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Wind Power in China: Has China Greenwashed the Global Energy Sector?

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ABSTRACT

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Due to years of serving as the world's manufacturing hub, and appropriately developing a global reputation of being environmentally-unfriendly, China has since sought to rejuvenate its image by becoming an international leader in the realm of wind power. However, if one were to pull back the curtain on China's wind energy program, they would find that the Chinese Communist Party may be intentionally putting on a facade. By reporting the number of wind turbines constructed nationally, but not the number of turbines actually generating electricity, China has hoodwinked the worldwide energy sector and general public. The idle wind turbines cost China not only valuable energy, but also roughly $2 Billion annually in forgone revenue. In order to achieve wind success, China must deal first with its most significant bottleneck: an outdated and inefficient energy grid infrastructure. By choosing to build wind turbines before constructing a Smart Grid to support their energy transmission, China has shot itself in the foot environmentally, geopolitically, and economically. This thesis exposes an important defect in China's energy system and will be of use to all with interests in business ethics, the environment, engineering, and economists alike.

ACKNOWLEDGMENTS

Without the many people that have provided me with guidance and support throughout the past two terms, my thesis would not have come to fruition. Most of all, I must thank my thesis advisor Bradley G. Lewis for his enthusiasm in my ideas, valuable questions, and guidance throughout the process.

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Chapter 1 - Introduction:

The last 15 years have ushered in colossal growth in China's wind power sector. Entering the wind energy picture only around 2000, China in just one decade became home to 50% of the world's installed capacity of wind turbine generators (WTG). In addition, by 2009 China had trumped Denmark, Germany, Spain, and the United States to become the world's leading manufacturer of WTGs.[1] Wind power has had major investment at the highest level, the Chinese Communist Party, for many reasons including its minimal environmental impact and low cost. Currently the chief non-hydro renewable source across China, wind energy is expected to maintain its influence and potentially help mold China into an "ecological civilization," as compared to the industrial revolution of the western world.[2] All in all, it is clear that China is utilizing wind power as a political and conservational transition from a fossil fuel based energy sector into a decarbonized renewable based energy system.

In light of China's recent and swift ascent to becoming a world leader in wind power, I conduct this thesis with the intention of not only adding sagacity to this international discussion, but also so as to invoke several concerns and unforeseen challenges to China's role in the wind sector. Because China emits roughly one quarter of Earth's greenhouse

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[1] Keith Bradsher, "China is leading the race to make clean energy," *The New York Times*, January 30, 2010, accessed February 1, 2016, http://www.nytimes.com/2010/01/31/business/energy-environment/31renew.html?_r=0

[2] 中国网, "第八部分," *大力推进生态文明建设, 时间*, November 11, 2011 [personally translated], accessed January 14, 2016, http://v.china.com.cn/18da/2012-11/11/content_27074139.htm

gases, environmentalists largely debate whether they will permanently damage Earth's environment or lead an ecological revolution.

Before looking into China's energy related issues, I will begin by explaining China's political atmosphere and energy history in Chapter 2. This chapter will highlight how the central role of China's government is advantageous to the nation's abilities to pass renewable legislation. Next, in order to depict China's progress-to-date and future outlook of wind power generation, I'll provide in Chapter 3 an analysis of the Chinese Communist Party approaches which have been instrumental in the immense increase of Chinese onshore wind turbine construction. Using specific policy procedures which are claimed to have empowered China's development, I will examine their system design with the goal of revealing how China fundamentally constructed its wind program. Specifically, I'll touch upon the feed-in-tariff (FIT) for wind, created in 2009, which has been crucial to providing financial incentives for China's wind sector growth.

Next, in Chapter 4, I will discuss how China's weak regulation, outdated grid, and feeble transmission lines have curtailed wind power growth potential. Also in this chapter, I will provide evidence that China has shown a tendency to build its energy system backwards, perhaps in order to inflate its international environmental reputation. Chapter 5 introduces the potentially instrumental role that the Smart Grid would have in the success of China's transition to a renewable energy system. However, that analysis also highlights a deeper systemic bottleneck, which China may be setting up for themselves by developing transmission lines before a regional grid which can support such lines.

The final section, Chapter 6, covers the economic, social, and environmental costs of wind power and the Smart Grid system. This section suggests that China's barriers to wind success may have delayed the completion of their energy transition by several years, as well as accounted for significant extra costs. The result is a subjective fact-based study and forecast for academics and politicians worldwide to use to gain a better understanding of the past and future of China's rapidly progressing energy sector. For clarification purposes, I must state that this thesis will only dissertate onshore wind power, because offshore wind power currently represents only 0.002% of China's total wind power production.[3]

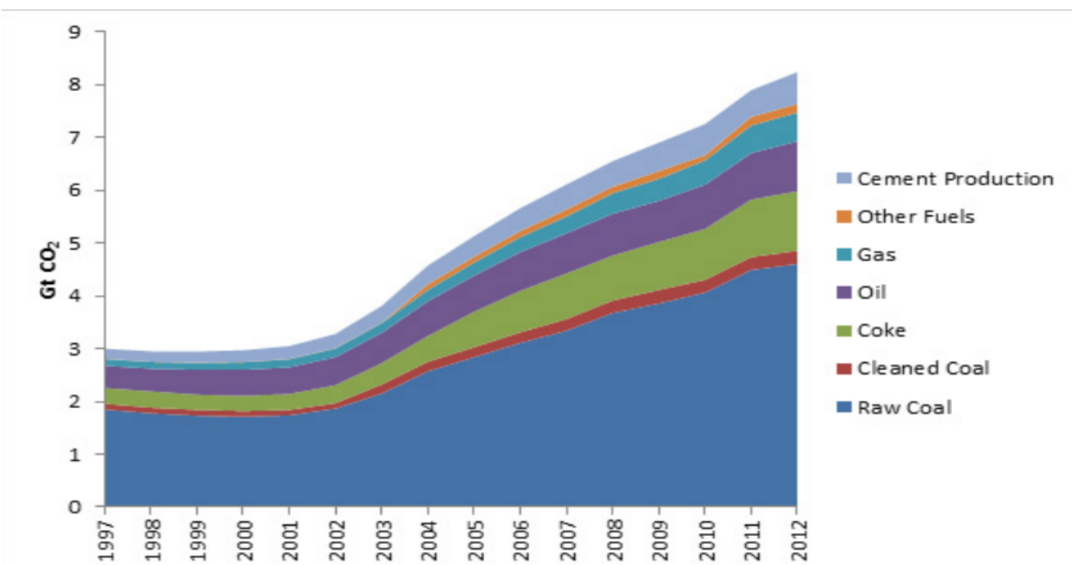
With the intention of clarifying the opportuneness of this thesis, I begin by first providing background on the state of China's current electricity system, with special attention on its anthropogenic effects. From 1950-2012, China's cumulative emissions from burning fossil and cement production totaled 130 Gigatons (GT) of CO_2.[4] To put that in perspective, with 8.50 GT of $C0_2$ in 2012, China was responsible for 25% of worldwide carbon emissions that year.[5] Furthermore, according to predictions by the International Energy Agency (IEA), China's electricity sector will be responsible for 60% of the growth in China's energy driven carbon emissions. Taking a closer look at China's carbon footprint, in 2012, about 90% of China's energy consumption came from fossil fuels (figure 1): 70% from coal consumption, 12% from oil and 8% from gas. Considering that China only amasses 6% of Earth's total land area yet it produces roughly 25% of its carbon emissions,

[3] Steve Sawyer and Klaus Rave, "Global Wind Report Annual Market Update 2014," *Global Wind Energy Council (GWEC),* 2014.
[4] Zhu Liu, "China's Carbon Emissions Report 2015," *Sustainability Science Program and Energy Technology Innovation Policy research group*, Harvard Kennedy School of Government, 1, (2015), accessed January 12, 2016, http://belfercenter.ksg.harvard.edu/files/carbon-emissions-report-2015-final.pdf
[5] Liu, "China's Carbon Emissions Report 2015," 4.

the subject matter of this thesis is germane for all future projections about Earth's anthropocene.[6]

Lastly, its important to note that, interestingly, the large majority of my sources have been written in English, with most articles published by international agencies on global energy outlooks. Therefore, while I was able to survey some journal articles written in Chinese, most Chinese scholars instead chose to publish their works in English. Perhaps this is the case due to government censorship of articles, but nevertheless I have used my Chinese language proficiency to translate and interpret the few articles I have come across. Finally, this thesis will not contain data-driven analysis due to issues of restricted access to a reliable data-set on Chinese wind-energy statistics; however, the statistics which I do provide are the most current statistics published by renowned global energy agencies who are granted access.

Figure 1:



[6] "The World Bank Arable land (% of land area), last modified February 28, 2016, http://data.worldbank.org/indicator/AG.LND.ARBL.ZS

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Chapter 2 - Political Framework and Energy History

Before looking into the Chinese government's wind power policies, I will first explain how the Chinese socialist market economy functions and subsequently how it seeks to increase wind power development. From 1949 to 1976, Chairman Mao Zedong oversaw the Chinese government as a totalitarian regime, wherein government officials were appointed instead of elected. However, following the Cultural Revolution and Mao's death, power transferred to Chinese leader Deng Xiaoping who sought to revitalize the economy by adding free-market aspects to the centrally controlled economy. Originally, Deng's plan was based on "usage value," which differed from capitalism in that goods and services were produced for the needs of society, not for profit generation and capital accumulation.[7] From the 1980s onwards, however, China transitioned to the socialist market economy it now operates by opening up to international trade. While 75% of China's GDP in 1978 came from state-owned enterprises (SOE), as of 2008 only 25% of China's total GDP came from SOEs.[8] Nonetheless, SOEs have been on the rise in China since 2008 due to the CCP insecurity that its once dominant hand in the market has been weakened.

