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Leading the Renewable Energy Revolution

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China is a particularly important place in which to examine the opportunities for renewable energy development due to the size of its current energy demand and its projected renewable energy market potential. In addition to promoting renewable energy development, China is committed to developing indigenous renewable energy technology industries, motivated by the economic—as well as the environmental—benefits these technology industries provide. Already a global leader in solar thermal technology manufacturing and in manufacturing small hydro and wind turbines, China also has burgeoning solar photovoltaic (PV) and utility-scale wind turbine industries. With newly enacted national legislation to promote the development and dissemination of these technologies, many of China's renewable energy markets are just now beginning to mature. The entry of Chinese manufacturers into rapidly expanding global markets may drive down costs and increase the viability of renewable energy technology utilization worldwide, in both developing and developed country applications.

China consumes and produces more coal than any other nation in the world: two-thirds of its total primary energy consumption and three-quarters of electricity generation come from coal. Consequently, China is the second largest national emitter of carbon dioxide after the United States. Because its energy consumption and carbon emissions are

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growing rapidly, China is expected to surpass the United States in these two categories sometime in the next few decades. Energy use has grown faster than GDP in China over the past three years, with coal comprising more than two-thirds of the increase in primary energy supply over this time period.¹ Although the Chinese government has historically promoted an energy development plan that relied on indigenous energy resources as much as possible, oil imports are now rising rapidly to meet new demand, stimulating increased energy security concerns.²

However, a substantial mismatch exists between the geographic distribution of China's abundant coal resources and China's major centers of population, industry, and economic growth. Both the highest quality and highest concentration of coal reserves are generally found in the north, while the energy-hungry and economically dynamic areas of southern and eastern China only have about 5 percent of national coal reserves.³ These regional resource imbalances have played a role in triggering power supply crises. For example, seasonal fluctuations in hydropower have led southern China to increase its demand for coal-fired power in drought periods, precipitating a nationwide "power famine" or "coal rush."⁴ In addition, the transmission of power over thousands of kilometers from the economically underdeveloped west and north to the major load centers of the east and south significantly adds to the cost of the electricity supply and also constrains the development of the power sector.

It is in this context that China has begun to pursue renewable energy options. Renewable energy technologies

can generate electricity in places where fossil fuels are scarce, promoting domestic energy security while reducing environmentally damaging emissions. Wind energy has proven to be a particularly valuable contribution to China's energy mix by providing a cost-competitive option in regions where coal is scarce and electricity prices are highest—primarily along China's eastern coast. Wind electricity prices, although higher than coal electricity prices, are competitive with electricity prices from new natural gas plants, new nuclear plants, and even hydropower plants when the power is transported over long distances.

China's Emergence in the Global Wind Power Industry.

Wind is increasingly becoming a viable option internationally; although electricity generated from wind power currently represents only a half a percent of global electricity production, it is the fastest growing energy source in the world, with annual installations increasing at an average rate of over 30 percent per year for the past decade.⁵ Demand for wind power is projected to double over the next four years.⁶ China is part of this global trend of scaling up wind power; by the end of 2005 China had installed an estimated 1,260 megawatts, a more than 20-fold increase compared to a decade earlier.

However, even with these growth rates, wind power's overall share in China's electricity portfolio remains small, and this situation is unlikely to change. The 30 gigawatts of wind power capacity designated for development by 2020 in current government energy plans is small relative to the estimated 230 to 270 gigawatts of new coal power capacity and 200 to 240 gigawatts of hydropower

capacity planned to be built over that same time frame.⁷ Wind power's share in China's entire electricity portfolio will likely increase from around 0.2 to 3 percent between now and 2020 (projected penetrations for other renewables are illustrated in Figure 1).⁸

If wind power's total contribution to China's sizable energy demand is likely to remain small, why pay attention to China's wind development initiatives? China, along with many other countries, is looking not only to expand its domestic use of renewable energy, but also to develop the indigenous industries to serve this demand. Although wind may remain a small share of total electricity generation in China, it still represents a demand for around 20,000 wind turbines by 2020, and current policies dictate that these turbines be made in China.⁹ The total installed

capacity of wind globally (currently around fifty-nine GW), is expected to double before 2010.¹⁰ This projected global demand is stimulating many nations to look toward developing domestic wind technology industries, and China is aggressively using policies to support its own domestic manufacturers as they look toward competing in the global market.

