LEANING INTO THE WIND
Building Sustainable Wind Power in China

Lauren Caldwell, Emily Chen, Felix Zhang
May 9, 2014

SAIS
JOHNS HOPKINS
SCHOOL of ADVANCED
INTERNATIONAL STUDIES

This is one of a series of case studies prepared for the class Case Studies in Sustainable Development: Smart Cities and Urban Innovation. The information presented here is not intended to propose solutions or to make recommendations. Instead, it provides a framework for examining issues affecting urban centers globally through the lens of sustainable development.

Introduction

South of the Gobi Desert, about 1,200 miles west of Beijing, are vast fields lined with more than 3,500 fiberglass wind turbines.[1] Jiuquan prefecture, Gansu province, is located in northwestern China and home to one of China's latest superlative endeavors. The Jiuquan Wind Power Base is one of several multi-gigawatt megaprojects planned by China's National Energy Administration to reduce carbon emissions and expand the country's renewable energy capacity. Upon its completion in 2015, the Jiuquan Wind Power Base will be the largest wind power collective in the world.

Investment in renewable energy has become a priority for the Chinese government. Pollution levels in the country have reached an all-time high, prompting concern both domestically and internationally. In January 2013, a report concluded that severe air pollution had reduced average life expectancy by 5.5 years in northern China. The research attributed higher instances of heart disease, cancer, and strokes to toxic air.[2] In 2011, about 69 percent of China's energy consumption was supplied by coal, compared to the world average of about 40 percent. China emitted the world's highest levels of energy-related carbon dioxide (8,715 million metric tons) the same year.[3]

Local officials are optimistic about the megaproject's potential: "The Jiuquan Wind Power Base, after being put into full operation, can reduce carbon dioxide emissions by 16 million tons annually," said Li Jianhua, Communist Party chief of Jiuquan.[4] In 2015, the projected installed capacity of the wind farms (15 GW) could theoretically replace four coal-fired power plants.[5]

Unfortunately, the Jiuquan Wind Power Base is not performing as planned. In 2011, only 68 percent of the turbines in Gansu province continuously generated power, according to the Jiuquan municipal energy bureau[6]—and other organizations have estimated even lower figures. Many of the turbines in Jiuquan have been idle since the day they were constructed.

The National Energy Administration is faced with a dilemma: Can large-scale renewable energy transition China toward a sustainable pattern of growth, fueling the needs of industry while reducing harmful pollution and the country's dependence on coal? Should the central government continue to promote and invest in the Jiuquan Wind Power Base, as well as similar megaprojects in the future, given these early-stage challenges? The National Energy Administration must make the right decision: the strength of its economy, the health of its people, and its international reputation are at stake.

Sources: CCTS China Travel; Understand China

Declaring War on Pollution

Every five years, the Chinese central government releases strategic plans to guide the country's economic and social development. The 12th Five Year Plan (2011-2015) shifted the focus to sustainable growth, including plans to address environmental protection, public health, wealth distribution, and rural-urban disparities. The 12th Five Year Plan proposed a 40 percent reduction in overall carbon emissions between 2005 and 2020. It also called for a substantial increase in energy produced by renewable resources, reaching 20 percent of total generation by 2015. To achieve this target, China will increase installed wind capacity to 200 GW by 2020, 400 GW by 2030, and 1,000 GW by 2050.[7]

The National Energy Administration (NEA), a department of the National Development and Reform Commission (NDRC), is responsible for formulating and implementing energy development plans. In February 2014, the NEA released its latest guidelines for wind power projects, approving 27 GW of wind installations for construction in 2015. The NEA has approved more than 100 GW of wind generating capacity since 2011, and the total installed capacity is expected to reach 90 GW by the end of 2014.[8]

"The new plan brings a clear message that the state authority will continue to push and give strong support for the development of wind power," said Yi Yuechun, executive deputy director of the National Renewable Energy Information Management Center.[9]

In March 2014, at the annual National People's Congress (NPC) in Beijing, Premier Li Keqiang announced that the government would "declare war" on pollution with the same tenacity that it approached poverty reduction.[10]

How Do Wind Turbines Work?

The most common type of wind turbine is the horizontal-axis wind turbine, as illustrated on the left. Horizontal-axis wind turbines have two or three blades, which are shaped similarly to the wing of an airplane. As air passes the blade, the blade's shape creates uneven air pressure, causing the blade to spin around the center of the turbine. A rotating shaft within the turbine spins a series of gears at rapid speed, which generates electricity. At the top of the turbine, a weather vane that is connected to a computer rotates the turbine to ensure that it faces the wind, capturing the most wind energy.

Wind farms are often located in hot deserts or windy prairies, where wind flows at a more constant rate throughout the year. Since wind is greater at higher altitudes, wind turbines can extend from about 40 to 120 meters in height.

Sources: Department of Energy[11], Lews Castle UHI (Creative Commons)[12]

Financial Incentives for Wind Power: Feed-In Tariffs

Financial incentives for producing and using renewable power include national funding, discounted lending, tax preferences for renewable energy projects, and most notably, feed-in tariffs.