In 2012 Xi Jinping became the President of the People's Republic of China, replacing widely revered past President Hu Jintao. The current Chinese government, like the US government, has three branches: the People's Congress (lawmakers), the executive branch

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[7]Shobhit Shen, "Socialist Economies: How China, Cuba And North Korea Work," *Investopedia,* August 15, 2014, accessed November 18, 2016, http://www.investopedia.com/articles/investing/081514/socialist-economies-how-china-cuba-and-north-korea-work.asp

[8] Peter R. Orszag, "Private Companies are Driving China's Growth," *BloombergView,* October 14, 2014, accessed February 14, 2016, http://www.bloombergview.com/articles/2014-10-14/private-companies-are-driving-china-s-growth

(administration), and the court. The major difference though is presence the Chinese Communist Party. In order to work in government or law enforcement, you must be a party member. The Party essentially runs side-by-side with the Chinese government, meaning that each government position has a party position that matches its status and power.[9] This means that every provincial government will have its own party secretary who will ensure that each action falls in line with Party rules and regulations. Hence, the Party secretary truly holds the power. Party dominance becomes important when wind and grid development are considered in their regional respects.

Another imperative aspect of the Chinese Communist Party is its management of about 160,000 SOEs. China's SOEs are legal entities created by the CCP with the ability to operate in nationwide commercial activities on the government's behalf.[10] A relatable example is the U.S. owned mortgage company duo Freddie Mac and Fannie Mae, which are technically considered to be government-sponsored enterprises (GSE). Unlike the U.S. though, China's SOEs have dominated its market economy for years, often disrupting the market's invisible hand by state controlled price variations and decisions.

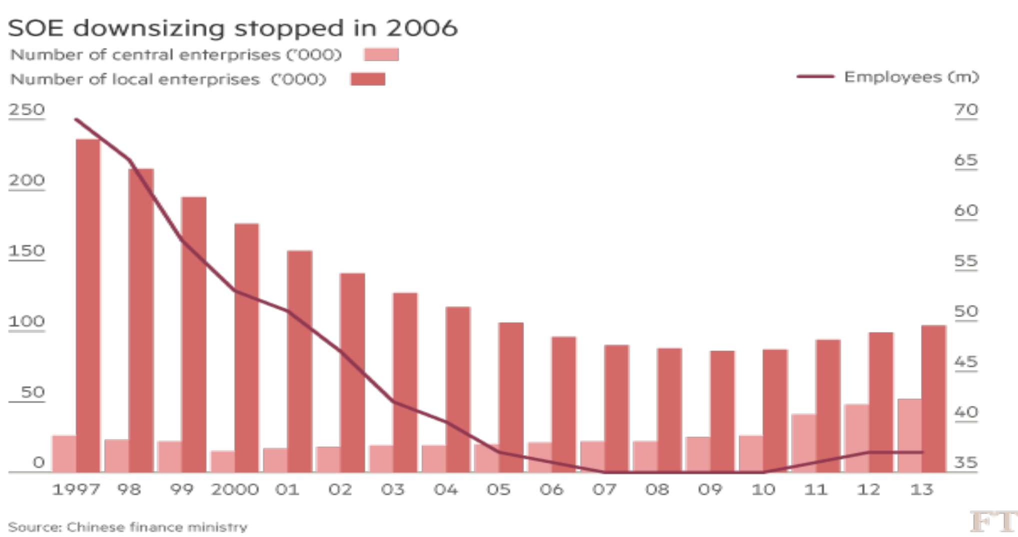
While you would think that such enterprises should have slowed down by now, Yukon Huang, former China director of the World Bank, points out "President Xi Jinping believes that a large state-enterprise sector is good."[11] President Xi is referring to the 'zombie enterprises' of our Western world who have become 'too big to fail,' as seen in the

[9] Megan Alnada, "How China is Ruled," BBC News, December 18, 2015, accessed January 4, 2016, http://news.bbc.co.uk/2/shared/spl/hi/in_depth/china_politics/government/html/1.stm
[10] "State-Owned Enterprise – SOE," Investopedia, January 7, 2016, http://www.investopedia.com/terms/s/soe.asp
[11] Gabriel Wildau,"China's state owned zombie economy," Financial Times, February 29, 2016.

bailouts during the 2009 recession. As a result, President Xi has continued to promote both an economy as well as an energy sector that is partly controlled by the CCP's rule. As displayed in figure 2, with data provided by the Chinese finance ministry and Financial Times, although China successfully downsized SOEs from about 240,000 local enterprises to less than 100,000 in 2009, one can notice that the trend became positive after 2009, indicating an increase in the volume of SOEs.[12] In addition, the number of centrally owned enterprises increases throughout the years 2000 and 2013, showing the government's increasingly controlling hand on the industrial sector and economy.

China's two largest SOEs are the State Grid Corporation of China (SGCC) and the China Southern Power Grid Company (CSGC). The SGCC supplies power to about 88% of China's regional grid while the CSGC accounts for the remaining 12%. The SGCC is not only listed as seventh on the Fortune Global 500 list, with assets exceeding $430 billion USD, but also partially owns and operates electricity grids in Portugal and Brazil.[13] The government

Figure 2:



[12] Wildau, "China's State owned zombie economy," 2.
[13] "Fortune Global 500 List," Fortune, December 31, 2015, http://fortune.com/global500/

ownership of these colossal enterprises is central to China's ability to make a decision at the highest level, and see it come to fruition in a matter of days. In the U.S., a decision at the highest level may take months or years to take effect after passing legislation. Therefore, when the SGCC proposed in 2011 that is would spend $400 billion on power grid construction and $100 billion on Smart Grid investment over the next five years, planning and construction began promptly after.[14] The CSGC, which controls the three provinces with the richest hydro resources in China, has pledged $15 billion to Smart Grid investment.[15] However, while political structure should certainly play to China's advantage, this paper finds that external factors, such as a global reputation as a polluter, have driven China to build their energy system inefficiently. This prediction will be discussed further in Chapter 5.

The Chinese government has four state-run agencies that oversee the development of the Chinese Smart Grid and the wind power program. The National Development and Reform Commission (NDRC) oversees all aspects of economy development including, for the smart grid, controlled electricity pricing, benchmarks for FIT and sales tariff, and authorization of review and approval of Smart Grid and wind construction projects.[16] The National Energy Agency (NEA) acts as a vice-ministerial department to the ministerial agency NDRC. The agency produces and publicizes China's domestic energy policy and development targets, which includes renewable energy outlooks as well as Smart Grid

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[14] "Smart Grid Technologies Continue to Spread," Worldwatch Institute, February 27, 2013, accessed February 2, 2016, http://www.worldwatch.org/smart-grid-technologies-continue-spread

[15] "Smart Grid in China – a R&D Perspective," Innovation Centre Shanghai, July 1, 2013,, accessed January 17, 2016, http://assets.fiercemarkets.net/public/sites/energy/reports/chinasgreport.pdf

[16] Dexter Roberts, "China's Economic Policy Factory: The NDRC," Bloomberg Business, June 20, 2013, accessed February 18, 2016, http://www.bloomberg.com/bw/articles/2013-06-20/chinas-economic-policy-factory-the-ndrc

construction planning. The State Electricity Regulatory Commission (SERC) manages the daily operation of China's power generation corporations as well as utility companies. Finally, the Ministry of Science and Technology (MOST), since assigned in the 12th Five-Year plan, has played a vital role in the development of state-of-the-art technology for both wind turbines and Smart Grid. On a grander level, what drove the need for these agencies to be created?

While the transition to an open market economy has led China to become the world's largest manufacturing economy in just 30 years, it has also transformed China into a virtual emissions economy, wherein about 25% of China's carbon emissions are produced by domestically manufactured products that are consumed overseas. Using a rule of thumb test, 25% multiplied by 25% gives 6.25%; this is the percentage of the world's emissions attributable to Chinese manufacturing. We can compare this to Germany's carbon emissions, wherein domestic manufacturing plants account for 3% of its national emissions. Using the same rule of thumb test, we find that 0.09% of the world's emissions are attributable to Germany's manufacturing. It is easy to see how China's explosive growth has come with many consequences, chiefly public concern over greenhouse gas emissions. For these reasons, the Chinese government's motivation behind using financial and political capital to fund the renewable sector, especially wind, should become clearer. To comprehend the issue in further depth, one must observe to what degree coal, the fundamental cheap and abundant energy resource, has fueled the Chinese economy and destroyed the Chinese environmental image.

Once powering almost 80% of China's energy sector, coal resources in China are quickly abating. By the end of 2007, China's ratio of coal reserves to production per year was 45 to 1 while by the end of 2014 the ratio diminished to 30 to 1.[17] This means that in 7 years, China utilized 15 years of coal reserves suggesting that the current reserves of 30 years will likely run dry earlier than 2046.[18] Considering that just this year President Xi Jinping announced a peak in Chinese carbon emissions by 2030, it is likely that the nation will quickly begin to rely more heavily on wind and nuclear power generation. Yet, it is not out of the question that China is looking for other coal reserves to provide themselves with some "polluted" cushioning during the energy transition period.