Over the past two decades, renewable energy technologies have been transferred from several industrialized countries to China in an effort to alleviate

environmental and health problems stemming from China's dependence on coal and in some cases to promote rural energy development. Simultaneously, China has been developing its own renewable energy technologies through domestic research and development programs. Wind power technology has been particularly successful in China due to excellent wind resources and rapid technological improvements in the domestic wind industry. The government has taken several steps to directly encourage local wind turbine manufacturing, including policies that encour-

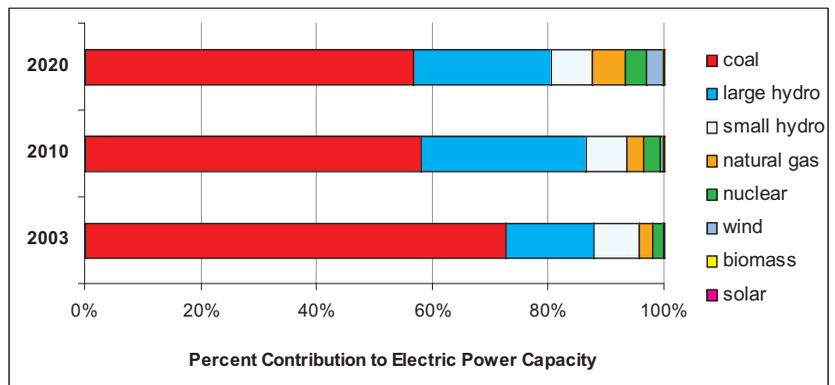


Figure 1. China's Electricity Generation Capacity: Current and Projected Shares of Renewables

age joint ventures and technology transfers in large wind turbine technology, as well as policies that mandate locally made wind turbines. Policymakers have also used differential customs duties to favor domestic rather than overseas turbine assembly and have allocated public research and development (R&D) support to wind power technology development. A series of government-run tenders known as "wind concessions" are expected to facilitate the development of about 3,500 megawatts of new wind power capacity in the next four years,

and locally produced turbines must be used. A National Renewable Energy Law that went into effect in January 2006 builds upon this concession program by mandating that a competitive bidding process be held for most large wind projects, and again, that turbines be manufactured locally.

The number of turbines being produced locally in China is growing at an even faster rate than that of total wind turbine installations. However, China is

bines in China could reduce costs by 20 to 40 percent, with early company reports supporting this estimate.¹¹ Countries with lower wage rates such as India and China expect to be able to realize cost savings compared to their European and American counterparts through domestic manufacturing. This cost reduction is potentially significant for those turbine components that are particularly labor intensive, such as rotor blades.¹² Many overseas turbine manufac-

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currently producing only a half a percent of the world's wind turbines, indicating that Chinese companies are still a long way from being global industry leaders. Danish and German turbine manufacturers still dominate the world market as they have for many years; however, there are signs that they are losing ground. Spanish manufacturers have been gradually increasing their global market share, with the leading Spanish manufacturer recently surpassing the leading U.S. manufacturer's sales for 2004. Indian manufacturers have also been rapidly expanding into the global market, including European markets long dominated by local companies.

Although wind turbines manufactured in China are smaller than the advanced turbines being sold in Europe and the United States, low cost remains the main attraction of Chinese turbines. Studies have estimated that producing wind tur-

ners are shifting their turbine production facilities to China, currently spurred by policies mandating the use of locally made turbines in domestic projects, along with expectations of forthcoming cost savings.

