GENI Global Energy Network Institute

Renewable Energy Potential of China: Making the Transition from Coal-Fired Generation

Peter Meisen
President, Global Energy Network Institute (GENI)
www.geni.org
peter@geni.org (619) 595-0139

Steffanie Hawkins
Research Associate, Global Energy Network Institute (GENI)
shawkins1017@gmail.com

Table of Contents

Executive Summary

China is one of the world's fastest growing countries in multiple aspects. China possesses enormous potential for the development of renewable energy. The government has recently set targets to be reached by 2010 and 2020 for installed generating capacity. The two main sources of renewable energy for China will be from hydropower and wind power. Hydropower (China accounts for 12% of world hydropower) is expected to reach a capacity of 190 GW by 2010 and 300 GW by 2020. Wind, the other large source of renewable energy, is expected to reach 10 GW by 2010 and 30 GW by 2020. Biomass is expected to reach a capacity of 5.5 GW by 2010 and 30 GW by 2020. Solar is expected to reach 300 MW by 2010 and 1.8 GW by 2020. These are reasonable goals for China, but there still remains more potential for the country.

This potential is against a backdrop of significant need for renewables. In 2006, China became the world's largest polluter passing the US, emitting 6,200 million tons of carbon dioxide. According to the Energy Information Agency (EIA), in 2004, China accounted for 17% of world total carbon dioxide emissions, with an expected increase to 40% of the world total between 2005 and 2030, if current energy trends continue.

China is the world's largest producer and consumer of coal, accounting for 69% of China's total energy consumption. The EIA reports that as of 2005, China had 28,000 coal mines and was adding a new 500-megawatt coal fired power plant every four days, adding up to approximately 91 new coal-fired power plants a year. This is an aggressive number of plants to open every year. Not only is coal the largest contributor of carbon dioxide but also has several known health effects. In 2009, *China Daily* reported that every 30 seconds babies are born with defects, totaling almost one million cases a year. The highest rates of birth defects are in Shanxi province, China's largest coal-mining center producing 630 million tons of coal in 2007. Lung cancer in China has also gained public attention as deaths due to lung cancer have risen 465% over the past 30 years. In April 2008, the Chinese Ministry of Health reported that the rise in deaths of lung cancer was directly related to environmental consequences as well as lifestyle. Because of these and several other reasons, it is essential that the Chinese government begin the shift to renewable energy and away from coal-fired electricity generation.

In China's 10th five-year plan, 2001 to 2005, the Chinese government set goals to increase installed capacity of renewable energy. Overall, the plan was moderately successful in promoting renewable energy, and it increased installed capacity almost 25%. As of 2007, hydroelectric accounted for 20.7% of total energy capacity; nuclear accounted for 1.2%; geothermal, solar, wind, and biomass combined only accounted for 0.5% of energy capacity. Conventional thermal remained the largest source by far, accounting for 77.6% of installed capacity.

China is a world leader in hydropower development, in terms of both project size and generating capacity, with the world's largest hydropower station along the Yangtze River. Hydropower remains the government's top priority in developing renewable energy, because the technology is well developed, and China is relatively experienced in the area. While China's goal remains at 300 GW by 2020, the World Watch Institute projects that China has a potential of 500 GW of generating capacity.

Wind is expected to become China's second largest source of renewable energy in China. Since the first wind farm project in 1990, China has seen considerable increase of installed generating capacity and is expected to double this capacity in 2009. While the current goal remains at 30 GW by 2020, the National Renewable Energy Laboratory of the Chinese Academy of Meteorological Sciences estimates that China has a potential of 235 GW of generating capacity on mainland China, with larger potential offshore. The largest wind resources potential lies in Inner Mongolia.

China is also looking to develop solar power, though not as much emphasis seems to have been given to solar generation. China is the world's largest producer and exporter of photovoltaic (PV) solar cells. As the largest producer of PV cells, it exported almost 95% of those cells to other countries, because the price remained too high to be competitive with other forms of energy within country. As a result, the government has implemented subsidies to help defray the cost of solar power and plans to increase capacity to 1.8 GW by 2020. According to Professor Yin Zhiqiang, it is estimated that over 90% of China can support some form of solar power, mainly located in Western China. Another part of solar power in China that is relatively large is solar thermal water heaters (SWH). The market for SWH has exponentially grown over the past decade with an annual production of 13 million square meters in 2004.

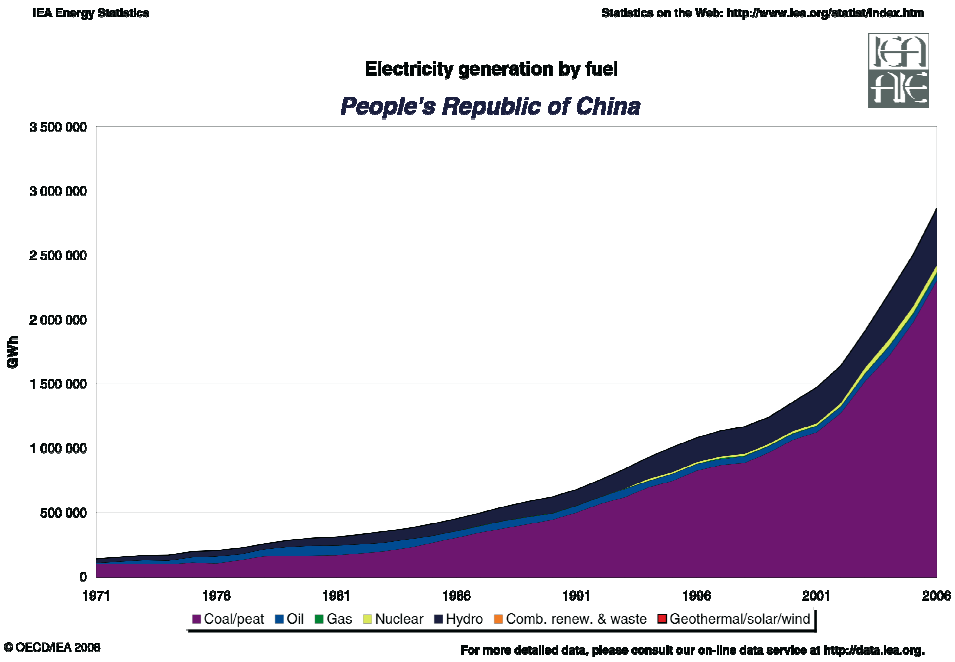
The last primary source of renewable energy in China is biomass. China has an extremely large rural population with a large resource of biomass for energy. There are approximately 4 billion tons of crop residue and wood fuels used for energy in rural areas. The government is making strides to develop and make more efficient use of biomass in rural areas, because the industry is already established. According the C.Z. Wu and several other scholars, biomass technology in China has a sizeable market potential in making use of biomass waste, and it is economically feasible. The development of biomass technology in the areas with the largest supply of biomass waste, the rural areas, will benefit those who need reliable and efficient electricity. The development of biomass in the rural areas is a win-win situation.

Current Energy Patterns

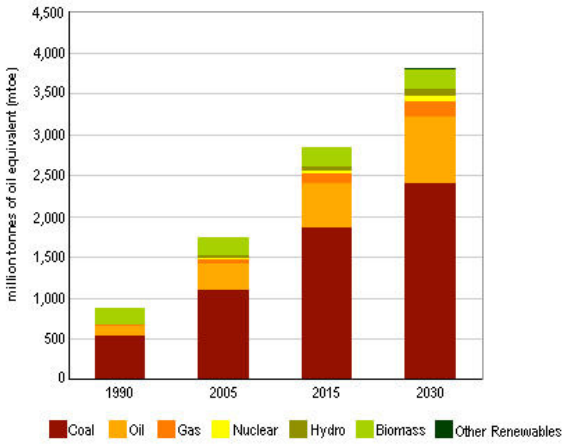
Consumption & Generation

In 2006, China was the second largest consumer of energy, behind the United States, consuming 73.808 quadrillion Btu's (Quads), almost double its 2000 consumption. China has experienced an annual growth in consumption of 8.9% since the late 1950's[1]. Thus, China's economic engine is doubling energy demand every 8 years. The total generating capacity includes coal, petroleum, natural gas, nuclear, hydroelectric, and other non-hydroelectric renewable sources[2].