According to the U.S. National Renewable Energy Lab, "feed-in tariffs (FITs) are the most widely used policy in the world for accelerating renewable energy (RE) deployment, accounting for a greater share of RE development than either tax incentives or renewable portfolio standard (RPS) policies."[13] A feed-in tariff is a policy tool that incentivizes investment in renewable energy technologies by offering long-term purchase contracts, access to power grids for distribution of RE-generated electricity, and purchase prices that vary depending upon the costs of producing energy. The purpose of feed-in tariffs is to offer renewable energy producers some financial certainty and to boost investor confidence in the long-term price stability of renewable energy.

In July 2009, the NDRC announced nationwide wind power feed-in-tariffs for four categories of onshore wind projects based on regional wind resources. Under this program, the costs of wind power generation that exceed the costs of coal-powered electricity generation would be shared between provincial grid operators and the central government. Areas with greater supplies of wind will have lower tariffs, whereas areas

with lower wind supplies will be offered higher tariffs. Power grid operators must pay a sizeable premium on the average of 0.35 RMB per kilowatt hour (kWh) for coal-fired electricity. The tariffs range from 0.51 RMB (US$0.08) to 0.61 RMB (US$0.10) per kWh and will last for the operational lifespan of a wind farm, usually about 20 years.[14]

In 2005, the Standing Committee of the National People's Congress (NPC) passed the Renewable Energy Law, requiring at least 70 percent of wind farm components to be produced domestically. In December 2009, Chinese lawmakers amended the Renewable Energy Law to require power grid operators to purchase all electricity generated by renewable energy producers. Grid operators may apply for subsidies from a new Renewable Energy Fund administered by the Ministry of Finance and supported by both the national budget and by electricity surcharges on end-users of 0.004 RMB per kWh, which is projected to rise.[15] The amendment also requires power grid operators to improve transmission technologies and capacity to distribute more electricity generated by renewable energy.

The Jiuquan Wind Power Base: "Three Gorges on Land"

Jiuquan prefecture is located in China's Hexi Corridor, a 600-mile passage along the Gobi Desert in Gansu province. The region is rich with natural resources and wind power capacity, and provides a climate and topography that is suitable for the construction of large scale wind farms, with comparison to other provinces in China.[16] The Jiuquan Wind Power Base, which comprises the collective wind farms in the region, had the capacity to generate 6 GW of wind energy as of 2012—enough energy to power the entire United Kingdom.[17]

The municipal government plans to nearly triple this capacity by 2015. Wu Xuesheng, head of the energy bureau of the Jiuquan Municipal Development and Reform Committee, said, "Our goal is to reach 15 GW of installed wind-power capacity in 2015 and add another 25 GW by 2025, so that total capacity is going to reach 40 GW."

If this plan is successful, the Jiuquan Wind Power Base would generate enough energy to replace ten coal-generated power plants in 2025. Li Jianhua, Communist Party chief of Jiuquan, claims, "The Jiuquan wind power base, after being put into full operation, can reduce carbon dioxide emissions by 16 million tons annually."[18]

Seven substations and a 1,780 kilometer high-voltage transmission line connect Jiuquan's power base to the national east-west power grid to distribute wind power to the eastern region. Jiuquan's New Energy Equipment Manufacturing Industrial Park, the largest of its kind in China, has attracted thirty-five domestic major renewable energy equipment providers. Dubbed the "Three Gorges on Land," Jiuquan's wind farms will cost approximately $17.5 billion to complete. [19] The wind power equipment sector generated $6.8 billion in sales revenue at the end of 2011.

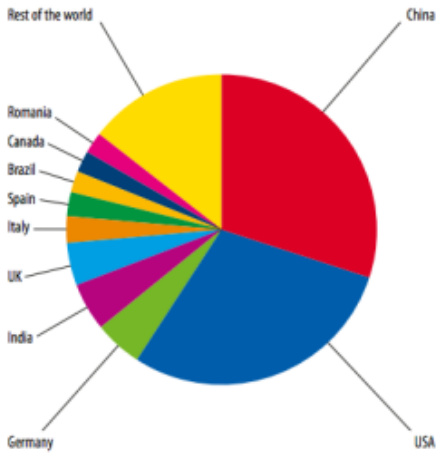
When the 2005 Renewable Energy Law was passed, China's wind power capacity accounted for only 2.1 percent of global installed wind power capacity. By 2012, China's share skyrocketed to 27 percent of global capacity, exceeding that of the United States

(21 percent) and Germany (11 percent).[20] The cost of producing a wind turbine in China is approximately 70 percent of the international cost. Four Chinese wind turbine manufacturers rank in the top ten global producers by market share, according to Bloomberg New Energy Finance.[21]

However, the speed and scale of Jiuquan's rapid construction of wind farms has raised concerns about power generation and distribution capacity. Only 20 percent of Jiuquan's wind peak capacity is converted into electricity, compared to the 25 to 30 percent world average for wind farms, due to the intermittent supply of the region's winds. [22]