Aside from depleting resources, coal has introduced several other issues for China's energy sector. Joanna Lewis, in her 2013 book *Green Innovation in China*, argues that the greenhouse gas emissions, generated from China's many coal power plants, have induced Chinese Communist Party members to shift environmental regulation towards promotion of a non-fossil fuel based economy.[19] Lewis adds that coal based power plants emit toxic gases such as sulfur dioxide, nitrogen oxide and mercury which are deleterious to human health as well as to arable terrain.[20]

The issue is so severe that several sources have estimated that acid rain costs China 2.5% of its GDP annual. These costs are incurred when acid rain damages crops, causes

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[17] David Winning, "China's Coal Crisis," *Wall Street Journal*, November 16, 2010, accessed November 28, 2016, http://www.wsj.com/articles/SB10001424052748704312504575617810380509880

[18] "BP Statistical Review of World Energy," *BP,* June 2015, accessed February 1, 2016, https://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2015/bp-statistical-review-of-world-energy-2015-full-report.pdf

[19] Joanna Lewis, "Green Innovation in China," *Insert Publishing Organization*, 2013.

[20] http://www.ucsusa.org/clean_energy/coalvswind/c02c.html#.VlPey_mrTgk

deforestation, deteriorates buildings, and pollutes water sources etc. Whilst personally sightseeing at China world famous Leshan Buddha, the world's largest stone Buddha, it is easy to see that the symbol of peace and harmony has become visibly deteriorated by acid rain, and now become a symbol of the Chinese pollution problem. In an odd way, China's understanding of this has actually made them look at the overall costs of coal, not just private monetary ones. For a country which seeks economic prosperity, one can observe why Chinese lawmakers have now began to address coal power plants as an issue.

Air pollution caused by industrial factories and coal power plants has resulted in significant human respiratory issues. While public disclosure of deaths related to pollution was censored until 2014, Chen Zhu, Chinese government health minister, announced that somewhere between 350,000 and 500,000 premature deaths annually in China are attributable to greenhouse gas emissions.[21] In fact, air pollution has become the fourth largest threat to the health of the Chinese people, only behind dietary habits, heart disease and smoking. Another major health risk to the Chinese people is coal mining, which is estimated to account for roughly 5% of the workforce. Coal mining is responsible for half of industrial fatalities, killing 4,746 mine workers in 2006 (an average of 13 workers per day).[22]

Coal has also led to several obstacles with respect to its transportation. Because the majority of China's coal production is located in the Western and Northern highlands, and

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[21] Malcolm Moore, "China's airpocalypse kills 350,000 to 500,000 each year," Telegraph UK, January 07, 2014, accessed February 18, 2016, http://www.telegraph.co.uk/news/worldnews/asia/china/10555816/Chinas-airpocalypse-kills-350000-to-500000-each-year.html
[22] Amber Mehmood, "Chinese coal mines: The industrial death trap," *The Aga Khan University Hospital Karachi*, September, 2009, accessed December 18, 2016, http://ecommons.aku.edu/cgi/viewcontent.cgi?article=1006&context=pakistan_fhs_mc_emerg_med

about 60% of China's population lives along the Yangtze River valley in the East,[23] the transportation of the coal is costly and has cramped the railway system. Suffering from an outdated industrial railway system, China has seen coal deficits and increasing prices because coal production has outpaced the capabilities of the railways.

One of the largest steps by the Chinese Communist Party to address global warming has actually become their transparency on the issue. As previously mentioned, China censored all comments on climate change's effects on human health until recently. Showing further progress, by 2014, Chinese news sources have been releasing reports about China's serious consequences from pollution. China Daily, one of the central government's primary outlets to its population, announced in an article that China's coastal regions saw a sea level rise of three millimeters annually between 1980 and 2014 (which is higher than the world average).[24] Other articles point out the severity of sea level rise along China's major coastline cities of Shanghai, Guangzhou, Hong Kong, stating that a rise of a meter would submerge over 35,000 square miles in these regions that accounted for 70% of China's GDP in 2010.[25]

Political transparency on climate change stepped to the forefront of China's domestic challenges when, in 2009 at the United Nations General Assembly, General Secretary of the Chinese Communist Party Hu Jintao gave a speech highlighting China's struggles and hopes for environmental betterment going forward:

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[23] Patrick Chovanec, "Closing the Gap between China's Cost and Interior," *Wordpress Inc*, January 13, 2011, accessed February 3, 2016, https://chovanec.wordpress.com/2011/01/13/closing-the-gap-between-chinas-coast-and-interior/
[24]Xinhua, "China's sea level rise higher than world average," *China Daily*, February 28, 2015, http://www.globaltimes.cn/content/909454.shtml
[25] Ibid.

> Achieving mutual benefit and win-win outcomes should be the goal of our effort. Developed countries should support developing countries in tackling climate change, since it also serves their long-term interests. In the years ahead, China will intensify our effort to conserve energy and improve energy efficiency. We will endeavor to cut carbon dioxide emissions by a notable margin by 2020. We will vigorously develop renewable energy and nuclear energy to increase the share of non-fossil fuels in primary energy consumption to around 15 percent by 2020.[26]

General Secretary Hu has been instrumental in campaigning for China to lead human civilization into an ecological civilization, with development that bolsters harmony between nature and humans while paving a path of political and economic vigor.[27] Most significantly, Chinese government officials have begun to materialize these feelings into numerical targets for electricity and pollution contraction goals.

In their 11th five-year plan (2006-2010), a guideline of social and economic initiatives implemented by the central government, China vowed to reduce energy consumption per unit of DSP by 20% in five years and diminish discharge of major pollutants by 10% in the next five years.[28] In the 12th five-year plan was China's announcement that they would supply 15% of energy demand by 2020 from non-fossil fuel sources. 'Non-fossil fuel sources' and 'renewable energy sources' actually differ though in that nuclear energy is included as a non-fossil source.

President Xi Jinping has announced that China's nuclear power, which currently accounts for 3% of the energy mix, will generate at 110 power plants by 2030, amounting

[26] Federal News Service, "Hu Jintao's Speech on Climate Change," *New York Times*, September 22, 2009, accessed January 14, 2016, http://www.nytimes.com/2009/09/23/world/asia/23hu.text.html
[27] Yu Keping, "Search for balance in China: a quest for dynamic stability,: Peking University East Asia Forum, September 22, 2013, accessed January 14, 2016, http://www.eastasiaforum.org/2013/09/22/a-quest-for-dynamic-stability
[28] "The 11th Five-Year Plan," Chinese Political Party, 2015, accessed January 20, 2016, http://www.gov.cn/english/special/115y_index.htm

to an investment of $79 billion of government funds.[29] President Xi has planned for this increase to account for 9% of China's electricity sector, despite concerns still amidst regarding Japan's Fukushima disaster. Immediately following the Fukushima disaster, China suspended its nuclear program and numerous scholars published articles on how the nuclear crisis will upsurge expenditure in renewable energy development. However, China has since began constructing 31 additional nuclear power reactors, which will augment its already large base of 27 nuclear reactors in operation. All of China's nuclear reactors are located along the East coast, so that they can provide immediate energy to the heavily populated load centers of the East.

As one can see now, four year after Fukushima, China has also relied on increased nuclear power generation to uncouple China's energy sector from nonrenewable sources. Additionally, since China has essentially tapped all of its hydroelectric potential at 20% of China's total energy, both nuclear and wind, the two most affordable and efficient non-fossil fuel energy sources for China, stand in the limelight as practical options to help reach national energy targets.

Nuclear and wind actually work cohesively because nuclear provides base-load generation, the electrical power needed to satisfy minimum energy demand daily.[30] Wind, on the other hand, is used as a peaking energy source because it is generally utilized only when there are peaks in energy demand. Therefore, both wind and nuclear, which are

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[29] "China to invest $78 bn to build 110 nuclear power plants by 2030, will overtake US," Firstpost News Source, October 17, 2015, accessed December 2, 2015, http://www.firstpost.com/world/china-to-invest-78-bn-to-build-110-nuclear-power-plants-by-2030-will-overtake-us-2471414.html

[30] Chris Clarke, "Explainer: Base Load and Peaking Power," KCET ReDefine Environment, July 5, 2012, accessed January 4, 2016, http://www.kcet.org/news/redefine/rewire/explainers/explainer-base-load-and-peaking-power.html

complementary power generation sources, should see increased political and economical investment going forward so as to safeguard the health of Chinese citizens, protect China's public image and to have reliable power generation sources going forward. Knowing the Chinese government's reasons for promoting non-fossil fuel energy sources, including wind, I will now address China's wind power policies that have enabled growth in the wind sector.

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Chapter 3 - Chinese Wind Power Regulation

Addressing international calls for reductions in greenhouse gas emissions, the Chinese Communist Party has, since 2000, invigorated its enactment of legislation set to increase investment and development of the wind sector. In this portion of the thesis, I will first provide an overview on China's first several wind regulations and their outcomes. Following this outline, I will expound upon two wind power policies which I believe have been the most conducive to China's surging wind sector. The two policies are the Renewable Energy Law and the FIT for wind development. Accompanying a review of the procedures of these programs will be an analysis of the challenges the central government experiences with ineffectiveness of policy administration to grid owners and wind developers.[31]

China's wind power policies can be summed up by four key decisions: First, China implemented the Renewable Energy Law which compiled a plan and laid out clear targets for the penetration of renewable energy into the energy mix. Second, the competition in wind concession projects played a key role in lowering the cost of wind power generation. Third, China implemented a FIT policy and set aside a government fund to ensure the success of the program. Finally, China's ability to manufacture wind turbines locally and provide policies to ensure domestic success has played a key role in the success of China's wind industry.