[1] "Energy consumption in China: past trends and future directions". Energy Economics. Vol 27, Issue 1, Jan 2005, Pp 195-208.
[2] "International Energy Statistics", Energy Information Administration (EIA), eia.doe.gov



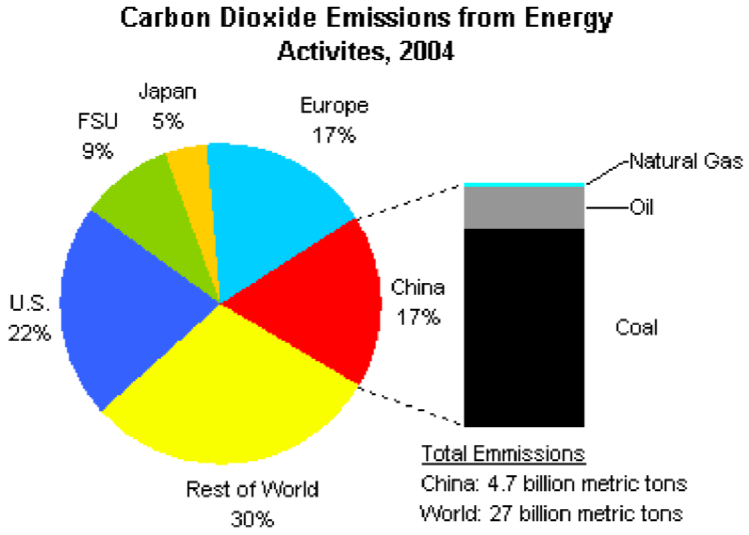
While the amount of renewable sources is increasing slowly, the use of coal and oil as generation of electricity is steadily increasing and is projected to account for approximately 80% of energy production by 2030[3].



The level of CO_2 emissions within China has also sharply increased within the past decade. In 2004, China was the world's second largest producer of carbon dioxide emissions behind the US. By 2006, China had become the world's largest CO_2 emitter, emitting 6,200 million

[3] "Projected Energy Growth in China by Energy Source" Earth Trend 2008, http://earthtrends.wri.org/updates/node/274.

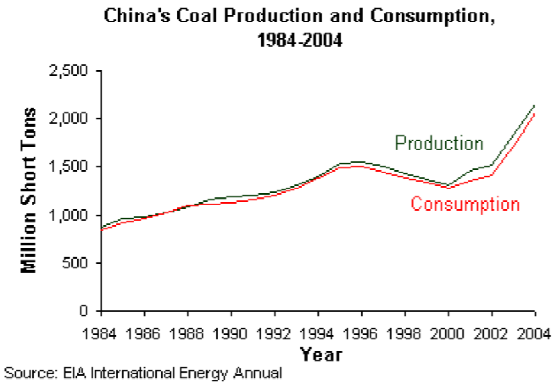
tons, an 8% increase from 2005[4]. The International Energy Agency predicts that if current policy remains unchanged, China will account for 40% of worldwide CO_2 emission growth between 2005 and 2030.



Source: EIA International Energy Annual

For this reason, it is essential that the Chinese government begins now to create and implement incentives and policies that will move China toward clean, renewable energy sources and away from coal-fired generation.

Coal

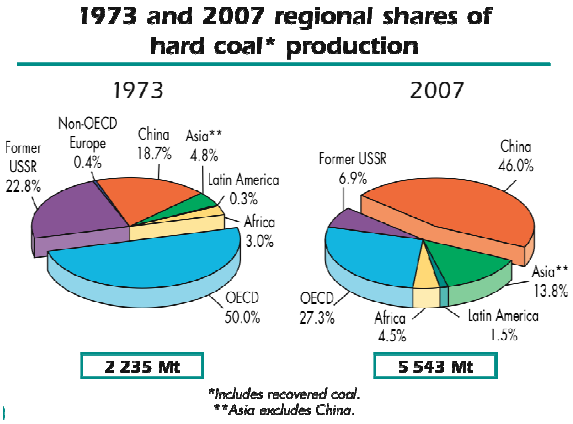


Source: EIA International Energy Annual

In 2000, China consumed 1.28 short billion tons of coal; by 2007, it had consumed 2.77 billion, a 53% increase[5]. China is the world's largest consumer and producer of coal,

[4] Vidal, John and David Adam. "China Overtakes US as world's biggest CO_2 emitter". Guardian.co.uk.

accounting for 69% of Chinas total energy consumption. China is by far the largest coal supplier in the world, producing 46% of the world's total coal supply, a significant increase from 1973 when it only produced 18% of the world's supply[6].



Source: International Energy Agency

While many of the other regions have maintained or reduced levels of coal production, China has shown significant growth in coal production over the past three decades. By the end of 2005, it was reported that China had 28,000 coal mines[7]. China has been reported as adding a new 500-megawatt coal fired power plant every four days, approximately 91 new power plants a year[8]. Coal consumption tends to be concentrated in four different industries: power generation, building material, metallurgy and chemical production, power generation being the largest user of coal -- accounting for over 50% of production and consumption[9]. Both domestic and foreign experiences show that "coal-fired power generation is the main contributor of coal consumption"[10]. Coal-fired power generation required low investment, short construction periods, low electricity production costs and an abundant resource of coal.

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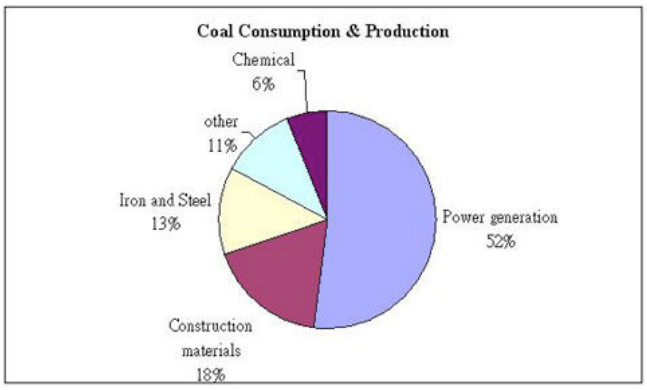
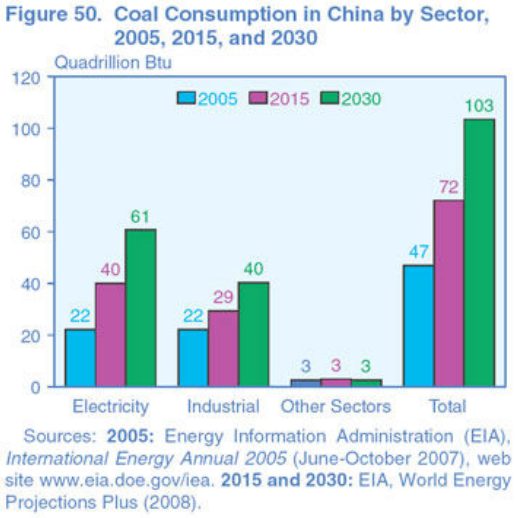
[5] "International Energy Statistics", Energy Information Administration (EIA), eia.doe.gov
[6] International Energy Agency. Key World Energy Statistics 2008. Iea.org
[7] "Country Analysis Briefs: China", EIA, eia.doe.gov
[8] Krupp, Fred and Miriam Horn. "Reconsidering Coal". Earth: The Sequel. Pp 179
[9] "The PRC Coal & Coke Industry", New Technologies Holding Group, http://www.ntholdingcorp.com/industry.htm
[10] He, Youguo. "China 's Coal Demand Outlook for 2020 and Analysis of Coal Supply Capacity". China Coal Industry Development Research and Consulting Co. Ltd.