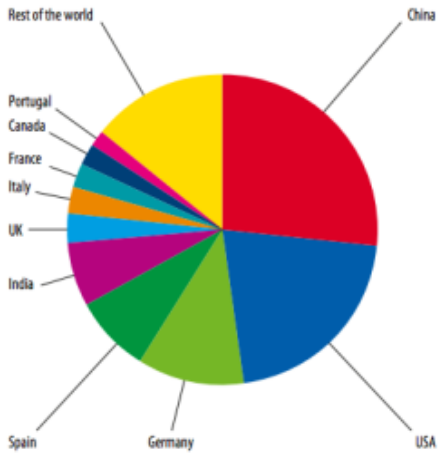
Global Installed Wind Capacity

TOP 10 NEW INSTALLED CAPACITY JAN-DEC 2012



Country	MW	% SHARE
PR China**	13,200	30
USA	13,124	29
Germany	2,439	5
India	2,336	5
UK	1,897	4.2
Italy	1,273	2.8
Spain	1,122	2.5
Brazil	1,077	2.4
Canada	935	2.1
Romania	923	2.1
Rest of the world	6,385	14.3
Total TOP 10	**38,326**	**85.7**
World Total	**44,711**	**100.0**

TOP 10 CUMULATIVE CAPACITY DEC 2012



Country	MW	% SHARE
PR China**	75,564	26.8
USA	60,007	21.2
Germany	31,332	11.1
Spain	22,796	8.1
India	18,421	6.5
UK	8,445	3.0
Italy	8,144	2.9
France**	7,196	2.5
Canada	6,200	2.2
Portugal	4,525	1.6
Rest of the world	39,853	14.1
Total TOP 10	**242,630**	**85.9**
World Total	**282,482**	**100.0**

** *Provisional Figure*

Source: CleanTechnica[23]

China's Renewable Energy Targets: September 2013
(GW and grid-connected)

	2012 Actual	2015 Goal	2020 Goal
Wind	**62**	**104** 99 onshore 5 offshore	**200** 170 onshore 30 offshore
Hydro	**249** 20 pumped hyrdro	**290** 30 pumped hydro	**420** 70 pumped hydro
Solar	**3**	**35**	**50**
Biomass	**4**	**13**	**30**

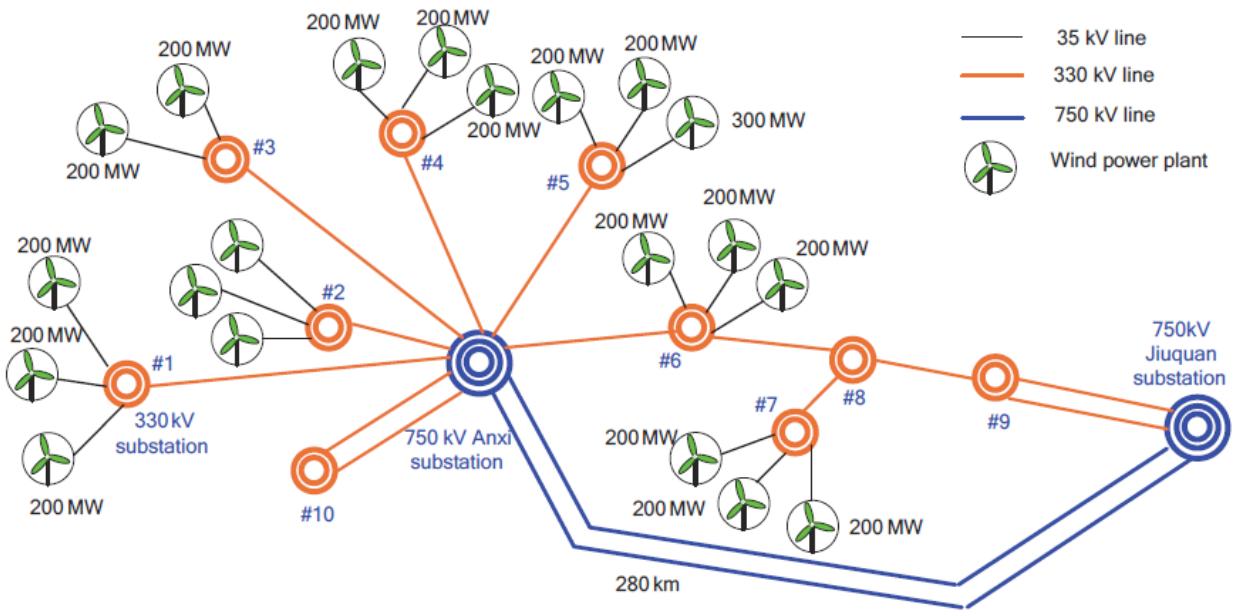
Source: The Energy Collective[24]

