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The East (Wind) is Red: A Survey of China's Wind Energy Policy and Development

This paper was prepared for the course “Asian Energy Security,” with Kent Calder.

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INTRODUCTION

Over the past 5 years, China has installed nearly 40,000 megawatts (MW) of wind power capacity, and with thousands more MW worth of projects to be completed in the coming years, it will continue to be the largest wind power market in the world. Recent surveys have found a great potential for both on-shore and off-shore projects, with the first off-shore project completed in 2010. The domestic wind turbine manufacturing industry has grown from only a minor role in the local market to include some of the world's dominant wind players. Yet despite this exponential growth unprecedented in both pace and scope, China's emerging wind industry remains poorly understood beyond the headline growth numbers, as studies from just a few years ago are wildly out of date.

This paper provides a survey of China's wind energy development, examining changes in policy and industry over recent years to seek key factors for its success. This paper finds that by clearly defining the government's commitment to renewable energy and forcing the state-owned grid to purchase all renewable energy produced, Chinese policy has provided the income certainty necessary for large scale business investment. Solely state-owned power generation firms have moved to develop large scale wind projects while domestic firms with strong industrial backing have taken advantage of technology licensing and acquisitions to quickly expand their wind turbine production. Chinese firms are likely to continue to dominate domestic production, but the implications for the international wind industry remains unclear. All major wind producers are involved with overseas firms and full exports remain virtually non-existent.

The remainder of this paper is organized as follows: Section II provides a brief overview of China's evolving energy challenges; Section III presents data on China's wind potential and recent wind energy development in comparison with other large economies; Section IV examines the evolution of policy initiatives that have supported wind; Section V describes the state of the wind manufacturing industry; and Section VI concludes.

CHINA'S ENERGY DILEMMA

China's interest in wind energy stems from the complex energy challenges it faces, part of what has been called the "Asia-Pacific energy dilemma:" skyrocketing demand, modest resource endowments and growing dependence on foreign suppliers.[1] To this list, I would also add environmental degradation, a growing concern throughout the region and worldwide. The past 15 years have seen all these concerns become grow ever more intense, degrading any sense of energy security that may have existed. With the Chinese government's legitimacy largely predicated on their ability to provide economic growth, they have had little choice but to pursue energy in all forms, even as it has driven them further into their energy dilemma.

Booming economic growth and rising standards of living have created a rapidly growing demand for electricity across China. From 1997 to 2009, annual electricity consumption roughly tripled

[1] Brown, Jeffrey, Toufiq Siddiqi and Kang Wu. "The Asia-Pacific Energy Dilemma." in Kang Wu, Fereidun Fesharaki and Sidney Westley, eds. *Asia's Energy Future: Regional Dynamics and Global Implications.* Hong Kong: Everbest, 2007.

to 3500 TWh (see Figure 1), requiring construction of hundreds of new power plants whose output has barely kept up with demand. This increase in power consumption is without comparison in other large economies: India's developing demand only doubled over the same period to a much smaller 870 TWh, while the mature market in the U.S. has decreased in recent years to about 4150 TWh in 2009. To provide the cheap electricity necessary to maintain growth, China has had to tap all resources available, and in China, coal is what has been available. As seen in Figure 2, coal has been the core of electricity generation for decades, preceding the reform era and keeping apace economic growth despite its high pollution costs. Local governments' piecemeal planning has resulted in coal power through often hastily built and inefficient small-scale plants, only exacerbating emissions problems. Emissions of sulfur dioxide and nitrogen dioxide, two combustion by-products known to pose health risks and cause environmental acidification, are some of the highest in the world.[2] Paired with growing consumption of petroleum and petroleum products, China's environmental problems are becoming only more pressing, reaching a level that is literally off the charts.[3]

Even to sustain current energy supplies requires increasing dependence on foreign sources, with coal recently joining oil on the list of energy imports. Domestic mining operations were able to keep up with coal demand until 2009, when China became a net coal importer.[4] Though domestic supply will continue to provide the vast majority of needs, China is projected to be a growing net importer of coal through 2035.[5] Oil progressed through a similar threshold in 1993, when China first became a net oil importer,[6] and the country now imports about 54% of its oil, mostly from the Middle East.[7] Domestic energy production has continued to grow, but has not kept apace demand such that total energy is now 9.3% reliant on imports.[8] Though there is little explicit risk to China's energy imports in today's global trading system, leaders remain unaccustomed to this dependency and would prefer to minimize the potential shocks that could destabilize the economy.

In the face of these problems, China's energy strategy has long been characterized as vague macro directives from top leaders,[9] the sum of which is now coalescing into an "all-of-the-above" strategy. In the short-term, China will continue to rely heavily on fossil fuels. It is diversifying its suppliers as much as possible, working out deals around the world, but this action only minimizes the risk of a single disruption in supply. It fails to address the problems of overall foreign dependence and pollution. In the long-term, China needs to move to cleaner resources

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[2] Lu, Streets, Zhang, Wang, Carmichael, et al. "Sulfur dioxide emissions in China and sulfur trends in East Asia since 2000." *Atmospheric Chemistry and Physics.* Vol 10, 2010. pp. 6311-6331.

[3] The U.S. Embassy in Beijing's air quality monitoring gave a rating of "Crazy Bad" when pollution went far beyond the programmed scale maximum.
Chin, Josh. "Shanghai's Air Bad, But Crazy Bad?" *Wall Street Journal - China Real Time Report.* Nov 25, 2010. Online. Dec 22, 2010.

[4] "International Energy Statistics - China Energy Profile." *U.S. Energy Information Administration*. Jun 30, 2010. Online. Dec 22, 2010.

[5] "International Energy Outlook 2010 – Coal." *U.S. Energy Information Administration.* Online. Dec 22, 2010.

[6] "International Energy Statistics – China Energy Profile."

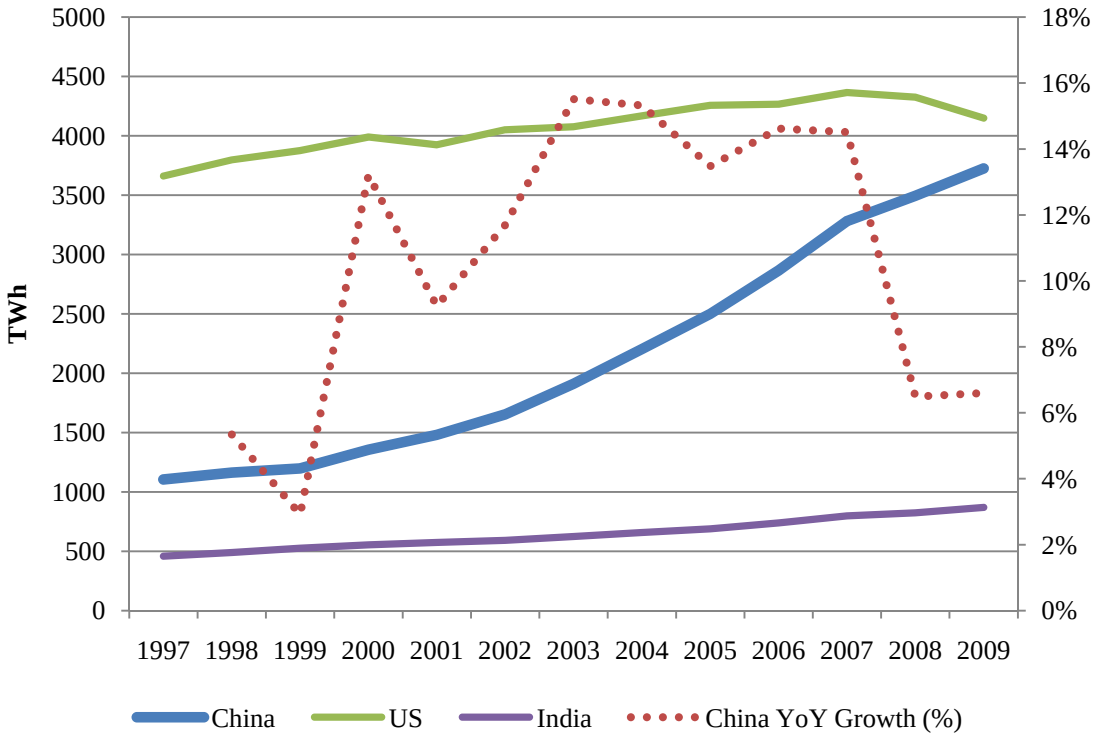
[7] Author's calculation using data from
China Statistical Yearbook 2010. *National Bureau of Statistics*. 2010. Online. Dec 21, 2010.

