WORLDWATCH REPORT 177

Green Jobs

Working for People and the Environment

MICHAEL RENNER, SEAN SWEENEY, AND JILL KUBIT

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On the cover: Workers install solar panels on a building in Atlanta, Georgia, U.S.A.
National Renewable Energy Laboratory

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Acknowledgments

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About the Authors

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Sean Sweeney is the director of the Cornell Global Labor Institute (GLI) and is the former director of the Cornell Labor Studies program based in New York City. Sean initiated a series of conferences on "Labor and Sustainable Development," which culminated in the North American Labor Assembly on Climate Crisis: Building a Global Movement for Clean Energy in May 2007. In 2006, the GLI convened the Global Trade Union Task Force on Development Alternatives. Sweeney is also a member of the climate change working group convened by the International Trade Union Confederation. His publications cover the international labor movement, trends in global political economy, the changing industrial relations system in the United States, the growth of temporary and precarious employment, and the offshoring of production.

Jill Kubit is the assistant director of the Cornell Global Labor Institute. At the GLI, she has organized several major conferences and events on labor and sustainable development, including the U.S. trade union delegation to attend the December 2008 U.N. climate talks in Bali, Indonesia, and the North American Labor Assembly on Climate Crisis: Building a Global Movement for Clean Energy. Jill is currently working to develop policy, educational training, and concrete assistance tools for trade unions interested in climate change, green jobs, and sustainable development. She also conducts research for and manages the Global Trade Union Task Force of Development Alternatives project.

Summary

The pursuit of so-called "green jobs"—employment that contributes to protecting the environment and reducing humanity's carbon footprint—will be a key economic driver of the 21st century. "Climate-proofing" the global economy will involve large-scale investments in new technologies, equipment, buildings, and infrastructure, which will provide a major stimulus for much-needed new employment and an opportunity for retaining and transforming existing jobs.

The number of green jobs is on the rise. The renewable energy sector has seen rapid expansion in recent years, with current employment in renewables and supplier industries estimated at a conservative 2.3 million worldwide. The wind power industry employs some 300,000 people, the solar photovoltaics (PV) sector an estimated 170,000, and the solar thermal industry more than 600,000. More than 1 million jobs are found in the biofuels industry growing and processing a variety of feedstocks into ethanol and biodiesel.

Construction jobs can be greened by ensuring that new buildings meet high performance standards. And retrofitting existing buildings to make them more energy-efficient has huge job potential for construction workers, architects, energy auditors, engineers, and others. The weatherization of some 200,000 apartments in Germany created 25,000 new jobs and helped retain 116,000 existing jobs in 2002–04.

The transportation industry is a cornerstone of modern economies, but it also has the fastest-rising carbon emissions of any sector. Relatively green auto manufacturing jobs—those in manufacturing the most-efficient cars currently available—today number no more than about 250,000 out of roughly 8 million in the auto sector worldwide.

Modern rail and urban transit systems offer a greener alternative, but they need fresh commitment and investments to reverse the job erosion of recent decades. In growing numbers of cities, good jobs are being generated by the emergence of bus rapid transit systems. There are also substantial green employment opportunities in retrofitting old diesel buses to reduce air pollutants and in replacing old equipment with cleaner compressed natural gas (CNG) or hybrid-electric buses. In New Delhi, the introduction of 6,100 CNG buses by 2009 is expected to create 18,000 new jobs.

The steel, aluminum, cement, and paper industries are highly energy-intensive and polluting. But increasing scrap use, greater energy efficiency, and reliance on alternative energy sources may at least render them a pale shade of green. Worldwide, more than 40 percent of steel output and one-quarter of aluminum production is based on recycled scrap, possibly employing more than a quarter million people.

Recycling and remanufacturing jobs worldwide number many millions, but incompatible definitions and a lack of data gathering make a global tally impossible. China alone is thought to have some 10 million jobs in this sector, and the United States has more than 1 million. In developing countries, recycling is often done by informal networks of scavengers. Brazil, which boasts a high rate of aluminum recycling, relies on some 500,000 scrap collectors. Cairo's 70,000 Zabaleen recycle as much as 85 percent of the materials they collect.

Summary

Agriculture and forestry often still account for the bulk of employment and livelihoods in many developing countries. Small farms are more labor- and knowledge-intensive than agroindustrial farms are, and they use fewer energy and chemical inputs. But relatively sustainable forms of smallholder agriculture are being squeezed hard by energy- and pesticide-intensive farms and by global supply chains. Organic farming is still limited. But because it is more labor-intensive than industrialized agriculture, it can be a source of growing green employment.

Afforestation and reforestation efforts, as well as better stewardship of critical ecosystems more generally, could support livelihoods among the more than 1 billion people who depend on forests, often through non-timber forest products. Planting trees creates large numbers of jobs, although these are often seasonal and low paid. Agroforestry, which combines tree planting with traditional farming, offers significant environmental benefits in degraded areas—including carbon sequestration. Some 1.2 billion people already depend on it to some extent.

There is additional job potential in efforts to adapt to, and cope with, climate change. Building flood barriers, terracing land, and rehabilitating wetlands is labor-intensive work. Efforts to protect croplands from environmental degradation and to adapt farming to climate change by raising water efficiency, preventing erosion, planting trees, using conservation tillage, and rehabilitating degraded crop and pastureland can also support rural livelihoods.

The potential for green jobs is immense. But much of it will not materialize without massive and sustained investments in the public and private sectors. Governments need to establish a firm framework for greening all aspects of the economy, with the help of targets and mandates, business incentives, and reformed tax and subsidy policies. It will also be critical to develop innovative forms of technology transfer to spread green methods around the world at the scale and speed required to avoid full-fledged climate change. Cooperative technology development and technology-sharing programs could help expedite the process of replicating best practices.

To provide as many workers as possible with the qualifications they will increasingly need, an expansion of green education, training, and skill-building programs in a broad range of occupations is crucial. Resource extraction and energy-intensive industries are likely to feel the greatest impact in transitioning to a low-carbon future, and regions and communities highly dependent on them will need assistance in diversifying their economic base, creating alternative jobs and livelihoods, and acquiring new skills. This is known as a "just transition."

Green jobs need to be decent jobs—offering good wages and income security, safe working conditions, dignity at work, and adequate workers' rights. Sadly, this is not always the case today. Recycling work is sometimes precarious, involving serious occupational health hazards and often generating less than living wages and incomes. Growing crops at biofuels plantations in countries like Brazil, Colombia, Malaysia, and Indonesia often involves excessive workloads, poor pay, exposure to pesticides, and oppression of workers.

These cautionary aspects highlight the need for sustainable employment to be good not only for the environment but also for the people holding the jobs. Still, an economy that reconciles human aspirations with the planet's limits is eminently possible.

Defining Green Jobs

In October 2007, the online global career and recruitment service MonsterTRAK launched "GreenCareers," a service allowing both entry-level and experienced job seekers to identify environment-friendly jobs and companies. The company noted in a survey of its users that, "80 percent of young professionals are interested in securing a job that impacts the environment in a positive way, and 92 percent give preference to working for a company that is environmentally friendly."[1*]

The surging interest in the intersection of environment and employment comes at a time of profound crisis in both areas. With the rising specter of climate change, humanity faces a severe environmental emergency. Both the 2007 assessment by the Intergovernmental Panel on Climate Change (IPCC) and the widely noted *Stern Review*, which warns of the catastrophic economic consequences of climate inaction, have lent new urgency to countering what may be humanity's greatest challenge ever.[2]

Economic activity and employment depend in fundamental ways on avoiding continued resource depletion and safeguarding ecosystems and ecological services. Without timely action on urgent environmental problems, many jobs could be lost due to resource depletion, biodiversity loss, increasing natural disasters, and other disruptions.[3]

Addressing the climate challenge requires a multipronged approach, including the development of more-benign technologies, greater efficiency of energy and raw material use, altered lifestyle and consumption choices, economic restructuring, and environmental restoration efforts. It also requires adaptation to those changes that now seem inevitable and perhaps irreversible. This amounts to no less than a fundamental ecological transformation of the economy.

myclimate

Workers collect agricultural waste for a biofuel power plant in India.

At the same time, the world faces equally challenging employment problems. Global unemployment stands at roughly 6 percent, affecting some 190 million people.[4] In addition, many of the 3 billion or so people aged 15 or older who have jobs confront vulnerable employment situations. Some 487 million workers do not earn enough to rise above the $1-a-day level of extreme poverty, and an estimated 1.3 billion workers earn less than $2 a day.[5†] Many people, particularly in developing

* Endnotes are grouped by section and begin on page 44.

† All dollar amounts are expressed in U.S. dollars unless indicated otherwise.

countries, work in "informal" situations marked by very low pay, dangerous conditions, and no health insurance.

Tens of millions of young people enter the labor market each year, but not all of them secure gainful employment. In 2008, even as 40 million new jobs were being created, the International Labour Organization (ILO) projected world unemployment to grow by 5 million.[6]

Figure 1. Green and Decent Jobs? A Schematic Overview

Particularly in countries with large populations of young people, the need for jobs in coming decades will be intense; already, youth unemployment represents a major challenge for all societies. And many existing workers struggle to hold on to their jobs in the face of growing outsourcing, a steady pace of automation, and other worries about job and income safety.

The pursuit of "green jobs"—employment that contributes to preserving or restoring environmental quality and avoiding future damage to Earth's ecosystems—will be a key economic driver in the 21st century. Achieving a low-carbon global economy requires large-scale investment in new technologies, equipment, buildings, and infrastructure—which will be a major stimulus for much-needed employment.

Energy and transportation are particularly critical, as they account for a large share of greenhouse gas emissions. But all sectors—agriculture, manufacturing, and construction, as well as scientific, technical, administrative, and service activities—need to undergo a greening process. Green jobs will eventually span a wide array of skills, educational backgrounds, and occupational profiles. In many existing industries and occupations, environmental awareness and applied green literacy will become increasingly important.

Some green jobs are easily identifiable—for example, people employed in installing solar panels or operating wind turbines. Other changes that help put the economy on a more sustainable footing—such as efforts to boost the efficiency of energy, water, and materials use—also involve some degree of "green" employment. But because there is no clear threshold to define this efficiency, it can be difficult to decide which jobs are truly green. Moreover, a workplace may introduce green technologies and practices in ways that are hard to detect from the outside. Blue-collar workers may be transformed into green-collar workers fairly quietly as they respond to subtle changes in day-to-day practices and methods.

A narrow definition of green jobs might focus solely on the environmental credentials of a job. However, green jobs also need to be decent jobs—with regard to wages, career prospects, job security, occupational health and safety, and worker rights. (See Figure 1.) People's livelihoods, rights, and sense of dignity are bound up tightly with their employment; jobs need to provide equal hope for the environment and the jobholder. A job that is exploitative, harmful, or fails to pay a living wage (or worse, condemns workers to a life of poverty) is hardly reason for celebration. Decent work conditions must be as important to advocates for the environment as environmental concerns are to advocates for labor.

As the world moves toward a low-carbon, sustainable economy, those companies, countries, and regions that are leaders in green innovation, design, and technology will be more likely to retain and create new green jobs. The laggards, meanwhile, may incur substantial business and job penalties.

Green jobs may arise in different locations than the old jobs in extractive and polluting

Defining Green Jobs

industries, presenting a substantial challenge to places that depend heavily on these industries. But some cities and regions have begun to successfully reinvent themselves. Toledo, Ohio, a typical "rust-belt" city in the United States once dominated by automotive firms, has become a desirable location for solar companies. Glass manufacturers there have reoriented themselves from making car windshields to making solar panels.[7]

Resource-extractive and heavily polluting industries are likely to feel the greatest impact of the move toward sustainability. But blocking environmental action would not necessarily save jobs in these industries. Because of the rapid pace of automation and resource depletion, employment is already shrinking in many of these sectors, even as output grows. In fact, jobs are *more likely* to be at risk in industries where environmental standards are low and "clean-tech" innovation is lagging. As the urgency of sustainability rises, so does the cost of a do-nothing strategy that misses opportunities for early action.

Renewable Energy

The transition to a low-carbon economy that is less reliant on fossil fuels will undoubtedly have negative job implications for the oil, gas, and coal industries. Yet even today, the extractive industries do not employ many people. In most countries, growing mechanization in the fossil fuel and other mining sectors has meant fewer jobs with each passing year, irrespective of environmental efforts.

NREL

Maintenance worker on a wind turbine.