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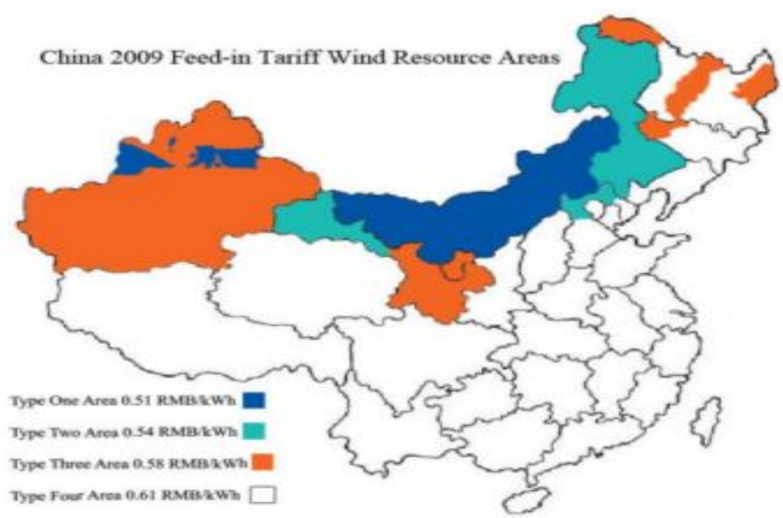
[31] Luke Filei, "China's renewable power projects policy and certain issues regarding enforceability of power," *CMS Law Now*, May 10, 2002, accessed January 7, 2016, http://www.cms-lawnow.com/ealerts/2002/10/china8217s-renewable-power-projects-policy-and-certain-issues-regarding-enforceability-of-power-pur?cc_lang=en

The Renewable Energy Law of 2006 became the turning point for China's wind sector success. Chinese Reuters analyst Wu Qi described the law as instrumental because it provided the structure for the FIT system. Through research, I discovered that the Renewable Energy Law however did not have the impact described above until amendments were added to the law in 2007. Still, the law made it necessary for the Chinese government to coordinate targets for development, produce efficient plans, and make sure that such plans could be supported by sufficient budgets. In reading the NDRC's actual text in Mandarin Chinese for the 2006 law, I discovered that in Article 14 the NDRC requires hundreds of Chinese ministries (provincial governments) to create their own renewable targets which must include the exact ratio of the province's energy which will be produced by renewable generation.[32] Article 14 is only one example of the several strengthened obligations which the NDRC places on provincial governments and grid companies to incorporate renewable power.

Image 1:



[32] "Renewable Energy Law of the People's Republic of China," China News Source, February 14, 2011, accessed December 20, 2015, http://www.china.org.cn/china/LegislationsForm2001-2010/2011-02/14/content_21917464.htm

Crucial to the success of China's wind program was the revision of the FIT in August of 2009, which strongly intended to bring profitability to the wind industry. The FIT separated China's land mass into four price brackets hinged on differences in wind intensity. The FIT ranged from ¥0.51 per Kilowatt Hour (KwH) in very windy areas to ¥0.61 per KwH in regions with low wind intensity, as displayed in Image 1.[33] By introducing four different tiers in pricing, grid operators in areas with low wind intensity will buy wind at a higher price. This allows the NDRC to ensure that less profitable opportunities still provide financial benefit.

The FIT essentially offers wind developers a stagnant energy price for two decades of a wind farm's functional operation. In order to successfully provide a guaranteed cost, the NDRC implemented a cost-sharing mechanism so that no grid company would have to bear the monetary burden for electricity costs. Cost sharing essentially ensures that even if one grid companies province purchases significantly more wind farms than others, that region will not be subject to any penalties for purchasing larger amounts of wind power.

In an effort to levelize the price of renewable power with the cheap costs of coal, the NEA announced in 2006 a "Trial Measure on Management of Cost Sharing for Renewable Power Generation Prices and Expenses." This mandated that any differences in the cost of renewable energy and the cost of coal power would be shared at the regional level. This was done by opening a trade system for renewable power generation surcharge credits. Any companies who purchased wind at a surcharge price, that is the price above coal power, would be granted a certain number of credits which they could then sell to

[33] "The National Development and Reform Comission announced regional feed-in tariffs for PV projects and new distributed PV subsidy specifics, Azure International, March 18, 2013.

companies who are looking for credits. The idea is similar to a cap and trade system, however the NDRC overlooks and verifies that credit trading in this circumstance.

Moving away from the cost sharing framework for China's renewables, I will now describe China's FIT, which has been keystone to incentivizing producers and safeguarding the profitability of wind power. China's FIT is considered a market independent FIT because it operates on a fixed price model, providing constant prices regardless of the market's energy prices. Changes in market conditions such as inflation or prices of oil would therefore not affect the FIT prices. The fundamental idea of the FIT is to provide an incentive for wind developers to build wind farms in a country where coal-fired power prices are significantly less than those for wind generation. In other words, this market-independent FIT will establish higher revenues in the early years of a wind farm. The success of the FIT can be seen by China's increase in wind capacity of 37,928 Megawatts (MW) over 2010 and 2011, surpassing the U.S. and becoming home to the world's largest wind power installed capacity.[34]

It would be unfair to leave out a major drawback of China's FIT: while the market-independent FIT does increase both the speed and financial backing necessary to build wind turbines, it accomplishes both of these at the cost of efficiency. With regard to wind turbines, efficiency refers to a wind farm's capacity factor, which is the ratio of energy actually produced to the maximum amount of energy that a wind farm could produce at full capacity. An example would be if a grid was connected to 20 wind farms, but could only efficiently receive energy from 4 of them because the capacity is greater than the demand.

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[34] J. Matthew Roney, "World Wind Power Climbs to New Record in 2011," Earth Policy Institute, March 14, 2012, accessed February 15, 2016, http://www.earth-policy.org/indicators/C49/wind_power_2012

For that reason, the capacity factor for those 20 wind farms would be 20%, which is actually not much lower than true China's turbine capacity factors.

In comparison to other nations, China's turbine capacity factors are actually very low, meaning that their wind farms actually generate little electricity. Statistics from the IEA in 2012 stated that 1 MW of wind capacity produce 1,956 Megawatt Hours (MwH) of electricity in the U.S. annually while it produced only 879 MwH in China.[35] While one could point to low winds for the reason of a wind farm to have low capacity factor, the truth cuts much deeper for China. Their issues are mainly caused by an outdated energy grid and inefficient transmission lines which haven't even been extended to many of the wind farms. At the core, China has built thousands of wind farms which are essentially not functional until they can be grid-connected. Why would they do this? This issue of installed capacity and inefficient construction by the Chinese will be covered in depth in Chapter 5, and is at the heart of China's barriers to wind success.

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[35] "IEA Wind 2012 Annual Report," Executive Committee of the Implementing Agreement for Co-operation in the R&D of Wind Energy Systems of the IEA, July 2013, accessed February 29, 2016, https://www.ieawind.org/annual_reports_PDF/2012/2012%20IEA%20Wind%20AR_smallPDF.pdf

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Chapter 4: Grid Integration and Curtailment Issues

While before 2002 China's energy supply was managed by China's provincial governments, since the inception of China's power systems reform that year, the Chinese power grid has been owned and operated by the two colossal grid companies, CSPG and SGCC. The two companies, both still technically SOEs, are in charge of planning and allocation, financial decision-making, power transmission and distribution, and lastly the operation and maintenance of the entire grid infrastructure.[36] Constructing a reliable, efficient, and successful grid network is, as you will see, not easy nor cheap. Making matters worse, it seems the ruling party is managing certain investment decisions in the wrong order, because it has resulted in China becoming a leader in building the world's most wind turbines that do not generate electricity.

The SGCC and CSPG, though, do not control the national grid of China. This is because there is no national grid. Alternatively, China has six regional grids, five of which are owned and operated by the SGCC while the CSPG operates the final grid. As a result, there is limited monitoring or communication between the regional grids to allow for any sharing to mitigate any localized shortages. The U.S. comparatively was forced into better grid system coordination by blackouts. Peaking demand rises in China in the late spring and early summer as temperatures heat up and air conditioning is necessary. Likewise, hydropower and reservoir levels decrease until the wet season arrives in summer, resulting in a need for expensive and/or environmentally-damaging fossil fuels to be imported. This is disadvantageous to China as its coal resources are already scarce. The

[36] Xin Li, "Decarbonizing China's power system with wind power," PhD diss., Oxford Institute, January 2015, https://www.oxfordenergy.org/wpcms/wp-content/uploads/2015/01/EL-11.pdf

grid's drawbacks can be categorized as a network issue, as what is clear here is the need for a unified grid system such as the high-efficiency Smart Grid system.

Two additional paramount barriers to China's wind industry success are the issues of grid integration and curtailment. Because the majority of China's wind development to date has been centered in massive wind farms which are thousand of miles away from load centers, China has struggled to devise an efficient method to transmit that energy from the wind-hub centers of the West to the consumer load centers of the East. For example, the installed capacity of wind power in Gansu, Northern Hebei, and Western and Eastern Inner Mongolia totals amounts to 50% of China's total.[37] In spite of this, the electricity consumption in these regions accounts for only 10% of China's total. Hence, a reliable and efficient transmission system is desperately needed to send the produced wind energy to load centers of the East, such as Shanghai.

While many laws state that renewable energy globally should be given preferred access to the energy grid, China's current wind power policies currently offer too few financial incentives for grid companies to build the high-efficiency voltage transmission lines necessary transmit power from the Northwest to the industrial centers in the Southeast. While China has established itself as the leading wind turbine producer in the world, and also boasts that it leads the world in wind installed capacity, National Energy Administration officials reported in 2012 that as many as one-third of China's wind farms are not connected to the transmission grid. Citigroup published a report that, in 2013, as

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[37] Yixin Dai, "The Innovation Path of the Chinese Wind Power Industry," PhD Diss., German Development Institute, 2014, https://www.die-gdi.de/uploads/media/DP_32.2014_neu.pdf

many as 40% of Chinese wind turbines were not connected to the energy grid.[38] While this is attributable in part to the lack of incentives for grid corporations to interconnect China's energy network, one thing is for sure - the disconnected wind turbines are a significant waste of investment and energy.