[8] Author's calculation. China Statistical Yearbook 2010.

[9] Cheng, Joseph. "A Chinese View of China's Energy Security." *Journal of Contemporary China.* Vol 17, No. 55, May, 2008. pp. 297-317.

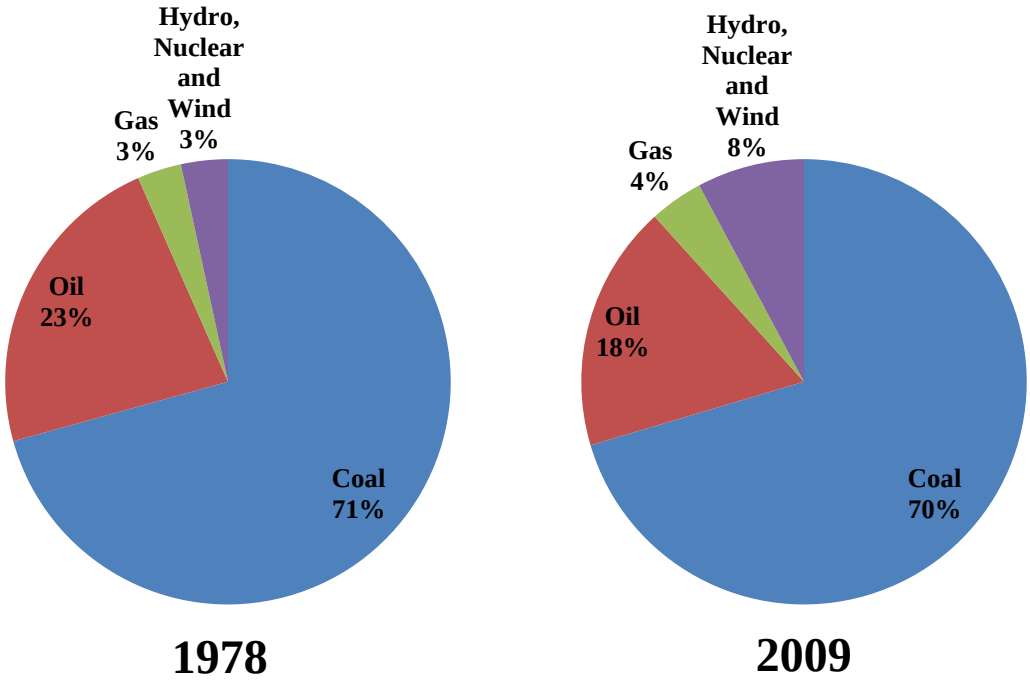
with fewer foreign inputs, such as nuclear and renewable energy. Many long-term nuclear and renewable energy project targets have been set for 2020, but, as discussed below, wind has managed to exceed all expectations, reaching its goals by the end of 2010.

Figure 1: Electricity Consumption and Growth[10]



[10] "BP Statistical Review of World Energy 2010." *BP*. Online. Dec 19, 2010.

Figure 2: China Energy Consumption by Generation Type, 1978 and 2009[11]



DEVELOPING CHINA'S WIND RESOURCES

Wind energy addresses many of the challenges faced by Asian nations, providing clean energy with domestic resources. It is little wonder that China has embraced wind over the past few years given its significant on-shore and off-shore wind potential, the full scope of which is only now becoming fully understood. Advances in measurement technologies and the strategic will to seek out new wind projects has provided a wealth of new data, spurring the development of many new wind farms. China's eagerness to realize its wind resources has resulted in a very rapid growth in wind capacity in only a few years time.

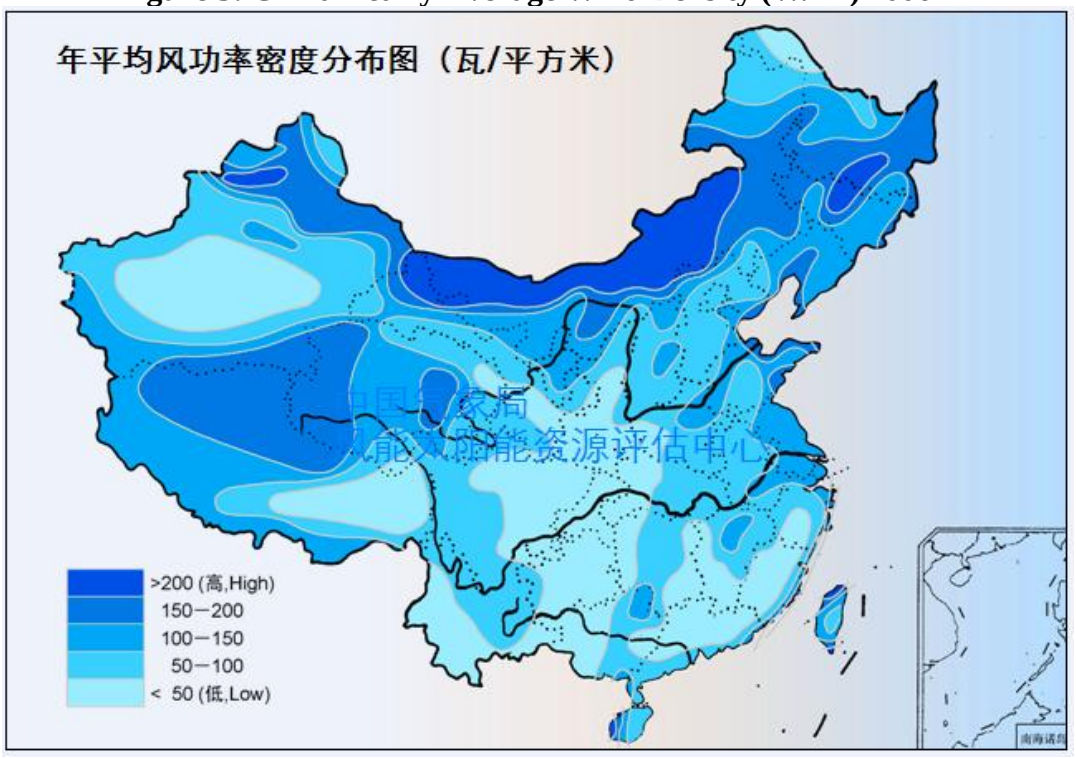
Measuring China's Wind Resources

China has significant on-shore wind potential. If price was no object, a recent article in *Science* by Michael Elroy et al. estimates fully realized wind power could provide 24,700 TWh of

[11] China Statistical Yearbook 2010

electricity each year,[12] roughly 6.6 times 2009 electricity consumption as reported by BP's *Statistical Review of World Energy*. The geographical distribution of wind relative to China's economic centers, however, presents many obstacles to realizing more than a fraction of this potential wind power at reasonable prices.[13] Figure 3 provides a map of 2006 average wind density estimates from China's Meteorological Bureau (中国气象局), showing the concentration of wind potential in the north and northeast. Higher resolution estimates from NASA (Figure 4) and the U.S. Department of Energy (Figure 5), show the best on-shore wind even more tightly concentrated in a band through Inner Mongolia province, with some more moderate wind potential in the west and along the east coast. Elroy's regional wind estimates suggest that 59% of wind potential is in the provinces he defines as north-northeast, an area with only 33% of China's GDP (only 23% if southernmost Shandong province, furthest from the best wind, is excluded from his northeast grouping).[14] Another 39% of wind potential is in the northwestern provinces and Tibet, which together account for a mere 5% of GDP. That leaves only 2% of potential on-shore wind power in the eastern and southern provinces, home to 72% of China's GDP and the majority of its people.

