacts of biofuels projects need very close scrutiny. As the brief discussion below indicates, biofuels projects clearly create employment. However, not all biofuels-related jobs can be counted as green or decent. As a matter of fact, current studies suggest that most of these jobs fail either test (and some biofuels projects entail serious costs in terms of livelihoods and food security for communities in developing countries).

Job Prospects

Biofuels development entails jobs both in the agricultural sector and in processing industries. Brazil's ethanol industry is said to employ about half a million workers. In the United States, the ethanol industry is estimated to employ between 147,000 and 200,000 people from farming to biofuels plant construction and operation.[284] Testifying before the U.S. Senate in September 2007, Daniel Kammen, director of the Renewable and Appropriate Energy Laboratory of the University of California at Berkeley, points to projections that every billion gallon of ethanol production may create 10,000 to 20,000 jobs.[285]

Other countries are also hopeful that biofuels can create a significant number of jobs:[286]

- France hopes its proposed biofuel program may generate 25,000 additional jobs by 2010.
- Spain has slightly more than 10,000 jobs (4,948 in biomass for heat generation; 2,419 in biofuels; and 2,982 in biogas).[287]
- Colombia's ethanol blending mandate may add 170,000 jobs in the sugar ethanol industry over the next several years.
- In Venezuela, an ethanol blend of 10 percent might provide 1 million jobs in the sugar cane ethanol industry by 2012.
- The World Bank estimates that a region-wide blend of ethanol—10 percent of gasoline and 5 percent of diesel—could yield between 700,000 and 1.1 million jobs in sub-Saharan Africa.
- In Nigeria, cassava and sugarcane crops might sustain a biofuels industry and create more than 200,000 jobs.[288]
- Chinese officials think that, long term, as many as 9 million jobs could be created through large-scale processing of agricultural and forestry products into fuels—some 6 million jobs in agriculture and industry for biodiesel, and 2.9 million for bioethanol.[289]
- Indonesia and Malaysia are the leading palm oil producers, and a growing share of palm oil is being diverted to biofuels production. Malaysia, the largest producer, has an estimated a half million

people employed in this sector (and another 1 million people whose livelihoods are connected to it)—many of them Indonesian migrant workers.[290] Indonesia is planning a major expansion and, according to the Singapore Institute of International Affairs, is projecting some 3.5 million new plantation jobs by 2010.[291]

The labor intensity of biofuels harvesting compares favorably with conventional fuels. On average, biofuels require about 100 times more workers per joule of energy content produced than the capital-intensive fossil fuel industry.[292] Much depends on the choice of feedstock, however—which itself is determined by local availability, yield, and overall cost. Oilseed crops in developing countries hold the most promise for job creation because they must typically be harvested manually rather than with the help of machinery. The castor oil, or momona, plant is a particularly labor-intensive crop. India is the largest producer and exporter of castor oil worldwide, followed by China and Brazil.[293] In Brazil, harvesting castor oil requires 0.3 jobs per hectare, compared with jatropha (0.25), palm (0.2), and soybeans (0.07).[294] India's National Biodiesel Program says that a jatropha farm could provide employment equal to 313 person-days per hectare in the first year of plantation and 50 person-days per hectare over the next 30–40 years.[295] Jatropha holds promise elsewhere in the world as well.[296] (See Box II.1-5.)

Box II.1-5. Jatropha Project in Mali

Beginning in 1999, the Mali Folkecenter Nyetaa embarked on a large-scale, 15-year jatropha-fueled rural electrification project in Garalo, southern Mali. The project was nominated for the 2007 Clean Energy Awards. Some 1,000 hectares of jatropha plantations will produce feedstock for a 300 kilowatt power plant providing clean energy to more than 10,000 people. Generators were installed in May 2007.

Jatropha curcus, a shrub-like oilseed plant, is not only sufficiently resilient to grow under arid conditions, but it can help restore eroded land. In Mali, the jatropha-based biofuel will replace imported diesel, immunizing the area against the economic shocks of increasing fossil fuel prices and insecurity of supply. Unlike numerous export-driven biofuel programs, the Garalo project puts local needs and livelihoods first. It has potential for building a vibrant and dynamic economy in remote villages in Mali, providing local added value, local employment, and local income generation.

The lessons learned can be useful in other developing countries—particularly elsewhere in Africa, where biofuels development can benefit the rural poor if the right kinds of policies, especially protecting and improving land rights, are adopted.

Source: See Endnote 296 for this section.

