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Employment impacts of a 'green' energy transition in China

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Before the US financial crisis that began in 2008, China was the 'factory' of the world, utilizing energy intensively for such processes as steelmaking, papermaking and concrete production. As such, energy emissions in China increased dramatically until 2007, with much of the energy being provided by the labor-intensive coal industry. Under the 11th five-year plan, China resolved to increase its energy efficiency, setting out to reduce energy consumption while continuing to increase economic growth, and to increase the usage of 'green' technologies to 15% of all energy used by 2020. The Renewable Energy Law of 2007 set a guideline for China's energy reduction goals, to quadruple the national GDP while only doubling the country's electricity usage by the year 2020. Currently, there are virtually no studies on the employment effects of a 'green' transition to explore what impact the current energy goals, or potentially 'greener' energy goals, would have on China's labor force. This paper seeks to analyze the effects on employment of a 'green' transition.

Keywords: renewable energy; coal; oil; gas; hydropower; nuclear energy; wind energy; thermal energy; green energy; labor; employment

1. Background

Before the US financial crisis that began in 2008, China was the 'factory' of the world, utilizing energy intensively for such processes as steelmaking, papermaking and concrete production. Consumption in developed countries was high, and to meet production demands, developed regions were using up a combination of raw materials, energy and labor. As such, energy emissions in China increased dramatically until 2007, with much of the energy being provided by the labor-intensive coal industry.

It is generally agreed that the current energy usage situation is environmentally unsustainable, since China is already producing environmentally altering emissions. Under the 11th five-year plan, China resolved to increase its energy efficiency, and imposed stricter standards on emissions, which began to have a small impact in 2007. Research on the previous period, under the 10th five-year plan, had shown declining efficiency, and under international pressure to improve its environmental status, China set out to reduce energy consumption while continuing to increase economic growth.

China has set out to further reduce SO_2 and CO_2 emissions by 2010 and to increase the usage of 'green' technologies to 15% of all energy used by 2020 (Karplus 2007). The 2004 National Energy Strategy and Policy Report (NESP), written by the Development Research Center of China's State Council, recommended that China supply an additional 90 to 100 GW

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of capacity by 2020. Of this capacity, 60 to 70 GW would be provided by small-scale hydropower, 20 GW by wind power, 1 GW by biomass-fired electricity, and the remainder by small increases in solar, geothermal, ocean and tidal energy (Sinton et al. 2005).

The Renewable Energy Law of 2007 set a guideline for China's energy reduction goals, to quadruple the national GDP while only doubling the country's electricity usage by the year 2020. Between 1980 and 2000, the GDP doubled, pulling 50 million people out of poverty and achieving the double electricity growth that the government hopes to duplicate (Sinton et al. 2005). In the years since 2000, however, the numbers have not been as impressive; instead the ratio has been closer to 1.2 to 1.4 percentage points of electricity growth for every 1% growth of the economy.

In addition to the plans for an overall cut in energy usage, the Renewable Energy Law also made new policies that positively impact on renewable energies of all kinds. To begin with, all utilities will need to purchase 100% of approved renewable energy facilities' output, which would include energy produced by solar, wind, geothermal, biomass and small hydroelectric plants (World Nuclear Association 2009). This guarantees to investors in these fields that they will have customers, reassuring them of a safety net for their investment.

Currently, there are virtually no studies on the employment effects of a 'green' transition to explore what impact the current energy goals, or potentially 'greener' energy goals, would have on China's labor force. This paper seeks to analyze employment effects of a 'green' transition.

The government has, when closing both small and state-owned coal mines, recognized to varying degrees (more so after the year 2000) that displaced workers would need additional social insurance.[1] However, in either state or local mine closures, assistance rendered has been insufficient, and particularly in the case of small mine closures, further guidance and financial assistance from the central government is greatly needed.

The question is, can the renewable energy sector create enough jobs to replace those in the 'dirty' energy sectors, and where would new jobs be located? According to the National Development and Reform Commission, the renewable energy sector will produce approximately 2 million jobs (Guizot 2007). However, a simultaneous shift out of the coal sector, in various regions of China, should be examined to determine whether reducing usage of 'dirty' energy sources will create additional economic issues, such as geographically concentrated unemployment sectors that will need to be addressed through policy measures.

In this paper, we first look at coal, oil and nuclear energy resources in terms of technology and usage. Next, we look at 'green' energy sources in the same fashion. We follow with a discussion of energy resources in terms of employment and production. We then build a model to show that China's transition from a labor-intensive, 'dirty' energy sector to a skilled labor-intensive 'green' technology sector will result in job losses in some provinces and job gains in others. We conclude with policy recommendations.

We do not analyze demand-side issues, such as usage efficiency, and take pricing as a given. Other scholars have elsewhere modeled efficiency measures related to China's goal to quadruple GDP while only doubling energy use from 2000 to 2020, which, in terms of policy recommendations, would require improving efficiency of energy use in production, transportation, and building (see Lin et al. 2006). Efficiency has not been sufficiently addressed in the leadership circles and, like pricing issues, is a political issue since there are many different parties involved. Pricing is also a point of conflict, with suppliers seeking higher energy prices and demanders seeking lower energy prices. The central government's managed energy pricing policies for oil in particular has come under intense scrutiny when market equilibrium does not occur (see Downs 2006). Certainly, efficiency regulations and pricing issues will play a key role in providing incentives for firms to use renewable energy sources, and, along with supply-side issues, are important considerations.

2. Current energy regime

One of China's largest environmental problems, and largest problems overall, is the increasing generation of greenhouse gases, such as sulfur dioxide, carbon dioxide and nitrogen oxide. Much of the problem is created by the use of coal, which is more pernicious in its unwashed state.

Coal

Coal has become the main fuel source for China's explosive development. Production of coal developed and expanded after 1949, increasing through reform and peaking at 32.9 EJ in 1996 (Chen and Chen 2007a). The government encouraged peasants to operate small and medium-sized coal mines in the mid-1980s, and to consolidate and close uncertified small and medium-sized mines in the mid-1990s. Production of coal decreased in 1998, with layoffs in state-controlled coal mines; further declined in 1999 under the '14.40' Project which closed deficit and low-quality coal mines; and thereafter under the policy to close thousands of small and illegal coal mines (Chen and Chen 2007a). Coal production, however, increased after 2000 as supply and demand were rebalanced. Coal currently makes up 68.7% of China's energy usage and with continued economic growth, demand is expected to increase.