Long-Range Transmission Capability

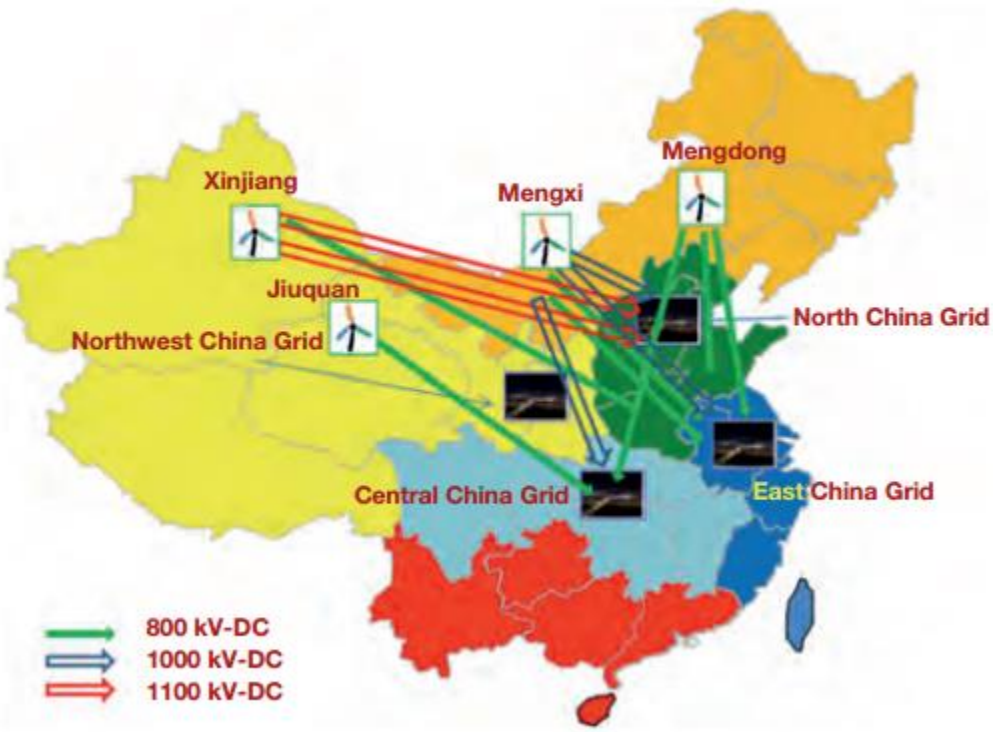
The Jiuquan Wind Power Base, which is located on the western end of the Gansu provincial grid, is 1,000 kilometers from the grid's nearest power load center. Until February 2014, the local Jiuquan-Jiayuguan grid delivered electricity from the wind farm to the load center via 330 kV transmission lines, which are not robust enough to accommodate the wind farm's enormous capacity. For several years, the lack of adequate long-distance transmission infrastructure, combined with intermittent generation and insufficient local electricity demand, has created a bottleneck and forced wind farm operators to intentionally curtail wind generation. In 2010, 12.4 percent of the farm's total capacity was curtailed. In 2011, 43 percent of the wind capacity at the farm's Yumen site remained idle.[25]

In February 2014, the State Grid Corporation completed construction of a 2,200-kilometer 800 kV ultra-high voltage direct current (UHVDC) transmission line, which will transmit electricity generated in Jiuquan to larger cities in the eastern Shanxi and Henan provinces. Another planned UHVDC line from Jiuquan to Hunan Province is expected to begin operation in 2015.[26] UHVDC lines have greater capacities and are capable of transmitting electricity for long distances, while experiencing fewer losses. While these lines, which have a combined capacity of 16 GW, will help to reduce the bottleneck problem, they are still vulnerable to the intermittent nature of wind generation.

Without advanced forecasting technology, extremely rapid changes in wind speed can lead to load-side outages, which can result in voltage collapse and the disconnection of wind generators from the grid. In a white paper on grid integration of large-capacity renewables, the International Electrotechnical Commission proposed "wind-fire bundling," the use of thermal plants to smooth out fluctuations in wind generation, to allow these UHVDC lines to withstand at least ordinary wind disturbances.[27]



Schematic Diagram of the Jiuquan Wind Power Base.
Source: International Electrotechnical Commission.



Proposed UHVDC plan to transmit electricity from 10 GW power bases in northern and western China to high-demand cities in the east.
Source: International Electrotechnical Commission.[28]

Baseload and Peak Load

Baseload demand refers to the minimum expected consumer demand level for electrical power. Baseload power plants are needed to provide a continuous supply of electricity with high capacity factor and stable output. *Peak demand* describes sustained periods during which consumer demand for electrical power is expected to be significantly higher than average. Periods of peak demand are handled by peaking power plants, which can be ramped up and down quickly.

A significant challenge faced by wind farm developers lies in the unconventional nature of wind power, which is highly variable and cannot be easily ramped up or down due to its dependence on climatological and meteorological factors. Wind power's generation profile is also generally "anti-peak": wind speeds tend to be the highest closer to midnight, when consumer demand for electricity is the lowest.[29] The process of storing this excess energy for peak demand periods is known as *load balancing*.

The most common method for load balancing, used in 99 percent of grid energy storage worldwide, is pumped-storage hydroelectricity (PSH), in which electricity is used to pump water into reservoirs, to be released through turbines to generate electricity when needed. Fluctuations in the wind generation profile could also be smoothed out using a more predictable secondary reserve energy source, such as natural gas or coal. In the absence of energy storage facilities, grid operators may also regulate peaks in generation through *curtailment*, the act of intentionally shutting down power plants to reduce excess electricity generation, which could otherwise be a burden on weak grid infrastructure vulnerable to sudden changes in voltage.[30]

Load Balancing and Storage for Large-Scale Wind Power

Wind generation is intermittent and unpredictable in nature, so its generation profiles may not align with the peak electricity demand profiles of its consumers. Generally, wind resources are strongest at night, whereas peak consumer electricity demand usually occurs between 10 a.m. and 3 p.m. A peak load regulation system can help the wind farm to provide a stable supply of electricity to the grid.