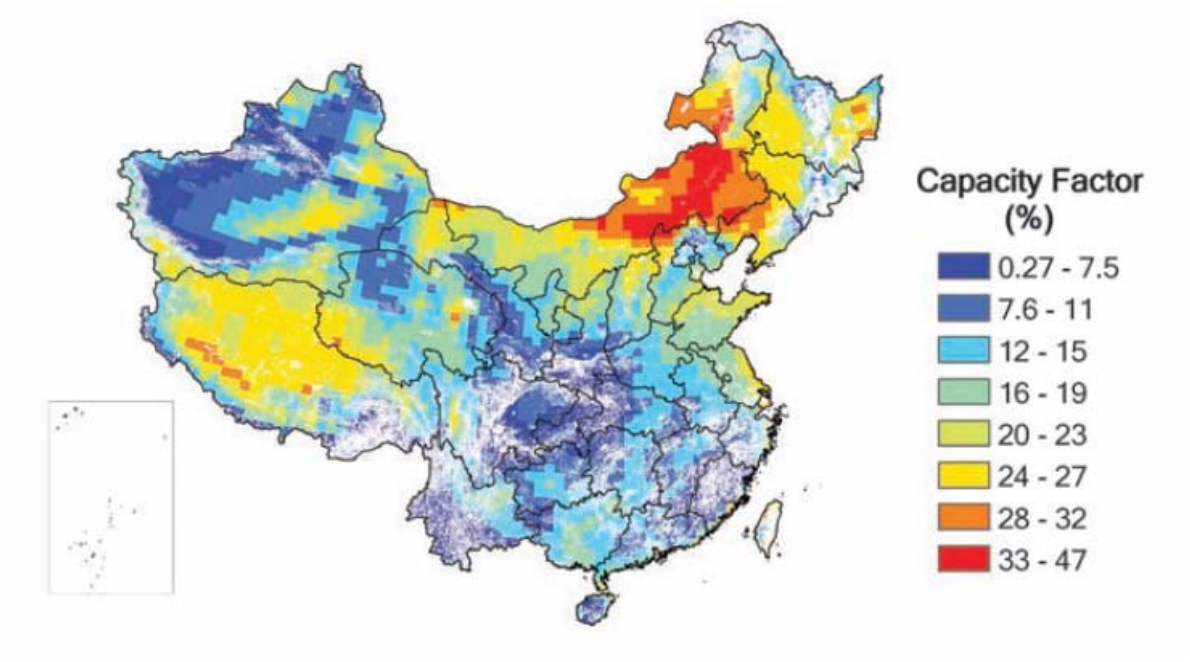
Figure 3: China Yearly Average Wind Density (W/m^2) 2006[15]



[12] Elroy, Michael et al. "Potential for Wind-Generated Electricity in China." *Science.* Vol. 325, 2009. pp. 1378-1380
[13] Elroy places a low price of 0.41RMB/kWh, or roughly US$0.06.
[14] Author's calculations from:
Wind data: Elroy
GDP data: China Statistical Yearbook 2010
[15] Center for Wind and Solar Energy Resources Assessment 风能太阳能资源评估中心. Zhongguo Qixiang ju 中国气象局. Online. Dec 23, 2010.

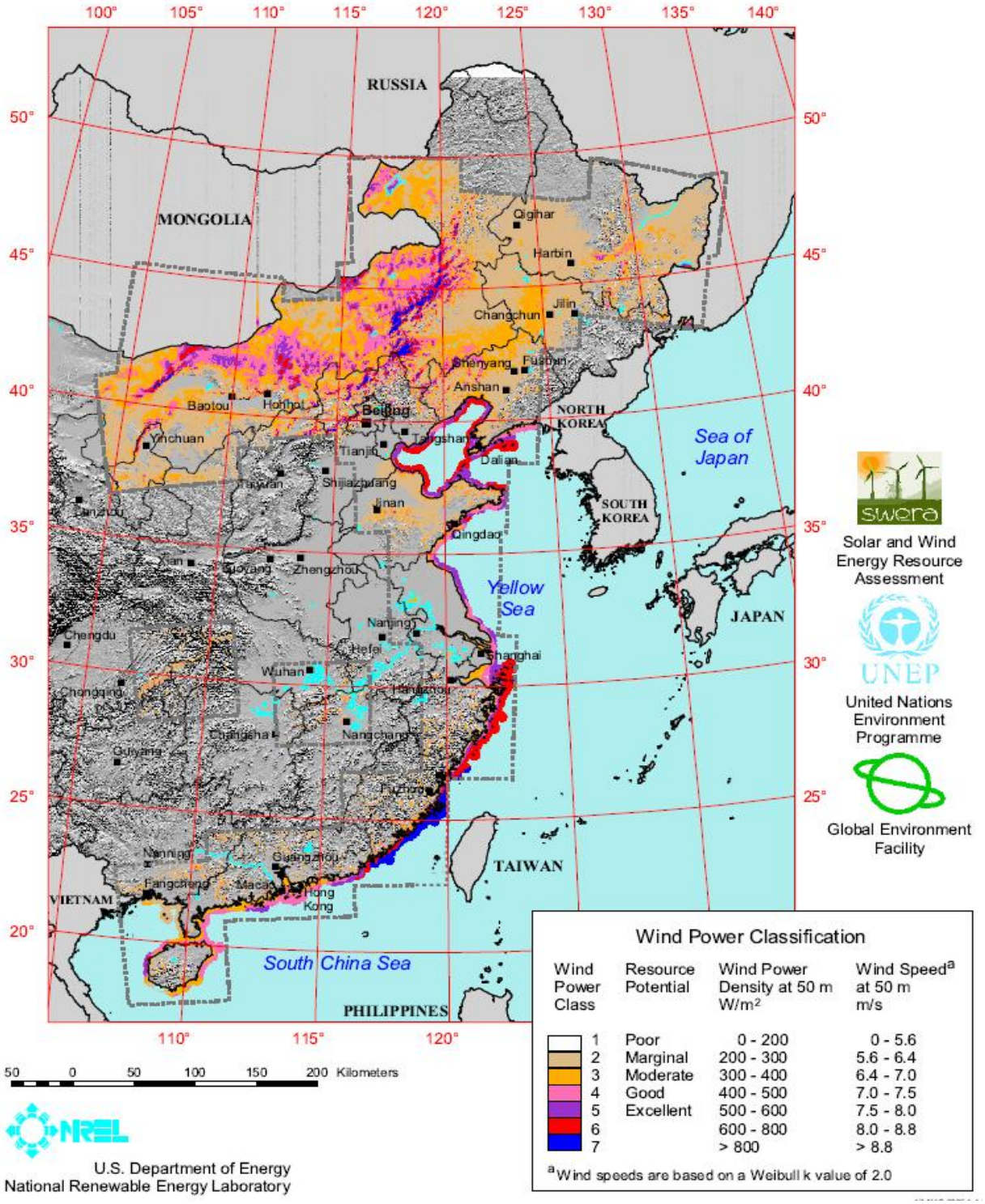
Off-shore wind may have greater potential in serving China's economic centers. As Figure 5 shows, there are excellent sites all along the coast. Full coastal potential within 100km of the shore is estimated at 11,580TWh per year, though how much of this will be feasible is still under study.[16] Technical and cost complications in water deeper than 30 meters may prevent development of many projects, while annual typhoons in southeastern provinces may present too great a risk. Regardless, coastal provinces are all developing off-shore wind plans, with the first 102 MW project already completed near Shanghai in 2010.[17]

Figure 4: Potential Capacity Factor for 1.5MW 80m Turbine[18]



[16]Qin Haiyan, Liu Mingliang, et al. "China: An Emergin Offshore Wind Development Hotspot." *World Wildlife Fund.* 2010. Online. Dec 19, 2010.
[17] Hsu, Jeremy. "China Powering Up First Offshore Wind Farm." *Popular Science.* April 5, 2010. Online. Dec 22, 2010.
[18] Capacity factor refers to the percent of capacity likely to be realized over a year of operation. Map source: Elroy, Michael et al. "Potential for Wind-Generated Electricity in China." *Science.* Vol. 325, 2009. pp. 1378-1380

Figure 5: China Wind Map – East China and Off-shore[19]



[19]This map ignores settled areas and slopes of more than 20° from consideration.
"International Wind Resource Maps – East China" *National Renewable Energy Laboratory (NREL).* Online. Dec 23, 2010.

Wind Development

China got a relatively late start on significant wind projects, but as many media headlines exclaim, its path to the top of the wind energy world has been faster than any of its planners had expected, breaking all precedent for rapid expansion. But interpreting figures reporting a doubling in capacity or the size of the market in megawatts is very tricky in a vacuum. Many reports manipulate isolated figures in the absence of all reference points. To put wind development in perspective, the figures in this sub-section provide data from several other large economies possessing different economic and wind market characteristics summarized in Table 1. Utilizing these other countries for comparison, Figure 6 illustrates the significance of China's abrupt and sizable entry into wind development, while Figure 7 compares the overall pattern in total installed capacity.