Work in biofuels processing typically requires more technical skill and thus is likely to offer better pay than feedstock production and harvesting. Brazilian workers in ethanol refining receive about 30 percent more than laborers involved in sugarcane harvesting.[297] But the number of jobs that may be created in processing is far lower than those in harvesting biofuels crops—and will vary from country to country. In the U.S. state of Iowa, instead of the hoped-for several hundred jobs, each 50 million gallon refinery has on average created only about 35 direct jobs and another 100 indirect jobs.[298]

Small-Scale versus Large-Scale

A 2007 Worldwatch Institute assessment of biofuels for the German government made it clear that biofuels can be pursued in starkly different ways: "At their best, biofuel programs can enrich farmers by helping to add value to their products. But at their worst, biofuel programs can expedite the very mechanization that is driving the world's poorest farmers off their land and into deeper poverty.[299]

Ownership of processing plants is a critical element for ensuring that biofuel revenues are retained in the local or regional economy, rather than flowing out to international investors. In the United States, farmer cooperatives controlled close to 40 percent of biofuels refining capacity at the beginning of 2006. However, this may have been the high point. Just 18 months later, their share had shrunk to 34 percent, and it is expected to decline further. The next generation of biofuels technologies may be up to five times more expensive and thus largely beyond the financial reach of cooperatives.[300]

Around the world, similar questions abound. Small-scale, labor-intensive biofuels programs can benefit small farmers and agricultural laborers and boost the fortunes of rural areas. And, as a February 2008 assessment for the International Fund for Agricultural Development (IFAD) notes: "The labour-intensive biofuel production capability of the developing world's small farmers appears to be relatively more environmentally friendly than large-scale, commercial, monocropping operations in the developing world."[301]

But a future marked by plantation-style, capital-intensive monocultures will have the opposite result. If governments back a rapid scaling-up of biofuels production, they will de facto favor large farm operators, processors, and distributors, because doing so requires more mechanized, capital-intensive operations. Already, farmers around the world are being squeezed by seed and fertilizer companies, manufacturers of tractors and other farm machinery, food processors, and middlemen. It is uncertain at best whether biofuels development can be expected to break with this dominant pattern.

A November 2007 briefing note by Oxfam International acknowledges that under the right conditions, biofuels can "offer important opportunities for poverty reduction by stimulating stagnant agricultural sectors, thus creating jobs for agricultural workers and markets for small farmers." Oxfam notes that the first biodiesel cooperative was launched in Brazil in 2005, providing improved livelihoods for around 25,000 families.[302]

But the briefing note also cautions that Brazil's sugarcane industry has historically been marked by exploitation of seasonal laborers and by the takeover of smaller-scale farms by large plantation owners, often by violent means. And increasing reliance on mechanical harvesting has translated into falling employment in the country's sugarcane sector, from 670,000 in 1992 to 450,000 in 2003.[303] By 2008, the number of sugarcane field workers was estimated at just 300,000. São Paulo state, where almost 80 percent of ethanol production takes place, is trying to improve working conditions and aiming to eliminate manual cane cutting over the next few years. Cane cutters

are increasingly facing stagnant wages and unemployment. Poorer northern states feel the repercussions in the form of reduced remittances from migrant laborers.[304]

The hugely inequitable distribution of land, wealth, and associated power in Brazil is a major problem, and the Landless Rural Workers Movement has identified biofuel expansion as "the principal enemy" of agrarian reform. A 2007 report by the Global Forest Coalition argues that "the massive inflow of investment has permitted the 'sugar barons' (a handful of very wealthy land-owning sugar producers) to consolidate and expand their control over Brazilian sugar and ethanol production in partnership with multinational agribusiness. Companies like Archer Daniels Midland, Bunge, and Cargill (which now owns the country's biggest ethanol refinery in São Paulo, along with an associated 36,000 hectares of plantation) control much of Brazil's soy production."[305]

Working conditions within the sugarcane sector in Brazil—where some 200,000 people work as harvesters—are notorious, marked by crowding, poor hygiene and nutrition, and violence by company security guards against workers. Many find themselves in a form of debt peonage that results from exorbitant charges for transportation, accommodation, and food by employers. These are not decent jobs by any stretch of the imagination.[306] In many other developing countries, plantation labor standards are also typically dismal, marked by exploitation and even forced labor.[307] (See Box II.1-6.)