Wind farms can be connected to energy grids in two ways. The first option, the transmission network, will require transformers to support higher voltages than if the farm were connected via the distribution network. Usually, each wind turbine in a farm will be connected to a step-up transformer, located at the base of the wind turbine, which is used to increase the generating output of the turbine. This is displayed by image 2. An entire wind farm will host a collection of grounding transformers which will accumulate generated power and transmit it to a collector step-up transformer.[39] From that substation, the energy will subsequently be transported to the energy grid. As a result, turbines connected by the transmission network are more costly due to the costs of installing transformers. The high cost of transformers represents a general issue across wind power.

Image 2:

China, in 2012, began to actively seek to alleviate

[38] Vivian Wai-yin Kwok, "Weaknesses in Chinese Wind Power," Forbes, July 20, 2009, accessed January 20, 2016, http://www.forbes.com/2009/07/20/china-wind-power-business-energy-china.html
[39] "How are Transformers Integrated into Wind Farms?" Transformer Protector, December 2014, accessed December 14, 2016, http://www.transproco.com/how-are-transformers-integrated-into-wind-farms/

their transmission issues by beginning development of high-efficiency reliable transmission lines. Generally, if the wind farm is not far from the point of grid connection, a high voltage alternating current (HVAC) connection is typically used. Because China's issue is long-range, it has been quickly building high voltage direct current (HVDC) transmission lines. HVDC lines are crucial for China's wind network development because they're able to reduce losses by converting energy from an alternating current, to a direct current, and back again to an alternating current at extremely high-speeds and efficiency. In order to address blockages in the transmission system, the State Grid and South Grid construction corporations of China are in the process of installing twelve state-of-the-art long range transmission lines. Eight of the twelve lines will be HVDC, one of which will connect the Inner Mongolia and Jilin provinces to the congested Eastern centers where it's needed.

Geopolitically, national renewable organizations normally develop their own economic framework for who bears the costs for an energy source to be connected to the grid. In many countries, the wind farm owner is responsible for these costs. Alternatively, as seen in China, the transmission system operator must bear the cost of whatever transmission system modifications are necessary for wind farm connection. The cost of grid connection accumulates to about 15% of the total cost of an onshore wind farm.[40]

A further issue for China's wind industry is that the construction of the grid has been much slower than the scale of wind power expansion. From 2010-2015, for example, energy consumption in the Northeast grew at a rate of 5% annually, whilst the mean yearly increase of installed wind power capacity was 25%. Clearly seen, the rate of growth of wind

[40] "Renewable Energy Technologies: Cost Analysis Series," International Renewable Energy Agency, June 2012, Volume 1: Power Sector, Issue 5/5, accessed January 20, 2016, http://www.ourenergypolicy.org/wp-content/uploads/2012/06/RE_Technologies_Cost_Analysis-WIND_POWER.pdf

power potential is five times that of regional electricity demand. The fundamental cause of the oversupply is the incapability of China's regional grids and transmission systems. Notwithstanding that China improved its wind curtailment problem thanks to endeavors by all relevant regions in 2013 and 2014, the ratio of wind curtailment in both Inner Mongolias, Hebei, and Heilongjiang were still well above 10%, and the ratios for Jilin and Gansu approached 20%.[41] A 2016 Bloomberg news report summed it up as that "China's wind farm operators have suffered from idled capacity for years as the rush to build projects in the windiest areas of the nation surpassed the grid's ability to absorb and transmit the power."[42]

In addition, in the Three North (Heilongjiang, Jilin, and Liaoning) region where China's wind resources are plentiful, flexible power sources are limited, and the energy structure is simple: pumped storage and gas power solely accounted for just 2% of the total energy makeup. As a result, capability for peak regulation, especially in the frigid eight-month long winters of northern China when household heating systems are on at full-blast, is usually very limited. In other words, local grid companies restrict the percentage of potential wind power penetration in favor of the more reliable, and more environmentally-damaging, coal power. It is reported that throughout the winter of 2010, Inner Mongolia wind companies forfeited a loss of roughly $80 million in revenue due to approximately 950 million kilowatt-hours of curtailed wind generation.[43] Ironically, the opportunity cost

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[41] Diana Furchtgott-Roth, "**Regulating to Disaster: How Green Jobs Policies Are Damaging America's Economy," (New York: Encounter Books 2012), 97-98.**
[42] "China's Idled Wind Turbines Rise in 2015 After Record Installs," Bloomberg News, February 3, 2016, accessed February 26, 2016, http://www.bloomberg.com/news/articles/2016-02-03/china-s-idled-wind-turbines-rise-in-2015-after-record-installs
[43] Ibid.

of intentionally reducing wind usage during China's winter is substantial because wind blows significantly stronger in that season.

Due to a compact market size, a lack of flexible electricity capability, and few peak resources, the majority of China's current wind power resources are vulnerable to remaining sunk costs.[44] The SGCC and CSPG proposed in 2014 the West East Electricity Transfer Project, which aims to build four transmission lines linking together the wind-heavy Eastern Inner Mongolia with Shandong and Jiangsu, and the wind concentrated Western Inner Mongolia to Tianjin and Shaodong. The lines will have capacities for the transmission of 6-9 Gigawatts (GW) each and, due to a hefty state-provided investment of ¥85 billion, are on track to be completed for 2017 and 2020, respectively. Such developments make a substantial declaration to both potential domestic wind developers as well as global environmentalists that China is taking strides towards achieving a renewable economy. Ultimately, unless several HVDC lines are built quickly from the Three North region to the Southeast, any additional construction of large-scale wind farms in the region would be a foolish waste of resources - and such resources could be more efficiently allocated towards grid and transmission development.

Honestly, how could the world's arguably largest economy continue to build thousands of individual wind turbines and leave them operational yet unconnected? "A nationwide transmission line takes three to five years to build, but a wind farm only takes a year to build, said former Goldwind CEO Yu Wuming. And that's why, said Goldwind's Zhu Xinxiang, "40 percent of the electricity generated by Dabancheng in the past year went

[44] Li Junfeng, "2014 China Wind Power Review and Outlook," Chinese Renewable Energy Industries Association, January 2015, accessed January 14, 2016, http://www.gwec.net/wp-content/uploads/2012/06/2014%E9%A3%8E%E7%94%B5%E6%8A%A5%E5%91%8A2%E8%8B%B1%E6%96%87-20150317.pdf

nowhere. The energy could have powered a million homes, preventing air pollution and reducing China's carbon footprint, but there weren't transmission lines in place to carry it all."[45]

China became the world's first country to pass the 100 GW mark for installed capacity, with a total of 145,100 MW of wind turbines installed to date. They also broke the record for the first time a single country installed more than 20 GW in a year, 2015. The greater than anticipated installations were attributable to the NDRC's proposed reduction to the onshore FIT, which provoked wind developers to build quickly before costs increased in early 2016. While this is a rational decision, it is of course very costly. But if there is one term here that should be your focus, it is *installed capacity*. It is the only statistic that China will publicly disclose regarding their wind successes. What does it mean and why?

A wind farm with an installed capacity of 100 MW means that with optimal wind conditions, that entire wind farm can produce 100 MW of electricity in one hour.[46] Technically, because each 1.5-2 MW turbine can power about 332 homes, China's 114,609 MW of installed capacity could power over 38 million Chinese homes. Instead, because wind power depends on the presence of wind and the ability of the turbine to capture that wind, turbines have a capacity factor calculated by measuring the actual turbine output as a proportion of its maximum generation capacity. Chinese wind turbines, which can typically generate between 1.5-2 MW per turbine, have an average annual capacity factor of 18% -

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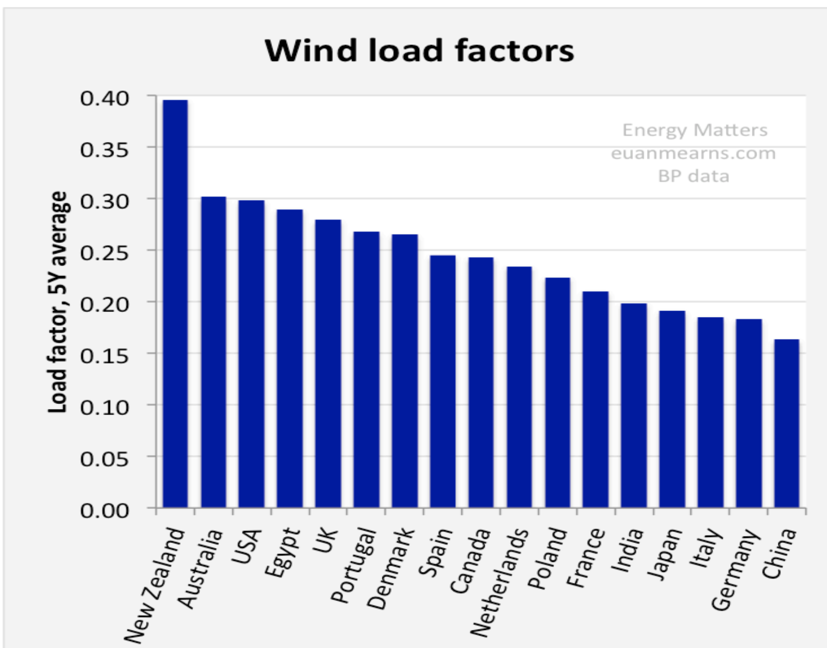
[45] Rob Schmitz, "China taps faraway frontier for renewable energy," Marketplace News, December 02, 2015, accessed January 25, 2016, http://www.marketplace.org/2015/12/02/world/china-taps-faraway-frontier-renewable-energy

[46] "Installed Capacity Definition," Exploring Green Technology, July 2012, accessed December 21, 2015, http://exploringgreentechnology.com/glossary/installed-capacity-definition/

meaning that a 2 MW turbine in reality generates on average 0.4 MW annually.[47] The 80% unused power potential of the wind turbine is caused by a mixture between grid integration and curtailment issues. This is significantly lower than the US capacity factor of 30% annually and this is primarily due to the US Smart Grid system, higher efficiency US wind turbines, and little-to-no intentional wind curtailment. Therefore, as displayed in figure 3, while the Chinese wind sector is larger than that of the U.S., the U.S. systems are about twice as effective.