Table 1: Relevant Characteristics of Comparison Countries

Country	Economy	Wind Base	Wind Development
China	Developing	Large	Fast developing
U.S.	Developed	Large	Fast developing
Germany	Developed	Large	Mature
India	Developing	Moderate	Moderate developing
Japan	Developed	Small	Slow

China only developed its first grid connected wind project back in 1986, prior to which wind had been used only to supply off-the-grid rural areas. Development of prototype wind power plants proceeded slowly in the 1980's and early 90's, mostly funded by foreign governments and firms. By 1994 new government incentives began to make wind commercially viable, but liberalizing reforms in China's balkanized electricity market brought price pressures and uncertainty, depressing interest in wind.[20] In the 2000's, a consistent focus on renewable energy finally materialized around positive policy discussions and the industry began its rapid growth. Within the five years from 2004 to 2009, the domestic wind market grew into the largest in the world. The only other country with a somewhat comparable pattern of wind installation is the United States, though even it was surpassed by China's installation rate in 2009 and was likely surpassed in total capacity during 2010. Germany, who at the end of 2009 was near-even with China in terms of total installed capacity, added its turbines much more gradually over the course of a decade. While it has also grown significantly, India and its star turbine manufacturer, Suzlon, are much smaller in relative scope. Energy poor Japan, the world's third largest economy, is surprising in its relative inaction in the wind market, even during the recent wind boom.

The speed of China's wind growth is truly remarkable, but such a rapid rise is not without its problems. Domestically produced turbines supposedly suffer from less efficient technology and frequent breakdowns, while developers have often built the incorrect types of turbines due to lack of wind data.[21] Even while new wind turbines have been sprouting across the country, the

[20] Xia and Song

[21] Different types of turbine can take advantage of different types of wind, such as intense bursts or constant slow wind.
Cyranoski, David. "Beijing's windy bet." *Nature.* Vol. 457, 2009. pp. 372-374

electrical grid has simply not been able to keep up. It is estimated that 28% or more of total wind capacity is not connected to any distribution grid, leaving the turbines to "sunbathe," for months on end.[22] Even when they finally manage to get connected, there are still other problems. As discussed in the preceding sub-section, wind resources are isolated from demand centers, meaning large energy loss over the long-distance transmission lines necessary to bring wind to market. Furthermore, exploding electricity demand already strains the grid companies' transmission capacity, meaning there is little excess to handle intermittent power sources like wind.[23] It remains difficult for the low tech electric grid to adjust the output of thermal plants in order to tap into wind when it is available, meaning wind often gets passed up for steady thermal electricity.

All of these problems depress China's wind capacity factor (CF), an efficiency measure calculating how much of a power source's maximum potential energy is realized in a given time period. Estimates for China's CF range from 23% for operating turbines[24] to as low as 12% for the total fleet, compared to more developed systems in the West whose CF is estimated at 25-35%.[25] Thus, even though China has the most installed capacity, the amount of electricity it actually realizes from its turbines may be much less than in other large wind bases, such as the US and Germany. Furthermore, as a fraction of total electricity, China's wind share is still rather small (see Figure 8). Calculating energy estimates using data on power of the installed base and likely CF, China may only be obtaining 0.73-1.0% of its electricity from wind, compared to roughly 1.5% in India, 2% in the U.S. and nearly 10% in Germany! This leaves a long way to go for China to reach the National Development and Reform Commission's (NDRC) stated goal of 8% of electricity from non-hydropower renewables by 2020.[26]

Such lofty targets suggest that China will continue to be a growing wind market for many years to come depending on one's model for market progression. Xia and Song use trends of past growth to estimate a logistical model with China's market reaching an inflection point near 2015 and hitting a plateau by 2020.[27] Though Denmark fits their mathematically elegant model over a 30 year time frame, their estimates incorrectly predict the path for larger countries like Germany, who have continued in consistent growth beyond their predicted plateau dates. A large slowdown in China seems unlikely when taken together with new targets and data on technical wind potential, though a deceleration to a more linear growth path may occur. Whatever outcome of the Chinese market, it will largely be determined by Chinese policy directives, the topic of the following section.

Ni Chunchun, pp. 22-23

[22] Xie, Xina and Michael Economides. "Great Leap Forward for China's Wind Energy." *Energy Tribune.* Jul 30, 2009. Online. Dec 23, 2010. http://www.energytribune.com/articles.cfm?aid=2139

[23] Zhang, Lina and Yang Dingdu. "China's green energy goes to waste in distribution bottleneck." *Xinhua News.* Dec 23, 2009. Online. Dec 23, 2010.

[24] Cyranoski, 2009.

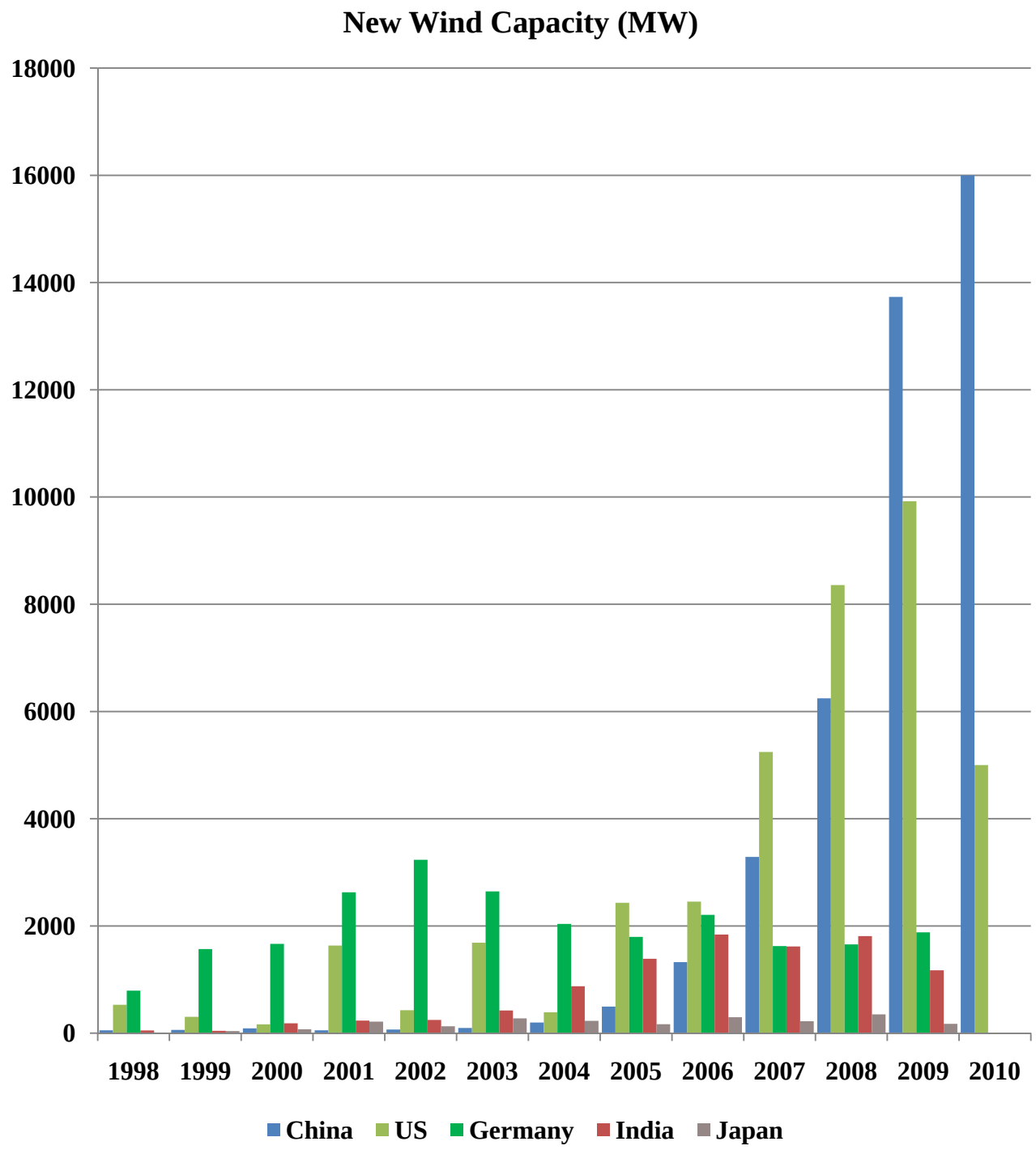
[25] See Elroy, Boccard

Boccard, Nicolas. "Capacity Factor of Wind Power: Realized Values vs. Estimates." *Energy Policy.* Vol. 37 (7), 2679-2688.