Coal usage itself is a problem, but 'dirty' coal in particular has created great pollution problems. China faces severe water shortages, particularly in areas where coal is cut, and washing equipment requires a large capital investment, so that much of the coal that has been sold and burned is unwashed and produces much higher sulfur dioxide and particulate emissions (Thomson 2003). Coal combustion produces 90% of sulfur dioxide emissions and 50% of nitrogen oxide emissions.

In addition, although China has become one of the frontrunners in coal gasification, a process that extracts the energy from coal in cleaner and more efficient fashion than traditional methods,[2] it faces some large difficulties in using this process. The most immediate is that gasification plants still cost about 10% to 20% more per megawatt than traditional coal-fired power plants, not even including carbon dioxide capture that most supporters showcase as a major benefit for the process, even though it has yet to be utilized. Even with the proper incentives, technical difficulties inhibit gasification from its full potential. Plants would require large amounts of water to produce the syngas, and the majority of China's coal reserves exist in the northern part of China, including Shanxi and Inner Mongolia provinces, which is suffering from severe water shortages already. With no solution in sight, for the present day most of the area will have to continue mining coal using traditional methods.

Oil and natural gas

As gas prices have radically fluctuated over the past few years, speculation has turned to China's place in the oil industry, and to the implications of its consumption and production rates. When the Communist party came into power in 1949, it inherited three oil fields capable of producing fewer than 2000 barrels a day, and none of the three had potential to become large producers (Ebel 2005). The first major onshore oil field was discovered in 1959 at Daqing in northeast China, and oil production grew steadily thereafter. Over the following decades, China managed to completely change the industry, allowing production to rapidly increase until finally in 1983 China became the largest oil exporter in Asia hitting a peak of 712,000 bbl/d in 1985.

However, owing to a large increase in demand for energy, oil imports increased after 1992, jumping to over 3.00E+18 J (Chen and Chen 2007a). Since then, the country's desire for oil has grown ever larger in absolute terms.

More recently, the past four years have shown tremendous growth in the consumption of oil with only a relatively small increase in the production. Consumption increased by half a million barrels a day from 2005 to 2006, up to 7.4 Mmbbl/d, representing 38% of the world's total increase in demand (Energy Information Agency 2006). Consumption in the same time period, between 2007 and 2008, increased 11.9% to 215 million tons (CPCIA). Production of oil has essentially stagnated, forcing China to search for oil elsewhere to make up for its significant need of oil.[3]

Since 1998, China's petroleum industry has been organized into three companies that have very loose specialties and all are publicly traded, although the government continues to own a majority stake in each of them. In general, China National Petroleum Corporation (CNPC) and its affiliates tend to dominate in the north and west while focusing mainly on oil and gas exploration and production. Onshore oil production amounts to about 85% of the total production and a quarter of this, about 900,000 bbl/d occurs in China's largest oil producing field, CNPC-owned Daqing.

The second company, Sinopec, focuses more in the south and engages in more consumer-based activities such as refining and distribution. Sinopec owns China's second largest oil producing field, Shengli, which produces 500,000 bbl/d and was discovered in April 2004. For the most part, CNPC and Sinopec own virtually all of China's oil refineries and operate the domestic pipeline network. China National Offshore Oil Corporation (CNOOC) specializes in the offshore regions that make up the last 15% of total production.

Natural gas recovery began in 1980 and grew slowly until 1997. From 1998 to 2002, natural gas production grew very rapidly, owing to the discovery of large-scale gas fields in Zhungeer, Talimu, Shanxi-Gansu-Ningxia and Sichuan (Chen and Chen 2007a). Natural gas makes up a small percentage of China's energy consumption, at 3% (Energy Information Administration 2009). Natural gas also burns much cleaner than other fossil fuels, making it an attractive alternative under the ever-increasing pressure for cleaner air.

Over the past decade, consumption of natural gas has been steadily increasing alongside production. Because natural gas until recently was used almost exclusively as a feedstock in chemical fertilizer and as an energy source at oil and gas fields, there are many areas in which natural gas usage could be expanded.

Even though production has been able to keep up with consumption so far, the Chinese realize that this will not always be the case. At the end of 2007, China had proven reserves of natural gas at only 1.88 tcm (66.54 tcf), 1.1% of the world's total. At the production rate of 2007, the reserves would last only 27.2 years, and since production and consumption have been increasing at an ever faster rate, the reserves will probably be depleted much sooner than that. In anticipation of the time when they do run out of domestic resources, Chinese officials and leaders of the top three oil companies have begun to search outside their borders for more natural gas. In particular, most of the Central Asian countries have entered into agreements with China. While the exact routes for all of these different pipes have not been released yet, it seems that most pipes will be linked together into a larger project called the Central Asia–China gas pipeline.

Nuclear energy

The first nuclear power plant was implemented in Qinghsan in 1991, at 300 MW. Additional plants were constructed in Daya Bay, Ling'ao and Tianwan, becoming steadily more powerful (Chen and Chen 2007a). China over the past few decades has built 11 nuclear stations, with 11 more plants under construction, 26 planned and 10 firmly proposed (World Nuclear Association 2009). In addition to these reactors, 16 provinces, regions and municipalities plan to build nuclear power plants during the 12th five-year plan (2011–15) (World Nuclear Association 2009). Under the Renewable Energy Law they hope to increase nuclear energy to 40 GW by 2020.[4] This would mean China would have to build at least six to eight new plants a year, every year, up until that date, to accommodate 40 GW by 2020 (Guizot 2007).