By contrast, renewable energy sources are enjoying rapid growth, albeit from a small base. A relatively low number of countries—among them Japan, Germany, the United States, China, Brazil, Spain, and Denmark—accounts for the bulk of renewables capacities.[1] Data suggest that at least 2.3 million people are employed in the renewable energy sector worldwide; however, global figures are not available for all renewables sources.[2] (See Table 1.) The bulk of these measurable jobs are in biomass production (mainly biofuels), followed by solar thermal, wind power, solar photovoltaics (PV), hydroelectric, and geothermal.

Several countries have reasonably good estimates of their renewables employment. Germany, for example, boasted 259,000 direct and indirect jobs in the sector in 2006.[3] The consulting firm Roland Berger projects this may grow to 400,000–500,000 jobs by 2020, and to 710,000 by 2030.[4] Spain's renewables industry employs 89,000 workers directly and an estimated 99,000 indirectly, for a total of 188,000.[5] In the United States, a 2007 study for the American Solar Energy Society found that the renewables sector earned $39 billion in revenues in 2006 and employed close to 200,000 people directly and 246,000 indirectly.[6] In China, an estimated 1 million people are employed in the wind, solar PV, solar thermal, and biomass industries.[7]

Wind Power

As of April 2008, global installed wind power capacity topped 100,000 megawatts (MW), more than 20 times the capacity in 1995.[8] Europe alone accounts for 66 percent of this capacity and dominates the sector in both manufacturing and installations.[9] The continent's turbine manufacturers controlled roughly 90 percent of worldwide sales in 1997 and still hold an 80 percent share today.[10] Globally, the leading wind turbine manufacturers are based in Denmark, Germany, Spain, the United States, and India.[11]

Renewable Energy

According to the World Wind Energy Association, there were more than 300,000 jobs in wind energy at the end of 2006. This includes direct and indirect employment as well as jobs in associated fields such as marketing and technical and financial services.[12] Germany dominates in employment, with some 82,000 direct and indirect jobs, though Spain is not far behind. In Denmark, where wind employment grew from less than 10,000 jobs in 1996 to some 21,000 in 2002, unsteady policy support in recent years has led employment to stagnate. Similarly, in the United Kingdom, where wind conditions are far more favorable than in Germany, weak policies have translated into limited wind energy development, with only some 4,000 domestic jobs.[13]

Wind development in the United States is being driven far more by state governments than by the federal government. Even though new wind installations are expanding rapidly, the country still imports most of its turbines and blades from Europe.[14]

One of the world's leading wind turbine manufacturers is India's Suzlon. The company employs more than 13,000 people directly—about 10,000 in India and the rest in China, Belgium, and the United States.[15] Spare-parts production and turbine maintenance are helping to generate much-needed income and employment in India.[16]

The Chinese government has facilitated the establishment of a domestic wind turbine industry by imposing import duties and requiring that 70 percent of turbine components be made in China.[17] The share of domestically produced turbines grew from 25 percent of installations in 2004 to 41 percent in 2006.[18] However, few Chinese companies have fully acquired the expertise to produce precise and reliable blades, gearboxes, and other critical parts.[19] China's turbine industry still confronts shortages of both experienced wind engineers and a range of components.[20]

Wind power development can provide employment opportunities in economically weak regions. Spain, for example, requires wind developers to establish a local manufacturing base to ensure job creation in wind-rich areas.[21] In northern Germany, the infrastructurally weak coastal areas have benefited from wind development. And in the United States, reinvigorating the industrial "rust belt" could be a much-needed antidote to the loss of rural manufacturing jobs.[22] (See Sidebar 1, next page.)

In a 2006 study, Greenpeace and the Global Wind Energy Council outlined three scenarios for employment from future wind energy development: a conservative "reference" scenario based on 2004 projections by the International Energy Agency (IEA), a "moderate" scenario that assumes the successful imple-

Table 1. Estimated Jobs in Renewable Energy, Selected Countries and World, 2006

Renewable Energy Source	World*	Selected Countries	
Biomass	1,174,000	Brazil	500,000
		United States	312,300
		China	266,000
		Germany	95,400
		Spain	10,349
Solar Thermal	624,000-plus	China	600,000
		Germany	13,300
		Spain	9,142
		United States	1,900
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
Hydropower	39,000-plus	Europe	20,000
		United States	19,000
Geothermal	25,000	United States	21,000
		Germany	4,200
All Renewables	2,332,000-plus		

**Countries for which information is available.*
Source: See Endnote 2 for this section.

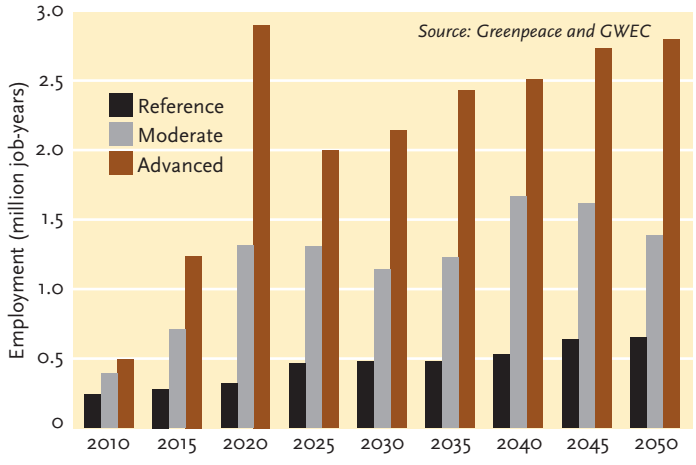
Sidebar 1. From Rustbelt to Windbelt

In 2005, the Spanish wind turbine manufacturer Gamesa redeveloped an abandoned eight-hectare U.S. Steel plant in Bucks County, Pennsylvania.* The manufacturing of blades, nacelles, and towers now employs more than 300 skilled laborers in this formerly blighted area. In Clinton, Illinois, Texas-based manufacturer Trinity reconfigured a long-vacant freight-car plant to produce towers for wind turbines. And in Oakley, Ohio, Cast-Fab, an old metal foundry, has been transformed to churn out iron hubs and castings for wind turbines.

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 from lease payments that typically run from $2,000 to $5,000 per turbine per year. For example, Sherman County in eastern Oregon—a typical "one-crop" county—has benefited from royalty payments to landowners, a shored-up local tax base, and 80–100 construction jobs.

Source: See Endnote 22 for this section.

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



mentation of current targets for wind development worldwide, and an "advanced" scenario that posits more far-reaching policy support for wind energy. Under the most optimistic scenario, the number of wind energy jobs is projected to grow to 2.8 million by 2050.[23] (See Figure 2.)

* Units of measure throughout this report are metric unless common usage dictates otherwise.

Solar Photovoltaics

Global production of solar photovoltaic cells reached a record 3,733 MW in 2007, a more than 20-fold increase over 1998.[24] Japan is the leading producer, and in 2007 China overtook Germany to become the second largest producer.[25] Roughly 90 percent of China's PV production is for export, principally to Germany and Spain.[26] Germany continues to dominate in PV installations, with nearly half the global market in 2007.[27]

Job figures for Germany put direct and indirect PV employment at 26,900 in 2006 and 35,000 in 2007.[28] Japan had an estimated 9,000 PV jobs in 2005, though this figure seems implausibly low given the country's leading role in this industry.[29] The true number is likely similar to Germany's.

In China, rough estimates indicate some 55,000 current jobs in the PV sector.[30] One study projects that employment could reach 100,000 by 2020 and perhaps 5 million by 2050.[31] But there are concerns about how well these jobs pay. The breakneck speed of solar development also entails significant pollution dangers. One key silicon supplier, Luoyang Zhonggui High-Technology Co., has reportedly dumped toxic byproducts, rendering land infertile and exposing communities to dangerous concentrations of chlorine and hydrochloric acid.[32]

Based on a rough estimate, global employment in solar PV manufacturing may come to at least 170,000. Several countries that currently do not play a major role in solar PV may see rapidly growing employment in coming years, including Australia, Brazil, India, Malaysia, South Korea, and Thailand.[33] While solar cell production is concentrated in a handful of countries, employment in retailing, installing, and servicing solar panels offers considerable promise for communities around the world. In Kenya, where more than 200,000 solar systems have been sold since the mid-1980s, a successful PV assembly project initiated in the Nairobi slum of Kibera provides young people with new employment opportunities. Kenya has one of the largest and most dynamic solar markets in the developing world, with about 10 major PV import compa-

nies and an estimated 1,000–2,000 solar (non-specialist) technicians.[34] Similarly, microloan programs in Bangladesh have proven successful in bringing PV household systems and associated jobs to rural areas.[35] (See Sidebar 2.)

In a 2007 report, the European Photovoltaic Industry Association and Greenpeace International projected future employment in solar PV using three scenarios: a conservative "reference" scenario based on IEA assumptions, a "moderate" scenario assuming continued but low-level political support for PV, and an "advanced" scenario positing additional policy support and dynamic growth. The study concluded that, under the best scenario, as many as 6.3 million jobs could be created by 2030.[36] (See Figure 3.)

Solar Thermal

China is the undisputed global leader in solar heating, accounting for some two-thirds of global installed capacity. More than 10 percent of households in China now use the sun to heat their water.[37] Luo Zhentao, director of the Solar Thermal Energy Utilization Committee of the China Association of Rural Energy Industry, estimates that the country's solar water heating sector may employ as many as 600,000 people.[38]

The outlook is for continued rapid expansion. According to estimates, China might reach 400 million square meters of installed capacity by 2020 and 800 million by 2030—up from only 100 million in 2006. Domestic production is expected to more than double by 2020.[39] With such developments, employment could grow substantially, though the currently fragmented field of manufacturers will presumably yield to fewer and larger producers, resulting in job consolidation and somewhat higher labor productivities.[40]

The European Renewable Energy Council (EREC) estimates employment in the European solar thermal sector at more than 20,000 full-time jobs.[41] But this appears to be highly conservative. Within Europe, Germany accounted for 50 percent of the solar hot water market in 2006.[42] Estimates of German employment have risen from 12,500 to 19,000 people, while Spain has about 9,000 jobs.[43] The Italian solar thermal industry provided nearly 2,000 full-time (direct and indirect) jobs in 2006, with 3,000 estimated for 2007.[44]

Based on these figures alone, a more realistic European figure might be in excess of 30,000 jobs. EREC projects that European

Sidebar 2. Solar Entrepreneurs in Bangladesh

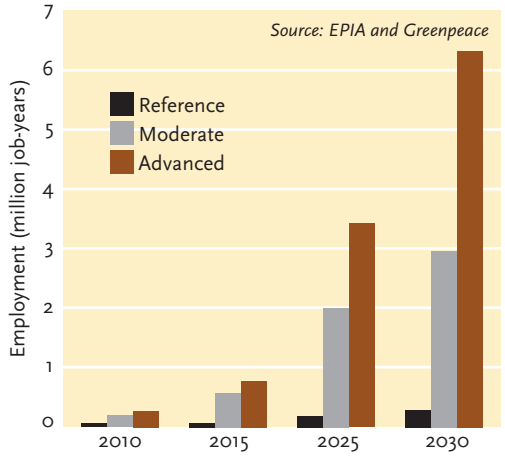
In Bangladesh, the not-for-profit company Grameen Shakti (GS) has installed more than 100,000 solar home systems since 1996. With one of the fastest-growing solar PV programs in the world, the company hopes to reach 1 million households by 2015. In homes with solar systems, women no longer have to clean kerosene lamps every evening, and families are no longer exposed to dangerous indoor pollutants.

GS emerged out of the Grameen Bank micro-lending experience. To make solar systems affordable to rural communities, the company puts together financial packages based on installment payments. GS emphasizes community participation by training youth and women as certified technicians and in repair and maintenance. To date, some 660 women are installing, repairing, and maintaining solar systems, as well as producing accessories; more than 600 youth have also been trained.

In the coming years, GS aims to create 100,000 jobs through renewable energy and related businesses. The solar systems are helping to launch new businesses such as community TV shops, solar-charged mobile phone centers, electronic repair shops, and handicrafts. Existing businesses, meanwhile, are able to operate at extended hours, helping to increase sales and employment.

Source: See Endnote 35 for this section.

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



employment might grow to more than half a million people over the next several decades. Nearly half the current solar thermal jobs are in retail, installation, and maintenance—positions that are held mainly in smaller companies located where the solar thermal market develops.[45]

Courtesy Grameen Shakti

A solar power kit being delivered in rural India.

Biofuels

World production of biofuels increased some 20 percent in 2007, to an estimated 54 billion liters. The fuels, produced mainly from corn, soybeans, sugar cane, and palm oil, account for roughly 1.5 percent of the global liquid fuel supply. The United States and Brazil together produce 95 percent of the world's ethanol, providing massive subsidies for this activity, while Germany dominates biodiesel output.[46]

Vigorous debate has raged over the economic and environmental merits of biofuels, including whether these fuels compete directly with food production and contribute to rising food prices.[47] A variety of factors—among them the type of land used, choice of feedstock, type of agricultural operation, and processing methods—have a bearing on the cost, net energy use, carbon balance, and environmental impacts associated with biofuels, such as potential air and water pollution, deforestation, and threats to biodiversity.