[26] Fu Jing. "China considers higher renewable energy targets." *China Daily.* Jul 06, 2009. Online. Dec 23, 2010.

[27] Xia and Song. pg. 1971

Figure 6: Additional Wind Capacity Added – Select Countries 1998-2009[28]



[28] Based on data from BP Statistical Review of World Energy 2010. Data for year 2010 is based on estimates confirmed in statements by Li Junfeng, Secretary General of the Chinese Renewabe Energy Industry Association. Morison, Rachel. "Global Wind Installations Up 22% in 2010, China Leads Growth." *Platts.* Feb 2, 2011.

Figure 7: Installed Wind Capacity in Selected Countries (MW)[29]

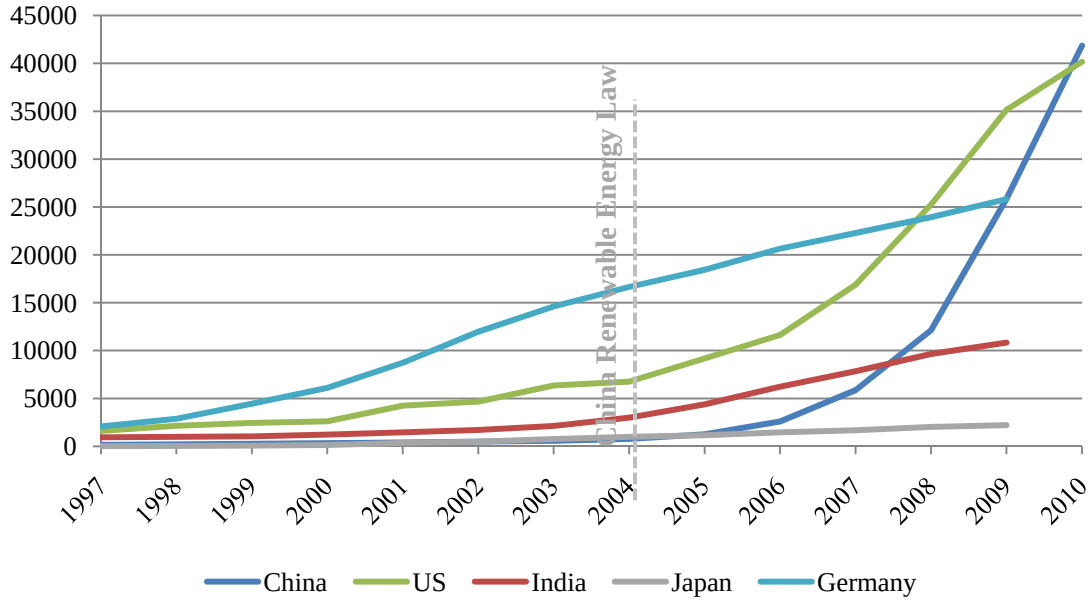
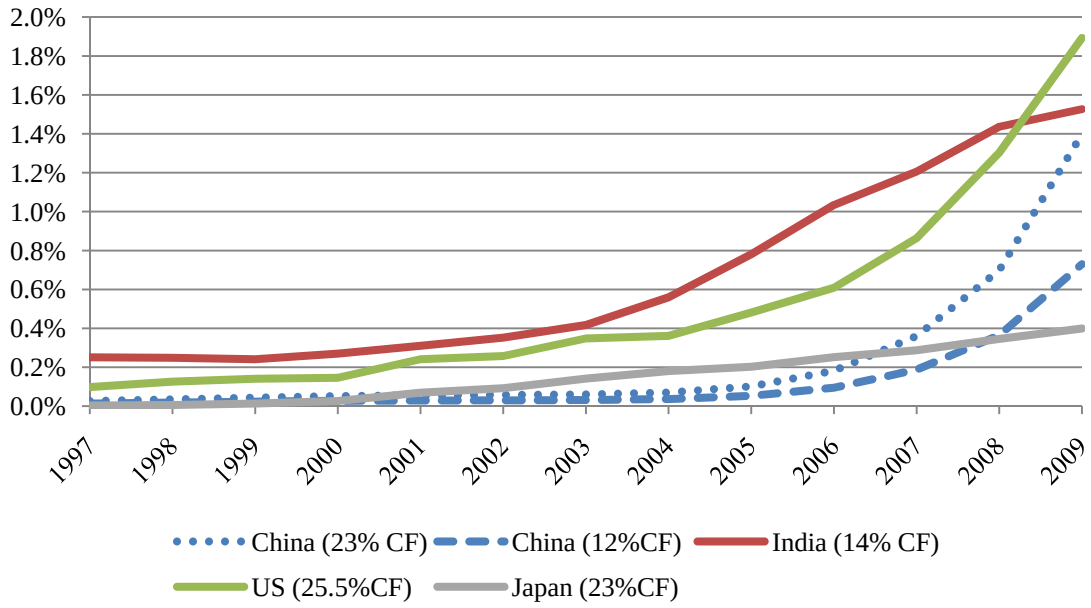


Figure 8: Estimated Wind Energy as Percentage of Total Electricity[30]



[29] BP Statistical Review of World Energy 2010.

[30] Author's calculations based on BP data. Comprehensive sources on the capacity factor (CF) are difficult to locate. Boccard finds the average of several developed Western countries to be approximately 23% , which I use as a baseline. He finds the U.S. average to be 25.5%. McElroy notes others who have found the average U.S operating CF to be about ~35%, while China's is at 23%. Lack of grid connectivity for many wind farms may place China's total CF much lower. I have used 12% as a low base. Elroy, Boccard.
India: http://www.eai.in/forum/viewtopic.php?f=19&t=212

POLICY INITIATIVES AND GOVERNANCE

The vast majority of wind farms provide electricity at higher cost than fossil fuels, but simple accounting costs fail to capture the security and environmental benefits of renewables. To stimulate the development of wind, governments rely on a variety of policy tools: feed-in tariffs, mandatory targets, government tenders, tax incentives, and local content requirements are but a few of the policies used.[31] China has struck upon a particularly potent policy mix in recent years. Part financial incentives, part mandate and part party influence, it has accumulated gradually before coming together to fuel a takeoff in 2005. This section reviews some of the most important policy developments for wind energy in the past 15 years, and discusses potential future directions.

Riding the Wind 1996-2000

In the 1990's, most of China's wind development was small scale and experimental, reliant on foreign government's soft loans to establish demonstration wind farms. The Chinese government was somewhat interested in wind, but put off by the high costs of imported turbines, so in 1996 it launched the "Ride the Wind" (*chengfeng* 乘风) program. The program provided funding for 240 MW of turbines with a 40% local content requirement, aimed at setting up a domestic manufacturing capability for 0.6 MW turbines.[32] The National Debt Wind Power Program tried to stimulate wind development with access to low interest loans using government debt, while the State Development and Planning Commission (precursor to today's NDRC) also established direct government funding for research and development through national and provincial budgets. These efforts failed to grow into a wider policy initiative, however, and funding for projects remained strictly on an ad-hoc basis.[33] Overall, policy in the late 90's laid some groundwork for domestic wind manufacturing, but failed to address the cost problem of renewable energy. Without any effort to address demand, there was little significant interest in wind.

Tenth Five-year Plan 2001-2005

China's tenth five year plan laid out a goal of increasing production capacity of solar, wind and geothermal energy,[34] showing the government's explicit commitment to renewable energy. In the same year, the Ministry of Finance moved to cut the VAT tax, the most significant tax in China, by 50% for wind power manufacturers and developers, while decreasing tariffs to 5% on components.[35] Provinces began to see the central government's commitment and advanced their own local development incentives.[36]

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[31] Lewis, Joanna and Ryan Wiser. "Wind: A Local Industry." *reFocus*. Mar 2007. pp. 36-41
[32] Lew, Debra and Jeffrey Logan. "Energizing China's Wind Power Sector." National Renewable Energy Lab. April 2004. Online. Dec 22, 2010.
[33] Wang, Feng, Haitao Yin and Shoude Li. "China's renewable energy policy: Commitments and challenges." *Energy Policy.* Vol 38, 2010. pp. 1872-1878
[34] Li Junseng. "Renewable Energy Policy in China: Overview." *National Renewable Energy Laboratory.* 2004. Online. Dec 22, 2010.
[35] Xia and Song 1969-1970
[36] Li Junseng. "Renewable Energy Policy in China: Financial Incentives." *National Renewable Energy Laboratory.* 2004. Online. Dec 22, 2010.