Although people normally place nuclear power alongside wind and solar power as a green energy source, nuclear power is a non-renewable source just like coal and oil. To reach the goal of 40 GW, China will need 4058.4 tons of natural uranium in 2010. Although China's annual uranium output is considered a national security secret, their proven reserves are not, with more than 300,000 tons in 300 mines. At these amounts, China can support itself for only another 10 or 20 years (Wang 2008). Already about half of the used uranium comes from imports and Chinese companies have been traveling around the world trying to secure resources. For now, Kazakhstan, Russia, Namibia and Australia have been the suppliers, although the China Nuclear International Uranium Corporation has set up a mine in Niger and considered Uzbekistan, Mongolia, Algeria and South Africa as potential suppliers.

At the other end of the process, nuclear energy also creates waste products, and with ever-increasing production comes more and more waste. Assuming that China reaches its goal of 20 GW by 2010 and 40 GW by 2020, the annual spent fuel waste would be 600 tons in 2010 and 1000 tons in 2020 with the cumulative waste then being 3800 tons and 12,300 tons respectively. China now has to contend with what to do with all the waste. The country began construction on a centralized spent fuel storage facility at Lanzhou Nuclear Fuel Complex near Yumenzhen in Gansu province in 1994. The project plan has a storage capacity of 550 tons and could be doubled. Additional reprocessing plants are under way.[5]

3. 'Green' energy in China

We next look at 'green' energy production, in terms of hydropower, thermal power, wind energy and solar power.

Hydroelectric energy

The first hydropower station was constructed in Xindian in 1904, and by 1949, there were six hydropower stations (Chen and Chen 2007b). Additional stations were constructed thereafter. In 2005 hydroelectric power accounted for 79 GW, though China has not yet finished building. By 2020, the Chinese government will require that 200–240 GW of power must come from dams, which would require 7–9 GW of new hydroelectric power every year – the equivalent of a Three Gorges Dam built every two years. While it may be a one-time sunk cost, these projects would still require $13 billion to $23 billion every year (Guizot 2007). The benefits from dams certainly seem to have been obvious to generations of Chinese leaders, combining flood control and electricity generation, one of which has plagued China for millennia and the other will plague the country for perhaps just as long.

Many dams have been quietly making their mark in an understated fashion; small hydropower plants (those with up to 25 MW capacity) help rural communities receive electricity without the need for transmission lines. China has been adding 6000 MW of capacity annually leading to a total of about 50,000 MW by the beginning of 2008. Government officials hope to continue adding 10,000 MW of hydropower every year after 2010. One of the more helpful pushes towards the development of small hydropower plants was the standardization of designs, making the replacement of parts much easier. Because of the ease with which these dams can be put up and their efficiency once they are running, about one-third of China's 2300 counties relies on small hydropower for electricity (Ramakrishnan 2008).

Geothermal energy

The first geothermal plant, Yangbajing power plant, was constructed in Fengsun in 1970 and provides around 40% of total electricity to Lhasa (Chen and Chen 2007b). An additional geothermal power unit was installed in Naqu, Tibet in 1994. In 2005, China had a total of five plants, three in Tibet, one in Guangdong and one in Hunan. The government plans on 100 MW of energy being produced in this method by 2010, and 500–1000 MW by 2050.

Right now, there are 103 geothermal fields that can extract 332.83 million cubic meters of usable resources, although there are 214 fields that have reached the preliminary evaluation stage with extractable resources of up to 500 million cubic meters per year. Unfortunately geothermal energy only accounts for 0.5% of China's total energy usage, due in large part to the remote location of efficient fields situated mostly in northern Tibet and western Yunnan; however, as seen by the amount of reserves it has, geothermal energy does have growth potential (TMCnet 2006).

Solar energy

China is a frontrunner in solar power, with good reason. Sunlight increases dramatically from east to west and south to north, with the maximum sunlight in the Qingzang Plateau (Chen and Chen 2007b). In 2007 China had 80 MW of solar photovoltaic on rooftops and lampposts around the country, although this number will increase (Biello 2008). By 2010, China hopes to produce the equivalent of 4.67 million tons of standard coal through solar energy. Tibet already produces 100 MW mostly in small villages that otherwise would not have electricity (Guizot 2007).

Thirty million people in 7 million households live in 28,000 villages spread throughout the Chinese countryside. Because of the immense size of China and the particularly harsh terrain that covers most of the country, in whatever form, 60% of counties still suffer from severe electricity shortage. The cost of building power lines to bring coal-generated energy to these remote villages makes electricity extremely expensive; however solar power does not have these excess expenses. Passive solar collectors are used in rural areas, while solar ovens are used in Qingzang Plateau. All of these villages make up a part of the potential market for solar power (Red Orbit 2009).

China both produces and consumes half of the world's solar water heaters, and the market still has growth potential, with 58.52% of Chinese households having the intention of either buying solar water heaters or replacing their gas/electric heaters with solar ones within the next five years. Experts estimate that the country will maintain an annual growth rate in solar water heater consumption of 20–30% for the next few years, leading to an overall area of solar water heaters installed in China by 2010 at about 100 million square meters (Red Orbit 2009).[6]

Although solar power requires direct sunlight, which can be scarce in cities, it comes with a lack of unwelcome by-products, a quiet, unobtrusive design, and suitability for remote areas.

Wind energy

Windmill power generators were put in use from 1958 onward, with medium-sized and large wind power generators implemented in the 1980s. Wind energy use remained relatively low until 1998, when the 'Wind Development Plan' sought to improve wind technology and develop resources in poor areas (Chen and Chen 2007b). In 1990 only 20 megawatts of energy came from wind, but by 2005 this number had increased to 320 MW (Guizot 2007).

One of the biggest obstacles facing wind energy in China is the lack of an extensive grid structure that can push energy from west to east. While China may have the area needed to handle large-scale wind farms, particularly in Inner Mongolia and Xinjiang, the majority of energy use occurs on the coastline. The solution to this problem comes from two changes happening simultaneously. First, population and economic development have been slowly moved west. Cities like Chengdu and Kunming have flourished under recent prosperous times, and this trend is expected to increase as major first-tier cities in the east, including Beijing, Shanghai and Shenzhen, reach commercial saturation points, and companies begin to search for new markets. This means that as wind farms produce more and more energy, the need for it in western areas will also gradually increase.