Figure 3:



With rising global recognition of the disaster on the anthropocene, and a country like China acting as the factory for nearly all global markets, it seems reasonable that China would want to spotlight their environmental successes so as to develop a clean-energy

[47] "Presenting the facts about industrial wind power," National Wind Watch, September 2014, accessed January 24, 2016, https://www.wind-watch.org/faq-output.php

international reputation. By publicizing their colossal growth of installed capacity, China is able to gloat to environmental protection agencies that they have the largest wind power potential capacity in the world. As explained before, much less than half of these wind turbines are even running and of those that are, they are still subject to their capacity factors of about 20%. Henceforth, while the Chinese party points to the statistic that 6% of their total national electricity mix is wind generated, they are deceiving us. Wind power which actually penetrates the Chinese grid solely accounted for 2.78% of national electricity consumption. The vice chairman of the Chinese Wind Energy Association (CWEA), Shi Fengpei, demonstrated in 2015 that the Chinese Communist Party only sets national energy goals and documents statistics based upon installed capacity. Fengpei grieves that the CCP avoids disclosing any measures of true electricity generation from wind.[48]

With the headway from the West East Electricity Transfer Project, China has disclosed targets for national transmission capacity to reach 300 GW by 2020 and 400 GW by 2030. One must remember that installed capacity is useless without transmission capacity and, to that subject, we come to two important questions: whether wind be given priority access to the transmission lines and what capacity of the total will be attributable to wind power? Currently, there lies no answer to these questions, but they certainly provoke a topic for future research.

Incorporating wind power into any national energy system requires reform on a grand scale in order to ensure optimal efficiency and integration. Instead of building from the ground up, hence beginning with the grid modifications and later constructing

[48] Shi Fengpei, "Booming Wind Power Market and Industry in China," (Report, Chinese Wind Power Association, 2014), 8

thousands of wind turbines, the Chinese have instead done this process vice versa. The CCP is motivated to appear to be a nation leading the charge in green energy when, in reality, they leave thousands of turbines blowing in the wind yet generating no electricity. Due to a combination of international ruckus and wasted potential revenue, China's two leading grid companies have finally began accommodating their partly unoperational grid to their operational turbines. At the current rate, it will take five years for China to begin alleviating issues of power shortages in the load centers of the East. Many questions are still left unanswered, and it will ultimately be up to the CCP to be truthful and take responsibility for their environmental future. Offering my opinion, I recommend that the Chinese forfeit all current investment into wind power construction and maintenance in order to secure maximum funding for Smart Grid construction; only after the grid is constructed and equipped with state-of-the-art communication and digital process systems should China pursue further wind power development.

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Chapter 5: Smart Grid Analysis

If you wanted to transport water from the Adirondacks down to New York City, would you start by pouring water down the mountains? No, because that's senseless. But China has done something not much different by proposing to transport energy from the Northwest of China to the East without connecting most of their wind turbine fleet to the energy grid. Both strategies are pointless, and they highlight the importance of building from the foundation up. Attempting to decarbonize China's power system using wind power without an efficient energy grid is pointless. China needs a power system which can support a variety of energy resources and thousand-mile-distances all in the name of developing a renewable-based low carbon energy system. China needs a strong regional grid system paired with an interconnection of each of these. China needs a Smart Grid - and fast.

The Smart Grid, devoted to creating a cleaner and more efficient energy system, is designed with the intention to decrease carbon emissions, to resist weather-related and cyber-related disturbances, and to manage independently with high efficiency. In an effort to achieve total reliability, the Smart Grid is made capable of instantaneous inspection, monitoring, and communication. Because of its efficient structure and far-reaching capabilities, the Smart Grid is the optimal choice for China to ensure a renewable future.

A Smart Grid will be influential for the production of the Chinese renewable-based low carbon energy system for three primary reasons. First, the Smart Grid can accommodate the integration of all renewable power generation sources in both concentrated and distributed ways. With this functionality, the Grid can optimally transmit energy from regional grids all the way to load centers thousands of miles away. Secondly,

China has a major structural advantage here because their power transmission and distribution sector is government owned by means of the SGCC and CSPG. Here, China can make a great leap forward by using not only the government ownership of the grid sector, but also the Chinese market's tendency to maintain low equipment costs. Financially, as previously mentioned, the state-owned SGCC is extremely wealthy and powerful. As a result, the government's central role in the economy can expedite China's Smart Grid development and, thereby, save China annually approximately $2 billion in net losses caused by idle turbines. In other words, ironically speaking, centralization here actually helps.

While supply side issues, specifically grid-related, were discussed in the previous chapter, China's demand side faces its own difficulties. Because China's population is rapidly urbanizing to cities on the East Coast and Central China, areas which are several thousand miles from China's most wind-concentrated provinces, China has struggled to meet the high energy demand. McKinsey, a worldwide management and consulting firm, reported in 2015 that 60 percent of Chinese people now live in urban environments, as compared to only 20 percent when China opened as a free market economy under Deng Xiaoping in 1979. This expansion in urbanization drives a colossal demand for power consumption which, given the actual diurnal patterns of activity, leads to peaks and troughs in the load system. The power load in provinces controlled under the SGCC in 2014 and 2015 increase substantially, by 13% annually, which is higher than the load increases of 12%, 9%, and 8% in 2011, 2012, and 2013 respectively.[49] Because wind is most efficient as a peaking power, the impact of a Smart Grid would be beneficial to both the energy-

[49] Li Junfeng, "2014 China Wind Power Review and Outlook," 2.

demanding load centers as well as to the energy sector by means of a levelized energy demand and supply. Essentially, a Smart Grid ensures efficiency by making sure that supply of energy is equal to demand for energy, and that any inconsistencies in that will be accounted for.

Because China's largest issues are regional grid integration and curtailment, the majority of China's current Smart Grid investment is in transmission, distribution automation, and automatic metering reading.[50] Distribution automation is used to improve reliability in the grid system by use of real-time monitoring and control of energy distribution.[51] Automatic metering reading ensures the transfer of technological information, such as consumption and diagnostic readings, from energy systems to central databases for payment, troubleshooting, and inspection purposes.[52] These two systems coupled together will allow real-time monitoring of the energy grid system, thereby enhancing reliability, energy efficiency, and cost efficiency. China's Smart Grid development will target four pivotal aspects of the power system: transmission, distribution, consumption, and power-generation.

China's Strong Smart Grid plan was pioneered in May of 2009 by the SGCC. The proposal highlighted seven crucial aspects to developing China's Smart Grid which are laid out in table 1. The eight-year plan, costing currently $92 billion USD, is split into three phases within the 12th Five-year plan: Phase one focuses on necessary research and development by means of planning and piloting projects. This plan, set for 2009-2010, has

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[50] Jianbo Yi, "Innovative Testing and Measurement Solutions for Smart Grid," Wiley Publishers, April 24, 2015, accessed via Schaffer Library Online January 10, 2016.
[51] "Distribution Automation," National Electrical Manufacturers Association, October 10, 2014, accessed January 25, 2016, https://www.nema.org/Policy/After-the-Storm/Pages/Distribution-Automation.aspx
[52] "Reduce Costs, Calls and Foot Traffic with Real-Time AMR Meter Reads," Sensus, 2015, accessed March 2, 2016, http://sensus.com/solutions/automatic-meter-reading-amr/

been completed with over 40 pilot projects being tested and many successful. For the Chinese environmental agencies, announcing a plan to do something and actually accomplishing it are usually mutually exclusive. This has been the result of the second phase of China's plan, set for 2011-2015. The SGCC planned to fully construct the UHV grid and distribution grid, build the Smart Grid control and interactive service system, and have 99.73% reliability rate in energy distributions. They also planned to have smart meters in widespread usage. Due to massive internal issues, the SGCC is currently three to ten years away from achieving each of their targets highlighted in phase two. Phase three, set for 2016-2020, aimed for the completion of the Smart Grid, with UHV transmission

Table 1:

Aspect	Requirements	Key technologies
Generation	Raise safe operation of power system by a substantial magnitude Promote large-scale deployment of renewable energy Promote R&D on utility-scale energy storage technology to adapt to the rapid development of intermittent power supply	• Coordination technology between the grid and the regular plants • Integration and control technology for renewable energy • Large-capacity energy storage technology
Transmission	Improve the transmission capacity greatly and reduce transmission cost Optimize the operating conditions of transmission network Improve the stability level of power system and promote system interconnection Realize condition assessment, fault diagnosis and online status maintenance and risk early warning	• GPS positioning, advanced intelligent detection and inspection technology • Intelligent diagnostic analysis and decision technology • Condition based maintenance, life-cycle equipment management and intelligent disaster prevention technology
Transformation	Improve system stability and reliability, transmission capacity, as well as the health level Provide information for smart dispatch of power system Enhance the level of substation assets management and operation	• Intelligent substation automation technology • Integration of online testing and intelligent diagnosis • Intelligent detection device and automatic verification device
Distribution	Enhance the reliability of power supply, system efficiency and terminal power quality Realize distributed generation, energy storage and micro network interconnection Coordinate operation optimization, efficient interaction of demand side management, and realize integration management of distribution assets	• Power distribution automation system and integrated intelligent distribution network control technology • Distribution dispatch and information system • Distributed generation/storage and micro network access and coordinated control technology
Utilization	Enhance the quality of power supply service Improve terminal energy efficiency and grid operation efficiency Raise the proportion of clean energy in terminal energy consumption Promote energy conservation and emissions reduction	• Real-time data-mining and management of customer consumption patterns and behaviors • Intelligent community/buildings • intelligent customer service system • Customer-side distributed power and energy storage system
Dispatching	Realize networked data transmission and visualization of operation monitoring Realize dynamic safety assessment and refined dispatch Realize automatic operation control and optimized generation-grid coordination	• Energy management system • wide area measurement system (WAMS) • Dynamic stability test and early warning system • Schedule management system
Information platform	Realize whole process information integration Realize resource optimization and risk management on grid level Improve interactions among grid operator and key stakeholders Realize smart decision in big data system Provide communication carriers for Internet of Things (IOT) and expand its applications	• Modern information technology • Big data platform for the whole process of power supply chain • Integrated communication platform • Business collaboration and interoperability platform

capacity to reach 400 GW, and for China to become "world leaders in management, technology, and equipment." [53]

The plan's second phase aimed to accelerate the construction of China's ultra-high voltage (UHV) lines, construct urban-rural transmission networks, develop operational interactive control of the Smart Grid, and create necessary digital applications and equipment for ensured grid reliability. Though lagging significantly behind the 2009 plan, China's public disclosure of their efforts have rung well in the Chinese market. Since Liu Zhenya, chairman of the SGCC, announced they would send excess renewable energy from China's northwest regions to the Central and Eastern consumption centers with the goal of retiring hundreds of coal-fired plants, investors have been bullish on energy infrastructure securities. [54] Amid a nine-month long general Chinese company stock market drought, power grid equipment maker's stocks have been increasing in 2016. While this could certainly be seen as the result of a positive reaction from the Chinese general public, perhaps it is on a larger scale due to an influx of investment by CCP officials to subsequently boost Chinese domestic confidence in the energy sector.

In spite of stock investor's enthusiasm of China's UHV system, according to true measures of UHV construction, the CCP seems to be again successfully sugarcoating the truth in order to increase public favorability. In 2009, SGCC leaders announced that they had "fully grasped the core technology" necessary to execute Ultra High Voltage energy distribution, and announced an initial funding amount of $92 Billion to achieve full

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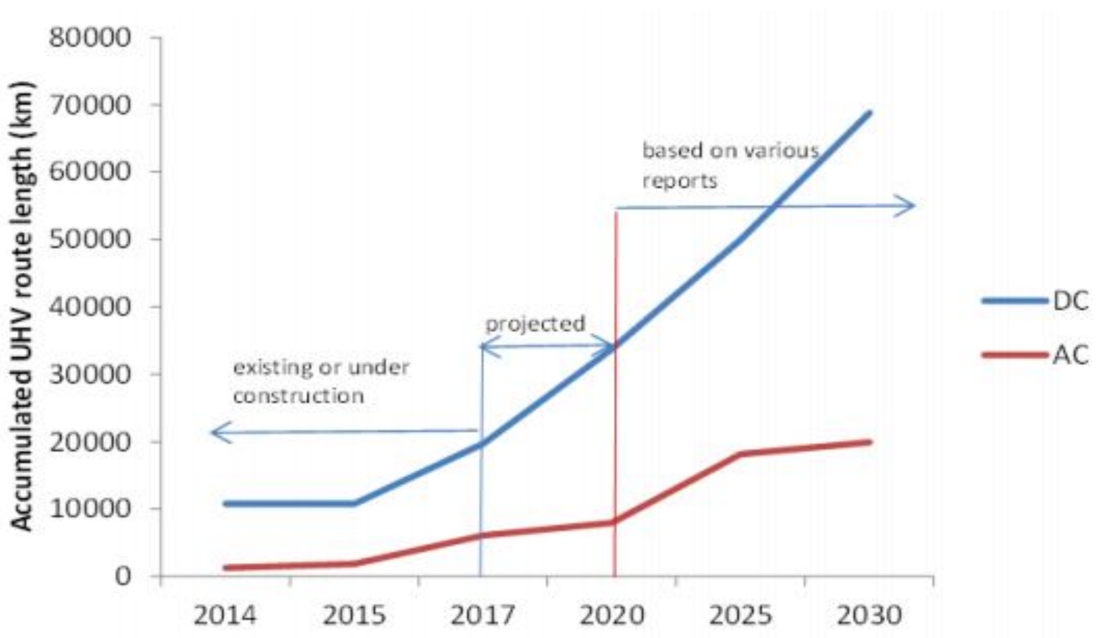
[53] "Electricity Transmission Systems," World Nuclear, November 2015, accessed February 12, 2016, http://www.world-nuclear.org/information-library/current-and-future-generation/electricity-transmission-grids.aspx

[54] "Ultra-high voltage equipment makers set to benefit from China's clean air push," South China Morning Post, February 16, 2016, accessed February 22, 2016, http://www.scmp.com/business/article/1913439/ultra-high-voltage-equipment-makers-set-benefit-chinas-clean-air-push

implementation by 2020. Five years later, the SGCC laid out a seven-year plan to construct 37 UHV lines by 2020, covering over 55,000 miles (89,000 km), in which 11 would be built by the end of 2015; yet, only eight lines stretching a total distance of 7,500 miles (12,700 km) had been built by the end of 2015.[55] Hu Xinmin, senior manager of Hong Kong based economic consulting firm Lantau Group, hypothesized that "to meet this original 2020 target, China would need to more than double its UHV development effort, which seems unlikely given the challenges."[56] As demonstrated in figure 4, provided by the Lantau Group, at China's current rate of construction, it is estimated that it will take about 15-20 years longer than they had expected to reach their target of 89,000 km. When considering the number of companies that have contract plans to construct the equipment for the

Figure 4:



[55] "China's under-utilised ultra-high-voltage power lines no silver bullet to rid grid of bottlenecks," South China Morning Post, February 14, 2016, accessed February 24, 2016, http://www.scmp.com/business/article/1912878/chinas-under-utilised-ultra-high-voltage-power-lines-no-silver-bullet-rid
[56] Ibid.

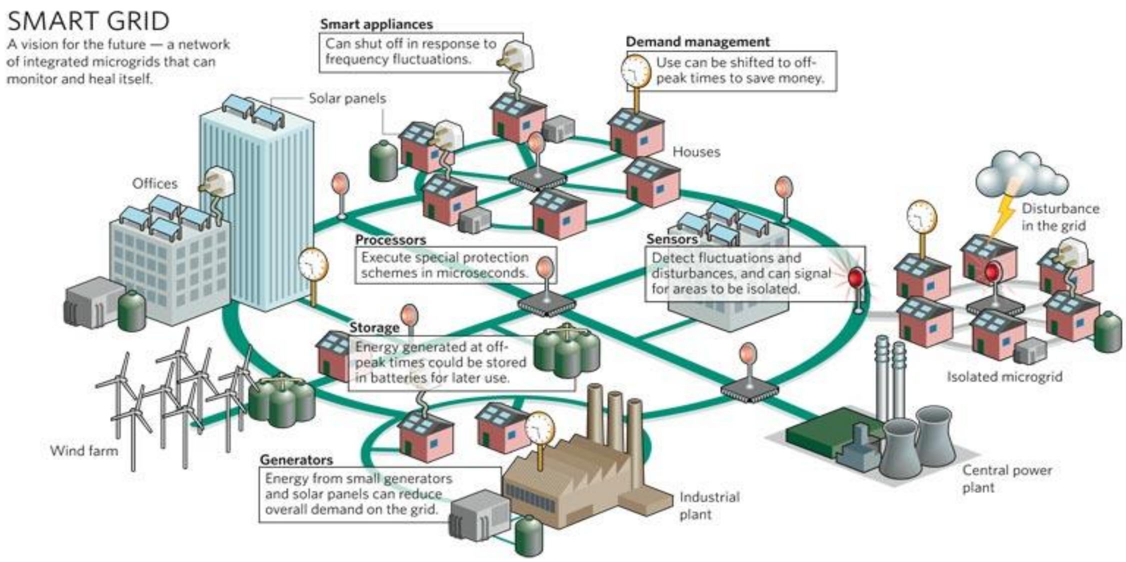
transmission lines, they will be sorely disappointed when the projected schedule falls short of the actual schedule.

The sluggish construction progress can be attributed to differing views between the NEA and SGCC on the precise amounts of interconnection needed between each regional grid, how to curtail energy demand growth, and how to deal with system integration and delays. GE China Wind's financial manager, Florence Xu, agreed with this analysis and added that the NEA's views diverge with the SGCC's chiefly in their preference to strengthen regional grids at this stage, as opposed to inter-connecting regional grids. This organizational dispute brings to the surface a principal inherent characteristic of the Chinese economy.

China's intention to be the first nation with the plan to utilize UHV lines as the "heart" of its regional power grid network interconnection is hogwash. There is a reason that China is the first to do this, and in my opinion it does not yield them a long-term beneficial outcome of any form. With regard to their energy infrastructure, China seems to think short-term actions will result in a better reputation and stable results. Instead, China is once again moving backwards. By putting their focus on developing UHV lines first, China is committing the same mistake they have made when they began erecting wind turbines without readily available means of connecting them.