Source: New Technologies Holding Group

Shenhua Group Corporation Limited reported a total coal production of 114.68 million tons in 2006, marking the seventh year in a row of a 10-million annual production increase. At a 10-million ton production increase rate, by 2020, China will be producing over 250 million tons of coal a year. China's coal consumption is expected to rise to 60.6 quadrillion Btu's at an average increase of 4.1% a year[11]. Because of limited reserves in oil and natural gas, coal will remain the primary near-term source for power generation for both industrial and domestic consumers

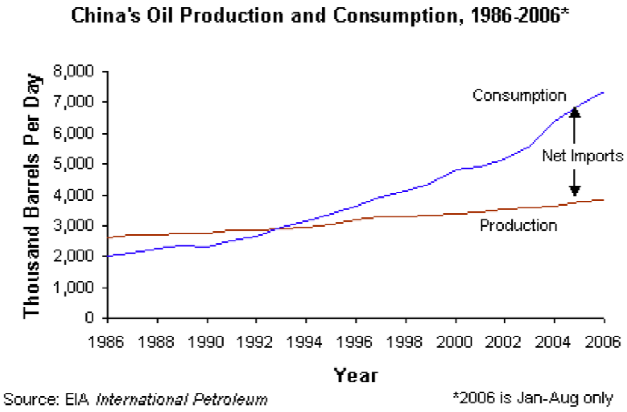


The most obvious side effects of heavy reliance on coal are those on health. The *China Daily* reported in 2009 that every 30 seconds babies are born with defects, totaling nearly one million cases per year. The highest rates of birth defects are reported in Shanxi province. Shanxi province also happens to be the largest coal-mining center in China, producing 630

[11] "Chapter 4. Coal" International Energy Outlook 2008. EIA, eia.doe.gov

million tons of coal in 2007, roughly a fourth of the total coal production in China. The director of the Shanxi provincial family planning agency linked the environmental pollution from coal to the rising birth defects in the province[12]. There are also western studies done by Columbia and Yale Universities that link air pollution to chromosomal damage and the births of underweight babies. Lung cancer is a growing concern as the number of deaths due to lung cancer has risen 465% over the past 30 years, while production of coal has increased 27 percent. In April 2008, a Ministry of Health official reported that lung cancer has replaced liver cancer as the top killer among malignant tumors; this rise was linked directly to environmental pollution as well as lifestyle[13](increase in smoking). It is not only the consumption of coal that is environmentally damaging but the entire process from the mining to the actual burning and waste disposal.

Oil & Petroleum



China is the world's second largest consumer of oil behind the United States and the third largest net importer of oil. In 2008, China produced 3.9 million barrels of oil per day, 97% of which was crude oil. In 2008, China consumed 7.9 million barrels of oil a day, 389,000 barrels per day increase from 2007[14]. This leaves China with a proven oil reserve of 16

[12] Lelyveld, Michael. "China Coal Linked to Birth Defects". Radio Free Asia. www.rfa.org. 2009 Feb 9.
[13] "Death By Lung Cancer Soars in China". www.chinaview.cn. 2008 April 29. http://news.xinhuanet.com/english/2008-04/29/content_8074947.htm
[14] "International Energy Statistics", Energy Information Administration (EIA), eia.doe.gov

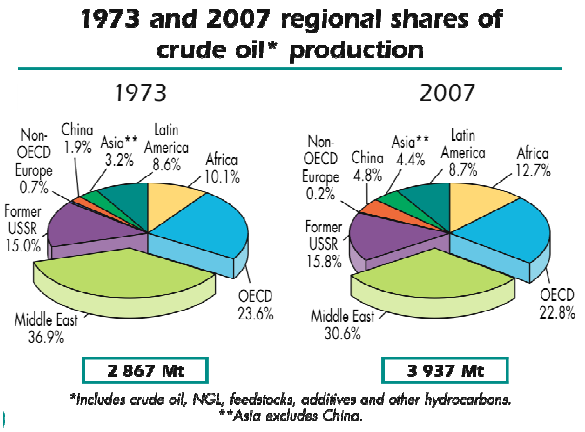
billion barrels. Its resulting petroleum based carbon emissions totaled 9.6 billion metric tons, an increase of approximately 71 million metric tons from 2006.[15]

China's petroleum industry is divided into two integrated firms, China National Petroleum Corporation (CNPC) and China Petroleum and Chemical Corporation (Sinopec). China National Offshore Oil Corporation (CNOOC) is also part of the industry mainly dealing with offshore production and development. The largest producing oil fields in China are already mature, where oil production has peaked and is in decline. This has lead to the exploration of reserves in the western interior provinces and offshore fields[16].

Major Chinese Oil Fields by Production, January 2006	
Field	**Production (bbl/d)**
China National Petroleum Corporation (CNPC)/PetroChina	
Daqing	929,268
Liaohe	256,991
Xinjiang	222,524
Changqing	162,422
China Petroleum and Chemical Corporation (Sinopec)	
Shengli	535,531
Sinopec Star	78,567
Zhongyuan	67,092
China National Offshore Oil Corporation (CNOOC)	
Total offshore	519,108
Source:	

China has maintained its production of oil over the past three decades, increasing only slightly; especially in comparison to the increase in production of coal. Today, China's oil production only accounts for slightly less that five percent of the world's total oil supply; a number that is expected to fall in the coming decades[17].

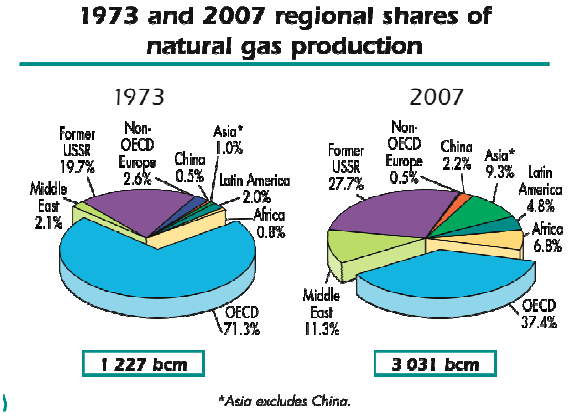
[15] "International Energy Statistics", Energy Information Administration (EIA), eia.doe.gov
[16] "Country Analysis Briefs: China", EIA, eia.doe.gov
[17] International Energy Agency. Key World Energy Statistics 2008. Iea.org



Source: Key World Energy Statistics 2008, IEA

Natural Gas

In China, natural gas is currently a minor fuel source in the energy production, representing only 3% of total energy consumption in 2005, with gas consumption expected to rise by 5.5% a year[18]. China still remains one of the smaller producers of natural gas, accounting for only 2.2% of the worlds total natural gas production[19].