Biofuels development entails jobs in both feedstock production and fuel processing. In Brazil, increasing reliance on mechanical harvesting has translated into falling employment in sugarcane cutting, from 670,000 in 1992 to just 300,000 in 2008.[48] Cane cutters increasingly face stagnant wages and unemployment.[49] In many developing countries, sugarcane and palm oil plantation labor standards are typically dismal.[50] Biofuel processing jobs require more technical skill and are likely to offer better pay, though there are fewer of them.[51]

In the United States, the biofuels and biomass sector employed an estimated 313,000 people in 2006, including in supplier industries.[52] China is believed to have some 266,000 people working in biomass, Germany about 95,000, and Spain slightly more than 10,000.[53] Other countries, including France, Colombia, Indonesia, Malaysia, Venezuela, Nigeria, and other sub-Saharan African nations, are also hopeful that biofuels can create a significant number of jobs over the next several years.[54]

Small-scale, labor-intensive biofuels programs can in principle benefit small farmers and agricultural laborers in rural areas. For example, Brazil's first biodiesel cooperative, launched in 2005, improved the livelihoods of some 25,000 families.[55] But ambitious production targets are more likely to lead to capital-intensive monocultures that favor large operators, processors, and distributors. Control of distilleries and other facilities is being consolidated in many countries.[56]

A concerted drive to produce biofuels on a large scale could lead to widespread clearance of critical ecosystems and to the displacement of poor communities.[57] In Colombia, as monoculture plantations of oil palm and sugar cane expand into the biodiversity-rich Choco forest and elsewhere, soldiers and paramilitary groups are reportedly evicting and killing people to make room for these crops.[58] Similarly, in Indonesia's West Kalimantan province, more than 5 million indigenous people whose livelihoods are tied to intact forests risk displacement by oil palm expansion.[59] Sawit Watch, an Indonesian NGO, reported that in 2006, more than 350 communities were involved in land

conflicts over the proposed or ongoing expansion of oil palm plantations.[60] Similar clashes have occurred in Tanzania and Uganda.[61]

Much of the biofuels development to date has focused on exports to automobile-centered nations. But these fuels have far greater potential. In southern Mali, the Folkecenter Nyetaa embarked on a large-scale, 15-year jatropha-fueled rural electrification project that will substitute for imported diesel and provide clean energy to more than 10,000 people.[62] In Bangladesh, Grameen Shakti plans to construct 200,000 biogas plants (using waste from cows and poultry 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.[63]

According to a Woods Hole Research Center report, India could create some 900,000 jobs in biomass gasification by 2025. Of these, 300,000 would be with manufacturers of gasifier stoves (including masons, metal fabricators, etc.) and 600,000 in biomass 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 jobs generated in biomass collection and on biomass plantations.[64]

Buildings

Worldwide, buildings use an estimated 30–40 percent of all energy.[1] This includes not just the energy required to operate these structures, but also the stored or embodied energy it takes to produce the building materials (steel, tile, glass, carpeting, etc) and the energy used to transport the materials to construction sites. According to the Intergovernmental Panel on Climate Change (IPCC), buildings have the single largest potential of any sector for reducing greenhouse gas emissions, with cuts of 29 percent by 2020 possible.[2]

In developing countries such as India and China, where urbanization and expansion of the middle class are occurring rapidly, building-related emissions and energy use are projected to increase dramatically. More than 50 percent of new building construction worldwide now takes place in Asia, mainly in China. Over the next two decades, 300 million Chinese are projected to move into urban centers, and China alone will add 2 billion square meters of new construction each year, doubling its building stock by 2020.[3]

Investments in "green" or high-performance buildings can drastically reduce emissions, materials, and water use and have the potential to reduce energy use by 80 percent or more. Measures include integrating efficient heating, cooling, lighting, and water systems; using passive solar and other alternative energy sources; retaining energy through efficient insulation and windows and thermal mass; and using recycled, reused, or low-energy building materials. Yet green building remains a niche market—in part because of high upfront costs, but also because the cost is often perceived to be higher than the evidence indicates.[4] Other barriers include short-term profit motives over long-term savings, fragmentation within the building sector, lack of education and available resources, and an absence of mandatory standards.[5]

Green building offers tremendous potential for green jobs. The building and construction sector currently employs more than 111 million people worldwide.[6] In the United States alone, the Apollo Alliance projects that investing in high-performance buildings (retrofitting as well as new construction) could result in the creation of 827,260 jobs. This would require $89.9 billion in investments, tax incentives, R&D outlays, and promotion of new building codes and standards.[7]

Eleven countries—accounting for half of all new construction worldwide—are members of the World Green Building Council, and dozens more are in the process of forming national councils or adopting certification standards.[8*] Established green building standards include LEED (in the United States, Canada, and India), BREEAM (United Kingdom), Green Star (Australia and New Zealand), and Passivhaus (Australia, Germany, and the United Kingdom).[9] There are currently more than 40,000 LEED-accredited professionals involved in green building design, construction, operations, or maintenance in the United States; 1,500 LEED-accredited professionals in India;

* Members are: Australia, Brazil, Canada, India, Japan, Korea, Mexico, New Zealand, the Philippines, Taiwan, the United Arab Emirates, the United Kingdom, and the United States.

Buildings

1,197 BREEAM-licensed assessors in the United Kingdom; and 900 Green Star professionals in Australia.[10] These numbers will likely keep rising as green building takes over a larger share of the construction market.

According to the IPCC, the largest potential within the building sector for reducing greenhouse gases by 2030 is in retrofitting and replacing equipment.[11] Retrofitting provides work for auditors, engineers, estimators, and project managers, as well as jobs in the construction trades (pipe fitters, sheet metal workers, HVAC technicians, engineers, electricians, etc.).[12] The Clinton Climate Initiative's Energy Efficiency Building Retrofit Program, active in 16 of the world's largest cities, is providing $5 billion for retrofitting municipal buildings and also offers incentives for private owners to retrofit existing buildings. The related C40 Large Cities Climate Leadership Group provides support for energy-efficiency programs in 40 megacities worldwide.[13]

The most ambitious retrofitting project to-date was initiated by the German Alliance for Work and the Environment. From 2001–06, an estimated $5.2 billion (€3.8 billion) of public subsidies stimulated close to $20.9 billion (€15.2 billion) in investment and resulted in 342,000 apartment retrofits (insulation, advanced heating technologies and controlled air ventilation systems, and PV or solar thermal systems).[14] By 2004, 25,000 full-time equivalent (FTE) additional jobs had been generated and another 116,000 were saved, even as recession hit the construction sector. The German government increased funding for the retrofit program in 2005 to almost $2 billion (€1.4 billion) per year.[15] For every $1.4 billion (€1 billion) invested in the program, 25,000 additional jobs are expected.[16] In 2006, an estimated 145,000 additional FTE jobs were created.

Several studies document the job-creation potential of retrofits elsewhere:

- The European Trade Union Confederation reports that it would cost $4,300 billion (€3,145 billion) to retrofit the EU's residential building sector so as to reduce carbon dioxide emissions by 75 percent. Implementing such policies would lead to 1.4 million FTE jobs by 2050, and 2.6 million by 2030 (if carried out over a more compressed time frame).[17]
- A 2005 Ecofys study of the 10 EU new member states—Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia—projected 50,000 to 185,000 jobs by retrofitting the existing residential building stock.[18]

Courtesy Ecofutures Building, Inc.

Energy-saving structural insulated panels (SIPs) being installed as the roof of a residential addition in Boulder, Colorado.

- The Canadian government estimates that implementing a retrofitting program on a national scale would result in 5,600–7,840 person-years of employment. That represents 20 jobs for every $1 million invested, or 1 job for every $50,000.[19]

Both new green construction and retrofitting are likely to stimulate jobs in the manufacturing of green building components and systems, including efficient lighting, HVAC, waste, water filtration, insulation systems, alternative energy sources, and energy-efficient appliances. Producing energy-efficient appliances requires more skilled labor than manufacturing inefficient ones.[20] The U.S. Department of Energy predicts that standards for clothes washers, water heaters, and fluorescent lamp ballasts will create 120,000 jobs in the United States through 2020.[21] The Apollo

Alliance estimates that an investment of $3.5 billion to modernize appliance standards would result in 29,876 jobs.[22]

Lighting is one of the lowest hanging fruits for energy efficiency because the transition can occur at relatively low cost with existing technology and provides immediate results. From 1995 to 1998, Mexico carried out the first large-scale energy-efficiency lighting program in a developing country, replacing old lighting with 1 million compact fluorescent bulbs (CFLs) in households. The ILUMEX program generated jobs and provided training opportunities for indigenous people. Smaller programs have also been implemented in Belize, Bolivia, Brazil, Costa Rica, Cuba, Ecuador, Peru, and Venezuela.[23]

Victoria Baxter

Traditional lamp shade in Mexico, with a compact fluorescent installed.

Manufacturers of CFLs and LEDs (light-emitting diodes) are likely to see tremendous growth in these areas. The three major multinationals that have traditionally dominated the incandescent lighting market—Philips, GE, and Siemens' Osram Sylvania—are anticipating a switch away from incandescent lights to more efficient ones. Philips and Sylvania already lead the LED market, with a 50 percent share.[24] In the photonics industry, which has five major markets (one of which is LED lighting and displays), the estimated number of jobs in the EU is expected to grow from 500,000 in 2003 to 1.5 million in 2010.

Energy-efficiency measures in the building sector remain underutilized, however. The sheer number of buildings that need to be retrofitted is staggering. Although exact figures are unknown, it is easy to imagine that a worldwide transition to energy-efficient buildings could create millions or even tens of millions of jobs and would green much of the existing employment in the building sector.

Transportation

The transportation sector is a cornerstone of modern economies and an important source of jobs. It is also very resource intensive. As of 2004, transportation claimed 26 percent of world energy use and was responsible for 23 percent of energy-related greenhouse gas emissions.[1] The sector's carbon emissions are projected to rise more than 30 percent by 2010 (relative to 1990 levels)—the fastest increase of any economic sector.[2] Aviation plays a significant role in this growth; even though new aircraft today are 60–70 percent more fuel-efficient than those designed 40 years ago, the rapid expansion in the industry is expected to outweigh any current efficiency improvements.[3]

Road transport accounts for 74 percent of transport-related carbon dioxide (CO_2) emissions and for the majority of transportation jobs.[4] Measures to reduce the sector's environmental footprint range from relatively narrow technical changes to broad, systemic solutions. Greater fuel economy, for example, is a critical component because it translates directly into reduced CO_2 emissions. It can also help to reduce a vehicle's air pollutants, although fuel economy and low emissions do not always go hand in hand.[5]

Hybrid vehicles are one path to achieving higher fuel efficiency. In 2007, some 541,000 hybrids were produced worldwide, representing 0.7 percent of passenger vehicle production.[6] Because hybrids contain an electric engine in addition to a conventional gasoline motor (plus a battery to power the extra motor), their production entails more employment than a regular car. The development of hybrids and plug-in electric vehicles will likely be a boon for manufacturers of nickel metal hydride and lithium ion batteries, with associated employment gains.[7] (It must be noted, however, that auto companies are increasingly introducing so-called "muscle hybrids" that are designed more to boost acceleration and horsepower than to improve fuel economy.[8])

Courtesy Better Place

A Better Place protype electric car. Better Place and Renault-Nissan plan to deploy hundreds of test cars, thousands of charge spots, and several battery-swap stations in Israel by late 2009.