A study conducted by researchers at the Gansu Electric Power Company investigated different options for regulating power at Jiuquan. The study concluded that traditional pumped-storage hydroelectricity systems, which account for 99 percent of bulk storage capacity in power plants worldwide, were unsuitable for a large-scale wind farm, because they required accurate forecasts of regular daily fluctuations in electricity load. In addition, the environmental fragility of the Hexi Corridor, where Jiuquan is located, does not allow for the large-scale construction of storage facilities. The researchers instead found that conventional thermal power plants, which can predictably generate baseload

electricity, were the most economically and technically viable solution for balancing intermittency in generation at a large-scale wind farm.[31]

In 2009, the Jiuquan Development and Reform Commission made plans, in conjunction with its expansion of wind power, for an additional 13.6 GW of coal-fired capacity to be built by 2020. In an interview with NPR, the chairman of the Jiuquan Development and Reform Commission, Wang Jianxin, commented that "adding more polluting coal-fired power plants is unavoidable if you want to be green."[32]

Renewables Competing with Renewables

Some advocates of renewable energy argue that renewable resources—like wind or solar—will replace coal-fired power plants, thereby reducing carbon emissions. Yet according to recent reports, investments in renewable energy are not strongly associated with the reduction of energy produced from fossil fuels. In fact, renewable energy may be more likely to displace other forms of renewable energy.

In 2013, China announced installation targets of 10 GW for solar, 18 GW for wind, and 21 GW for hydroelectric—doubling the installation rate for solar, while wind remained steady. The National Energy Administration also substantially increased its 2015 solar targets from 21 GW to 35 GW.[33] These solar targets may spell trouble for wind: Northwest China—including Xinjiang, Inner Mongolia and Gansu provinces—offers optimal conditions for both wind and solar resources. As solar installation rates increase, there will be more competition for access to the grid. Wind and solar also compete for feed-in tariffs—and under China's current policies, solar is granted a higher feed-in tariff rate than wind. Furthermore, wind and solar compete for state funding, since most wind and solar companies are large state-owned enterprises.[34]

Recent studies in the United States have come to similar conclusions. Richard York, a professor at the University of Oregon, studied whether increasing the amount of energy produced from alternative sources (nuclear, hydro, wind, solar, geothermal, biomass and biofuels) would result in a reduction of energy produced from fossil fuels. He found that each kilowatt-hour produced from non-fossil fuels displaced 0.089 of energy from fossil fuels. (To put it another way, it takes more than 11 kWh of energy from renewables to displace 1 kWh of energy from fossil fuels.) Even worse news for wind and solar: Non-hydro renewables did not displace any fossil fuel energy.[35]

Financial Concerns

Until late 2012, feed-in tariffs for wind power were financed through a surcharge levied on electricity customers and administered by provincial grid companies. Based on installation costs and wind resources, Jiuquan was classified as a Class II area, and received a tariff of 0.54 RMB per kWh. However, between 2010 and 2012, Jiuquan faced a shortage in revenue, due to a two-year delay in subsidy payments to wind developers

across China. This problem was especially prominent in the provinces of Inner Mongolia, Xinjiang, and Gansu, which have the greatest wind capacities but relatively small local load, and insufficient end-users from which to collect funding to cover the subsidies. The national government was slow to reimburse the operators for electricity sold.

While the delays in payments began in October 2010, it was not until December 2012 that the NDRC began reforming its subsidy system by centrally administering funds through the Ministry of Finance and ordering provincial grids in eastern China, which consumed most of the electricity generated by the wind farms, to transfer a total of 5.8 billion RMB in tariff payments to wind farm operators.[36] In late 2013, the NDRC announced that it planned to reduce feed-in tariff rates for wind power, due to continuous shortfalls in funding.[37]

While poorly-performing state-owned wind farm operators can be supported by the central government, the effects of low profit margins and a recent slowdown in installations are passed down the supply chain to domestic wind turbine manufacturers, who are increasingly unable to obtain contracts to finance heavy amounts of debt. In September 2013, it was reported that manufacturers in Jiuquan were experiencing a loan crisis. At that time, the manufacturers had borrowed 16.1 billion RMB (approximately $2.6 billion) from the Industrial and Commercial Bank of China (ICBC), Bank of China, Agricultural Bank of China, and China Construction Bank, 11.1 billion RMB of which was outstanding in September.[38]

Sinovel, the largest wind turbine manufacturer in China and the second largest in the world, suffered 3 billion RMB in losses in 2013, five times its losses from the previous year. As of February 2014, it was threatened with a downgrade in its credit rating due to its rising debt levels.[39] To reduce costs, Sinovel plans to cut 930.5 million RMB in funding for two of its manufacturing bases, including its Jiuquan Manufacturing Base.[40]

Solar Company Suffers China's First Corporate Bond Default

On March 7, 2014, China experienced its first domestic corporate bond default as Shanghai Chaori Solar Energy Science & Technology Co. failed to make a full interest payment of 89.8 million RMB ($14.7 million). The solar cell manufacturer had been operating at a loss for three years, with a net loss of 1.33 billion RMB ($216.6 million) in 2013.[41]) Chaori was only able to pay 4 million RMB of the amount due. The company's financial distress was largely because it had "expanded into building solar farms to produce power rather than just manufacturing panels, which is much cheaper," according to Bloomberg New Energy Finance.[42]