Perhaps the most significant policy enacted during this period was the NDRC's launch of the wind power concession system. Initially selling prime wind development areas to select enterprises, it quickly evolved into a complex auction incentive system, coupled with a local turbine content requirement of 50%. The NDRC and its local branches put up sites for auction, guaranteeing the winning firm 30,000 full load hours (roughly 10-15 years of operation for most wind farms) to be purchased at a price included in their bid, and at the average market price thereafter.[37] The final bid amount would include the firm's investment and operating costs, plus their bid price for 30,000 hours worth of electricity. The provincial NDRC office, State Grid Company, provincial power companies, bidding agencies and technical advisors would evaluate bids, with central NDRC approval required for projects larger than 50MW.[38] How bids are specifically evaluated is unknown, but one can speculate as to preferences toward domestic firms and state-owned enterprises.[39]

By themselves, the initiatives launched in the tenth-five year plan period did not generate a large wind market, but were steps in the right direction. It would take the creation of China's Renewable Energy Law to finally create demand and spark growth.

Launch of the Renewable Energy Law 2005-2007

Entering into draft consideration during December of 2004, the Renewable Energy Law (REL)[40] was wide in scope, bringing deep changes to the development of all renewable energy in China. Approved by the National People's Congress on February 28, 2005, the REL created a host of new requirements that completely changed the nature of China's wind market and greatly strengthened the effects of past policies. The most important element of the REL is Article 14, which requires electrical grid companies to connect all renewable projects (even encouraging connection in areas with no grid) and forces them to purchase all renewable energy produced. Article 29 even gives the law teeth, requiring grid companies that fail to purchase renewable energy to compensate the developer for any losses and threatens a punitive fine if the grid does not correct its behavior. In exchange for shouldering the burden of more expensive renewable energy, the REL allows grid companies to collect a surcharge to recoup losses,[41] but it is unclear how much of these losses can be reasonably covered in this manner. In practice, grid companies are only allowed to charge fees to recoup losses related to the premium cost of generating renewable electricity, but not for the formidable capital expenses of building power lines to wind turbines and other renewable energy producers, many of them in remote areas.[42] There seems to be little concern for the State Grid Corporation, the 8th largest corporation by revenues in the world.[43] Even if the REL forces losses on the grid sector monopoly, it guarantees wind developers that their product will be purchased and provides the foundation for the ongoing growth in wind turbine sales.

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[37] Wang, Q. 2010
[38] Zhou, Yun and Quanfeng Wang. "Wind Power in China." *University of Gavle.* June 2009. Online. Dec 19, 2010.
[39] Cyranoski, David. "Beijing's windy bet." *Nature.* Vol. 457, 2009. pp. 372-374
[40] "Renewable Energy Law of the People's republic of China." *National People's Congress of the PRC.* Aug 25, 2009. Online. Dec 22, 2010.
[41] REL. Article 20.
[42] Bradsher, Keith. "China Leading Global Race to Make Clean Energy." http://www.nytimes.com/2010/01/31/business/energy-environment/31renew.html?pagewanted=2
[43] "Global 500" *CNNMoney.com.* 2010. Online. Dec 23, 2010.

The REL went even further than the above steps, creating a variety of financial supports as well. A public fund using tax revenue was established for renewable development, issuing R&D grants and subsidizing developer's loan interest.[44] Banks were "encouraged" to provide preferential loans to wind developers and manufacturers, a uniquely Chinese strategy. The state-owned banking sector routinely takes "window-guidance" on which sectors to extend preferential loans to. Developers have embraced bank finance during the ensuing wind market boom, financing many projects with 80% debt.[45] Bank finance has also reportedly been expanded to include preferential terms for customers of Chinese turbine manufacturers.[46] Tax benefits were also permitted for renewable energy projects,[47] though no guidelines have been published, leading to ad-hoc use by local governments seeking to encourage their favored developments.[48] Likely knowing the demand they were unleashing with all of this support for wind energy, the NDRC issued a 70% local content requirement on July 4, 2005, ensuring a large role for the domestic wind industry.[49]

Combined with the terms of the REL, projects under the 2003 concession system quickly increased. By the end of 2006, 2550MW worth of projects were underway,[50] and by mid-2008, 3400 MW had been completed or planned.[51] Other projects accelerated as well, using a similarly mandated bid system in the REL.[52] The structure of the Chinese energy market created some problems in the tender system, however, with large state utilities underbidding on projects in order to capture resources for use in the long-term, blocking out private and foreign commercial competitors.[53] Some firms began to buy up sites without intent to develop them, forcing the NDRC to release a notice in 2006 requiring enterprises to actively invest in renewable energy and stating that they must comply with any future renewable energy quotas.[54] While ensuring development, incentives to underbid on projects grew as utilities sought to lock up prime wind resources early, to ensure easier attainment of future quotas. All of this required revising the bid system such that the electricity price component of bids was decreased to a 40% weight, and then

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[44] REL, Article 24
[45] McElroy
[46] Ming Yang energy's customers are reported to have access to preferential credit from the Industrial and Commercial Bank of China.
Brasher, Keith and Tom Zeller. "Wind Power for Boston, Made in China." *The New York Times.* Dec 15, 2010. http://www.nytimes.com/2010/12/16/business/energy-environment/16windside.html
[47] REL, Article 26
[48] Wang, Yin and Li. 1874
[49] National Development and Reform Council 国家发展和改革委员会. "Notice on the requirements relating to the construction and management of wind power. 国家发改委关于风电建设管理有关要求的通知." Jul 4, 2005. Online. Dec 22, 2010. Available: http://www.ndrc.gov.cn/zcfb/zcfbtz/zcfbtz2005/t20050810_39031.htm
[50] Xia, Changliang, and Song Zhanfeng. "Wind energy in China: Current scenario and future perspectives." *Renewable and Sustainable Energy Reviews* 13 (2000) 1966-1974
[51] Ni Chunchun. "China's Wind-Power Gneration Policy and Market Developments." *IEEJ.* Dec 2008. Online. Dec 19, 2010.
[52] REL, Article 13
[53] Wang, Qiang. 2010. pg 707
Han, J et al. "" *Energy Policy.* Vol 37, 2009. 294102951, pg. 2945.
[54] National Development and Reform Council 国家发展和改革委员会. "Regulations regarding renewable energy. 可再生能源发电有关管理规定." Jan 5, 2006. Online. Dec 22, 2010. Available: http://nyj.ndrc.gov.cn/zywx/t20060206_58763.htm

further decreased to 25% in 2006. Since 2007, the auction system has completely changed such that the winner is now the company closest to the average bid, excluding the high and low bids.[55]

Extremely low bids continue to be an issue (though potentially desired outcome) on concession projects, which are priced significantly lower than non-concession developments.[56] Industry experts say that the 2008 average concession bidding of 0.45RMB/kWh is barely break even, with losses either hidden in a firm's other operations or being generated by carbon credit sales through the Kyoto Clean Development Mechanism.[57] Unlike in countries with built in feeder-tariffs, there is no fixed price premium for wind in China, forcing down the price for wind.[58] In other countries, stiff price competition may seem detrimental to the development of wind industry, but there is anecdotal evidence that in the Chinese case, intense price competition has driven out foreign bidders, leaving only state-owned enterprises (SOE's) to compete in an uneconomic environment.[59] Some note that the Chinese price for wind (0.63RMB/kWh) is lower than nearly every country except Norway (0.32RMB), Sweden (0.53RMB) and US (0.55RMB) as evidence of the abuse of this process.[60] Regardless of one's position on the mercantile aspects of the industrial development, these regulations have been highly successful in promoting Chinese wind growth at affordable prices.