Source: Key World Energy Statistics 2008, IEA

China's production and consumption of natural gas has begun to grow rapidly, in large part because of China's 11th five-year-plan which called for the increase in the percentage of natural gas in primary energy sources to account for 5.3% by 2010. Production increased to 1956 billion ft^3 in 2006, a 10% increase from the year before, while consumption increased to 1995 billion ft^3 in 2006, a 17% jump from the previous year[20]. "Results show

[18] "Chapter 3- Natural Gas" International Energy Outlook 2008. EIA, eia.doe.gov
[19] International Energy Agency. Key World Energy Statistics 2008. Iea.org
[20] China Energy Profile. Energy Information Administration

that China could cut 1 million tons of particulates, 3 million tons of sulfur dioxide and carbon emissions by 70 million tons each year if it boosts gas utilization to 10 percent of total energy demand by 2020"[21]. Adding another five percent to the already projected 5.3% of natural gas in primary energy sources could be part of the next five-year plan, creating the possibility for reaching that 10% target. The EIA has estimated that China's proven natural gas reserves total 2.3 trillion cubic meters. China's Coal Bed Methane (CBM) or coal bed gas reserves, gas extracted from coal beds, total 30-35 trillion cubic meters. Only 10 percent of this gas could be used to fuel 100 large combined cycle power plants for 30 years (each 1 gigawatt combined cycle plant consuming approximately 1 billion cubic meters of gas a year[22]). This would produce approximately 10.3×10^{15} Btu's, which could account for almost 14% of China's 2006 energy consumption. The EIA estimates that by 2030, China will have an installed natural gas fired power generation capacity of 339 gigawatts, a 13% annual growth rate[23].

Renewable Energy

In China's 10th five-year plan, it mapped out goals to increase its installed capacity in several different sectors of renewable energy. Within this plan, they wanted to increase annual solar hot water heating to 11 million square meters, while also increasing production capacity of solar cells to a cumulative 53 MW. In the wind sector, it planned to increase installed capacity to 1.2 GW. It planned to increase bioenergy to supply 2 billion square meters of fuel. In order to achieve some of these goals in 2003, the government passed the Renewable Energy Promotion Law. Incentive policies in the law were structured to encourage development of renewable technologies while providing market opportunities for renewable energy companies in order to allow local governments, companies and individuals to both promote and utilize renewable energy[24]. Overall, the 10th five year plan was successful in promoting renewable energy, with installed capacity increasing almost 25% during the time period.

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[21] Logan, Jefferey and Dongkun Luo. "Natural Gas and China's Environment".
[22] Logan, Jefferey and Dongkun Luo. "Natural Gas and China's Environment".
[23] "Reference Case Projections for Electricity Capacity and Generation by Fuel", EIA, eia.doe.gov
[24] "Renewable Energy in China: Renewable Energy Policy in China Overview". National Renewable Energy Laboratory. www.nrel.gov/docs/fy04osti/35786.pdf

Installed Electric Capacity in China 2000-2003

In million kilowatt hours

	2000	2001	2002	2003	2004	2005	2006	2007
Hydroelectric	72.9	79.3	83.0	86.1	94.9	105.2	117.4	128.5
Nuclear	2.17	2.17	2.17	4.5	6.1	6.8	6.9	7.6
Geothermal/Solar/ Wind/Biomass	.52	.64	.75	.87	1.0	1.3	1.9	3.4
Conventional Thermal	223.4	237.5	253.0	265.5	289.7	329.5	391.4	484.0
Total Capacity	299.1	319.7	338.9	356.9	391.8	442.9	517.5	623.5

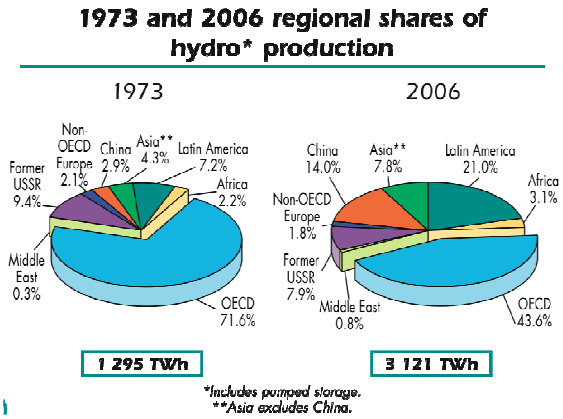
Values from EIA International Energy Statistics

As of 2007, hydroelectric accounted for 20.7% of total renewable energy capacity, while nuclear accounted for 1.2% and geothermal/solar/wind/biomass contributed just 0.5%. Conventional thermal, primarily coal, remained the largest source of energy in China, contributing 77.6% of the installed capacity. There still remains an enormous potential of untapped renewable resources in the geothermal, solar, wind and biomass sectors.

Hydropower

Hydro electricity is by far China's largest supplier of renewable energy. In 2007, they had an installed capacity of 118 GW and generated 423 billion KwH[25]. China has grown significantly in the amount of hydro electricity it produces, accounting for 14% of the world's total hydro production. The Three Gorges Dam is now the largest hydropower station in the world with an 18.2 GW rating.

[25] "International Energy Statistics", EIA. Eia.doe.gov



Source: Key World Energy Statistics, IEA

According to the Energy Information Agency, in 2007 China had almost 430 billion kilowatt hours of hydropower generation and consumed the same amount, with an installed capacity of 128.5 GW. Studies estimate that China has an exploitable capacity of 500 million kilowatt hours, yet only has 25% of that actually installed[26]. Two of the largest recent hydroelectric projects are the Three Gorges Dam located along the Yangtze River with a total generating capacity of 18.2 GW; the other is the along the Yellow River with a generating capacity of 15.8 GW[27].

Nuclear

Like most other types of primary energy sources, nuclear power is beginning to increase in China. Mainland China has eleven nuclear plants in operation, seven under construction and ten more to start construction soon. The plants in operation are located in Daya Bay (2), near Hong Kong, Qishan (5), south of Shanghai, Lingao (2), and Tianwan (2) [28]. The conveniences of nuclear plants is that they can be located near populated areas, decreasing the amount of transportation needed to get energy from the source to where it is needed.

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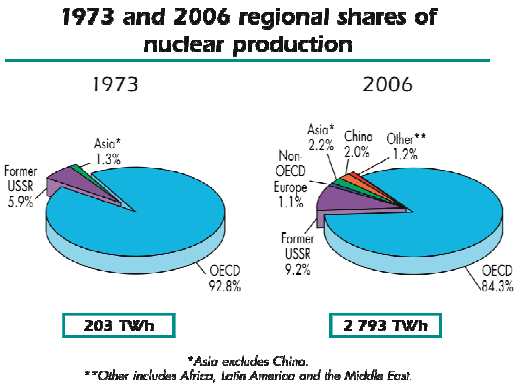
[26] Yang, Jianxiang. "Hydropower: A Viable Solution for China's Energy Future". World Watch Institute. Feb 13, 2007. http://www.worldwatch.org/node/4908
[27] "Nuclear Power in China". World Nuclear Association, http://world-nuclear.org/info/inf63.html
[28] "Nuclear Power in China". World Nuclear Association, http://world-nuclear.org/info/inf63.html

In 2007, the National Development and Reform Commission announced the target of nuclear generating capacity to reach 160 GW by 2030. China has increased its nuclear generating capacity in the past decade, but still remains only 2% of the worlds total generating capacity.



Source: Key World Energy Statistics, IEA

The eleventh five-year plan has fourteen proposed nuclear plants, the upcoming twelfth five-year plan expects to see some 16 provinces, regions and municipalities submit proposals for new nuclear power plants[29]. Some of the key points in China's nuclear energy policy include: pressurized water reactors as the main, but not sole, type of reactors; nuclear fuel assemblies are fabricated and supplied locally; and maximizing domestic manufacturing of plants and equipment.

Geothermal, Solar, Wind, and Biomass

The amount of installed generating capacity of the geothermal, solar, wind, and biomass sectors only amounts to 0.5% of total generating capacity. Because this is so low, it is generally all categorized into one sector, mainly "non-hydro renewable energies". Within the past couple of years, China has begun to focus on the enormous potential of these types of renewable energy, especially wind and solar. Currently China is a world leader in solar thermal production and use, accounting for 55% of global solar heating capacity.