In January 2013, Chaori had come close to missing an interest payment, but the Shanghai municipal government had pressured banks not to press the company for overdue loans so it could pay bondholders. The recent default, which occurred during the annual National People's Congress meeting, indicates that the government is willing to allow market forces to decide which companies survive, and whether

domestic companies default. “As long as there is no systemic risk, some defaults resulting from market forces will be allowed. This will encourage market discipline and correct the behavior of the issuers and the investors,” said Pan Gongsheng, a vice governor of the central bank, the People’s Bank of China.[43]

Bank of America analysts declared that the Chaori default was akin to China’s “Bear Stearns moment.”[44] Other analysts believe that Chaori’s default has no “systemic implications.”[45] Nevertheless, many speculate that more domestic companies in “overcapacity industries” may miss interest payments, now that the government is less willing to bailout those in financial trouble.[46]

Conclusion

“Without a smart grid capable of minimizing losses and storing renewable energy to meet peak demand, burning fossil fuels remains the only way to continuously meet China's growing energy needs.” *Scientific American*[47]

The Jiuquan Wind Power Base is scheduled to be completed in 2015. Upon completion, it will be the largest wind power collective in the world, with an installed capacity of 15 GW. Since 2011, the National Energy Administration has approved several multi-gigawatt megaprojects, totaling more than 100 GW of wind generating capacity. Therefore, China is well on its way to reaching its ambitious installed wind capacity targets: 200 GW by 2020, 400 GW by 2030, and 1,000 GW by 2050.

However, the Jiuquan Wind Power Base has encountered difficulties, ranging from technical challenges to loan crises. Only 20 percent of Jiuquan’s wind peak capacity is converted into electricity, compared to the 25 to 30 percent world average for wind farms, due to the intermittent supply of the region’s winds. Furthermore, wind developers in the region have experienced years of delays in subsidy payments. In recognition of persistent financial challenges, the NDRC announced in 2013 that it planned to reduce feed-in tariff rates for wind power. Finally, the largest wind turbine manufacturer in the country, Sinovel, suffered 3 billion RMB in losses in 2013. To reduce costs, Sinovel plans to substantially cut funding for two of its manufacturing bases, including its Jiuquan Manufacturing Base.

The National Energy Administration is fulfilling its mission, propelling the country toward the wind power construction targets mandated by the National Development and Reform Commission and the 12th Five Year Plan. Yet other targets—reducing pollution and the country’s dependence upon coal—remain unaddressed. If China wishes to transition to a more sustainable pattern of economic development, is large-scale wind power the right choice? If so, what steps must be taken to ensure success?

A Comparison of Distributed and Centralized Generation

Distributed generation refers to power that is produced where (or close to where) it is consumed. Distributed generation is not defined by size or energy source, but by location and application: While it is generally associated with renewable energy resources, such as wind or solar, it can also include diesel- or gasoline-powered backup generators.[48] Distributed wind energy systems range from 5-kilowatt turbines that directly generate power for homes, schools and farms to multi-megawatt turbines that generate power for local utility grids or microgrids. However, most distributed generation systems are smaller than 20 MW.[49]

In comparison, *centralized* (or utility-scale) *generation* refers to the production of large amounts of power at a single location. This power often must be transmitted a great distance from where it was produced. Utility-scale wind farms are usually larger than 20 MW and can include hundreds of turbines in a vast region. These wind farms may be located on land or offshore, depending on the location of the most reliable wind resources. Centralized generation at large power plants is the dominant form of power generation in the legacy electrical grid.[50]

When it comes to renewable energy, there are advantages and disadvantages associated with both distributed and centralized generation. Utility-scale projects are constructed in regions that offer optimal conditions for specific renewable energy resources. For example, wind farms are best located in high altitude, unpopulated coastal regions with reliable, unobstructed, high-speed wind.[51] When located and connected properly, utility-scale projects have the potential to produce large amounts of power with minimal environmental impact, with comparison to coal-fired power plants.

However, since utility-scale power plants are often located a great distance from where power will be consumed, the construction of transmission lines poses a considerable challenge. Most countries lack a grid that is capable of reliably transmitting intermittent sources of power across long distances. Furthermore, utility-scale projects require large amounts of land, which often presents a challenge when obtaining permits, and may negatively impact the environment or wildlife.

Distributed generation is associated with fewer energy losses, since power is not transmitted over large distances. Additionally, distributed generation to microgrids may offer greater reliability for consumers, since microgrids will not be affected by blackouts or other damage to the traditional grid. However, distributed generation systems inherently produce power at a smaller scale. Furthermore, while distributed generation may assist in meeting peak demand, it may also negatively impact reliability if the grid does not have the capacity to handle intermittent ebbs and flows of power.

In recognition of these comparative advantages and disadvantages, many scholars recommend a combination of distributed and centralized generation, as well as a modernized electrical grid, in order to minimize environmental and economic costs and

to provide greater reliability for consumers.