Fine Tuning the REL 2007-Present

The initial success of the REL was significant, but the system has still required several incremental improvements in the following years. In 2007, the NDRC announced goals for 15% of electricity from renewable by 2015 and created regulatory monitoring powers to ensure grid compliance with renewable purchase requirements.[61] Tariffs on turbine components were further reduced to 1%. [62] In early 2008, the 11th five-year plan set a seemingly ambitious target for 10GW of wind power by 2010, but it was easily reached by the end of that year.

In December 2009, the NPC passed a set of amendments to the REL to address several problems. It gave government organs the power to set renewable quotas and enforce them with more fines, creating a mechanism similar to the U.S. Renewable Portfolio Standards that require utilities to support renewable energy. [63] It also transferred renewable surcharges from grid companies to the government, from which grid companies can then acquire rebates.[64] This opens up the possibility of the government using extra funds to promote other renewable development.

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[55] Wang, Qiang. "Effective policies for renewable energy-the example of wind power-lessons for China's photovoltaic power." *Renewable and Sustainable Energy Reviews.* Vol 14, 2010. pp. 702-712
Han, J et al. "" *Energy Policy.* Vol 37, 2009. 294102951, pg. 2945.
[56] Wang, Qiang. pg. 707
[57] Fairly, Peter. "China Doubles Wind Watts." *IEEE Spectrum.* May 2008. pp. 11-12.
[58] Fairly
[59] Li, Junfeng and Eric Martinot. *Powering China's Development: The Role of Renewable Energy.* World Watch Institute: 2007.
[60] J. Han, pg 2496
[61] Ni Chunchun. pp. 9-10
[62] Xia and Song 1969-1970
[63] Finamore, Barbara. "China Renews Its Commitment to Renewable Energy." *Switchboard.* Feb 1, 2010. Online. Dec 23, 2010.
[64] Ibid.

Policy Perspective

The Chinese wind system under the REL has been highly successful, representing a firm commitment to the renewable sector. It has fostered massive growth in the wind market by mandating its consumption and continues to provide a consistent environment for businesses to operate in. Every action has moved the country toward renewable development, without any risk of subsidy expiration like in the United States. Under the direction of the state, China's SOE's may be able to pursue a longer-term strategy or suffer losses in ways that are not possible in most free-market democracies. India's early wind energy growth was largely promoted through similar heavy-handed tax sheltering and preferential financing, but has slowed since reforming to a system with fewer direct government interventions and more private investment.[65] Although often criticized for its domestic favoritism in the form of local content requirements, they are not that uncommon for successful wind countries, appearing in Spain, Brazil, and Canadian provinces.[66] Recent media articles and the U.S. government's pending WTO case against China suggest wind success has been the result of unfair trade practices, but looking at the set of policies above, it is only one part of a coordinated system. Whether through direct subsidies, grants, preferential finance, or simply preference during subjective bid evaluations, domestic firms are going to receive some degree of non-commercial support.

The Chinese system has succeeded in fostering a highly dynamic wind market around strong government controls, but it is not without risks. While China has succeeded in creating demand and supporting local industry, it puts a high degree of faith in the government's ability to evaluate bids and allocate subsidies. The greatest risk posed by the current regulatory structure is that some layer of government will fail in these respects, either misevaluating projects due to poor data, ignoring the costs dumped onto the grid operators, or misallocating subsidy funds. Such an outcome could lead to an even more underperforming wind base, or strain the finances of the firms racing to develop the sector. The NDRC seems to be aware of these risks, as many recent steps have been incrementally strengthened the government's ability to evaluate and monitor projects to ensure that the wind market does not get out of control. Overheating in wind manufacturing capacity remains a risk, but so long as the state supports the consumption side of the market, the supply side should manage to find its own equilibrium.

CHINA'S WIND INDUSTRY

In a highly favorable policy environment, China's wind turbine manufacturing industry has undergone rapid changes. While the majority of wind turbine components were always produced in China under the basic economics of producing large, immobile parts for wind turbines, there has been a marked shift in which companies are producing China's wind. As seen in Table 2, the market share of foreign owned firms has collapsed over the course of the last 5 years. While this may seem like shocking evidence of China's market manipulation, this shift is actually not far out of line with other markets. In 2005, domestic manufacturers' market share reached 60% in Germany, 76% in Spain, 61% in the U.S., 62% in India 62% and 100% in Denmark.[67]

[65] Tecco, Nadia and Elisa Vecchione. "Sustaining growth, sustaining the environment: a comparative analysis of wind energy policies in China and India." AISSEC Working Paper. 2009. Online. Dec 22, 2010.
[66] Lewis, Joanna and Ryan Wiser. 2007.
[67] Lewis and Wise, 2007. pg. 39

Table 2: Foreign vs. Domestic Manufacturers Market Share 2004-2009[68]

	2004	2005	2006	2007	2008	2009*
Foreign	75.4%	70.6%	58.8%	42.5%	24.4%	13.1%
Domestic	24.6%	29.4%	41.2%	57.5%	75.6%	86.9%

The 2009 market share for domestic firms may be evidence of some divergence from normal levels, but the Chinese wind market remains highly dynamic. It has yet to coalesce around a single firm as in Spain (Gamesa) or Denmark (Vestas), with dozens of firms still trying to find a market. Table 3 demonstrates how fractured the market remains, although there is some stability forming around the top three Chinese firms (Sinovel, Golden Wind and Dongfang Electric).

Table 3: Market Share of Top Firms 2004-2009 and Cumulative Installation Base[69]

Market Share of New Sales							**Cumulative Base in 2009**	
Firm	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**(MW)**	**Share**
Sinovel	--	--	5.6%	20.6%	22.5%	25.3%	5652	21.9%
Golden Wind	20.1%	26.4%	33.3%	25.1%	18.1%	19.7%	5351.05	20.7%
Dongfang	--	1.2%	0.7%	6.7%	16.9%	14.7%	3328.5	12.9%
China United	--	--	--	--	--	5.6%	792	3.1%
Mingyang	--	--	--	0.0%	2.8%	5.4%	895.5	3.5%
Xiangdian	--	--	--	0.2%	1.9%	3.3%	582	2.3%
Shanghai Electric	--	--	--	0.7%	2.9%	2.0%	475.5	1.8%
Yunda Windey	2.5%	1.4%	1.5%	2.0%	3.7%	1.9%	594	2.3%
Vestas	2.2%	14.6%	23.6%	11.2%	9.6%	4.4%	2011.5	7.8%
GE	8.4%	18.5%	12.7%	6.4%	2.3%	2.3%	957	3.7%
Suzlon	--	--	0.9%	6.2%	2.1%	2.1%	605.25	2.3%
Gamesa	36.2%	35.7%	15.9%	17.0%	8.1%	2.0%	1828.75	7.1%
RePower	--	--	--	--	--	1.4%	200	0.8%
Nordex	0.0%	1.8%	2.0%	1.7%	2.1%	0.8%	331.5	1.3%
Others	30.7%	0.4%	3.9%	2.2%	7.1%	9.0%	2248.45	8.7%
Total Install	197.35	502.35	1337.15	3303.65	6246	13803.2	25853	

[68] Author's calculations using data from : Various Years: "Zhongguo Fengdian Zhuangji Rongliang Tongji. 中国风电装机容量统计. China Wind Energy Association 中国风能协会. Online. Dec 19, 2010.
[69] Ibid.

The significance of the rise of the Chinese manufacturers for global wind development remains unclear. There is a degree of fear in coverage of Chinese firms' plans to expand and export,[70] but their global relationships are highly complex. The information in Table 4 highlights several key features of these manufacturers that appear only upon detailed inspection and reveal the tangled relationships of the global wind industry.

Virtually all of China's large wind firms are branches of large electronic industry or machinery conglomerates, launched within the past few years. They are manufacturing a single product line in much larger organizations (usually SOE's), giving them easy access to the technical and financial resources that a large firm can bring. For example, market leader Sinovel is a part of Dalian Heavy Industry and Crane Group, a multi-billion dollar a year firm with heavy equipment products ranging from chemicals to construction. These firms are able to pour money and people into their wind startups, even if it means taking significant losses in the start-up phase.