Displacements and Industry Consolidation

A concerted drive to produce biofuels on a huge scale could lead to the clearance of rainforests and other critical ecosystems and to the displacement of poor communities. "Published reports show that as much as 5.6 million square kilometres of land—an area more than ten times the size of France—could be in production of biofuels within 20 years in India, Brazil, Southern Africa, and Indonesia alone."[308] The chair of the U.N. Permanent Forum on Indigenous Issues has warned that 60 million indigenous people may be driven off their land to make way for biofuel plantations.[309]

A February 2008 assessment for IFAD agrees that, "there is risk of appropriation of land by large private entities interested in the lucrative biofuels markets. The poor, who often farm under difficult conditions in remote and fragile areas and generally have little negotiating power, may be tempted to sell their land at low prices or where land is 'de jure' owned by the state (typical in most African countries) find their land allocated to large, outside investors."[310]

In Colombia, the government supports expanding land devoted to palm oil cultivation from 300,000 to 700,000 hectares over the next four years.[311] Monoculture plantations of both oil palm and sugar cane are being massively expanded in various parts of the country, including the coastal, biodiversity-rich Choco rainforest. Reports indicate that soldiers and paramilitary groups are evicting and killing people to make room for plantations. [312] A 2007 report by the London-based NGO Christian Aid charges that, "there is an increasing body of evidence that state institutions are involved in this land grab. For example, the InterAmerican Commission for Human Rights has recognized the links between Urapalma [an oil palm plantation company], the paramilitaries, and the army." Some 300,000 hectares of land are cultivated by legitimate companies, but perhaps another 100,000 hectares are controlled by companies associated with paramilitary groups that have driven farmers off their land.[313]

Box II.1-6. Exploitation of Plantation Labor

While large-scale biofuels development may generate many jobs in sugarcane and palm oil plantations, the working conditions bear close watching. Oxfam International notes that the prevailing piece-rate system leaves many Brazilian sugarcane plantation workers earning just a little more than $1 per ton and effectively discriminates against women who are unable to cut as much as men. Workers sometimes end up in debt bondage effectively amounting to slave labor. Living conditions are often squalid. The Brazilian government has been combating abuses vigorously through its labour inspection services and the labour courts.

In Indonesia, the International Labour Organization found that poverty and low income of plantation workers are common: "There are frequent reports of denial of rights at work, poor quality employment, high levels of unemployment, unsafe working conditions and lack of income security, and inadequate representation of agricultural/plantation workers in social dialogue."

Intimidation and procedural obstacles emasculate effective labor rights for plantation workers. Medan-based company PT Musim Mas accounts for 20 percent of Indonesia's palm oil exports and operates the world's largest palm oil refinery. It refused to negotiate with Kahutindo, an independent union formed in 2004, over demands that minimum labor standards be implemented and that contract workers be treated fairly at a plantation and processing plant in Pelalawan, Riau province. According to the International Union of Food, Agricultural, Hotel, Restaurant, Catering, Tobacco and Allied Workers' Associations (IUF), the company fired 701 union members in retaliation for a strike in September 2005; police and soldiers assisted the company when it forcibly expelled workers and more than 1,000 family members from plantation-estate housing and schools.

Plantation workers have few rights, especially as Indonesia and Malaysia (a dominant palm oil producer) have not signed key ILO Conventions. Indonesian migrant workers laboring on Malaysian plantations are particularly vulnerable to predatory practices and forced labor. Regulations and monitoring are also weak or non-existent when it comes to the dangerous agrochemicals that many plantation workers are exposed to.

According to Oxfam, female workers on Indonesian oil palm plantations are routinely discriminated against in the form of lower wages than those paid to male workers. Also, "women are often drawn into unpaid work in order to help their husbands meet production quotas." On Malaysian plantations, women are recruited to spray dangerous herbicides and pesticides—often without proper training and safety precautions.

Source: See Endnote 307 for this section.

Indonesia and Malaysia have ambitious plans for expanding their oil palm plantations for biofuels purposes. Yet estimates of employment by such plantations vary enormously. And a 2006 study in Sambas, West Kalimantan (Indonesia), found that some 200,000 hectares of plantation land employed just under 2,000 people, compared with more than 200,000 small farmers who found subsistence and employment on 80,000 hectares of land—almost 260 times the employment potential.[314]