Diesel engines, popular in many European countries, typically consume 30 percent less fuel than gasoline engines and emit 25 percent less CO_2.[9] The consulting firm J.D. Power and Associates projects that global demand for diesel light vehicles will nearly double from 15 million in 2005 to 29 million in 2015.[10] But diesel engines are not a perfect solution: while new engine technologies and cleaner fuels have reduced sulfur dioxide emissions, diesels still emit far more nitrogen oxides and particulate matter than their gasoline counterparts.[11]

Transportation

How many of the world's auto-manufacturing jobs can be considered a shade of green? Car sales in the European Union allow a rough approximation. Currently, the most efficient cars available emit no more than 120 grams of CO_2 per kilometer. Among European manufacturers, 7.5 percent of vehicles sold met this benchmark. Among Japanese-made cars sold in Europe, the share was about 6 percent, and among Korean companies, it was about 4 percent.[12] Applying these percentages to the respective workforces yields rough estimates of "green" auto jobs. (Equivalent sales figures are lacking for the United States, but 120 grams per kilometer is roughly on a par with a fuel economy rating of 40 miles per gallon. According to U.S. Environmental Protection Agency data, 1.2 percent of all U.S. light vehicles sold in 2007 achieved a fuel economy rating of 40 mpg or more.[13])

The result of these calculations (which assume that the European sales percentages of Japanese and Korean-made cars hold up for all cars manufactured in these two countries, not just those sold in Europe) is an estimated quarter-million green jobs total.[14] (See Table 2.) This figure is still quite small relative to the automobile manufacturing industry's global employment of 8.4 million jobs.[15] Similar calculations for other countries that account for large chunks of the world's vehicle production and employment (such as China, Russia, Brazil, and India) seem less feasible.[16] Thailand, a smaller producer, has launched a promising initiative granting tax incentives to manufacturers that produce cars that consume no more than five liters per 100 kilometers (47 miles per gallon) and generate no more than 120 grams of CO_2 per kilometer.[17]

Sustainability in the transportation sector will require not just improved fuel efficiency, but also a transition to greater reliance on public transport. Efficient and affordable transport systems are essential for economic development and to ensure that workers have wide access to jobs and economic opportunity. But many cities lack viable urban transport systems.[18] The Apollo Alliance notes that in the United States, "sprawl and urban disinvestment have separated low income and minority residents from areas of job growth and drained resources for education, government services, and maintenance of existing neighborhoods."[19]

Investment in transport infrastructure—including light rail and tram tracks, bus lanes, stations, platforms, bike paths, and traffic signals—creates construction and maintenance jobs. These jobs are less energy- and carbon-intensive than automobile-manufacturing jobs and can, in principle, be regarded as green. [20]

Although comprehensive global employment statistics are lacking, public transportation—in particular urban transit—is a major employer. In the United States, transit agencies employed some 367,000 people in 2005, up from 311,000 in 1995.[21] According to the International Association of Public Transport (UITP), an estimated 900,000 people are employed in urban public transport in the EU-25. UITP has 2,900 members in 90 countries,

Table 2. Green Jobs Estimates in Vehicle Manufacturing

	European Union	Japan	South Korea	United States
Passenger-car manufacturing workforce	2,000,000	952,000	247,000	1,095,000
Share of vehicles emitting ≤ 120 grams of CO_2 per kilometer (percent)	7.5	6.3	4.3	n.a.
Share of vehicles achieving 40 miles per gallon or more (percent)	n.a.	n.a.	n.a	1.2
Jobs in manufacturing "green" vehicles	150,000	62,000	10,000	13,000

Source: See Endnote 14 for this section.

and national statistics from these countries suggest that the number of direct jobs in public transport amounts to some 1–2 percent of total employment.[22]

Many cities still rely on old and highly polluting diesel buses, suggesting there is significant job opportunity in retrofitting. In addition, newer buses that run on compressed natural gas (CNG) offer pollution-reduction benefits and are already fairly widely used in China, Egypt, India, Iran, Japan, and South Korea.[23] Authorities in India's capital, New Delhi, announced that 6,100 new CNG buses would be introduced between late 2007 and 2009, resulting in the creation of 18,000 new jobs.[24] But making these alternatives happen at a meaningful level and in timely fashion requires substantial financing.

A promising solution to many traffic and air pollution challenges is so-called Bus Rapid Transit (BRT). Originating in Curitiba, Brazil, such systems now exist in more than 70 large cities worldwide, including Beijing, Bogota, Glasgow, Jakarta, Los Angeles, Mexico City, Sydney, and Toronto.[25] Typical BRT features include dedicated bus-only lanes, special boarding platforms, high-capacity vehicles using clean propulsion technologies, integration with other routes and transit services, and focused urban development planning. Successful BRT systems have stimulated economic development and job creation along their routes.[26] Maintaining high-quality service also means ensuring good working conditions for drivers, who need to be well trained and are expected to take responsibility for their performance.[27]

In the developing world, large numbers of people depend on vehicles with two-stroke engines—motorcycles, motorcycle taxis, and various three-wheelers—for personal transport as well as income generation. But these vehicles generate significant air pollution, with a heavy toll on human health and the environment. Short of replacing these two-strokes with other transportation modes, retrofits offer substantial improvements in fuel efficiency and considerable promise as a source of green jobs.[28] (See Sidebar 3.)

Sidebar 3. Engine Retrofits in Southeast Asia

There are some 100 million two-stroke vehicles in Southeast Asia alone, with large numbers also found in South Asia. Envirofit, a U.S.-based independent nonprofit company, works to develop and disseminate direct-injection retrofit kits to improve the efficiency of two-stroke engines, running pilot projects in Vigan and Puerto Princesa, two cities in the Philippines. Retrofits eliminate the carburetor and inject fuel directly into the engine. Fuel consumption is reduced by 35–50 percent, and emissions of air pollutants are cut by as much as 90 percent.

Apart from the health and environmental benefits, the fuel efficiency offered by retrofits can mean big savings for drivers of two-stroke motorcycle taxis, and thus a big boost for their livelihoods. The retrofit kits pay for themselves in fuel savings in less than a year. To make the upfront costs affordable, the two pilot cities provide micro-financing, recognizing that many local taxi drivers have little disposable income. Envirofit works with local partners to develop self-sustaining businesses to install and service the kits, and it plans to expand into Bangladesh, India, Pakistan, and Sri Lanka.

Source: See Endnote 28 for this section.

For short distances, bicycles are a non-polluting mode of transport. Global bicycle production has fluctuated between about 86 million and a peak of 105 million in recent years, with five producers—China, India, the European Union, Taiwan, and Japan—accounting for 87 percent of production.[29] No good global employment statistics exist for this industry or for associated businesses such as rental services.[30] However, the Institute for Transportation and Development Policy (ITDP) notes that the number of modern bicycle rickshaws in India has grown from 20,000 in 2003 to more than 300,000 today. Reduced weight and greater comfort have allowed rickshaw operators to increase their incomes by 20–50 percent. ITDP is now helping to modernize the *becak*, a three-wheeled rickshaw used in Indonesia.[31] Uganda, meanwhile, was home to about 200,000 "boda bodas" (bicycle taxis) in 2000. In both Uganda and Kenya, the bicycles provide employment for large numbers of previously unemployed youth.[32]

For inter-urban and rural transport, rail is more fuel-efficient and labor-intensive than road transport.[33] Yet in many countries, trends

in inter-urban transport have strongly favored road vehicles. In the EU-25, rail accounted for just 900,000 jobs in 2004, or 11 percent of all transport service employment; the number of jobs was cut by 14 percent in 2000–04, even as the value-added grew 3 percent.[34] China's rail network grew by 24 percent in 1992–2002, but employment was nearly halved, from 3.4 million to 1.8 million, due to improved labor productivity. India's network grew only 1 percent but employment stayed nearly equal, declining from 1.7 million to 1.5 million over the same period, due in part to radically different policies.[35] In Africa, too, rail's market share has declined over the past 30 years or so, and infrastructure and quality of service have deteriorated steadily.[36]

Jason Rosenfeld

Perhaps the fanciest boda boda in Kisumu, Kenya. Boda boda use has quickly spread beyond Uganda.

Gaps in data availability prevent an accurate tally of green jobs in the transportation sector. There are also few comprehensive studies of the job effects of a substantial modal shift away from heavy reliance on cars and trucks and toward public transport systems. Assessments of alternative passenger transport policies conducted in Germany and Britain, however, offer useful insights, suggesting that an alternative transport policy offers not only fuel savings but also important job opportunities.[37]

Basic Industry

Industries that produce basic materials, such as iron and steel, cement, aluminum, and pulp and paper, are among the most energy intensive in the world. Production of these materials has increased two- to three-fold during the last three decades.[1] While it may be difficult to ever regard these industries as "green," steps such as increasing energy and materials efficiency, curtailing pollution, and enhancing recycling are key to reducing their environmental footprints. Using secondary materials, for instance, offers substantial energy savings relative to producing new materials from scratch—ranging from 64 percent for paper to 95 percent for aluminum.[2]

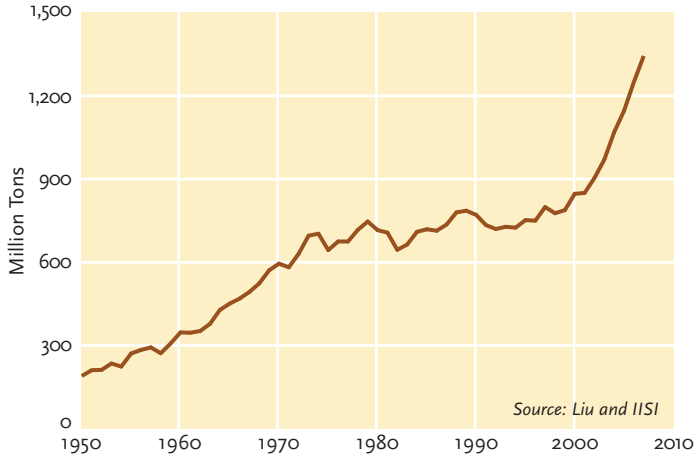
Iron and Steel

The demand for new buildings, vehicles, and other products has led to rapid growth in world steel production, totalling more than 1.3 billion tons in 2007.[3] (See Figure 4.) China is the dominant producer, followed by Japan, the United States, Russia, India, South Korea, and Germany.[4] Between 1990 and 2007, Chinese steel production alone soared from 66 million tons to 489 million tons.[5]

Steel is produced by two main methods. Blast furnaces and basic oxygen furnaces use iron ore, coal, and limestone, as well as recycled steel. Electric arc furnaces use primarily recycled iron and steel and electricity. Blast furnaces account for about two-thirds of world steel production (but about 90 percent of CO_2 emissions) and electric arc furnaces for about one-third. Outdated and highly polluting open-hearth furnaces have represented only some 2–3 percent of production in recent years.[6]

Steelmaking is responsible for 5 to 6 percent of human-caused carbon dioxide (CO_2) emissions.[7] On average, producing one ton of primary steel results in about two tons of emissions.[8] Technological advances have led to improved energy efficiency, greater use of byproducts, enhanced steel recycling, and substantial reductions in emissions per ton produced.[9] A 2007 assessment by the International Energy Agency concludes that if the best technologies now in use were applied worldwide, the industry's 2004 annual energy consumption could be reduced by 11–14 percent and its CO_2 emissions by 220–270 million tons per year.[10]

Figure 4. World Steel Production, 1950–2007



Steel-related energy intensity and carbon emissions vary greatly by country and by company. Japan's steelmakers are among the world's most energy efficient, while Russia and Ukraine still rely strongly on inefficient open-hearth furnaces.[11] Steelmaking in India carries a heavy environmental burden due to the use of low-quality coal resources. China, mean-

while, accounts for roughly half of the world's steelmaking-related CO_2 emissions—substantially higher than the country's 34 percent share of world steel production in 2007.[12] Chinese steelmakers on average use one-fifth more energy per ton than the international average.[13] But China has also made considerable strides, replacing open-hearth furnaces and smaller, inefficient blast furnaces with electric arc furnaces and introducing more-stringent environmental regulations.[14]

Craig Jewell

Crushed cars ready for recycling.