In February 2005, China passed the China Renewable Energy Law, promoting renewable energy. Proposed to go into effect January 1, 2006, the law created financial subsidies and

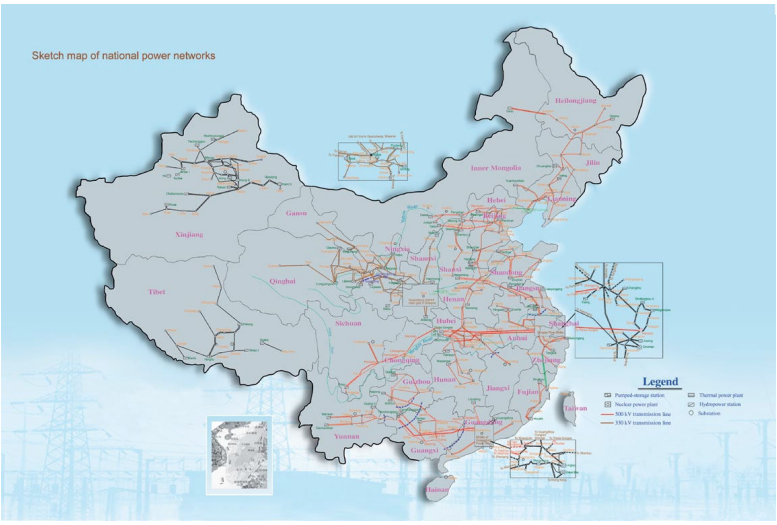
[29] "Nuclear Power in China". World Nuclear Association, http://world-nuclear.org/info/inf63.html

tax incentives for the development of renewable energy sources, like solar, wind, biomass, and geothermal. The law aims to increase Chinese renewable capacity to 15% by 2020 while investing $180 billion into renewable energy[30]. While financial incentives for renewable energy are increasing in China, the largest barrier to the development of renewable energy is still the cost-competition to coal. The average electricity cost from a coal-fired plant in China is between $0.04 and $0.06 per kilowatt-hour, whereas geothermal and hydro are between $0.02- $0.10/kWh, wind is between $0.05-$0.13/kWh, biomass is $0.05-$0.15/kWh, solar photovoltaic ranges from $0.25 to $1.25/kWh, and solar thermal is between $0.12- $0.18/kWh[31]. On a comparison scale, excluding externalities, currently nothing is cheaper than using coal-fired power plants to supply electricity.

National Grid

Since 2003, China has been divided into two different electricity suppliers. The government owned State Grid Corporation of China supplying electricity to most of northern and northeast China and China Southern Power Grid Corporation that supplies power to most of southeast China. The current electrical grid connects a number of the bigger cities to places where coal-fired electricity is generated. But the gap remains where no transmission lines extend from areas with strong renewable energy potential to highly populated areas.

[30] Li, Zijun. "China's Renewable Energy Law Takes Effect; Pricing and Fee-Sharing Rules Issued" Worldwatch Institute. Jan 18, 2006. http://www.worldwatch.org/node/3874
[31] Fridleifsson, Ingvar B. "Geothermal energy for the benefit of the people". Renewable and Sustainable Energy Reviews. Vol 5, Issue 3. Sep 2001. Pg 299-312.



Source: http://www.sp-china.com/powerNetwork/gs.html#

The China National Grid project is supported by the "High Performance Computer and its Kernel Software" project under the National High-Tech R&D Program[32]. The National Grid project plans to connect several grid points throughout the country. The two main hubs are at the CAS Network Centers in Beijing and the Shanghai Supercomputer Center in Shanghai. Other points include locations in Beijing, Hefei located in Anhui, Xi'an located in Shaanxi, Changsha, Wuhan, Chengdu and Hong Kong. The Chinese government plans to invest around $12 million to build the needed IT infrastructure.

Source: http://i.cs.hku.hk/~clwang/grid/CNGrid.html

[32] "About China National Grid", China National Grid. http://www.cngrid.org/cngrid-old-site/en_introduce.htm

Renewable Energy Potential

China has an enormous untapped renewable energy potential, and the government has recently realized these resources and is beginning to introduce measures to take advantage of that potential. A study by Research and Markets Ltd showed that between 2005 and 2030, China is planning to spend approximately 23% of global investment, about $1.2 trillion, on renewable energy. By 2010, they hope to have 10% of energy consumption coming from renewable energy, with 20% by 2020[33]. According to the same report, the government has set out targets for several different sectors of renewable energy. Hydropower, currently China's largest sources of renewable energy, is expected to reach a capacity of 190 GW by 2010 and 300 GW by 2020. Wind, another strong potential source, is expected to reach 10 GW by 2010 and 30 GW by 2020, (which is a possible under-estimation). Biomass is expected to reach 5.5 GW by 2010 and 30 GW by 2020. Solar is expected to reach 300 MW by 2010 and 1.8 GW by 2020. If all of these targets are met at the minimum target, this would provide China with 362 GW of new renewable energy capacity.

Hydropower

China is a world leader in hydropower development, in terms of project size and capacity, with the world's largest hydropower station located along the Yangtze River. In 2005, China had 117 GW of installed capacity with the above-mentioned goal of 300 GW by 2030. The Worldwatch Institute claims that China has a potential of 500 GW of hydropower capacity[34]. Along with nuclear and wind, hydro seems to be the governments top priority for the country's energy agenda because "the technology is mature, and China has relatively rich experience in this area, along with a fairly well developed domestic industry"[35].

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[33] Thompson, Rachel. "China: Clean and Renewable Energy Report to 2010". Research and Markets Ltd. (email)

[34] Yang, Jiangxiang. *Hydropower: A Viable Solution for China's Energy Future?.* Feb 13, 2007. Worldwatch Institute. http://www.worldwatch.org/node/4908

[35] Yang, Jiangxiang. *Hydropower: A Viable Solution for China's Energy Future?.* Feb 13, 2007. Worldwatch Institute. http://www.worldwatch.org/node/4908

China's powerful water resources lay mainly in the underdeveloped west with the largest demand for electricity situated along the coastal east. The majority of China's waterpower resources lie in Sichuan, Tibet and Yunnan, where the Yangtze begins in Tibet and runs through Sichuan; the Pearl River begins in Yunnan[36]. China currently has approximately 5 dams in operation with generating capacity ranging from 760 MW to 22.5 GW, most of them located in the Sichuan and Yunnan area. There are currently around 11 dams under construction, all with completion dates set before 2020[37]. China has done very well in tapping most of its major waterways for hydropower and has little capacity left to exploit.

Wind

Along with hydropower, wind power has a huge opportunity to become a leading source of renewable energy in China. The Chinese government has placed a significant emphasis on developing China's wind market and its potential generating capacity, already increasing its predicted generating capacity for 2020 to 30 GW. From 4 MW of installed wind capacity in 1990 to 567 MW in 2003, China has seen a considerable increase in the amount of power that it is receiving from wind farms across the country[38]. China currently has 12.2 GW of generating capacity and has claimed wind energy "as a key growth component in its economic stimulus package" with an expected doubling in capacity in 2009[39].