And if past and present are prologue to the future, an expansion of plantations will occur largely at the expense of the livelihoods of rural communities. In West Kalimantan, for instance, more than 5 million indigenous people, whose livelihoods are tied to intact forests, are at risk of displacement by palm oil expansion.[315] Losing Ground, a February 2008 NGO investigation of the human rights

impacts in Indonesia, notes that when oil palm companies seek to acquire land, they often "hold out the promise of providing employment for local communities and indigenous peoples. However, these promises often fall short and communities are left feeling deceived when it becomes apparent that many of the jobs created are temporary since plantation establishment requires much higher labour inputs than later plantation harvesting and management and that many of the jobs created are for casual day labourers who benefit from few of the protections afforded those with contracts. Additionally, wages for contracted work are frequently at or below the minimum wage, while the minimum wage itself often does not meet government's own standards for a decent living wage."[316] It is not surprising that "the plantation sector is the most conflict-prone sector in Indonesia." Local NGO Sawit Watch reported that in 2006, more than 350 communities were involved in land conflicts over the proposed or ongoing expansion of palm oil plantations.[317]

A range of African countries, including Benin, Ethiopia, Ghana, South Africa, Tanzania, Uganda, and Zambia, are planning to convert large tracts of farmland and forests to biofuels plantations. In Tanzania, thousands of small-scale rice and corn farmers have been evicted to make room for sugarcane and jatropha plantations. A Swiss company has its eyes on some 400,000 hectares in the Wami Basin, where more than a thousand small-scale rice farmers face displacement.[318]

What will happen to those driven off their land? "Many will end up in slums in search of work, others will fall into migratory labour patterns, some will be forced to take jobs—often in precarious conditions—on the very plantations which displaced them," warns Oxfam.[319] In Ethiopia, a drive to open land to foreign biofuels investors threatens to affect the livelihoods of many of the country's subsistence farmers. Plans by Uganda's government to clear half of the Mabira Forest Reserve, located at the edge of Lake Victoria, for sugarcane plantations for ethanol were halted by protests in October 2007. Likewise, the clearing of rainforests for oil-palm plantations on Bugala and Kalangala islands in Lake Victoria spurred strong local and international opposition, bringing the project at least to a temporary stop.[320]

© Eneraldo Carneiro / Still Pictures
Burning sugarcane plantation before cutting, Brazil.

There is growing consolidation in the biofuels sectors of many countries. Brazil's sugar ethanol industry may eventually be controlled by just six or seven large milling companies, compared with about 250 today. The country's biodiesel sector is already dominated by five producers, and a single company, Dedini, has built the bulk of Brazil's ethanol distilleries and biodiesel facilities[321] In China, there are only four companies that make the specialized precision boilers that are required for biomass power plants that burn corn and cotton stalks.[322] U.S. corporate giants Archer Daniels Midland (ADM) and Cargill are planning on major roles in ethanol and biodiesel plants in the United States and Europe, in soybean oil production in Brazil, and in trans-shipment facilities in Central America and the Caribbean. In Europe, too, large producers and distributors look to dominate the lucrative downstream portion of the biofuels industry.[323]

In coming years, cellulosic biofuels, derived from wood, grasses, or the non-edible parts of plants, may hold considerable potential. They would also help minimize a food-versus-fuel tradeoff. However, they require more capital-intensive, expensive production facilities, which makes it more likely that large corporate players will dominate this new field. Indeed, Brazil's Dedini, Dow, Dupont, Shell, PetroCanada, Volkswagen, and DaimlerChrysler are all showing interest—and will likely try to garner the bulk of profits for their proprietary technologies. The outcome will determine how much benefit—jobs, livelihoods, and revenues—will ultimately accrue to farmers and local economies.[324]

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A bottle of ethanol and some of the materials ethanol can be made from at the National Renewable Energy Laboratory, operated by the US Department of Energy. Scientists are developing economical processes for making cellulosic ethanol from materials such as corn stalks, poplar, switchgrass, and other non-edible plants. Golden, Colorado.

A wild biofuels boom could come at a steep environmental and human price. The numbers of existing and projected jobs (easily 1 million now and possibly climbing to at least 10 times that much in the future) need to be interpreted carefully, and close scrutiny of environmental impacts and labor standards is required.

Much of biofuels development to date has been focused on exports to automobile-centered nations. By contrast, biomass projects that focus on the needs of communities in poorer countries are few and far between, even though the jobs and livelihoods benefits may be more pronounced.