The use of recycled, or scrap, steel can be regarded as one key indicator of greening this industry and providing jobs that are a shade of green. In 2006, an estimated 41 percent of total steel production, or 496 million tons, was based on recycled steel.[15] Recycling saves 40 to 75 percent of the energy needed to produce virgin steel and helps to reduce CO_2 emissions.[16] In 2005, the share of scrap used by countries ranged from 86 percent in Turkey to 60 percent in the United States, 44 percent in Germany, 42 percent in Japan, 25 percent in Brazil, and 17 percent in China.[17] On the whole, developing countries have a lower share of secondary steel production because their recycling systems are still limited. According to one estimate, secondary steel use in India is only 4 percent.[18]

The U.S. iron and steel recycling industry recovered 71 million tons of scrap in 2007—equivalent to about 13 percent of the global total in 2006.[19] Assuming that companies in other countries employ a comparable number of people per ton of scrap recycled, this would yield a global figure of 225,000 jobs. (Of course, labor productivities vary widely by country—in 2001, China's was less than one-tenth that of developed countries.[20])

Waste avoidance in other areas of steelmaking can bring "green" jobs as well. Ferrous slags—valuable byproducts of iron and steelmaking used in road construction and as a feed for cement kilns—offer significant emissions reductions. In the United States, 21 million tons of iron and steel slag was recovered in 2005, providing employment for some 2,700 people in recent years.[21] Assuming comparable labor productivities in other countries, extrapolating these data suggests that slag recycling might employ some 25,000 people worldwide.[22]

During the last quarter of the 20th century, the global steel industry underwent significant restructuring and shed more than 1.5 million jobs.[23] Today, steel is no longer a labor-intensive industry. It is marked by rising globalization, ongoing consolidation, and substantial gains in labor productivity through automation and computerization.[24] In Europe, a business-as-usual strategy may lead to the further loss of 80,000 to 120,000 jobs (out of 370,000) over the next 20 years or so.[25] U.S. steel employment, currently at about 154,000 jobs—is expected to decline 25 percent during 2006–16. Generally speaking, low-skilled jobs are far more liable to be lost than jobs requiring greater education and training.[26]

Making steel mills greener and more competitive is a must for job retention. A 2007 European study argues that a comprehensive low-carbon steel strategy could save 50,000 jobs there.[27] The European Commission is currently supporting a long-term initiative—ULCOS (Ultra-Low CO_2 Steelmaking)—intended to develop breakthrough steelmaking technologies over the next 20 to 50 years with the potential to reduce CO_2 emissions by at least 50 percent.[28]

Still, more energy-efficient mills do not necessarily employ many people. In the United

States, electric arc furnaces are characterized by a lean workforce. They now produce more than 50 percent of the country's steel, up from 25 percent two decades ago, and are expected to continue to gain market share.[29]

Aluminum

Aluminum is used primarily in the aerospace and automotive industries, buildings and construction, and packaging. Between 1970 and 2007, world primary aluminum production grew from some 10 million tons to an estimated 38 million tons, and it is projected to reach 60 million tons by 2020.[30] (See Figure 5.) In addition to primary production, another 10 million tons or so is produced annually from secondary production based on scrap recycling.[31]

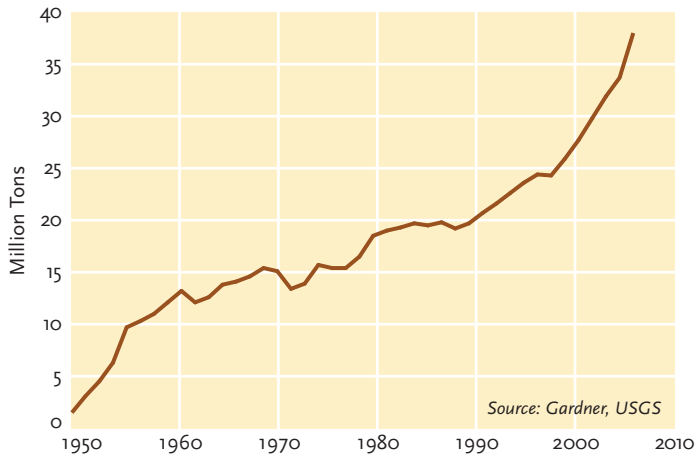
The aluminum industry accounts for roughly 3 percent of global electricity use and is among the most energy-intensive sectors of the economy.[32] It is not only a large emitter of CO_2 (in 2005, producing one ton of aluminum generated 10.5 tons of CO_2-equivalent, including emissions from transportation and ancillary processes), but also a major source of perfluorocarbons—greenhouse gases far more potent than CO_2.[33] More than 60 percent of the electricity consumed by aluminum smelters in 2005 was produced from hydropower plants, which can impose substantial costs on surrounding ecosystems and communities.[34] Coal-generated electricity accounts for roughly a third of the industry's energy consumption.[35]

The aluminum industry has become steadily more energy-efficient. World average energy use in smelting was more than 50,000 kilowatt hours (kWh) per ton in 1900, about 25,000 kWh in 1950, and only 16,000 kWh in 2000.[36]

As with steel, a major way to "green" the aluminum industry is by boosting secondary production. Recycling aluminum is far more energy efficient than manufacturing the metal from bauxite ore, using only 5–10 percent of the energy.[37]At least 400 million of the 660 million tons of aluminum produced worldwide since 1888 is still in productive use and thus potentially available for recycling.[38] Secondary aluminum production has grown steadily from about 2 million tons in 1970 to at least 10 million tons today (though some sources put the total at 12–14 million tons). It now accounts for roughly a quarter of the industry's overall output.[39]

The United States, Germany, and Japan have all boosted secondary production—to 54 percent, 62 percent, and 99 percent of total production in 2007, respectively. Russia, Australia, Canada, Brazil, and Venezuela have not invested much in secondary facilities, explained largely by their access to abundant hydropower or coal resources.

Figure 5. World Primary Aluminum Production, 1970–2007



Japan's experience is unique in that it has almost completely abandoned domestic primary production, switching instead to secondary production and imports of recycled aluminum.[40] According to the Japan Aluminum Association, as of December 2004, the country's aluminum industry employed 12,739 workers at 78 plants.[41]

In the United States, primary production has declined steadily since 1980, while secondary production jumped between 1980 and 1999 and has since declined.[42] During the past 40 years, the U.S. aluminum industry has cut its energy intensity by nearly 58 percent, though opportunities for further energy savings remain.[43] U.S. industry employment has hovered around 60,000 people in recent years.[44] Roughly 10 percent (6,071 people) were employed in secondary aluminum production

in 2002.[45] This suggests that secondary production employs considerably fewer people per unit of output than primary production does.

In the European Union, secondary aluminum production rose from 1.2 million tons in 1980 to more than 5 million tons in 2006, surpassing primary production in the mid-1990s.[46] Unlike the EU, Central European countries are still producing more aluminum from scratch than from scrap.[47] In 2003, the European aluminum recycling industry provided more than 10,000 direct and indirect jobs, according to its own estimates.[48] The industry's estimate for the total workforce in Western Europe is about 255,000 persons.[49]

China has massively increased its primary aluminum production, expanding output from 2.6 million tons in 1999 to 12.6 million tons in 2007.[50] Meanwhile, China's secondary aluminum production is also increasing, to more than 2.4 million tons in 2007, from more than 1.9 million in 2005.[51] The government hopes to increase consumption of secondary aluminum to 25 percent of total consumption by 2010, from 17 percent at present.[52]

Green jobs in the U.S., Japanese, and European aluminum industries number roughly 30,000. If the U.S. experience (where secondary production accounts for 54 percent of total output, but jobs in secondary production represent only 10 percent of the aluminum industry workforce) bears any relevance, then China's secondary production workforce may be more on the order of 30,000 to 40,000. This is a highly speculative figure, however.

Cement

Concrete is one of the most common and important building and construction materials. World cement production grew from 1.5 billion tons in 2000 to some 2.5 billion tons in 2007, and it is projected to surpass 5 billion tons by 2050.[53] China accounts for an estimated 41–47 percent of global production.[54] India is the second largest producer, at 145 million tons in 2005, followed by the United States at 101 million tons.[55]

The environmental impacts of cement production include heavy usage of energy and natural resources, land impacts from quarrying limestone and other materials, waste flows, and the generation of dust and pollutants.[56] Cement is responsible for approximately 5 percent of all greenhouse gases emitted worldwide.[57] For each ton of cement produced, carbon dioxide emissions typically run from 0.7 tons to just under 1 ton.[58] Between 1994 and 2003, the CO_2 intensity of cement production declined by 1 percent per year, but this was outweighed by increased production.[59]

Yet cement manufacturing has the greatest potential for reducing carbon emissions compared to other industrial sectors. By adopting existing best technology industry-wide, the industry could reduce its CO_2 emissions by an estimated 480–520 million tons per year and its total energy use by 28–33 percent.[60] Still, the rising global demand for cement will likely outweigh any emission reductions achieved through greater efficiency.

To produce cement, the raw materials calcium (typically limestone) and silicon (typically clay or sand) are ground and mixed, then heated in a rotary kiln to create pellets called "clinker." The process of creating clinker accounts for half of the industry's CO_2 emissions. The most widely used manufacturing processes for cement are wet, semi-wet/dry, and dry. The dry process consumes less water and uses about half the energy of the wet process. More-efficient rotary kilns utilizing the dry process are increasingly replacing inefficient vertical shaft kilns.[61] This is especially true in India, which now has some of the most efficient cement kilns in the world.[62]

Replacing up to 15 percent of the limestone used in clinker production with other materials could yield additional CO_2 reductions.[63] The best alternatives include fly ash, furnace slag, and pozzolanas (materials containing reactive silica and/or alumina).[64] Slag, a byproduct of the iron and steel industry, remains underutilized. Currently only 60 million tons of slag are used for concrete each year, and an additional 120–160 million tons could potentially be used.[65] The use of slag during the clinker process increases cement production by 15 percent without creating additional carbon

emissions. Potential carbon savings amount to 90–135 million tons per year.[66]

According to a 2000 analysis, Japan had the lowest CO_2 emissions per ton of cement, followed by Australia and New Zealand. The United States scored the worst with 0.99 tons of CO_2 per ton of cement.[67] (See Table 3.)

Roughly 850,000 people work in cement production worldwide.[68] Employment in Europe and the United States has decreased in recent decades, due mainly to automation and the closure of small cement plants.[69] Between 1999 and 2005, the EU-25 lost 6,290 jobs, or approximately 13 percent of its cement workforce. In 2008, the U.S. cement industry employed 20,800 workers, a decline of 29 percent from 1982 levels.[70]

Excluding China, the average number of employees needed to produce 1 million tons of cement declined from 555 in 1980 to 272 in 2000.[71] Due to the abundance of cheap labor, Chinese cement plants remained very labor intensive, in some instances requiring 10 times the workers of industrialized countries.[72] But China now plans to consolidate cement manufacturing into 60 key companies to meet energy-efficiency requirements and become more competitive globally.[73] As a result, many outdated or smaller plants have been or are slated to be closed.[74] This consolidation is likely to involve significant unemployment and retraining costs.[75]

Table 3. CO_2 Emissions per Ton of Cement Produced, Selected Countries, 2000

Country or Region	CO_2 Emissions (tons)
Japan	0.73
Australia and New Zealand	0.79
Former Soviet Union	0.81
Western Europe	0.84
China	0.90
Korea	0.90
Canada	0.91
India	0.93
United States	0.99

Source: See Endnote 67 for this section.

Because energy-efficient cement plants require fewer workers (a highly automated large plant can be effectively run by 200 or fewer employees), a greener cement industry is not expected to be a major source of new employment.[76] Remaining jobs will require higher levels of skill and enhanced training for workers.

Griszka Niewiadomski

In Poland, collecting corrugated cardboard for recycling using a converted baby stroller.

Pulp and Paper

Paper production has increased significantly over the past several decades. Half of all paper products are packaging, wrapping, and paperboard, another third are printing and writing paper, and the rest are newsprint, household, and sanitary paper.[77]

In 2004, global pulp and paper production totaled 355 million tons.[78] The United States was the largest producer of paper and paperboard in 2006, followed by China, Japan, Germany, and Canada.[79] (See Table 4, next page.) Paper use is rising at a rate of 3.6 percent annually and is expected to reach 600 million tons by 2020.[80] The United States and EU consume the most paper per capita, but growth in the industry is due primarily to China and India's rapidly expanding economies.

Pulp and paper is the fourth largest industrial energy user after the chemical, iron and steel, and cement industries, accounting for approximately 5.7 percent of total use.[81] The most energy-intensive phases of papermaking

Table 4. Paper and Paperboard Production by Country, 2006

Country	Production	Share of Total
	(million tons)	(percent)
United States	84.32	23.1
China	57.98	15.9
Japan	29.47	8.1
Germany	22.66	6.2
Canada	18.18	5.0
Finland	14.15	3.9
Sweden	12.07	3.3
Korea	11.04	3.0
Italy	10.01	2.7
France	10.01	2.7

Source: See Endnote 79 for this section.

are typically pulping and drying.[82] In 2004, recycled pulp accounted for the largest share of global pulp production, at 159 million tons, compared with 128 million tons of chemical pulp, 36 million tons of mechanical pulp, and 17 million tons of non-wood pulp.[83] Recycled pulp is more efficient in overall energy and material use and CO_2 emissions than chemical and mechanical processes. Non-wood pulp and paper, which accounts for 5–8 percent of the global paper market, is generally less-efficient and highly polluting.[84]

According to a 2007 analysis, between 1990 and 2003 the pulp and paper industries in OECD countries reduced their CO_2 emissions and heat energy consumption by 9 percent, but their electricity consumption by only 3 percent.[85] These gains were made through such measures as heat reduction, cuts in electricity use, and greater use of recycled pulp and materials such as biomass.[86] But the demand for faster machines and specialty papers has limited efficiency gains.[87]

China and India's mills are among the least efficient and depend on coal for power, although some of the most modern and most efficient mills are now being built in China. China and India—like other developing countries—also produce a large proportion of non-wood pulp (such as wheat, hemp, rice, bamboo, and sugar cane), which typically requires two times the energy of wood pulp and three times that of recycled pulp.[88] China, which traditionally used non-wood pulp for the majority of its paper production, has been closing many of these mills. By 2004, the share of China's pulp from non-wood sources declined to 24 percent, down sharply from 53 percent in 1990.[89]

Recycling is the most sustainable option for greening the pulp and paper industry.[90] (See Table 5.) It makes an indirect contribution to mitigating climate change by avoiding new forest clearing and also keeps large amount of waste out of landfills. Paper waste comprises approximately one-third of all municipal solid waste and creates large amounts of methane, which has 23 times the heat trapping capacity of CO_2.[91]

In 2005, the International Energy Agency reported that 45 percent, or 159 million tons, of pulp production was from recovered pulp.[92] The global paper recycling collection rate has increased from 24 percent in 1970 to 45 percent in 2004, due mainly to widespread adoption of recycling policies in industrialized countries.[93] Europe remains the strongest region with a recycling rate of 63 percent in 2006.[94] In the United States, the American Forest and Paper Association reported a 56 percent paper recycling rate in 2007—up from nearly 52 percent in 2005—and it set a new target of 60 percent recovery by 2012.[95] Canada reported an all-time high of 58 percent in 2007.[96]

Table 5. Environmental Benefits of 100% Recycled Content Compared with 100% Virgin Forest Fiber

Environmental Indicator	Copy Paper	Newsprint
	(percent reduced)	
Total energy consumption	44	39
Net greenhouse gas emissions	37	51
Particulate emissions	41	n.a.
Wastewater	46	17
Solid waste	49	55
Wood use	100	100

Source: See Endnote 90 for this section.