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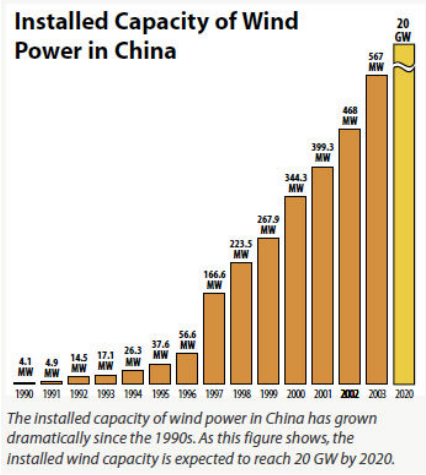
[36] Yang, Jiangxiang. *Hydropower: A Viable Solution for China's Energy Future?.* Feb 13, 2007. Worldwatch Institute. http://www.worldwatch.org/node/4908

[37] "Dams in China". Wikipedia.org. http://en.wikipedia.org/wiki/Category:Dams_in_China

[38] "Renewable Energy in China: Grid Connected Wind Power". National Renewable Energy Lab. http://www.nrel.gov/docs/fy04osti/35789.pdf

[39] Gow, David. "Wind power becomes Europe's fastest growing energy source". Tuesday February 3, 2009. Gardian.co.uk. http://www.guardian.co.uk/environment/2009/feb/03/wind-power-eu



The installed capacity of wind power in China has grown dramatically since the 1990s. As this figure shows, the installed wind capacity is expected to reach 20 GW by 2020.

China's wind sector was able to grow rapidly because of government intervention. In 1999, the National Development and Reform Commission (NDRC) along with the Ministry of Science & Technology released an official statement that included a rule setting wind power pricing "at a level that would repay capital costs with interest plus a reasonable profit"[40]. This was incorporated into policy and market development along with tax incentives. In 2004, the NDRC initiated the "Wind Power Concession Project" with a 20-year operational period with the aim "to reduce the in-grid wind power tariff by building large capacity wind farms and achieving economies of scale"[41]. By 2006, NDRC had approved the construction of 5 large wind farms, all of which require a minimum capacity of 100 megawatts[42]. Accordingly, the government hopes to create "incentives for companies to develop this renewable energy resource"[43] through this program. In 2006, when the Renewable Energy Law was put into effect, power grid companies were required to sign a "grid connection agreement with the wind power generating company and purchase the full amount of the wind power generated by it"[44]. While incentives have been

[40] "Renewable Energy in China: Grid Connected Wind Power". National Renewable Energy Lab. http://www.nrel.gov/docs/fy04osti/35789.pdf
[41] "Wind Power in China". EcoWorld. http://www.ecoworld.com/fuels/wind-power-in-china.html
[42] "Wind Power in China". EcoWorld. http://www.ecoworld.com/fuels/wind-power-in-china.html
[43] "Wind Power in China". EcoWorld. http://www.ecoworld.com/fuels/wind-power-in-china.html
[44] "Wind Power in China". EcoWorld. http://www.ecoworld.com/fuels/wind-power-in-china.html

put in place and the market size has significantly grown over the past couple years, coal still remain 33%-60% cheaper than wind power. Despite this fact the wind market continues to grow, and as it grows, the price of wind power is expected to decrease[45].

Wind Turbine Market in China
(estimates in millions of US dollars)

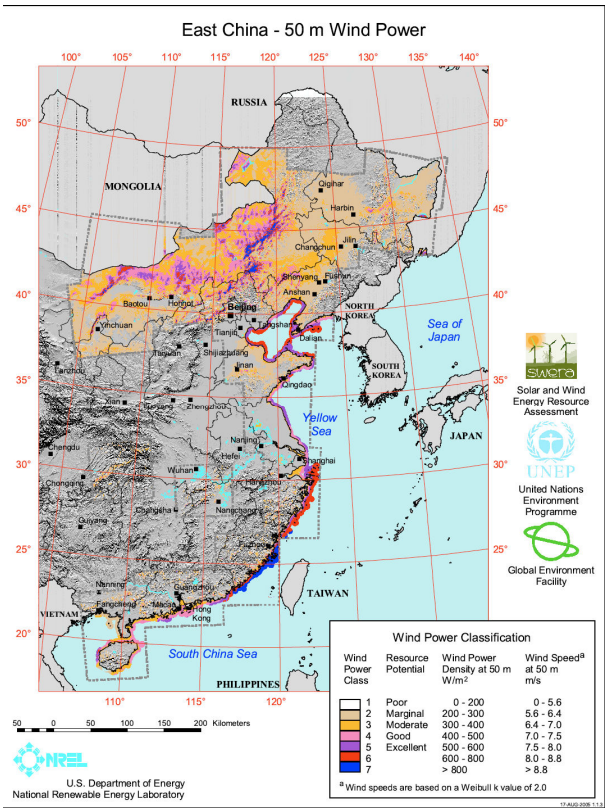
	2003	2004	2005
Total Market Size	61.9	188.6	315.3
Total Local Production	26.0	79.0	104.2
Total Exports	0.020	0.400	0.400
Total Imports	35.9	110.0	211.5
Imports from USA	0.001	0.001	0.072

Growth of the Chinese Wind Turbine Market

While China has significantly increased its generating capacity in wind power, there still remains a large untapped potential throughout China. According to the National Renewable Energy Laboratory (NREL), the Chinese Academy of Meteorological Sciences estimates China has a potential of 235 GW wind generating capacity on the mainland, with greater resource potential offshore. The following map shows the potential areas with high enough wind speeds to be able to efficiently generate electricity. From the map below, we can see moderate to excellent conditions in the northeastern area, mainly Inner Mongolia, a rural area that could fully utilize the option of wind power. The best conditions for wind power appear to be offshore, just off the coast of much of Eastern China with "above excellent" conditions all along the coast. As the NREL points out, China has a large area of shallow sea along the coastline and could possibly have an untapped potential of three times that onshore. Accordingly, the offshore potential is much more promising than the

[45] "Wind Power in China". EcoWorld. http://www.ecoworld.com/fuels/wind-power-in-china.html

onshore because of higher and more stable wind speeds[46]. Also by putting wind farms off-shore it makes the electricity more accessible to a majority of the demand.



With this market expected to continue to grow exponentially, many investors have taken interest in the expanding sector. Some of the investors include the "Big Five" power companies; Huaneng, Guodian, Datang, Huadian, Zhongdiantou, along with private firms and provincial energy leaders[47]. China has a huge potential for wind energy and is just beginning to tap into that potential. While coal still remains less expensive than wind power, as the market grows and technology advances, the world can expect to see decreasing turbine costs and customer prices for wind power. Until then, the government needs to continue to subsidize many of these firms to secure their position within the market.

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[46] "Renewable Energy in China: Grid Connected Wind Power". National Renewable Energy Lab. http://www.nrel.gov/docs/fy04osti/35789.pdf

[47] Li, Zijun. "China's Wind Energy Potential Appears Vast". Nov 2, 2005. Worldwatch Institute. http://www.worldwatch.org/node/57

Solar Power

China is one of the world's largest producers of photovoltaic cells and plans to increase its own solar power capacity to 1.8 GW by 2020[48]. In July 2009, the government announced that it would pay up to 70 per cent of the price of new solar power systems "in an effort to speed up development of clean energy industries"[49]. The government is willing to pay up to half the price of solar power systems, if more than 500 megawatts, over the next two or three years[50]. This price subsidy is in place with the hope of making solar power competitive with coal-fired power.

China has a large potential for solar power that currently remains untapped. According to Professor Yin Zhiqiang, President of China's Solar Energy Society, it is estimated that over 90% of China's territory can support some form of solar power[51]. In 2009, the Chinese government began construction of two large solar power plants in Qinghai and Yunnan with the largest potential for solar in the largely uninhabited Western China[52]. In 2006, China announced its plan to build the world's largest solar power farm, totally 100-megawatt generating capacity, in Gansu province[53]. The Chinese government has recently signed a Memorandum of Understanding with First Solar to build the world's largest solar farm in Inner Mongolia, a 2GW capacity to be completed in 2019.