In addition to the redistribution of energy growth, engineers are producing new technology that allows for more electricity, up to three to five times the current amount, to be carried through the same size wires without losing as much energy in transportation. While these new transmission wires still cost quite a bit more than traditional lines, producers expect the price to eventually become competitive (Johnson 2008). Between these two changes in the economy, China can build wind farms now with the present goal of powering more local communities like Urumqi in Xinjiang and Hohhot in Inner Mongolia, and the future goal of powering the economic giants in the east.

4. Employment and share of energy production

Now we turn to employment and share of energy production in both 'dirty' and 'green' energy production sectors.[7]

Coal statistics are reported by the National Bureau of Statistics in two sectors, the Coal Mining and Dressing sector (Industry Code 06_), and the Coal Gas Production and Supply sector (Industry Code 45_). The former employed 4,636,883 individuals in 2007, while the latter employed 158,840. Employment in coal mining alone accounted for over 60% of employment in all energy industries, with regard to both extraction and power generation. Employment in coal mining appears to be on the rise from 2003 onward. Shanxi Province provides the most employment in the coal mining industry, accounting for 20% of all jobs in the coal mining sector, followed by Henan (12%) and Shandong (11%), Heilongjiang (8%) and Sichuan and Anhui (both 6%). The other provinces account for 5% or fewer of all coal mining jobs. Coal produces around 80% of energy used, which amounted to 237,300 10^4 tons in 2006.

The National Bureau of Statistics uses two sector categories for the oil and natural gas industry, Crude Petroleum and Natural Gas Extraction (Industry Code 07_) and Oil Processing and Refining (Industry Code 25_). Together they employ 23% of all labor in the energy industry, with employment currently roughly equally divided between the two sectors. Petroleum and natural gas extraction employs the most people in Heilongjiang (14% of national total), Xinjiang (12%), Shaanxi (10%), Liaoning (10%), followed by Henan (9%), Chongqing, Hebei and Shandong (all three 7%), Tianjun and Jilin (6%), and the remainder under 5%. Oil refining employs the most individuals in Shanxi (23%) and Shandong (11%), followed by Liaoning and Heilongjiang (both 7%) Hebei (6%), and the remainder under 5%. Crude oil produces around 12% of energy produced, which amounted to 18,477 10^4 tons in 2006. Natural gas accounts for around 3% of energy produced, or 586 10^8 cubic meters in 2006.

The nuclear power industry, which consists of the statistical category Nuclear Power, 4413 employs the fewest people, comprising less than 1% of all employment in the energy industries. Currently, employment in this sector is around 5700, with most individuals located in Zhejiang (79%) followed by Jiangsu (20%). Nuclear energy accounts for less than 1% of energy produced, at 548 10^8 kWh in 2006.

Employment in the Hydropower Generation sector, 4412, has declined somewhat since 1999, and comprises 3% of employment in energy industries. Hydropower employment is based mainly in Sichuan, which accounts for 19% of the hydropower labor force, Hunan (11%), Hubei (10%) and Fujian (9%). The remaining districts each comprise 5% or less of the hydropower labor force. Hydropower accounts for between 2% and 7% of energy produced (depending on whether valued at calorific value or coal equivalent), at 4358 10^8 kWh in 2006.

Employees in thermal power generation (statistical code 4411), account for 10% of all employment in energy industries. Thermal power generation employs the most individuals in Heilongjiang (employing 13% of individuals in the industry), Henan (11%), Shandong (10%), and Jiangsu and Hebei (6%). The remaining provinces employ 5% or fewer of workers in the thermal power sector.

We note that data on labor and profit margins in the solar and wind power sectors are not separately collected (as individual categories) by the National Bureau of Statistics. Solar energy provides far less than 1% of all energy in China, while wind energy produces less than 1% of all energy, around 0.7 GW in 2004 (Cherni and Kentish 2007). Wind energy is produced primarily, in descending order, in Inner Mongolia, Hebei, Jilin, Liaoning, Guangdong, Xinjiang, Heilongjiang, Ningxia, Shandong, Gansu and Jiangsu (Shi 2007).

According to a study undertaken by Greenpeace (2008), assessments carried out in Germany, Denmark, Spain and the Netherlands show that for every megawatt of new capacity in wind energy, 15 jobs (in person-years) will be created, although employment in regular operations at wind farms will contribute 0.33 jobs for every megawatt of capacity. Employment in the solar energy sector is similar; for every megawatt of new solar energy capacity, up to 35.5 jobs will be created, although for regular servicing in the photovoltaic sector, up to 2.5 jobs will be created (REPP 2001). The average employment over the life of a solar energy facility is 7.41 per MWa, while over the life of a wind energy facility it is 0.71 per MWa (Kammen, Kapadia, and Fripp 2004).

More detailed information on employment and energy production can be found in Appendix I. Tables A2 and A1 contain information on mean sectoral and regional employment, as well as the coefficient of variation within these categories. Table A3 contains total regional energy employment. Table A4 contains information on energy production by sector.

5. Model: from a 'dirty' energy to a 'green' energy regime

In this section, we first describe past changes in terms of labor across energy sectors and regions. Then we construct a model that projects energy sector changes across employment using different scenarios, accounting for regional location.

Statistics shown here are from the China Energy Statistical Yearbook (2007). We are not given data for the wind or solar energy sectors, and nuclear energy data are sparse. We create data for the wind and solar energy sectors based on information on location of these sectors from credible sources outside the National Bureau of Statistics. Note that we do not treat employment in energy transmission and distribution, which would likely surge, in the future, in areas with undeveloped or underdeveloped grids.

Using statistics on employment in sectors and regions, we project the impact of China's energy goals at 2020 on jobs in these areas. We also assess the employment impact of our 'greener' scenario, and our 'greenest' scenario.

In doing so, we must make several assumptions. First of all, we assume that average regional distribution of labor per energy sector remains constant. For example, coal mining jobs do not shift to southern China, and do not become more or less productive.

We also assume that new wind energy jobs are created in provinces according to the current distribution: Hebei, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Gansu, Ningxia and Xinjiang, by percentages of installation and production specified in Shi (2007). We assume solar energy jobs are created by their current distribution in Tibet, Qinghai, Gansu, Xinjiang, Yunnan, Sichuan, Beijing, Shanghai, Shandong, Jiangsu, Guangdong and Inner Mongolia, by percentages specified in Wu (2008).