Cost reductions are also likely to result from China's contribution to cumulative global wind turbine production. Each doubling of wind turbine technology production is estimated to result in a 20-percent decrease in the marginal cost of the technology.¹³ Chinese firms produced the world's largest volume of small-scale (up to ten kilowatts) wind turbine generators in 2000, but only five companies in China manufactured grid-connected wind turbines in the range of 250 to 750 kilowatts. One to one and a half megawatt turbines are only under development.¹⁴ Growth in these areas, as well as in small-scale turbines, should drive down marginal costs.

Goldwind (*Jinfeng*) is the leading Chinese-owned utility-scale wind turbine manufacturer and has been the primary beneficiary of government policies that preferentially support the utilization of domestically manufactured wind turbines. Goldwind has captured between a fifth and a quarter of Chinese market share over the past few years, despite strong competition from the leading global wind turbine manufacturers. At the end of 2005, Goldwind turbines already represented about 17.5 percent of total wind turbine installations in China, and the company is rapidly expanding production. Moreover, in 2005 Goldwind installed 204 new wind turbine generators with a total capacity of 132.45 megawatts—their largest annual installation to date (up from 66 turbines totaling 39.6 megawatts in 2004). However, production of turbines is currently limited by the company's small size and limited manufacturing facilities.

Goldwind has produced more than 270 of its 600-kilowatt wind turbines. In 2004 it installed its first 750-kilowatt turbine, followed by another 63 machines in 2005. Goldwind is also developing a 1.2-megawatt turbine; its first model was just installed in Xinjiang in 2005 for field tests. Goldwind's turbines are not yet fully made of locally produced components, although domestic content increases every year. Initially blades were a limiting factor for making locally produced turbines, but Goldwind now uses blades made by Baoding, a blade factory in eastern China.

As local content utilized in Goldwind turbines has increased, costs reportedly have declined. As a result, Goldwind expects that domestically produced wind turbines will represent an increasing share of wind turbine sales in China. The

current policy framework promoting wind power in China suggests that this will most certainly be the case, due to the widespread use of mechanisms that directly promote the use of domestic wind turbines. As China's domestic manufacturers mature, there is certainly the potential that these companies will move towards exporting their turbines internationally. China's large-scale entry into wind turbine manufacturing could make wind power a more cost-effective option for countries around the world looking to leapfrog towards cleaner energy technologies.

China's Experience with Solar Energy Technologies.

China's other emerging renewable technology industries are building momentum as well—most notably the solar photovoltaic industry. Meanwhile, China's more highly developed renewable energy technology industries are maintaining global market dominance. China is a global leader in manufacturing small wind turbines, small hydro turbines, and solar thermal technologies.¹⁵

China has extensive experience with basic solar thermal technologies and has the largest solar water heater market in the world. With an estimated 64 million square meters of installations as of 2004 and a projected installation of 270 million square meters by 2020, China's utilization of solar water heater technology far exceeds that of all other countries combined (there are about 14 million square meters of installations in Europe and about 2 million square meters in the United States). The widespread use of solar water heaters in China has been tied to the unique opportunity for building-integrated technology. Although the solar hot water business was ini-

tially developed in smaller towns and villages in the 1980s, China's real estate boom, in combination with high-energy costs in urban areas, has resulted in the wide use of solar water heaters in newly constructed buildings. Importantly, consumer acceptance of this technology in China is also said to be quite high.¹⁶

China has the largest solar water heater manufacturing capacity of any country in the world. There are over 1,000 enterprises in China manufacturing solar water heaters, with 12 million square meters produced in 2003—double the number produced in China in 2000.¹⁷ Chinese solar water heaters are reportedly the most competitively priced in the world, and the industry employs some 250,000 people.¹⁸

As of 2005, China had installed about 75 megawatts of solar photovoltaics (PV), with over half being used for rural applications. Government plans aim for 450 megawatts to be installed by 2010 and 5,000 megawatts by 2020—including an 8-megawatt system in the Gobi desert that will be the largest grid-connected PV system of this type in the world.¹⁹ China's domestic PV production has scaled up extremely rapidly over the past few years and is projected to grow by another 400 percent in the next 5 years.²⁰ In 2001 China reportedly had 7 manufacturers producing 4.5 megawatts of PV cells, which represents a doubling of production from 2.1 megawatts in 1998, as well as about 1 percent of global market share. By 2005 China had the world's third-largest solar cell production capacity, with 30 major Chinese solar cell manufacturers comprising about 30 percent of global market share.²¹ Tests of some Chinese-produced solar modules exported to other markets have raised concerns about

product quality, which could be attributed to the relative infancy of the Chinese industry.²²