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[48] Thompson, Rachel. "China: Clean and Renewable Energy Report to 2010". Research and Markets Ltd. (email)

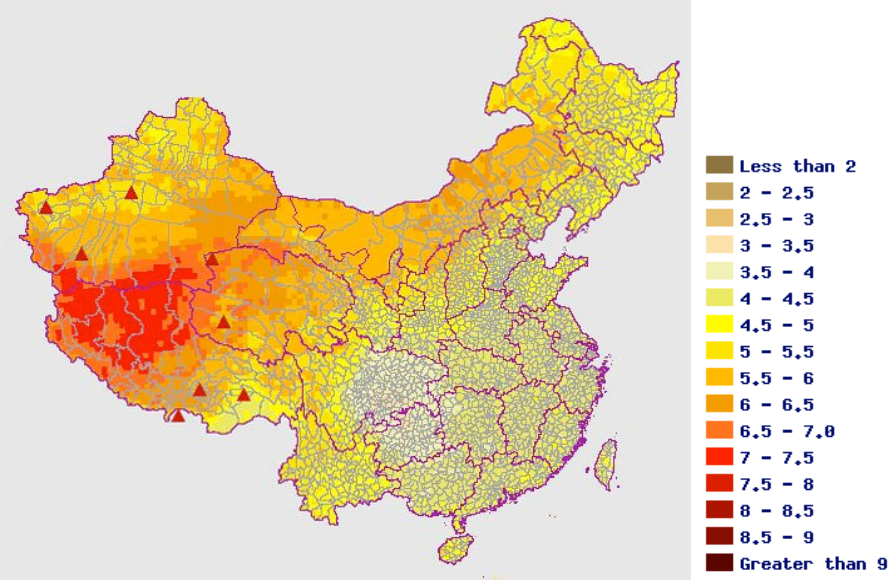
[49] "China to subsidize solar power projects" The *Malaysian Insider*. Fri July 31, 2009. http://www.themalaysianinsider.com/index.php/business/33094-china-to-subsidise-solar-power-projects

[50] China to subsidize solar power projects" *The Malaysian Insider*. Fri July 31, 2009. http://www.themalaysianinsider.com/index.php/business/33094-china-to-subsidise-solar-power-projects

[51] "China looks to a solar powered future". Sun Aug 8, 2004. http://angrychineseblogger.blog-city.com/china_looks_to_a_solar_powered_future.htm

[52] Solar and Wind Energy Resource Assessment. Swera.unep.net

[53] Kho, Jennifer. "China Wants Biggest Solar Plant". *Red Herring*. Nov 20, 2006. http://www.redherring.com/Home/19866



Solar Power Potential of China (SWERA)

China is the world's leading photovoltaic panel manufacture, yet 95% of the panels are exported[54]. According to Jonathan Watts, the global economic crisis has changed attitudes about PV panels, and the government plans to keep more of the panels within the country. The number of panels exported has decreased from 2007, where 99% of panels were being exported because of expensive PV costs and limited local markets[55]. China is making slow progress, but progress nonetheless, and China is heading in the right direction of cleaner energy practices.

Another big portion of China's solar power program is solar thermal power. Since its beginning in the 1980's, the Chinese market for solar water heaters (SWH) has significantly increased to become the world's largest SWH market[56]. But Li and Ru point out that while China has the largest market in the world, the per capita market is still small

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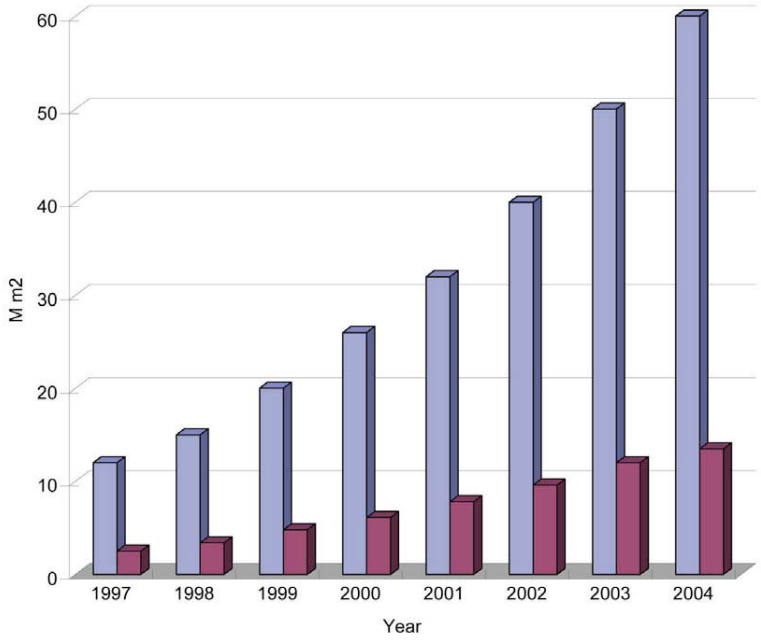
[54]Watts, Johnathan "China puts its faith in solar power with huge renewable energy investment". Guardian.co.uk. Tues May 26, 2009. http://www.guardian.co.uk/world/2009/may/26/china-invests-solar-power-renewable-energy-environment

[55] Biello, David. "China's big push for Renewable Energy". *Scientific America*. Aug 4, 2008. http://www.scientificamerican.com/article.cfm?id=chinas-big-push-for-renewable-energy

[56] Li, Junfeng and Runqing Hu. "Solar thermal in China: Overview and perspectives of the Chinese solar thermal market". Energy Research Institute, China. Sept 27, 2005. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B73D8-4H6GGSX-M&_user=4429&_rdoc=1&_fmt=&_orig=search&_sort=d&_docanchor=&view=c&_searchStrId=977757094&_rerunOrigin=google&_acct=C000059602&_version=1&_urlVersion=0&_userid=4429&md5=a19e97a2d506445c6ee2d8541b0f3802

and provides a tremendous opportunity for growth. In 1991, China had annual production at 0.5 million square meters; in 2004, annual production was 13 million square meters, an annual increase in production of 28.5%[57]. The following figure from Li and Ru shows the annual production (red) and cumulative installed capacity (in millions of square meters) of solar water heating systems in China by year. As we can see, the growth in the Chinese SWH market has been increasing exponentially but still provides plenty of opportunity for continued growth.



In February 2009, China announced its plans to build a solar thermal power plant outside of Beijing. When completed, it is expected to power up to 30,000 homes, generate up to 2.7 million kWh of electricity per year and eliminate 2,300 tons of CO_2 emissions from coal plants[58]. China needs to continue integrating SWH and solar power plants into the areas with the largest demand for electricity. That demand currently lies in the cities.

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[57] Li, Junfeng and Runqing Hu. "Solar thermal in China: Overview and perspectives of the Chinese solar thermal market". Energy Research Institute, China. Sept 27, 2005. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B73D8-4H6GGSX-M&_user=4429&_rdoc=1&_fmt=&_orig=search&_sort=d&_docanchor=&view=c&_searchStrId=977757094&_rerunOrigin=google&_acct=C000059602&_version=1&_urlVersion=0&_userid=4429&md5=a19e97a2d506445c6ee2d8541b0f3802

[58] Qi, Zhang. "Beijing to get solar thermal power". *China Daily*. Feb19, 2009. http://www.chinadaily.com.cn/bizchina/2009-02/19/content_7491243.htm

Biomass

Biomass in China is a larger energy source than most would think because of the huge rural population. 80% of biomass energy is located in rural China with the principle source being crop residue[59]. Approximately 4 billion tons of crop residues and wood fuels are burnt using stoves in the western rural areas[60]. The Chinese government is making strides to develop renewable energy in the rural areas, and since biomass as energy is already well established, they are looking at further development and higher efficiency of traditional biomass use[61].