Basic Industry

Despite rapid growth in output, global employment in the pulp and paper industry has fallen slightly, from 4.3 million in 1990 to 4.1 million in 2000.[97] U.S. employment dropped from 650,000–700,000 people in the mid-1990s to 473,330 in 2006.[98] Job losses are likely to continue as countries make technological and efficiency improvements.[99] The jobs that remain in this more-efficient sector could be considered a shade of green, and in many cases these efficiency improvements will be necessary to retain jobs.

Non-wood pulp and paper production remains a major source of income and employment, particularly in developing countries. Farmers in Asia and Africa sell their agricultural waste to mills to help subsidize their income. The shift away from such sources will result in the loss of income for farmers as well as actual job losses. Estimates for the number of jobs lost in China are as high as 1 million.[100] If these mills were upgraded and made more efficient, they could be a major source of green employment. A 2006 study concluded that through such modernization, China could significantly reduce pollution and energy and water consumption, while maintaining employment for 8 million people in the industry.[101]

Photodisc

Virgin raw material in the foreground, pulp mill in the background.

Recycling

Recycling makes an important contribution to reducing energy usage and pollution and provides more jobs than landfilling or incinerating waste.[1] But recycling practices vary widely across the planet. Some are subject to strict laws and others are essentially unregulated; some involve manual sorting, others are highly automated; some are sophisticated in terms of materials recovery, separation, and processing, but others are not. Recycling operations—and associated reprocessing and remanufacturing activities—are run by municipal governments, private companies, neighborhood associations, and others. This makes for a broad diversity of jobs and required skills, health and occupational conditions, and earnings.

Joel Jagnow

Recycling containers on one of the campuses of the Lutheran University of Brazil.

Due to this diversity, there is no complete tally of recycling jobs worldwide. In Europe, generally high recycling rates are likely to contribute to substantial numbers of jobs. And a recent U.S. report concludes that recycling now generates revenues of $236 billion annually and offers employment to 1.1 million people, up from just 79,000 in 1968.[2] Brazil has close to 2,400 companies and cooperatives involved in recycling and scrap trading, most of them small or micro-sized. The recycling sector employs some 500,000 people.[3] Aluminum-can recycling alone provides employment for close to 170,000 Brazilians.[4]

While recycling is of great value for resource conservation, it can entail dirty, undesirable, and even dangerous work, and it is often poorly paid. In many developing countries, recycling is performed by an informal network of scavengers. Efforts to form cooperatives have raised the pay levels and standards in some countries. In Brazil, 90 percent of recyclable material is collected by scrap collectors, who have organized themselves into a national movement with 500 cooperatives and 60,000 collectors.[5] Colombia has an estimated 100 scrap cooperatives that recover more than 300,000 tons of material each year. [6] And in Cairo, some 70,000 informal garbage collectors known as *Zabaleen* collect about one-third of the city's trash, recycling an astonishing 85 percent of what they collect. They sort usable materials and sell them to community micro-enterprises, helping to create local jobs and incomes.[7]

A prominent example of dangerous recycling work is ship dismantling, a major employer mostly in South Asia. Worldwide, between 200 and 600 large ships annually are

broken up after having reached the end of their useful life. Many thousands of people, often migrant workers, are employed in this sector. But the industry is marked by great environmental and human health hazards due to dangerous materials such as asbestos and polychlorinated biphenyls, high accident rates, and lack of protection for workers.[8]

In consumer electronics, discarded items such as computers, mobile phones, and iPods are often shipped to developing countries where untrained workers dismantle and sort the materials, typically without proper equipment and protection against toxins. China is a major destination for e-waste, receiving up to 70 percent of global shipments in addition to substantial amounts of domestic discards. Another 20 percent goes to India, Pakistan, Bangladesh, and Myanmar.[9]

China's electronics recycling industry is thought to employ some 700,000 people, 98 percent of them in small, informal settings. Some 440,000 are involved in collection, 125,000 in disassembly, 140,000 in materials recovery, and 600 in final disposal. The sector is fast-growing and anarchic, with migrant workers accounting for one-half to two-thirds of the workforce and a high rate of employee turnover, making it difficult to enforce safety, labor, and environmental rules. Salaries are generally low, and most employees are not covered by health insurance, unemployment, or pension plans.[10]

Vicky S

Aluminum cans crushed and baled for recycling.

According to *Recycling Magazine*, in total some 10 million people are believed to be involved in all forms of recycling in China.[11] Worldwide, increasing recycling rates will create substantial additional jobs, but the quality of many of these jobs is a major concern.

Food and Agriculture

The search for green employment opportunities in agriculture is faced with several formidable obstacles. On one hand are economic trends marked by liberalization and globalization, falling commodity prices, the increasing power of buyers and retailers vis-à-vis small farmers, and rich-country subsidies that benefit agribusiness.[1] On the other is the fact that agriculture has an immense environmental footprint, one made larger in recent decades as the sector has become more intensive and industrialized.

Agriculture accounts for 15 percent of global greenhouse gas emissions, according to data submitted to the United Nations. The sector's emissions are expected to rise nearly 30 percent between 2005 and 2020.[2] Other well-documented environmental challenges associated with intensive agriculture today include the depletion of groundwater resources, the pervasive use of chemicals, the contamination and genetic manipulation of food, the spread of animal diseases and waste due to livestock intensification, and the reduction of biodiversity.

The proportion of people making their main living from agriculture is in sharp decline. Productivity improvements in the global food system have, along with the globalization of food, generally reduced employment levels in agriculture and related industries. In 2006, 36 percent of the global population was employed in food and livestock production, down from 44 percent in 1995.[3]

In industrial nations, agricultural employment has plummeted more than 80 percent in some regions since 1950.[4] The share of food workers in manufacturing and retail jobs now dwarfs the numbers of farmers operating at the base of the supply chain. In the developing world, agricultural employment has not kept pace with population growth, though rural non-farm employment has increased dramatically and now accounts for roughly one in four rural workers.[5]

Today's food system is dominated by a few large companies. The 10 largest agricultural firms control about 80 percent of the world market, valued at $32 billion.[6] Just two companies distribute 80 percent of the world's grain.[7] As a result, small farmers that employ "greener" practices are losing out to large, capital-intensive producers and suppliers. This has contributed to rural unemployment and accelerated urbanization, with the rural-to-urban shift in the developing world now happening two to three times faster than it did in industrialized countries.[8]

Globally, there are about 450 million wage-earning employees in agriculture, though many smallholders also work for wages some of the time. While the movement toward waged employment is generally upward, in some countries the growth in informal labor contracts has intercepted or reversed this trend.[9] There are also concerns about decent jobs in agriculture.[10] (See Sidebar 4.)

Many opportunities exist for greener employment in today's food and agriculture system. Activities such as land terracing, contouring, and building irrigation structures are labor intensive and are urgently needed to prevent further resource degradation. Removing subsidies for chemical fertilizers and pesticides and embracing alternatives such as integrated pest management and greater crop rotation

and diversification would have positive job implications. This type of farming is knowledge-intensive and requires well-crafted research and extension systems, which could create significant employment.[11]

Jobs could also be generated as part of the broad effort to boost water productivity. Removing subsidies that make water inexpensive would create an incentive to conserve resources and stimulate investments in field leveling and drainage, generating on-farm employment.[12] Substantial investments in off-farm infrastructure are also required, supported by water management institutions staffed by people with the necessary background in hydrology. Additional investments will be required to store and save water, creating employment in producing, installing, and maintaining the necessary equipment.[13] The move toward integrated water management, which involves canal lining and micro-irrigation, also involves labor inputs. Other sources of work include rehabilitating dams, barrages, and embankments and combating soil erosion via tree planting and other measures.[14]

Payment for environmental services (PES) is another strategy that appears to have significant green employment potential. Activities such as watershed and forest protection generate universal social benefits, such as clean drinking water, carbon sequestration, and protection of biodiversity. The World Bank maintains that providers of these services should be compensated via payments from those who benefit from the services.[15] In Colombia, Costa Rica, and Nicaragua, for example, livestock practices that helped conserve forests resulted in a 10–15 percent increase in the incomes of cattle farmers, suggesting that PES can both protect the environment and generate rural employment.[16] And South Africa's "Working for Water" program has provided work for 25,000 previously unemployed people in the removal of water-intensive invasive vegetation.[17] A global shift toward PES could in principle generate very large numbers of jobs, especially when administered as public works projects.

A variety of measures can help reduce agriculture's greenhouse gas emissions, including more-efficient use of fertilizers to cut nitrous oxide emissions, reducing methane from animals by administering nutritional supplements and capturing the methane for fuel, and stopping the burning of crop residues.[18] Changes in agricultural land management, such as conservation tillage, agroforestry, and rehabilitation of degraded land, could also make a major contribution to greenhouse gas mitigation, enrich the soil, improve yields, and create jobs.[19]

Adapting to climate change could create employment as well. New irrigation schemes in dryland farming would create work, as might retrofitting existing ones as part of the adjustment to greater variability of rainfall. Climate information and forecasting, as well as research into crops adapted to new weather patterns, could generate specialized and high-skill employment.[20] Making these alterations on a significant scale, however, will require considerable resources at a time when investment in rural areas is worryingly low. [21]

Beyond these proposed changes to the current food and agriculture system, there is tremendous green employment potential in a radically altered, "post-industrial" global food regime—one based on "grow-local" practices and small farm production. In the developing world, where many communities still depend

Sidebar 4. Decent Work Deficits in Agriculture

Much of agricultural employment is characterized by low pay, long hours, and precarious contracts. The International Labour Organization reports that 70 percent of all child labor takes place in agriculture. Furthermore, the feminization and "casualization" of the waged agricultural workforce has grown in recent years, allowing for flexibility for larger growers while increasing precariousness for workers. This is particularly evident in the rapidly expanding new export industries such as cut flowers.

Only 5 percent of the world's 1.3 billion agricultural workers have access to any kind of labor inspection system or legal protection of their health and safety rights. Agricultural workers are twice as likely to die at work than are workers in any other sector. Among these fatalities are an annual 40,000 deaths from exposure to pesticides.

Source: See Endnote 10 for this section.

on small farms to grow food and raise animals, the issue of green jobs revolves around securing local food economies, preserving what is already relatively green, and perhaps making it greener still. Rural small farms tend to be labor-intensive, so investing in these systems could reduce unemployment by helping to smooth income seasonally and bid up local wages.[22] In industrialized countries, where just a tiny fraction of the economically active population makes its living from farming, a shift toward a local food regime could provide a boost to declining rural communities.

Vasant Dave

Farmers in Gujarat, India, selling their harvest by the roadside.