We use REPP (2001) which states that solar energy creates 7.41 jobs for every MW of energy capacity installed, and that wind energy creates 0.71 jobs for every MW of energy capacity installed. Current nuclear reactors are based in Guangdong, Zhejiang and Jiangsu, while plants firmly planned or under construction (to be constructed before 2020) are located in Guangdong, Zhejiang, Liaoning, Fujian, Shandong, Guangxi, Jiangsu, Hainan and Hubei (World Nuclear Association 2009). We use average numbers for jobs per GW of energy (500 jobs according to the US Department of Energy)[8] rather than China's given numbers since data are insufficient in terms of employment in nuclear power, and the numbers that are given may be inflated due to initial construction of plants.

We incorporate the number calculated from data from the National Bureau of Statistics for China's energy production in 2007, 697 GW,[9] which is in line with the given statistic of 710 GW (Graham-Harrison 2008), and we assume that production of energy as a whole is doubled by 2020, per the Renewable Energy Law of 2007. This would mean that the balance of energy, in addition to the 90 GW of 'green' energy, would be supplied by 'dirtier' sources. Finally, we use the average labor to output (GW) ratio in sectors currently to calculate future job creation.

We present first the current distribution of jobs in the energy industry as a whole, then follow with the distribution of jobs in 2020 under the 11th year plan. Then we create 'greener' and 'greenest' scenarios that project employment levels and distribution if the share of coal and oil are reduced, while the shares of renewable energy resources are increased. Using statistics on average energy output per job, we project the effects of a hypothetical energy industry transformation on job creation and destruction.

In the 'greener' scenario, we assume that, while doubling its energy usage, China will add: 140 GW hydropower, 80 GW wind power, 80 GW solar power and 5 GW thermal power. In the 'greenest' scenario, we assume that China adds: 280 GW hydropower, 160

Table 1. Regional percentage of total employment in four scenarios.

	Percentage of total energy employment currently (1)	% of total energy use 2020 planned (2)	% of total energy use in 'greener' scenario 2020 (3)	% of total energy use in 'greenest' scenario 2020 (4)	Net change (1) to (4)
Sichuan	5%	6%	7%	9%	4%
Guangdong	2%	2%	3%	5%	3%
Fujian	1%	2%	2%	3%	2%
Yunnan	1%	2%	2%	3%	2%
Hubei	1%	2%	2%	4%	2%
Guangxi	1%	1%	2%	3%	2%
Hunan	3%	4%	4%	5%	2%
Tibet	0%	0%	1%	2%	2%
Gansu	2%	2%	3%	3%	1%
Inner Mongolia	3%	3%	3%	4%	1%
Qinghai	0%	0%	1%	1%	1%
Jiangxi	2%	2%	2%	3%	1%
Zhejiang	1%	1%	1%	2%	1%
Xinjiang	2%	2%	3%	3%	1%
Guizhou	2%	2%	2%	3%	0%
Chongqing	2%	2%	2%	2%	0%
Hainan	0%	0%	0%	0%	0%
Shanghai	1%	1%	1%	1%	0%
Beijing	1%	1%	1%	1%	0%
Ningxia	1%	1%	1%	1%	0%
Jilin	3%	3%	2%	2%	0%
Tianjin	1%	1%	1%	1%	–1%
Jiangsu	3%	3%	3%	2%	–1%
Shaanxi	2%	2%	2%	1%	–1%
Anhui	5%	4%	4%	3%	–2%
Liaoning	6%	6%	5%	4%	–2%
Hebei	6%	5%	5%	4%	–2%
Heilongjiang	8%	7%	6%	5%	–3%
Henan	10%	10%	9%	7%	–4%
Shandong	11%	10%	9%	7%	–4%
Shanxi	14%	14%	11%	8%	–6%
Total energy jobs	6,644,780	12,530,829	12,886,226	13,047,254	

GW wind power, 160 GW solar power and 5 GW thermal power. These projections are within China's capacity according to Cherni and Kentish (2007). Table 1 contains the results.

The 'greener' is China's energy transition, the more jobs are created, and the more western and poor southern areas stand to gain. The net losers in our 'greenest' scenario are areas in the northeast that invest heavily in the coal industry. The biggest net loser in the 'greenest' transition is Shanxi, which is to be expected since the province is the biggest producer of coal. Shandong and Henan follow close behind. The biggest net winner would be Sichuan, one of the poorest provinces in China. A 'green' transition would improve the plight of China's poorest provinces, which are mainly concentrated in the western and central-western areas of the country.

China's planned transition, as it stands, will have almost no impact on labor reallocation across the country, since much of the energy will continue to be provided by coal and oil. The spread of nuclear technology from coastal regions to inland areas would enable leaders to replace coal mining and production jobs with jobs in nuclear power. A possible spread of nuclear technology, given a positive test of the AP1000 nuclear technology after 2013 (Li 2008), would greatly reduce ‘dirty’ energy sources while assisting employment levels. However, employment in nuclear energy will not be quite enough to fill the gap in the coal industry. Additional employment in the service or other sectors is necessary to ease a transition out of coal-based energy. Fiscal transfers from ‘green’ transition winners would not make sense, since winning areas are already poor and require fiscal transfers for poverty reduction (see Figure 1).

6. Policy recommendations

Fossil fuel energy is unsustainable in China. Coal is abundant but is the worst polluter of all energy sources, while natural gas and oil are relatively scarce. Nuclear energy might be promising, although contending with nuclear waste presents a problem. Something must be done.

In a transition from a ‘dirty’ to a ‘clean’ energy regime, China’s labor structure will be reconfigured. Barriers to migration make it difficult for those in ‘dirty’ energy jobs to take up ‘clean’ energy jobs. Therefore, providing other types of jobs to former ‘dirty’ energy employees during a transition to ‘green’ energy usage is critical, particularly in provinces in which energy provides a higher percentage of total employment.