Distributed Generation in China

Many of China's most well-known energy projects have been constructed on a grand scale: In 2006, China completed construction of the Three Gorges Dam, a massive hydroelectric power project on the Yangtze River. In 2009, China partnered with First Solar to construct a 2,000 MW photovoltaic power plant, the largest in the world, in the Mongolian desert. In 2014, Chinese company Trina Solar announced it would construct a 1,000 MW solar project in Xinjiang Province. Last year, China approved plans for the construction of more than a dozen new coal-to-gas bases—some nearly as large as the city of Los Angeles—in remote regions of the country. Finally, the Jiuquan Wind Power Base is projected to become the largest wind energy project in the world once it is completed.

There are signs that this trend may be shifting. The Chinese government has announced legislation to expand distributed generation, in response to bottlenecks in connecting existing wind and solar farms to the electrical grid. The National Energy Administration proposed a target of 20 GW of distributed generation systems by 2015 and 50 GW by 2020, a dramatic increase from the 2 GW recorded in 2013.[52] China's National Development and Reform Commission—the foremost economic planning agency—has encouraged power grid operators to improve access to the grid for distributed power generation, and has invited centrally-located Chinese provinces to serve as demonstration zones for distributed solar.[53]

However, representatives from several Chinese solar companies said they are skeptical of the targets. "The economics of distributed solar are in doubt," said Wang Xiangfu, chief executive of Shunfeng Photovoltaic International Ltd., in an interview with Reuters. "The goal is very difficult to achieve unless the state raises [subsidies]." China Energy News, a publication of the Communist Party-owned People's Daily, also noted it would be "difficult" to achieve the targets, given challenges ranging from low financial returns to poor quality rooftops.[54]

---

[1] "China completes 1st stage of largest wind power project." *Xinhua*. November 4, 2010. http://www.china.org.cn/environment/2010-11/04/content_21266813.htm

[2] Yuyu Chen, Avraham Ebenstein, Michael Greenstone, and Hongbin Lie. "Evidence on the impact of sustained exposure to air pollution on life expectancy from China's Huai River policy." Proceedings of the National Academy of Sciences of the United States of America. January 2, 2013. http://www.pnas.org/content/early/2013/07/03/1300018110

[3] "China." U.S. Energy Information Administration. February 4, 2014. http://www.eia.gov/countries/cab.cfm?fips=ch

[4] "China completes 1st stage of largest wind power project." *Xinhua*. November 4, 2010. http://www.china.org.cn/environment/2010-11/04/content_21266813.htm

[5] Jacopo Dettoni. "Wind Farms, Solar Panels and Killer Smog: Coal Still Reigns in China's Schizophrenic Energy Revolution." *International Business Times*. February 14, 2014. http://www.ibtimes.com/wind-farms-solar-panels-killer-smog-coal-still-reigns-chinas-schizophrenic-energy-revolution-1553615

[6] "Growing Pains of China's Wind Power Industry." *Xinhua*. May 28, 2011. http://www.chinadaily.com.cn/china/2011-05/28/content_12598392.htm

[7] National People's Congress. "12th Five Year Plan (2011-2015)." Translation by the Delegation of the European Union in China.

[8] Jianxiang Yang. "China issues 27GW plan for 2015." *Wind Power Monthly*. February 26, 2014. http://www.windpowermonthly.com/article/1282513/china-issues-27gw-plan-2015

[9] Jianxiang Yang. "China issues 27GW plan for 2015." *Wind Power Monthly*. February 26, 2014. http://www.windpowermonthly.com/article/1282513/china-issues-27gw-plan-2015

[10] "China to 'declare war' on pollution, premier says." *Reuters.* March 4, 2014.

[11] Department of Energy. "How Do Wind Turbines Work?" http://energy.gov/eere/wind/how-do-wind-turbines-work

[12] Lews Castle UHI. "Wind Turbine." Flickr. https://creativecommons.org/licenses/by/2.0/legalcode

[13] "A Policymaker's Guide to Feed-in Tariff Policy Design." National Renewable Energy Laboratory. July 2010. http://www.nrel.gov/docs/fy10osti/44849.pdf

[14] "China Market Overview." International Renewable Energy Agency. 2013. https://www.irena.org/DocumentDownloads/Publications/GWEC_China.pdf

[15] Eric Martinot and Li Junfeng. "Renewable Energy Policy Update For China." *Renewable Energy World*. July 21, 2010.

[16] Liu Yuanyuan. "Jiuquan, Gansu Province Drives Development of Wind Farms Along China's Hexi Corridor." *Renewable Energy World*. March 30, 2012. http://www.renewableenergyworld.com/rea/news/article/2012/03/jiuquan-gansu-province-drives-development-of-wind-farms-along-chinas-hexi-corridor

[17] Jonathan Watts. "Winds of change blow through China as spending on renewable energy soars." *The Guardian*. March 19, 2012.

[18] "China completes 1st stage of largest wind power project." *Xinhua.* "November 4, 2010. http://www.china.org.cn/environment/2010-11/04/content_21266813.htm

[19] Zeng Ming, Lü Chunquan, Ma Mingjuan, Peng Lilin, Yan Binjie, Li Na, and Xue Song. "Renewable Energy Development Thrives During China's 12th Five-Year-Plan." *Power Magazine.* December 12, 2012.