According to a Woods Hole Research Center report, India could create some 900,000 jobs by 2025 in biomass gasification. Of this total, 300,000 jobs would be with manufacturers of gasifier stoves (including masons, metal fabricators, etc.) and 600,000 in biomass production, processing into briquettes and pellets, supply chain operations, and after-sales services. Another 150,000 people might find employment in advanced biomass cooking technologies. These numbers do not include employment generated in biomass collection and biomass plantations.[325]

In Bangladesh, Grameen Shakti plans to construct 200,000 biogas plants (with waste from cows and poultry used as feedstock) by 2012. It has so far helped to construct some 1,000 plants in two years (providing electricity and alternatives to expensive kerosene for rural households), and there is growing interest among small business owners in using biogas for electricity. Further, the organization sees potential for as many as 2 million improved cook stoves; it has already trained more than 600 local youth in making, selling, and repairing such stoves, and set up 10 manufacturing units for parts such as metal grates and chimneys.[326]

Summary

A range of findings and estimates covering individual aspects of the renewables sector has been presented above. Table II.1-9 summarizes the most salient employment figures discussed in this section. These are both global estimates and combinations of data for individual countries for which numbers are available. The table suggests that current global renewables employment runs to about 2.3 million. It should be noted that this is an incomplete figure as global figures are not available for all renewables.

The section stressed that technological leadership in developing viable renewables rests with a rather limited group of countries. Not surprisingly, some of the most advanced economies are part of this group. But developing countries play a role a well. Via their strong role in solar thermal and biomass development, China and Brazil account for a large share of the global total. And although both countries have fulfilled leadership roles in developing the technologies behind these renewable sources of energy, many of their jobs are found not in R&D or in manufacturing, but in installations, operations and maintenance, as well as in biofuel feedstocks. This suggest that other developing countries—Kenya was mentioned as one particular example in the solar field—can also hope to generate substantial numbers of jobs.

Table II.1-9. Estimated Employment in the Renewable Energy Sector, Selected Countries and World, 2006

Renewable Energy Source	World*	Selected Countries	
Wind	300,000	Germany	82,100
		United States	36,800
		Spain	35,000
		China	22,200
		Denmark	21,000
		India	10,000
Solar PV	170,000	China	55,000
		Germany	35,000
		Spain	26,449
		United States	15,700
Solar thermal	624,000-plus	China	600,000
		Germany	13,300
		Spain	9,142
		United States	1,900
Biomass	1,174,000	Brazil	500,000
		United States	312,200
		China	266,000
		Germany	95,400
		Spain	10,349
Hydropower	39,000-plus	Europe	20,000
		United States	19,000
Geothermal	25,000	United States	21,000
		Germany	4,200
Renewables, Combined	2,332,000-plus		

**Countries for which information is available.*

Given strong and rapidly rising interest in these energy alternatives, future years may well see employment soar—possibly as high as 2.1 million in wind energy and 6.3 million in solar PV by 2030, and on the order of 12 million jobs in biofuels-related agriculture and industry. Installation and maintenance of solar PV systems in particular offer tremendous job growth. With regard to the impact of biofuels development on the agriculture sector, however, there are many questions that remain to be addressed and that will determine not only the quantity of jobs, but also their quality and broad impacts on rural livelihoods and economies.

The renewables sector is a possible source of large-scale green employment, but a conducive policy environment is essential for translating this potential into full-fledged reality. Leaders in this field will naturally regard renewables as part of national competitive economic strategies. For instance, as discussed earlier, Germany views its investment in wind and solar PV as a crucial aspect of its export strategy. The intention is to retain a major slice of the world market in coming years and decades. Thus, most German jobs in these industries will depend on sales of wind turbines and solar panels abroad. This is of limited issue while few countries possess the requisite scientific and manufacturing know-how, and while the markets for wind and solar equipment are experiencing rapid growth. But over time, the interest of new entrants to the renewables sector will inevitably clash with those who seek to dominate world markets.

In the solar thermal sector, once Chinese companies overcome quality problems, they are poised to capture a major portion of the global market with their low-cost products. While this is good news for Chinese workers, it could be bad news for European workers. In other words, as these still-new industries mature, many of the difficult issues that characterize conventional industries—competitiveness, wages, trade rules, etc.—will increasingly mark the renewables sector as well.

This report has pointed out several times that green jobs and decent jobs are not necessarily one and the same, and this point is worth repeating here. Today, far more information is available about quantities of jobs than about their quality. But to make the term "green jobs" meaningful, considerations such as wages, working conditions, and workers' rights will have to become an integral aspect of future policies and strategies. Only then can we truly speak of fair and sustainable development. Governments, communities, businesses, and labor unions all have a role to play in ensuring a satisfactory outcome.