The government has begun to carry out multiple projects nationwide in order to further the development of biomass. They have engaged in planting programs and reforestation in Wuhan county of Guangdong province. In 14 years, the area grew to 170,600 hectares with the coverage rate increasing from 31.5% to 49.4%, almost a 20% increase[62]. The annual capacity for energy production increased by 62.8%, an increase that could be duplicated in other parts of the country as well[63]. Another program that the government took on was improving cook stove efficiency, a large source of black carbon. From 1983 to 1996, stoves have been distributed throughout 177 million households, representing 76% of rural households in China[64]. The efficiency of improved woodfuel stoves is between 20% and 30%, "approximately 13.62 million tons of wood has been

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[59] Blauvelt, Euan. "Biomass in China". World Energy Discussion. Jan 14, 2008. http://worldenergydiscussion.blogspot.com/2008/01/biomass-in-china.html

[60] "Biomass Energy Use and Emission in China". ESCAP Virtual Conference. Regional wood Energy Development Programme in Asia. http://www.unescap.org/drpad/vc/conference/bg_cn_15_beu.htm

[61] "Biomass Energy Use and Emission in China". ESCAP Virtual Conference. Regional wood Energy Development Programme in Asia. http://www.unescap.org/drpad/vc/conference/bg_cn_15_beu.htm

[62] "Biomass Energy Use and Emission in China". ESCAP Virtual Conference. Regional wood Energy Development Programme in Asia. http://www.unescap.org/drpad/vc/conference/bg_cn_15_beu.htm

[63] "Biomass Energy Use and Emission in China". ESCAP Virtual Conference. Regional wood Energy Development Programme in Asia. http://www.unescap.org/drpad/vc/conference/bg_cn_15_beu.htm

[64] "Biomass Energy Use and Emission in China". ESCAP Virtual Conference. Regional wood Energy Development Programme in Asia. http://www.unescap.org/drpad/vc/conference/bg_cn_15_beu.htm

saved annually" because of this program[65]. If the government were to distribute improved cook stoves into 90%-100% of rural households, it would save Ghina over 15 million tons of wood a year. The third program was the development and utilization of renewable energy. As rural life increases, so does the demand for clean and reliable energy. In the 1990s as agricultural residue increased by 1.8%, 10% of it remained unused and was burnt in the field, while 35% of it was used at low efficiency, creating air pollution and waste of resources[66]. In 1999, the government enacted regulation that required 60% of all crop residues be used by the year 2002[67].

While many of these programs and plans have been useful in start up and development of biomass in China, there still remains a large untapped potential. According to C.Z. Wu and several others, biomass technology in China will have "advantages for competing with traditional power generation technologies"[68]. Accordingly, biomass gasification and power generation have a potential market in making use of biomass wastes. It is "economically feasible and can give a financial return" because of the low price of biomass waste and the lack of efficient power generation in rural China where the supply of biomass waste is the largest[69]. During Wu's study, they found that the biomass

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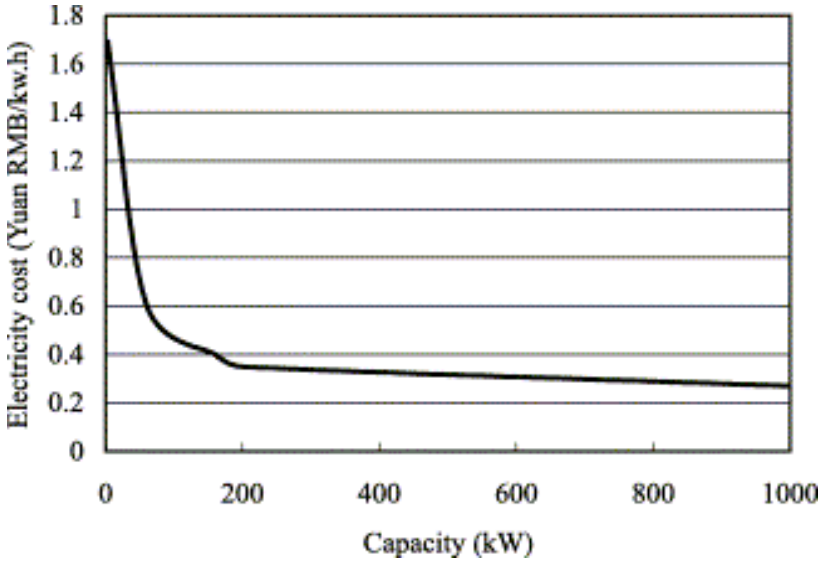
[65] "Biomass Energy Use and Emission in China". ESCAP Virtual Conference. Regional wood Energy Development Programme in Asia.
http://www.unescap.org/drpad/vc/conference/bg_cn_15_beu.htm
[66] "Biomass Energy Use and Emission in China". ESCAP Virtual Conference. Regional wood Energy Development Programme in Asia.
http://www.unescap.org/drpad/vc/conference/bg_cn_15_beu.htm
[67] "Biomass Energy Use and Emission in China". ESCAP Virtual Conference. Regional wood Energy Development Programme in Asia.
http://www.unescap.org/drpad/vc/conference/bg_cn_15_beu.htm
[68] Wu, C.Z. et all. "An economic analysis of biomass gasification and power generation in China". Science Direct. Jan 22, 2002.
http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V24-44YWKMG-5&_user=4429&_rdoc=1&_fmt=&_orig=search&_sort=d&_docanchor=&view=c&_searchStrId=981289473&_rerunOrigin=scholar.google&_acct=C000059602&_version=1&_urlVersion=0&_userid=4429&md5=5cec3cec3a5b2d52d12b53b0a5556593
[69] Wu, C.Z. et all. "An economic analysis of biomass gasification and power generation in China". Science Direct. Jan 22, 2002.
http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V24-44YWKMG-5&_user=4429&_rdoc=1&_fmt=&_orig=search&_sort=d&_docanchor=&view=c&_searchStrId=981289473&_rerunOrigin=scholar.google&_acct=C000059602&_version=1&_urlVersion=0&_userid=4429&md5=5cec3cec3a5b2d52d12b53b0a5556593

gasification and power generation unit capital cost was 60-70% of coal power stations and the operational costs were much lower than conventional thermal power plants[70]. According to these scholars, they recommend the development of medium-scale plants with generating capacity of 1000 to 5000 kW (1-5MW). The following image, from the same report, shows the price of electricity generated from biomass decreases as the capacity of the plant increases. Notice that the cost seems to plateau after 400 kW sizes, which is why medium-scale plants are highly recommended.



China obviously has a large rural population with a significant amount of biomass waste that can be used to generate electricity in the rural communities, with the need for reliable and efficient sources of electricity. The rural communities with the largest source of biomass waste are going to be able to benefit highly from the development of biomass technology in China over the coming years and is a very important aspect of renewable energy development.

[70] Wu, C.Z. et all. "An economic analysis of biomass gasification and power generation in China". Science Direct. Jan 22, 2002. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V24-44YWKMG-5&_user=4429&_rdoc=1&_fmt=&_orig=search&_sort=d&_docanchor=&view=c&_searchStrId=981289473&_rerunOrigin=scholar.google&_acct=C000059602&_version=1&_urlVersion=0&_userid=4429&md5=5cec3cec3a5b2d52d12b53b0a5556593

Concluding Remarks

China has a huge potential in several different sectors of renewable energy. Its large potential lies in the already well-established hydropower industry. Enormous untapped potential also exists in wind, solar, and biomass. The Chinese government needs to stop bringing coal-fired plants online, begin phasing out old coal-fired power plants and accelerate the development more clean sources of energy. The Chinese government is making great progress and is beginning to see the importance in this, yet huge unexploited renewable potential remains. Instead of following the rest of the world, the Chinese government possesses clean power resources where it can step up and lead the rest of the world in the development of renewable energy. Instead of letting the rest of the world criticize China for its lack of environmental responsibility, the Chinese government can make changes now and the rest of the world community can honor and emulate China's environmental responsibility.