[20]Jacopo Dettoni. "Wind Farms, Solar Panels And Killer Smog: Coal Still Reigns In China's Schizophrenic Energy Revolution." *IB Times*. Febuary 14, 2014. http://www.ibtimes.com/wind-farms-solar-panels-killer-smog-coal-still-reigns-chinas-schizophrenic-energy-revolution-1553615

[21] Sarah Wang. "The Answer to China's Future Energy Demands May Be Blowing in the Wind." *Scientific American*. September 10, 2009.

[22] Jonathan Watts. "Winds of change blow through China as spending on renewable energy soars." *The Guardian.* March 19, 2012. http://www.theguardian.com/world/2012/mar/19/china-windfarms-renewable-energy

[23] "Global Wind Power Capacity Up To 282.5 GW (~20% Increase in 2012)." *CleanTechnica.* http://cleantechnica.com/2013/02/12/global-wind-power-capacity-up-to-282-5-gw-20-increase-in-2012/

[24] Michael Davidson. "Transforming China's Grid: Sustaining the Renewable Energy Push." *The Energy Collective.* September 14, 2013.

[25] "Low Transmission Capacity Limiting Wind Farm Output." *Interfax: China Energy Weekly*. April 13, 2011.

[26] Cao, Junzheng, and Cai, Jim Y. "HVDC in China." *State Grid Smart Grid Research Institute*. August 28, 2013.

[27] International Electrotechnical Commission. "Grid integration of large-capacity Renewable Energy Sources." October 2012.

[28] International Electrotechnical Commission. "Grid integration of large-capacity Renewable Energy Sources." October 2012.

[29] Zeng, Ming and Zhang, Kun. “Overall review of China's wind power industry: Status quo, existing problems and perspective for future development.” *Renewable and Sustainable Energy Reviews* 24 (2013): 379-86.

[30] Li, X., K. Hubacek, and Y.I. Siu. "Wind Power in China – Dream or Reality?" *Energy* 37.1 (2012): 51-60.

[31] Xiao et al. “System Power Regulation for Jiuquan Wind Power Base.” *Proceedings of the CSEE.* April 5, 2010.

[32] Lim, Louisa. “China’s Wind Power Plans Turn on Coal.” *NPR.* December 10, 2009.

[33] Anders Hove. “Is China’s Solar Inc. Competing With China’s Wind Inc.?” *GreenTech Media*. April 1, 2013.

[34] *Ibid*.

[35] Kyle Niemeyer. “Study: Alternative Energy Has Barely Displaced Fossil Fuels.” *Ars Technica.* March 20, 2012

[36] Du, Yanfei and Wang, Jing. “Renewable energy tariff and quota trading subsidy program introduced.” *China Securities Network.* December 5, 2012.

[37] “NDRC Prepares Adjustments to Wind Tariff Policy.” *The Economic Observer.* September 6, 2013.

[38] Cao, Cheng and Wang, Jianhong. “Jiuquan Wind Power Base Experiences Weakness in Loan Repayment.” *Chinese Financial News.* November 25, 2013.

[39] Smith, Patrick. “Sinovel Warns of Massive Losses.” *Wind Power Monthly*. January 30, 2014.

[40] Smith, Patrick. “Sinovel cuts 10MW R&D centre funding”. *Wind Power Monthly.* February 25, 2014.

[41] “Chaori Solar Says Bonds May Be Delisted as Baoding Slumps.” *Bloomberg News.* March 12, 2014.

[42] “Chaori to Sell Solar Farms to Repay Bondholders After Default.” *Bloomberg News*. March 10, 2014.

[43] Lingling Wei. “China Experiments With Allowing Debt Defaults.” The Wall Street Journal. March 25, 2014.

[44] Justina Lee. “China Bear Stearns Moment Seen by BofA in Solar Default.” *Bloomberg News.* March 6, 2014.

[45] “Chaori Solar Says Bonds May Be Delisted as Baoding Slumps.” *Bloomberg News.* March 12, 2014.

[46] “Chaori Solar Says Bonds May Be Delisted as Baoding Slumps.” *Bloomberg News.* March 12, 2014.

[47] Sarah Wang. “The Answer to China's Future Energy Demands May Be Blowing in the Wind.” *Scientific American*. September 10, 2009.

[48] James A. Momoh, Sakis Meliopoulos, and Robert Saint. “Centralized and Distributed Generated Power Systems - A Comparison Approach.” *Power Systems Engineering Research Center: Future Grid Initiative White Paper.* June 2012.

[49] “How Distributed Wind Works.” Department of Energy, Office of Energy Efficiency and Renewable Energy.

[50] James A. Momoh, Sakis Meliopoulos, and Robert Saint. “Centralized and Distributed Generated Power Systems - A Comparison Approach.”

[51] Good Energy. “Installing a Wind Turbine - Site Selection.”

[52] Bloomberg News. “China to Increase Short-Distance Solar-Power Distribution.” *Bloomberg.* October 18, 2013.

[53] Li Shuo. “China’s Leaders Want ‘Revolution’ in Small-Scale Solar Power.” *China Dialogue.* October 4, 2013.

[54] Charlie Zhu and Swetha Gopinath. “Bright Prospects? China’s Rooftop Solar Goal Looks Too Ambitious.” *Reuters.* February 27, 2014.