Net losers that also employ a greater percentage of employees in the energy sector are Shanxi, Heilongjiang, Tianjin and Liaoning. These are areas that are not impoverished per se; they are better off than provinces in western China. However, particularly in Shanxi, these economies are reliant to some degree on employment in ‘dirty’ energy. This is not to say that reducing ‘dirty’ energy jobs would impoverish these provinces, but rather that job creation is necessary to create a smooth energy regime transition. Employment policies are essential in Shanxi and Heilongjiang (see Table 2).

If people do not have jobs to shift into when ‘dirtier’ industries reduce employment, local governments and residents will not support environmental policies. As was made clear in the classic case of Benxi city, which undertook an environmental rehabilitation program, people must continue to have jobs, or the health of the environment is meaningless to them (Liu et al. 2006).

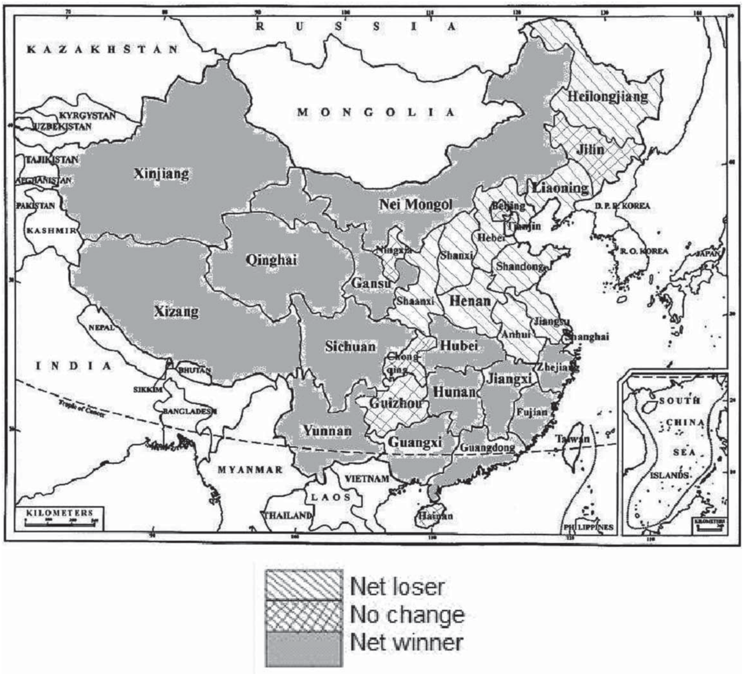
Ultimately, the central government must back programs to improve the environment in order for them to be successful. Local officials often lack knowledge and financial resources to promote such programs, and no local official would choose to be a net job loser, even if it means dramatically improving the environment.

A ‘green’ transition would help the poorest provinces, and the overall energy transition would most likely reduce inequality in China, which has been growing since reform and opening-up. China will benefit from a ‘green’ transition politically as well, as energy security is increased. A trend of increasing oil imports has been a cause of concern among the leadership, marking a departure from energy self-sufficiency which China had into the 1990s. Relying on renewable resources that are based in China will allow China to increase its self-sufficiency in energy.

7. Conclusion

Although China has set out to improve its current energy regime, there is no guarantee that it will change its energy industry enough to offset global warming. Part of the hesitation to shift into greener energy is due to concern over job losses and restructuring. This paper

Net Winners and Losers of "Greenest" Transition



Rural Poverty Rate

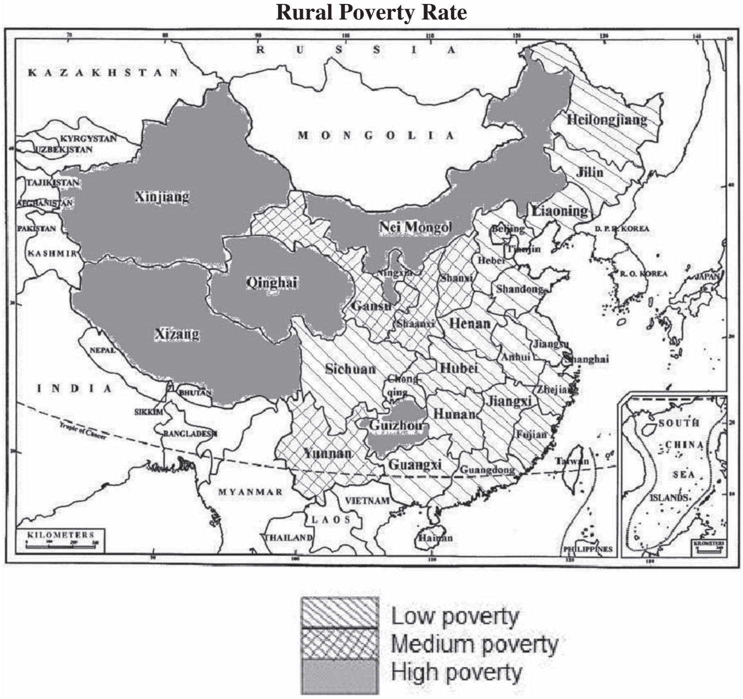


Figure 1. Top Map: Source: Authors' calculations; Bottom Map: Wang (2004).

Table 2. Provincial employment in energy as a percentage of total employment (all jobs).

District	2007 employment in energy as percentage of total employment in province
Shanxi	7%
Heilongjiang	4%
Xinjiang	3%
Ningxia	3%
Tianjin	2%
Inner Mongolia	2%
Jilin	2%
Liaoning	2%
Shandong	1%
Shaanxi	1%
Henan	1%
Qinghai	1%
Hebei	1%
Sichuan	1%
Anhui	1%
Chongqing	1%
Guizhou	1%
Gansu	1%
Hunan	1%
Jiangxi	1%
Beijing	1%
Jiangsu	0%
Shanghai	0%
Fujian	0%
Yunnan	0%
Hubei	0%
Zhejiang	0%
Guangdong	0%
Guangxi	0%
Hainan	0%
Tibet	0%

Sources: *China National Yearbook* (2007) and authors' calculations.

has sought to explore employment considerations in a greener transition, and finds that restructuring China's energy industry would offset not only global warming, but extreme poverty as well.