Small-farm agriculture involves a qualitative move away from environmentally harmful inputs and toward methods that utilize more human labor, farmer expertise, and community experience. Small farmers' organizations and agricultural workers' unions stress that land reform, access to markets, affordable finance, and other resources are all essential to sustainability.[23]

Small farmers play a critically important role in the developing world. In Brazil, small properties with less than 200 hectares generate more than 14.4 million jobs in the countryside, or 86 percent of rural employment. The 1996 Brazilian agricultural census showed that, using the average productive strategies of small-scale agriculture, every eight hectares cultivated produced one rural job, whereas large-scale mechanized farms required an average of 67 hectares per unit of rural employment.[24]

Small-scale agriculture in urban settings can be an important source of green jobs as well. In 1993, urban agriculture involved more than 800 million urban dwellers, farming both private and public land. In São Paolo, Brazil, agriculture is a major planned land use in the city's master plan, adopted in the 1990s.[25] Farm cooperatives, too, are important to any model of sustainability. More than half of global agricultural output is marketed through cooperatives, which employ some 100 million people worldwide, many in rural areas.[26]

The transition to sustainable agriculture will involve greater use of organic farming methods, another growing source of jobs. The global organics market reached $38.6 billion in 2006, with the vast majority of products being consumed in North America and Europe.[27] If the demand for organic produce continues to grow worldwide, employment growth in this area could become a more generalized and global phenomenon.[28]

Research provides some evidence that organic farming generates positive-sum employment gains while also protecting the environment. A study of 1,144 organic farms in the United Kingdom and the Republic of Ireland showed that organic farms employed one-third more full-time equivalents (FTEs) per farm than conventional farms. If 20 percent of farmland became organic in each country, this would bring 73,200 new jobs in the United Kingdom and 9,200 in Ireland.[29]

Similarly, an input-output analysis of organic apple production in the U.S. state of Washington found that for every $1 million in sales, organic apples generated 29.4 FTEs, whereas conventional farms generated 25.9 FTEs.[30]

Several studies note the employment benefits of organic production in the developing world.[31] In the Dominican Republic, where establishing and maintaining organic crops such as cocoa, coffee, and bananas requires intense manual labor, "the movement from rural to metropolitan areas is reduced by the

availability of local employment opportunities."[32] And in India, "Small farmers are showing preference for organic farming practices because it reduces their cost of cultivation... [and it] provides more employment to members of the farming families."[33] These studies suggest that the organic sector may offer a development path that is sustainable at the global level, and that organics provide what the United Nations Food and Agriculture Organization describes as "alternative employment opportunities for educated young people in rural areas with decreasing chances to make a living in the cities."[34]

But while these findings suggest employment and other social gains generated by organic farming, sometimes the differences between organic and conventional farms are harder to detect. A 2005 survey of organic farmers in California found that these farmers operate on razor-thin margins and often pay as poorly as conventional farmers. The organic producers felt squeezed by cheap imports on the one hand and large wholesale operations on the other.[35]

It is important to note that organic production is not synonymous with local food production. Studies show that food purchased from local growers, whether organic or not, generates considerably more income for local economies than does food purchased from supermarkets, via a "multiplier effect" that sustains and expands employment in the local area. For example, a survey of 900 food businesses in Devon, the United Kingdom, found that producers involved in the local economy hired more workers on average than those not involved locally.[36]

Another area of sustainable agriculture with high jobs potential is "fair trade." Fair-trade organizations promote sustainable farming methods and work to ensure that small producers in developing countries receive a fair price for their goods. The demand for fair-trade products—particularly tea, coffee, cocoa, and bananas—has grown dramatically in recent years. One large company involved in fair trade, Equal Exchange, showed an average annual growth of 32.5 percent between 1986 and 2006. In 2006, the company's sales were approximately $23.6 million, and it employed 94 full-time staff.[37] The National Cooperative Business Association reports that in Indonesia, 12,000 jobs have been created as a result of fair-trade exports to the United States.[38]

USDA NRCS

Farmer adjusting a gated-pipe drip irrigation system.

Presently, however, much of the employment in the global food system cannot be categorized as green. Indeed, the trends are moving away from green jobs rather than toward them. Although opportunities for green employment exist both within the existing global food system and in sustainable agriculture, much will depend on the policy and institutional frameworks established in the years ahead.

Forestry

Forests cover nearly 4 billion hectares, or about 30 percent of the world's land area.[1] In addition to retaining water, protecting soils, and supporting biodiversity, they serve as carbon "sinks"—absorbing carbon from the atmosphere and storing it in the wood, soil, and other organic material. In total, the world's forests store an estimated 4,500 gigatons of carbon dioxide, more than all the carbon currently found in the atmosphere.[2] Releasing this stored carbon, even over a long period of time, would have catastrophic effects on the planet.

Already, deforestation and forest degradation contribute more than 18 percent of all greenhouse gas emissions.[3] Between 2000 and 2005, an average of 12.9 million hectares of forests was destroyed each year, of which 6 million hectares was primary, biologically diverse forests.[4] Even after taking new forest growth and replanting efforts into account, net forest loss is estimated at 7.3 million hectares per year.[5]

Although data on employment in the forestry sector are sparse, the sector likely employs tens of millions of people and provides subsistence and income for hundreds of millions more. In principle, forestry-sector employment includes all of the work required to plant, harvest, sustainably manage, renew, and protect forests as well as to process both wood and non-timber forest products (NTFP), such as building materials, medicine, food, and crafts. Jobs in the forestry sector are generally considered to be underreported, due mainly to the seasonal, often part-time, nature of the work.

According to the United Nations Food and Agriculture Organization, 12.9 million people were employed in roundwood production, wood processing, and the pulp and paper industry in 2000.[6] (See Table 6.) An often-quoted estimate by Peter Poschen of the International Labour Organization puts the number of forest-sector workers in the "formal" sector at 17 million, and in the informal sector at 30 million, for a combined total of 47 million.[7] The World Bank estimates that the forestry sector employs 60 million people in total.[8] Another estimate is as high as 140 million.[9]

The vast majority of people whose livelihoods are dependent on forestry are not wage earners or even informal workers, but those who rely on the forest for subsistence as a source of food, fuelwood, and income. The World Bank estimates that roughly 1.6 billion people depend to varying degrees on the forest for their livelihoods.[10] Adding up all of these different forms of forestry employment brings a rough total of 957 million to 1.75 billion

Table 6. Formal Forest Sector Employment by Region, 2000

Region	Employment
	(million workers)
Asia and the Pacific	5.6
Europe	3.5
North America	1.5
Latin America and the Caribbean	1.2
Africa	0.55
Near East (Northern Africa, Central Asia, Western Asia)	0.4
World	12.9

Source: See Endnote 6 for this section.

Forestry

workers in the sector.[11] (See Table 7.)

The Intergovernmental Panel on Climate Change has identified several key land use changes that would help mitigate carbon emissions from the forestry sector, including reduced deforestation and forest degradation, forest conservation, afforestation/reforestation, and sustainable forest management.[12] Work in all of these areas could be considered green jobs.

Reducing deforestation is critical given its high contribution to greenhouse gas emissions. At the December 2007 U.N. Climate Change Conference in Bali, Indonesia, most of the discussions on avoiding deforestation revolved around "Reduced Emissions from Deforestation and Forest Degradation," also known as REDD schemes. The basic premise is that deforestation can only be avoided by creating economic incentives or compensation for conservation, with highly industrialized countries paying less-developed countries an amount commensurate to emissions avoided. In theory, these schemes would provide additional income for indigenous forest people and landless farmers—potentially a source of much-needed green jobs for rural and forest economies.[13]

REDD schemes are not a panacea, however. The unequal structure of land ownership, as well as corruption, may prevent the economic benefits from actually reaching the intended recipients. Critics also worry that the World Bank, governments, and non-governmental organizations will make decisions without consulting local communities, who in many cases have historically been stewards of the forest. Some critics believe that reliance on market-based mechanisms will simply continue the problems that now plague overseas development assistance in general. So far, there are very few examples of REDD schemes and little empirical data on whether these programs actually provide additional sources of employment and income for indigenous people in forest communities.

Unlike reforestation, afforestation entails creating new forest cover on land that was not formerly forested. While it may seem obvious that such projects would be considered green employment, it is important to consider what type of work is being generated. Currently, the industry standard is dominated by seasonal, contract work. The planting season is very short, particularly in temperate forests, where workers may be employed for as little as 8–12 weeks. Tree planting is generally low paid with few-to-no benefits. Payment is commonly determined by piece wages, which often leads to rushed work and long hours. Rigorous standards are needed to ensure that decent work is created with above poverty-level incomes. The amount of employment generated will also depend on the size of the project and whether the work is manual or mechanized. Mecha-

Table 7. Global Employment in the Forest Sector, by Type

Category	Number of Workers
	(millions)
Formal-sector employment	12.9 –17
Informal- and formal-sector forest-based enterprises	47–140
Indigenous people who primarily depend on natural forests for their livelihoods (hunting, gathering, shifting cultivation)	60
People who live in or near forests and depend on forest for additional income	350
Smallholder farmers who use agroforestry practices	500 million–1.2 billion
Total (rough estimate)*	957 million–1.75 billion

**It is extremely difficult to find accurate totals for the stated categories because: 1) there is a large range of estimates, and, 2) some of the categories are likely to overlap. The 1.75 billion is likely an overestimate.*
Source: See Endnote 11 for this section.

nized tree planting has a much lower labor intensity than manual planting, though it also generally increases safety and the ability for companies to pay higher wages.[14]

Agroforestry is a type of afforestation project that involves planting trees alongside crops and/or livestock on agricultural land to diversify and increase its productivity. Agroforestry provides multiple environmental benefits,

Courtesy Chris Bright, www.earthsangha.org

In the Dominican Republic, an association of small farmers has established a cooperative nursery of tree seedlings, including citrus, avocado, coffee, cocoa, and timber species.

including watershed protection, enhanced biodiversity, and improved soil quality, and has great potential to sequester and store carbon. According to the World Agroforestry Center, some 600 million hectares of unproductive cropland could be converted to high-productivity farming with a medium-level carbon sequestration potential.[15]

The World Bank estimates that nearly 1.2 billion people already depend on agroforestry to some extent for subsistence and income, particularly in Africa, Asia, and Latin America.[16] Examples of the benefits of agroforestry for farmers and the environment include:

- In East Africa, about 200,000 smallholder dairy farmers use agroforestry to produce fodder as an additional source of food for their livestock. Farmers who planted an average of 500 trees increased their farm income by over 25 percent, from $95 annually to $120.[17]
- In Tanzania, more than 300,000 hectares of degraded soil were renewed through the indigenous *ngitili* system, where native trees are planted on grazing land to protect it during the dry season. This process was shown to increase earnings, provide better nutrition, increase crop production, and reduce time spent collecting fuelwood.[18]
- A study of 200 farms in India showed rising incomes through the integration of multiple types of trees.[19] The increased income was attributed to selling fruit and timber as well as other activities such as basket weaving and raising livestock. Employment also increased from seasonal to year-round work, eliminating the need for farmers to migrate in search of additional work.

While it is widely accepted that comprehensive agroforestry practices increase income, these projects are limited by the lack of funds available. They tend to have large upfront costs and an extremely long payback period, and therefore must rely on external funding sources. Unless there are large, ongoing, sustainable sources of funds designated for agroforestry, these projects are unlikely to be scaled up in a way that makes a significant impact on deforestation and greenhouse gas emissions.

More than 50 different certification schemes have been developed worldwide to enhance sustainable forest management. The most common of these, the Forest Stewardship Council (FSC) and the Programme for Endorsement of Forest Certification (PEFC), grant their labels to wood products that are produced in a sustainable manner. While certification represents only a fraction of the global wood market and forestry sector, it has grown rapidly in the last few years. The area of PEFC certified forests, for example, increased from 32 million hectares in 2000 to 194 million hectares in 2007.[20] However, certification schemes are still concentrated largely in industrialized countries.[21] In 2005, the International Timber Trade Organization reported that less than 5 percent of tropical forests were sustainably managed.[22]

Forestry

Certain certification schemes have very specific standards for employment. The PEFC, FSC, and Malaysian Timber Certification Council all require that forestry operations comply with national labor laws and international agreements, meet minimum health and safety rules for workers, guarantee workers the right to join a union, provide training and education programs, and prohibit child labor.[23] But certification does not guarantee jobs. A Yale University study of certification schemes in developing countries found that employment levels increased in some cases, but declined overall in others. Certification puts limitations on the production of timber, which can lead to fewer hectares harvested and, in turn, fewer jobs.[24]

Sustainable land use changes in the forestry sector—such as avoided deforestation, afforestation and reforestation, agroforestry, and sustainable forest management—are desperately needed and will result in widespread economic changes. Due to the lack of information about employment in this sector, however, it is impossible to give a global quantification of green jobs that might be created through these projects. While these land-use changes may have some immediate negative consequences, sustaining this sector over the longer term is likely to have a positive effect on both the quality and quantity of employment.

Photodisc

Marshalling yard for timber ready to be turned into lumber.