Lacking any specialized knowledge in the wind industry, however, these firms are all dependent on designs and technology licensed or purchased from foreign firms. Windtec, an Austrian subsidiary of Massachusetts based American Superconductor (AMSC), has licensed a variety of technology to Sinovel. While firms like Gamesa and Vestas, who have manufacturing plants in China, feel squeezed by domestic competition, AMSC and others are benefiting from domestic growth by winning design contracts and selling components in China.[71] Gamesa may say it is surrendering to Chinese pressure on technology transfer and local content requirements, but others are finding a different role in the market by playing to their relative strengths.[72] Domestic manufacturers dominate the market in final product assembly, but they remain highly dependent on foreign imports for high tech components like electrical control systems and primary bearings, while items like blades require significant foreign help.[73] Chinese firms have not made any significant investments into wind R&D and likely lack the human resources to do so.[74] This is a completely different approach from India's Suzlon, which has pursued a more integrated supply chain, invested heavily in R&D at the high end of the market, and built a global network of subsidiaries to acquire a deeper knowledge-base.[75] On the whole, there has been a transfer of manufacturing to China supported by local content requirements, but there has been little shift in any complex components production or design.[76]

There has been a persistent fear that the newly large Chinese turbine manufacturers will begin to export their products and dominate world wind markets, but as of 2010, the threat has not materialized. In 2008 and 2009, only 39 wind turbines were exported, primarily by firms not

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[70] Bradsher, Keith. "To Conquer Wind Power, China Writes the Rules." *New York Times.* Dec 14, 2010. Online. Dec 23, 2010.
[71] "AMSC gets $445 mln contract from China's Sinovel." *Reuters.* May 17, 2010. Online. Dec 26, 2010.
[72] Brasher, Keith. "To Conquer Wind Power, China Writes the Rules." *The New York Times.* Dec 14, 2010. http://www.nytimes.com/2010/12/15/business/global/15chinawind.html
[73] Schwarz, Lou and Ryan Hodum. "China's Wind Power Industry: Localizing Equipment Manufacturing." *Renewable energy world.* Jul 18, 2008. Online. Dec 20, 2010.
[74] He, Yulin and Xinping Chen. "Wind turbine generator systems. The supply chain in China: Status and problems." *Renewable Energy.* Vol. 34, 2009. pp. 2892-2897
[75] Lewis, Joanna. "Technology Acquisition and Innovation in the Developing World: Wind Turbine Development in China and India." *Springer Science.* Nov 27, 2007. Online. Dec 20, 2010.
[76] J. Han, pp. 2948-2949

among China's big three manufacturers.[77] Xinjiang Goldwind's American subsidiary Goldwind USA is making efforts to expand into the U.S. market beginning with a $10 million pilot project in Minnesota,[78] but they project 63% of the project's spending will be utilized on domestic content by cost basis,[79] higher than the U.S. average of 50% local content.[80] Meanwhile, A-Power Energy Generation Systems, another Chinese firm with plans to jointly develop 240-300 turbines in Texas, plans to build a manufacturing plant in U.S.[81]

The impact of Chinese wind on the global wind industry is difficult to predict. Their products still suffer problems at home, and they lack expertise dealing abroad. The manufacturing of these large, complex, investment products is entirely different from the simple manufactures and consumer electronics that have come from China in the past. The worst case scenario is that wind turbines follow the path of China's high-speed rail industry, with local firms "re-innovating" and "self-innovating" foreign intellectual property for export, but this seems far-fetched at present.[82] A more likely scenario is that Chinese firms find themselves integrating into a complex global supply chain, delivering certain components while purchasing other technologies from other firms, much like the existing global wind leaders. If the addition of a few Chinese manufacturers can help drive down the cost of the high initial investment required to launch a wind farm, it can only help the global spread of wind power.

[77] "Zhongguo Fengdian Zhuangji Rongliang Tongji 2009. 2009中国风电装机容量统计. China Wind Energy Association 中国风能协会. 2009. Online. Dec 19, 2010.

[78] Bradsher, Keith and Tom Zeller. "China's Push Into Wind Worries U.S. Industry." *The New York Times.* Dec 15, 2010. http://www.nytimes.com/2010/12/16/business/global/16wind.html

[79] Goosens, Ehren and Baldave Singh. "Goldwind Winds Power Supply Deal for U.S. Wind Project." *Bloomberg Businessweek.* Dec 20, 2010. Online. Dec 21, 2010. http://www.businessweek.com/news/2010-12-20/goldwind-wins-power-supply-deal-for-u-s-wind-project.html

[80] Bradsher, Keith. "To Conquer Wind Power, China Writes the Rules."

[81] Burnham, Michael. "China's A-Power to Build U.S. Wind Turbine Factory." *The New York Times.* http://www.nytimes.com/gwire/2009/11/17/17greenwire-chinas-a-power-to-build-us-wind-turbine-factor-22742.html

[82] Shirouzu, Norihiko. "A Problem with California Plants to Tap Chinese Tech." *China Real Time Report.* Dec 15, 2010. Online. Dec 26, 2010.

Table 4: Primary Wind Manufacturers – Products and technology[83]

Firm	Parent Company	Turbine (MW):	Technology Source:	Agreement type	Production Stage
Sinovel	DHI-DCW Group	1.5	Windtec (Austria-US)	Licensed	Large-scale
		3	Windtec (Austria-US)	Joint-designed	Small-scale
Dongfang Wind	Dongfang Electric Group	1.5	REPower (Germany)	Licensed	Large-scale
		2.5	Windtec (Austria-US)	Licensed	Prototype
		1	Shenyang Industrial University	--	Trial
		2	Self-developed	--	Prototype
Goldwind	Goldwind Science & Technology	0.6	Jacobs (US)	Licensed	Large-scale
		0.75	REPower (Germany)	Licensed	Large-scale
		1.5	Vensys (Germany)	Licensed	Large-scale
		2.5	Vensys (Germany)	Takeover	Prototype
		3	Vensys (Germany)	Takeover	Prototype
Mingyang Wind Power	Guangdong Mingyang Electric Group	1.5	Aerodyn (Germany)	Joint-designed	Large-scale
		2.5-3	Aerodyn (Germany)	Joint-designed	Prototype
China United Power	China Guodian Corporation	1.5	Aerodyn (Germany)	Joint-designed	Large-scale
		3	GL Garrad Hassan (UK)	Joint-designed	Prototype
		3	GL Garrad Hassan (UK)	Joint-designed	Design
Zhejiang Yunda Wind		0.75	REPower (Germany)	Licensed	Large-scale
		0.8	REPower (Germany)	Licensed	Large-scale
		1.5	GL Garrad Hassan (UK)	Joint-designed	Large-scale
Shanghai Electric Wind	Shanghai Electric Group	1.25	DeWind (Germany)	Licensed	Large-scale
		2	Aerodyn (Germany)	Joint-designed	Large-scale
Hunan XEMC Windpower	XEMC	2	Darwind (Netherlands)	Takeover	Large-scale
		5	Darwind (Netherlands)	Takeover	Prototype
AVIC HuiDe Wind	China Aviation Industry Co.	1	Fuhrlander (Germany)	Licensed	Large-scale
		2	W2E (Germany)	Licensed	Trial
Huayi Wind	Huayi Electronics Group	1.5	Aerodyn (Germany)	Joint-designed	Small-scale
		2	REPower (Germany)	--	Large-scale
New United Wind	New United Group	1.5	Shenyang Industrial University	--	Large-scale
		2	Universität des Saarlandes	Joint-designed	Trial

[83] Compiled from company websites, news articles and translation of data from Qi Hesheng. "2010 Zhongguo zongzhuang qiye jiben qingkuang biao" *Zhongguo Nongji Xiuehui Fengneng Shebei Fenhui.* Jul 27, 2010. Online. Dec 23, 2010. Available: http://www.windpower-china.com/node/1578

CONCLUSION

The growth of China's wind industry is impressive in its scope and its future plans for both on-shore and off-shore wind are only more remarkable. As it leads the way in new wind development, China's renewable energy policy reveals just how much change can be brought by strong renewable requirements as spelled out in the REL. Production subsidies and financing can bring some small growth when the economics work, but the key to large wind growth has been the mandated purchase of all renewable energy. The state has forced pain on SOE utilities, but it has also fostered an enormous new industry. In the U.S., it can often be politically difficult to legislate in favor of an industry that has yet to grow, but China has demonstrated just how successful such policy can be. For any country seeking to mimic its growth in wind power, the components of China's wind success are clear and simple. Continuing on its current trajectory, the wind in the east will likely add a valuable component to the development of global wind energy.