Notes

1. Provisions for providing assistance to former coal workers were stipulated in the 'Notice by the Administrative Office under the State Council concerning the work of further closing and rectifying the small coal mines and coal mine safe production' (2001), the 'Notice of issuing the implementation methods for the closing and bankrupting state funded enterprises, deregulated enterprises of coal industry and non-ferrous industry' (Document No. 32, 2000), and the 'Comments on relevant issues in carrying out the Notice by Administrative Office under the Chinese Communist Party Central Committee and the Administrative Office under the State Council concerning the closing and bankrupting of the resources depleted mines' (Document No. 33, 2000) (ESMAP 2004).

2. In this process, two or more boreholes are dug into the coal seam. The plant ignites the coal and pumps oxygen through one of the boreholes to continue combustion, while the pressurized gases are brought into the plant through the other borehole. Because the gases are so concentrated when they reach the surface, the plant can easily capture pollutants, reducing the impact of coal on the environment. In addition, the process itself produces much lower amounts of pollutants including no sulfur oxide or nitrogen oxide, lower levels of mercury and particulates, and the ash that is responsible for most of the health ailments of people in surrounding areas stays underground (Fairley 2007). Once the gas has been brought to the surface, China's coal gasification plants mainly use one of two methods to transform the coal into a cleaner alternative, the more common and famous being the Fischer–Tropsch synthesis. Coal is transformed into a hydrogen-rich gas known as synthesis gas, or 'syngas' for short. This syngas can then be further worked with to form a fuel used as a substitute for gasoline and diesel fuels. Because of the ability to create this form, China can use coal not only to clean up its electricity production, but also to reduce its dependency on foreign oil for its ever-increasing fleet of new cars.
3. Another disruption that may have affected the large amount of imports in 2008 was that domestic prices had been capped during the period when global oil prices soared to over $100 a barrel, forcing local refineries to cut or halt production, forcing the country to increase imports (China Daily 2009).
4. Other departments believe that this number underestimates what the target needs to be: the State Energy Bureau says that the goal should be 50 GW, the China Electrical Council said 60 GWe, while the National Development and Reform Commission in May 2007 announced that it is shooting for 160 GWe by 2030.
5. A pilot (50 t/yr) reprocessing plant using the Purex process was opened in 2006 at Lanzhou or Jiayuguan. This is capable of expansion to 100 t/yr and was fully operational in 2008. A large commercial reprocessing plant based on indigenous advanced technology is planned to follow and begin operation about 2020. This is likely to be under international safeguards and situated in far western China. In November 2007 Areva and CNNC signed an agreement to assess the feasibility of setting up a reprocessing plant for used fuel and a mixed-oxide (MOX) fuel fabrication plant in China, representing an investment of €15 billion. In mid-2008 CNNC said that the focus was on Gansu province for an 800 t/yr reprocessing plant operated by Areva from 2025. High-level wastes will be vitrified, encapsulated and put into a geological repository some 500 meters deep. Site selection is focused on six candidate locations and will be completed by 2020. An underground research laboratory will then operate for 20 years and actual disposal is anticipated from 2050. There is already industrial-scale disposal of low and intermediate-level wastes at two sites, in the northwest and at Bailong in Guangxi autonomous region of south China.
6. China is currently the number one producer of the photovoltaic cells creating 1700 megawatts of the panels in 2007, half of the world's total (3800 megawatts), while only a little under 5% stays in the country (Biello 2008). Much of the reasoning behind this comes from China's lack of environmental laws. In other countries that force manufacturers to use pollution reduction equipment, the cost of production for one ton is approximately $84,500. Chinese companies can make the same ton for $21,000 to $56,000 (Cha 2008). That is still, however, too expensive for most Chinese consumers.
7. We look only at energy production, not transmission and distribution.
8. Each nuclear power plant creates 400 to 700 permanent jobs (Department of Energy 2008), with each plant worldwide producing an average of 1 GW of power.
9. This excludes the 'other' energy category.

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Appendix I. Employment data charts

Table A1. Coefficient of variation within regional/sectoral employment, between years 1999–2007.

	Coal mining and production	Oil and gas extraction and refining	Thermal power	Hydropower
Beijing	16	35	47	74
Tianjin	17	25	20	N/A
Hebei	6	52	4	31
Shanxi	17	32	8	11
Inner Mongolia	9	62	2	22
Liaoning	10	22	17	9
Jilin	11	37	12	17
Heilongjiang	12	44	24	16
Shanghai	11	24	38	N/A
Jiangsu	12	27	12	67
Zhejiang	43	10	8	11
Anhui	8	26	8	13
Fujian	33	12	5	8
Jiangxi	15	6	27	24
Shandong	4	26	13	173
Henan	8	14	12	84
Hubei	16	70	34	10
Hunan	8	31	6	3
Guangdong	48	33	10	18
Guangxi	29	9	7	9
Hainan	21	129	6	26
Chongqing	19	48	29	29
Sichuan	21	45	20	3
Guizhou	23	97	18	19
Yunnan	24	80	52	27
Tibet	N/A	N/A	N/A	35
Shaanxi	12	N/A	5	N/A
Gansu	7	20	22	15
Qinghai	17	90	102	22
Ningxia	7	24	13	56
Xinjiang	8	42	10	32

Sources: *China Industrial Yearbooks* (2000–2008).

Table A2. Mean per regional/sectoral employment, 1999–2007.