Pathways to a Sustainable Future

Recent months have seen a proliferation of studies and references to green jobs, with infectious optimism regarding the potential of sustainable employment. The growth in green jobs is already fairly significant, though significant data gaps exist. And the potential for further green job growth is tremendous—from opportunities to address the accumulated environmental ills of the past, to improving our ability to cope with climate change, to creating more efficient and viable economies.

The green employment that would result from these initiatives is many magnitudes larger than anything currently on the drawing board. Still, this optimistic assessment of the potential for future green job growth must be seen against the backdrop of some sobering realities that policymakers need to address. These include:

Green jobs are expanding, but not rapidly enough. This is especially true in light of the fact that the labor market is expanding by some tens of millions of people every year, but world unemployment is at record levels. Together, the unemployed and underemployed (those working hard without earning sufficient incomes) amount to 1 in 3 of the world's workers. Unemployment has hit young people, aged 15 to 24, the hardest, with 86.3 million youth representing 44 percent of the world's total unemployed in 2006.[1]

Green investment—and thus most of the green jobs in the foreseeable future—is found primarily in a relatively small number of countries. Countries like Japan and Germany that lead green technology development are likely to reap the bulk of the associated revenues and jobs. However, green jobs are still the exception in most developing countries, which account for some 80 percent of the world's workforce. More needs to be done to ensure that green employment becomes a truly global phenomenon.

The rising level of informality in the global economy constitutes a major challenge to green job growth. In addition, the chronic and worsening levels of inequality both within and between countries are a major impediment. The effort to advance decent work and pro-poor sustainable development is critical to building green jobs across the developing world in particular.

Unsustainable business practices remain prevalent and are often more profitable than green ways of doing business. Short-term pressures of shareholders and financial markets are not easily overcome. The early adopters of green business practices have to contend with companies—manufacturers and retailers—that command consumer loyalty through low prices achieved on the back of "externalized" costs. And surprisingly often, market failures, coupled with lack of green knowledge, impede action.

Striking the right balance between government and private sector action, financing a green jobs agenda, developing worker skills, and ensuring a "just transition" are critical to overcoming present obstacles.

Private companies have an important role to play in green job creation. Green innovation helps businesses stay at the cutting edge and hold down costs by reducing wasteful practices. However, the risk and profit appraisals typical of modern business behavior, the ever-

rising expectations of shareholders, as well as concerns about protecting intellectual property may impede the flow of capital into the green economy. Experience in various areas—from vehicle fuel economy to carbon trading—suggests that a purely market-driven process will not be able to deliver the changes needed at the scale and speed demanded by the climate crisis.

Today's business practices are too often driven by short-term considerations, whereas truly sustainable development requires a long-term approach. Governments must therefore establish an ambitious and clear policy framework to reward, support, and drive sustainable economic and social activity, and be prepared to confront those whose business practices continue to pose a serious threat to a sustainable future. Timely action on the scale needed will occur only with a clear set of targets and mandates, business incentives, public investment, ecological tax reform, and genuine public-private partnerships.

Expediting the development and diffusion of green technologies is critical to a global green jobs future. Innovative public-private partnerships can be part of the solution. Cooperative R&D centers that anchor green technology development in the public realm are another. And an adequately endowed global fund to speed the spread of green technologies and climate adaptation measures also deserves urgent consideration.

Investment creates employment. The good news is that global investments in "clean tech" (mostly renewable energy)—including venture capital, project finance, public markets, and R&D—expanded 60 percent in 2007, to $148 billion.[2] The United Nations Environment Programme (UNEP) estimates that financing for clean and renewable energies could reach $1.9 trillion by 2020.[3]

But other areas offer less cause for celebration. The *Stern Review* on the economics of climate change notes that investment levels in energy-saving technology in power generation have actually declined by as much as 50 percent in real terms over the last two decades.[4] For energy conservation, investments stood at a paltry $1.1 billion in 2006.[5] The International Energy Agency also concludes that, "R&D investment is not adequate given the magnitude of the climate challenge. Government spending on energy R&D has fallen, while the private sector is focused on projects with short-term payoffs."[6]

Moreover, it is worth bearing in mind that green jobs and decent jobs are not necessarily one and the same. Today, far more information is available about quantities of jobs than about their quality. The vast majority of the world's workers live in poorer countries where not just green, but also decent, work is scarce, jobs are often precarious, and levels of informality, unemployment, and underemployment are alarmingly high.

A sustainable economy cannot be built on "green for a few"—a few countries, a relatively limited number of workers, with regrettably few positive outcomes overall. It must mean "green for all"—creating decent work and stable communities and allowing for a fairer distribution of wealth.[7*] 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. The shift to a low carbon and sustainable society must be as equitable as possible. It must, in a phrase, be a "just transition."

To achieve social solidarity and to mobilize political and workplace support for the needed changes, policies are needed to protect those who are likely to be negatively affected by the green jobs transition—such as through income support, retraining opportunities, and relocation assistance. Social dialogue is a critical component of a Just Transition, especially in the workplace where the worker/union voice is needed to help determine the design of sustainable production systems and work practices. For example, joint labor-management

*The phrase "green for all" has been formulated to express the need for an inclusive green economy whereby green jobs offer employment options and careers for all social groups and constituencies, and not just for the privileged or already skilled. In the United States, this need for inclusivity has taken the form of a campaign, aptly named "Green for All."

committees and similar bodies could work to identify ways to improve energy and resource efficiency. In some instances, employers and unions are beginning to work together in greening the workplace, building on a long tradition of collaborating on occupational safety and health and other issues.

But just as there are risks and opportunities for workers, the same is true of many employers. Government support and assistance for business should be provided where needed. There are, however, differences of philosophy and approach between businesses and civil society actors (especially trade unions) around who should shoulder what responsibilities. Businesses frequently have a broad range of obligations to consider—to governments as taxpayers, to consumers, suppliers, and investors, as well as to employees and communities. They usually operate in a competitive marketplace and can often ill afford to make commitments to workers who are no longer required.

Examples of Just Transition are still few and far between. However, some governments, employers' organizations, and trade unions have set up social-dialogue arrangements to help foster this at the national level:

In **Spain**, industry-based roundtables have been established to identify and reduce adverse effects on Spain's competitiveness and workforce as the country seeks to comply with the Kyoto Protocol.

In **Germany**, a broad coalition of government, industry, unions, and environmental groups has collaborated around initiatives to renovate buildings for climate protection purposes, while at the same time creating green jobs.

In **the Netherlands**, social dialogue across civil society has brought forth a comprehensive energy plan to reduce the country's greenhouse gas emissions by half before 2030, based on 1990 levels.

In **the United States**, the idea of a Just Transition is embedded in proposed Congressional legislation on climate protection. The provisions include quality job training to any workers displaced, temporary wage assistance, health care benefits to workers in training programs, and other measures.

In **Argentina**, the government expounds the incorporation of environmental clauses in collective agreements and the participation of workers in policy processes to achieve sustainable development. Proposed plans offer training for trade union "environmental delegates" and promote good-quality green jobs in different economic sectors.

An even broader interpretation of Just Transition would address equity issues at the global level. Just as vulnerable workers should not be asked to incur the costs of solving a problem they did not cause, the same principle should apply to resource-starved countries that face major problems due to climate change caused by the emissions of the richer countries. The commitment by the wealthy countries under the Kyoto Protocol to assist poor countries with funds for adaptation to climate change, and to find ways to transfer green technology, will need to be met and extended into the next phase of the treaty.

Policymakers and public officials must also pay more attention to the "skills gap" that exists when it comes to supplying the green economy with the kind of workers it needs. In many wealthier countries, deindustrialization and offshoring of manufacturing have created a situation where companies in the fledgling green economy are struggling to find skilled workers. A 2007 survey of Germany's renewables industry, for instance, concludes that companies are already suffering from a shortage of qualified employees, especially in knowledge-intensive positions. The best approach to education and training—whether to focus on trade schools, universities, on-the-job training in the workplace, or some other arrangement—will vary by country and by educational system.

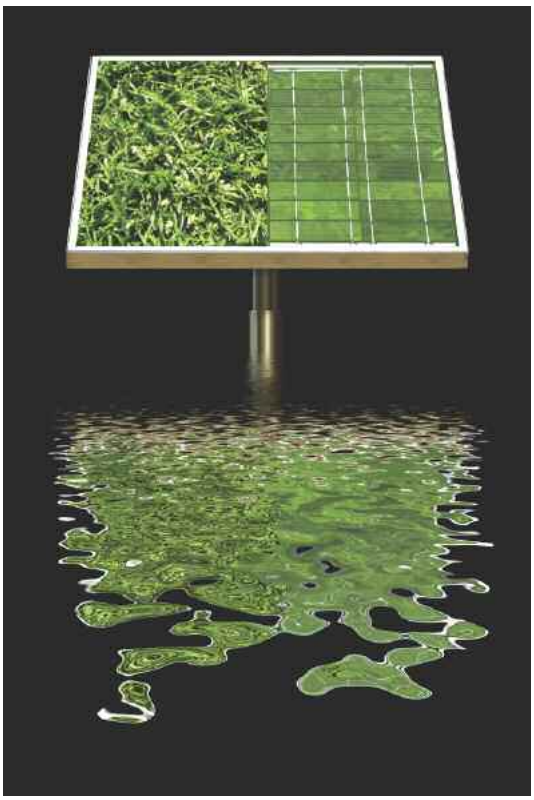
Solid R&D, engineering, and manufacturing capacities are a critical aspect of building green industries and jobs. Some occupations in the renewables sector or in energy efficiency require highly educated and even highly specialized personnel, including a variety of technicians, engineers, and skilled trades. At the cutting edge of technology development for

wind turbine or solar PV design, for instance, specialization has progressed to the point where universities need to consider offering entirely new study fields and majors. Still, green employment is not limited to high-end skills. Many positions demand a broader array of skill and experience levels, especially in installation, operations, and maintenance.

Alongside the skills gap is the "management challenge," which will require developing new perspectives, awareness, and managerial capacities. Managers must be willing and able to learn new skills, and to make use of the skills their subordinates have obtained.

Important equity issues exist with regard to minorities and genders. The doors to the new green economy need to be fully opened to those who had difficulty finding their place in the "old" economy for reasons related to discrimination or lack of skills, resources, or opportunities. Proposed U.S. legislation would provide up to $125 million in funding to establish job training programs, curricula, and job standards on the federal and state levels, and the "Green for All" campaign is working to secure $1 billion by 2012 to "create green pathways out of poverty" for 250,000 people in the United States.

Promoting such job training is equally important in developing countries. A variety of United Nations and other international agencies such as UNEP, the International Labour Organization, the United Nations Industrial Development Organization (UNIDO), and the Consultative Group on International Agricultural Research (CGIAR), working in conjunction with business, trade unions, and community organizations, could play a critical role in setting up green training and expertise centers in developing countries. In all countries, it is important to link green subsidies, tax breaks, and other incentives provided to companies with job quality and training standards. This would help to ensure the creation of what the Apollo Alliance and Urban Habitat have called "high-road jobs"—positions that provide decent pay and benefits as well as safe working conditions.



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The Worldwatch Institute is an independent research organization that works for an environmentally sustainable and socially just society, in which the needs of all people are met without threatening the health of the natural environment or the well-being of future generations. By providing compelling, accessible, and fact-based analysis of critical global issues, Worldwatch informs people around the world about the complex interactions among people, nature, and economies. Worldwatch focuses on the underlying causes of and practical solutions to the world's problems, in order to inspire people to demand new policies, investment patterns, and lifestyle choices.

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Green Jobs

Working for People and the Environment

"Green jobs"—employment that contributes to protecting the environment—will be a key economic driver of the 21st century. Green jobs can also ensure social sustainability, by offering good wages, income security, and safe working conditions.

Green jobs are on the rise. The renewable energy sector—wind, solar, and biofuels—has seen rapid expansion in recent years. In the building sector, high performance standards for new construction and retrofitting of existing buildings offer tremendous green-job potential. The transportation sector is also in need of major changes. Currently, no more than a quarter-million auto workers, out of some eight million industry-wide, manufacture fuel-efficient cars. Meanwhile, rail and urban transit systems offer greener alternatives.

Recycling jobs are plentiful—with an estimated 10 million in China alone—but they are at times precarious, low-paid, and driven by poverty. Organic farming, while still limited in scope, is far more labor-intensive than industrialized agriculture and offers growing employment opportunities. And reforestation projects create large numbers of jobs, though often seasonal in nature.

The potential for green jobs is immense. But realizing this potential will require a stable policy framework, sustained investments, and expanded training programs. Support will also be needed to help workers in existing resource-extractive and polluting industries smoothly transition to new jobs and livelihoods.

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