Currently, solar cell production in China—and around the world—is limited by the availability of silicon and wafers on the world market.²³ Annual solar module production capacity in 2005 reportedly reached a high of 635 megawatts, up from around 100 megawatts in 2004. This number exceeds China's cell production capacity, indicating China would need to import cells to maximize full use of its module production capacity.²⁴ Cell production capacity in 2004 was about 70 megawatts. There are at least 14 companies in China manufacturing solar-grade silicon and solar wafers, while Chinese production and export of solar-grade silicon grew by 50 to 100 percent in 2005 alone.²⁵ Hundreds of other Chinese firms are producing ancillary equipment such as PV pumping systems, inverters, charge controllers, DC lights, and test equipment.²⁶ It is estimated that \$5 to 7 billion in capital investment was made in the solar PV industry globally in 2005, with a growing percentage occurring in China.²⁷

Conclusions. The trend in China's renewable energy technology industries has been one of rapid growth. Some technologies, including small wind turbines, solar water heaters, small hydro turbines, and solar panels, are already being exported overseas. Chinese policies to promote renewable energy utilization over the past decade have had the ancillary goal of promoting renewable energy industry development, which has been realized successfully across most technologies. As China continues to grow and its demand for energy increas-

es, the domestic market for these technologies is substantial.

China's domestic market opportunity gives indigenous producers the testing ground they need to develop the technology and production scale that permits them to become global technological leaders. Consequently, the emergence of more and more Chinese companies in global renewable energy technology markets appears to be inevitable. The effect that this emergence will have on lowering technology costs worldwide is still somewhat uncertain, but early evidence from the wind and solar industries suggests that it could be significant. In addition to cost savings that may be specific to the Chinese labor market or to domestic innovations, the entry of new manufacturers that play a significant role in increasing global technology production will drive down technology costs as they move further down the learning curve.²⁸ China's role in manufacturing many small-scale renewable energy technologies has already made the technologies more accessible to less developed countries where small-scale renewables have played an important role in rural development initiatives. In addition, China is rapidly expanding its nanotechnology research programs, which current studies indicate is likely to be a key area for new solar power technologies.²⁹

Renewable energy technologies are not likely to displace conventional electricity technologies in the near term, but in certain regions, the penetration could be significant. Denmark gets about 20 percent of its electricity from wind power, and some German states as much as 15 percent. Offshore wind farm development, if it can overcome some technological and social obstacles, could make

wind's share increase even further. As energy security becomes an increasingly important issue, displacing fossil fuels has benefits beyond purely environmental ones. Many U.S. states are adopting renewable portfolio standards to force utilities to invest in renewable energy, not just for the environmental benefits, but also recognizing that a diverse portfolio can be the best hedge against volatile fuel price fluctuations.³⁰

It is clear that there is an increasing role for renewables, and that much of this new demand will be met by technology manufacturers in emerging markets. Until now, the most advanced renewable electric technologies have come from Europe, the United States, and Japan, but these countries risk losing market share if emerging economy-based manufacturers are successful in producing comparatively lower cost technology. India is already technologically ahead of China in manufacturing utility-scale wind turbines, and Brazil is looking to expand its use of renewables with new national legislation.

China's national renewable energy law may provide its existing renewable energy technology manufacturers with a signal of regulatory stability that is crucial to facilitating investments in new technologies. China's prior experience with small-scale renewables, combined with a domestic policy framework that supports indigenous manufacturers in the newer technology industries, makes it especially well positioned to expand into these emerging markets. In summary, there are many signs that China's renewable energy markets may be just starting to mature, and this is a phenomenon that other countries should be watching closely.

NOTES

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