	Coal mining and production	Oil and gas extraction and refining	Thermal power	Hydropower	Nuclear power	Total employment	Percentage of regional total
Beijing	33,661	28,561	9888	566	0	72,677	1%
Tianjin	7710	64,322	7089	0	0	79,121	1%
Hebei	256,993	70,235	46,148	2286	0	375,662	6%
Shanxi	763,829	118,411	47,115	2004	0	931,360	14%
Inner Mongolia	146,188	11,284	34,894	720	0	193,086	3%
Liaoning	208,894	131,569	46,257	4519	0	391,239	6%
Jilin	97,936	48,576	20,707	5225	0	172,444	3%
Heilongjiang	296,720	120,379	88,784	2464	0	508,347	8%
Shanghai	10,397	24,808	10,677	N/A	0	45,882	1%
Jiangsu	127,781	30,082	48,281	333	487	206,965	3%
Zhejiang	9936	12,434	32,060	9440	775	64,646	1%
Anhui	268,533	8161	25,570	3215	0	305,479	5%
Fujian	34,111	3348	8621	25,557	0	71,637	1%
Jiangxi	81,790	8148	11,061	15,557	0	116,556	2%
Shandong	501,384	143,863	80,058	29	0	725,334	11%
Henan	506,251	102,000	81,583	7357	0	697,191	10%
Hubei	25,744	18,945	20,388	26,492	0	91,570	1%
Hunan	150,933	21,550	14,798	31,359	0	218,640	3%
Guangdong	17,129	29,002	39,629	30,159	930	116,850	2%
Guangxi	21,479	2193	7228	21,495	0	52,395	1%
Hainan	704	168	2140	3801	0	6813	0%
Chongqing	90,003	2223	4868	10,545	0	107,640	2%
Sichuan	196,691	69,712	19,653	49,695	0	335,751	5%
Guizhou	105,110	3184	12,738	13,262	0	134,294	2%
Yunnan	46,960	4033	14,478	19,201	0	84,672	1%
Tibet	N/A	N/A	N/A	2545	0	2545	0%
Shaanxi	112,091	N/A	31,196	N/A	0	143,287	2%
Gansu	71,381	39,409	14,580	8212	0	133,582	2%
Qinghai	6753	11,045	1473	5074	0	24,345	0%
Ningxia	57,410	6446	9244	1081	0	74,182	1%
Xinjiang	44,452	93,359	14,971	7808	0	160,590	2%
Total Sectors	4,298,954	1,227,451	806,178	310,004	2193	6,644,780	
Percentage of Sectoral Total	65%	18%	12%	5%	0%		

Sources: *China Industrial Yearbooks* (2000–2008) and authors' calculations.

Table A3. Regional energy employment (detailed view).

District	Coal mining and dressing	Coal gas production and supply	Oil processing and refining (w/o nuclear fuel processing)	Crude petroleum and natural gas extraction	Thermal power generation	Nuclear power	Nuclear fuel processing	Hydropower generation
National	4,636,883	158,840	800,620	906,683	788,844	5722	5744	263,453
Beijing	21,018	7728	19,094	2518	6438	0	0	709
Tianjin	106	5270	15,840	58,299	8016	0	0	0
Hebei	225,765	8967	47,600	64,855	43,512	0	0	1839
Shanxi	931,883	2862	182,715	352	42,860	0	0	1475
Inner Mongolia	152,354	2391	14,695	5078	35,780	0	0	636
Liaoning	175,883	14,803	58,514	90,945	35,235	0	18	4359
Jilin	86,706	3139	8157	57,085	17,778	0	0	4399
Heilongjiang	349,972	9002	55,627	128,460	101,555	0	0	2594
Shanghai	0	9145	24,163	165	7930	0	0	0
Jiangsu	103,564	8826	22,122	18,990	50,069	1171	0	219
Zhejiang	5118	3601	11,252	0	35,505	4523	0	7773
Anhui	271,651	4129	7137	0	25,128	0	0	3206
Fujian	50,520	1379	4823	0	8496	0	0	22,917
Jiangxi	94,622	2070	8987	0	11,262	0	0	10,704
Shandong	497,080	15,423	89,462	67,134	76,647	0	0	116
Henan	554,031	13,638	25,496	81,782	89,130	0	30	5332
Hubei	21,832	3394	10,240	37,112	17,103	0	0	25,610
Hunan	164,225	2724	23,469	0	13,980	0	0	30,050
Guangdong	0	7901	25,678	2410	34,278	28	0	20,382
Guangxi	17,230	912	2170	0	7396	0	0	17,783
Hainan	0	647	664	32	1988	0	0	1365
Chongqing	115,199	6893	6591	1182	7496	0	0	7566
Sichuan	262,999	12,429	17,060	66,900	15,002	0	0	49,165
Guizhou	147,697	2490	5719	0	15,839	0	0	7503
Yunnan	71,831	2095	16,804	57	9311	0	0	14,482
Tibet	0	0	24,562	0	0	0	0	67
Shaanxi	127,228	3305	31,579	89,819	32,505	0	2051	3679
Gansu	74,389	1064	683	8225	12,552	0	3645	7072
Qinghai	7086	142	7657	16,583	155	0	0	6609
Ningxia	59,754	643	32,060	350	9891	0	0	241
Xinjiang	47,140	1828	32,060	108,350	16,007	0	0	5601

Source: China Data Online.

Table A4. Energy production.

Primary energy production (10^4 tce) (coal equivalent calculation)	1995	2000	2002	2003	2004	2005	2006
Raw coal (10^4 tn)	136,073	129,921	145,456	172,200	199,232	220,473	237,300
Crude oil (10^4 tn)	15,004	16,300	16,700	19,660	17,587	18,135	18,477
Natural gas (10^8 cu.m)	179	272	327	350	415	493	586
Hydropower (10^8 kW•h)	1906	2224	2880	2837	3535	3970	4358
Nuclear power (10^8 kW•h)	128	167	251	433	505	531	548
As percentage of primary energy production (%) (calorific value calculation)	1995	2000	2002	2003	2004	2005	2006
Raw coal	78.69	75.65	76.41	78.87	79.97	80.55	80.80
Crude oil	17.35	18.98	17.54	15.54	14.12	13.25	12.58
Natural gas	1.93	2.95	3.19	2.99	3.10	3.35	3.71
Hydropower	1.90	2.25	2.63	2.26	2.47	2.52	2.59
Nuclear power	0.13	0.17	0.23	0.34	0.35	0.33	0.32
As percentage of primary energy production (%) (coal equivalent calculation)	1995	2000	2002	2003	2004	2005	2006
Raw coal	75.30	71.95	72.25	75.07	75.96	76.49	76.68
Crude oil	16.60	18.05	16.59	14.79	13.41	12.58	11.94
Natural gas	1.90	2.80	3.02	2.84	2.94	3.19	3.52
Hydropower	5.85	6.69	7.49	6.34	6.73	6.83	6.99
Nuclear power	0.39	0.50	0.65	0.96	0.95	0.91	0.87

Source: China Data Online.