A smarter approach for the CCP, NEA and grid operators would be to assemble the Chinese energy system from the ground up. This means no more sugarcoating or working backwards. If China wants to achieve a low-carbon renewable economy operated through Smart Grid technology, they must first begin by restoring each of China's six regional grid systems. The Smart grid system is efficient and necessary, but as the image 3 demonstrates,

Image 3:



each regional system must first be strong before any excess energy from that system is transported via UHV lines to distant load centers. The whole is only as good as the sum of its parts and thus, put simply, the CCP and SGCC ought to begin complying with the NEA. If they don't, the bottlenecks will never leave the system and wind farm operators hopes that constructed UHV lines would relieve their distribution issues will be sorely disappointed.

In fact, as of 2016, China's UHV lines are already facing substantial difficulties. The utilization and efficiency of their multi-billion dollar long-distance transmission lines have been considerably lower than expected. The Lantau Group senior manager reported in February that "utilization of the UHV lines remains below expectations due to many factors such as the performance of connected generation plants… [and] constraints in the local power grids."[57] Additionally, figures from the SGCC state that the first three UHV lines had a

[57] "The Lantau Group on China: UHV," The Lantau Group, January 2016, accessed February 28, 2016, http://www.lantaugroup.com/files/tlgchina_uhv_jan16.pdf

capacity utilization of between only 21% and 56% in 2014.[58] A typical first-rate system would feature capacity utilization between 80% and 95%. These UHV lines were designed to be able to handle about 9 GW of transmission capacity, but meanwhile they have been transmitting far less than that. What we are seeing here is that China's regional grids are incapable of efficient outbound and inbound power transmission. The claim on the poor condition of the network is bolstered by testimony from Dennis Ip, head of utilities and renewables research at reporting agency Daiwa Capital Markets, who disclosed that this year the UHV line linking the Xinjiang and Henan provinces suffered its lowest utilization because, due to damage inflicted by huge load fluctuations, it was under maintenance for six months in 2015. To reiterate, a stronger regional grid would be capable of handling such fluctuations and electricity transmission.

The final aspect of the second phase of the Smart Grid deployment involves the installation of a smart meters on every Chinese household. Included as part of the pilot process, the State Grid has set an ambitious goal to have each home monitored by a Smart home meter individually by the end of 2017. The NDRC stressed that these meters will be crucial to ensure a stable pricing system for electricity. Also known as time-of-use pricing, step pricing will help the Smart Grid to better digitally monitor energy supply and demand, allowing the system to move the peak to fill the valley. In other words, energy shortages due a lack of infrastructural capabilities, which continue to be a struggle for the load center congested cities of the East, will no longer be an issue.

While China has to date installed smart meter technology in roughly 25% of nationwide homes and businesses, at this rate it seems unrealistic that they will be able to

[58] "China's under-utilised ultra-high-voltage power lines no silver bullet to rid grid of bottlenecks," 2016.

finish installment by 2018. A drawback for China's smart meter system is its limitations in functionality. With 400 million potential smart meter users, China's market is significantly larger than others. The United States, for example, has targeted a price per meter at between $100 and $150, which will include significant computing power and communications capability.[59] Due to the large Chinese market, they have targeted a much lower price per meter of $50, equipping the systems with lower quality and efficiency meters. China is valuing quantity over quality, which will lead to unfavorable outcomes when the smart meters face operational limitations when applied to the Smart Grid.

It should also be noted that much of China's smart meter system, even after full potential installment by 2018, will lack full functionality. This is because China has chosen to separate the communications and metering components in its smart meters. As a result, these state-of-the-art meters will likely not be technologically supported by the outdated network monitoring technology. In a sense, China is shooting itself in the foot by building backwards here. And this is not the first time they've done so; one must not forget China's building of wind turbines before the grid to support them or their expensive construction of UHV lines before ensuring stronger regional grids. Rather than designing a network digital system to monitor and report on the Smart Grid first, China has begun constructing auxiliary system components, which subsequently will incur unforeseen monetary and time management costs. It seems that China's investments are not conducted with the full intention of environmental and economic development, but more so to inflate intentional reputation. To clarify, because of the potential damage from mismatches, China risks

[59] Jeff St. John, "China Wants Time-Of-Use Pricing by 2015, One Meter per Home by 2017," January 14, 2014, accessed February 14, 2016, http://www.greentechmedia.com/articles/read/china-wants-time-of-use-pricing-by-2015-one-meter-per-home-by-2017

actually increasing the costs and failure rates, which in turn will likely have a positive feedback loop.

China's Smart Grid construction progress is trailing the State Grid's plan by at least five years. China may be facing a double-edged sword here because while the development of a Smart Grid would be hugely beneficial, it will be monumentally costly for the environment and economy. Each year China goes without an efficient grid results in 8 billion metric tons of carbon emissions released in the atmosphere, a value which equals the annual emissions of Russia, India, and the USA cumulatively.[60] Moreover, because at least half of China's wind turbines are still sitting idle, China loses the previously mentioned $2 Billion annually. The causes of China's struggling energy grid development can be pinpointed to a lack of efficient organization by the CCP. In other words, many credible sources lament China's decisions to mask the truth of their progress, and ultimately such sources feel China would benefit most from focusing first on a strengthening of the regional grids, then producing UHV lines and Smart technology, and lastly production and connection of wind turbine generators. If the regional grids remain weak, the entire Smart Grid will rest on an unsteady foundation. With the information in this paper, and disclosure from other sources, hopefully China will recognize that whitewashing the energy sector is perhaps the least efficient strategy to developing a low-carbon renewable based economy. One thing is for sure; any more time that the CCP and SGCC spend away from the regional grids will increase costs for what is already becoming an unaffordable venture. While it may be a large leap, it seems in many ways that China has

[60] "Each Country's Share of CO2 Emissions," Union of concerned Scientists, January 2015, accessed January 2, 9, 2016, http://www.ucsusa.org/global_warming/science_and_impacts/science/each-countrys-share-of-co2.html#.Vs4XK_TF_BE

actually retreated to its long-term monocultural approach with heavy control from the center, when instead an intelligent central plan would require giving up some power to the regions.

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Chapter 6: Economic & Social Costs of China's Wind Power and Smart Grid:

China has incurred financial costs from their wind power systems and Smart Grid of well over $200 billion since 2000. In addition, China's transition from a coal-based economy to a renewable based economy has led to sizable environmental and diplomatic costs. While assessing the comprehensive economic costs of China's wind program and Smart Grid is unrealistic due to CCP controllership and the utter scope of such operations, this chapter will use a combination of analytical reports and industry standard costs in order to draw conclusions on the economic feasibility and social outcomes of China's energy sector. Although this chapter highlights the economic advantages of wind power and grid installation, it will bring to light the major costs China will incur if such systems are not built efficiently.

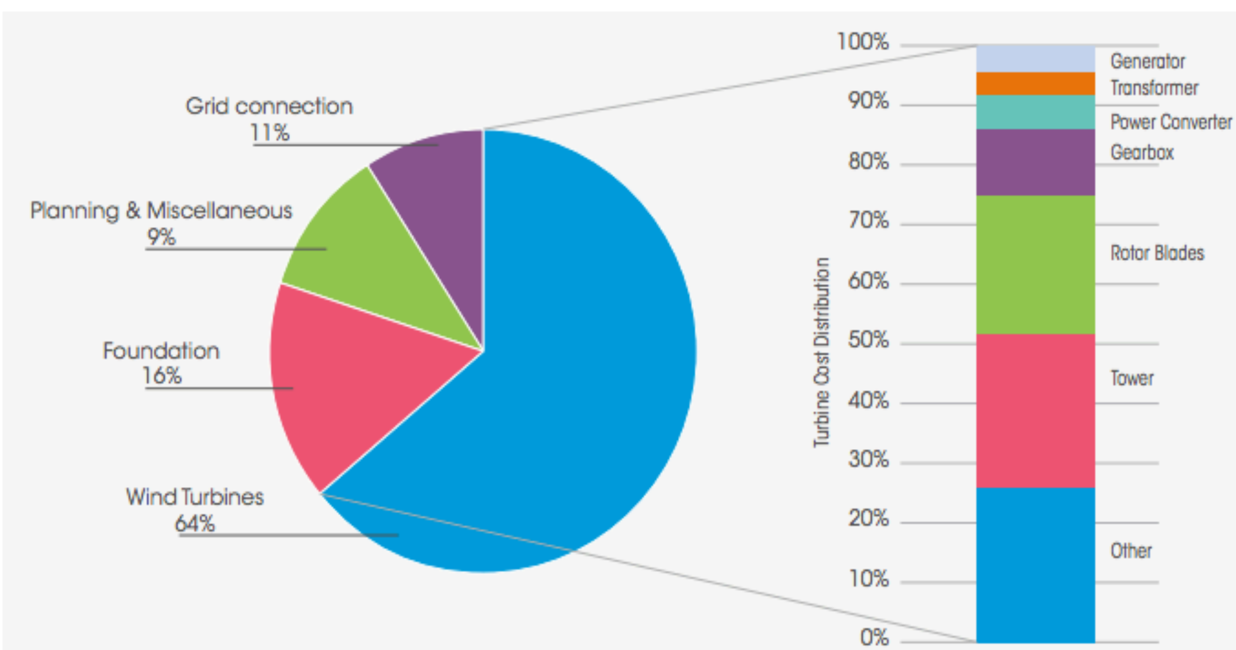
Though cost analytics can be very intricate, here we will be using a simplified approach using three cost indicators: equipment costs, total installed project costs, and the levelized cost of electricity generation (LCOE). An important note to consider is that the analyses used contain price indicators. Thus, costs and prices are determined by the level above or below the normal profit seen in a competitive market. Because the transition into a renewable-based energy sector is rarely well-balanced, as demonstrated by China's issues, the short-term can see prices increase well above costs if supply cannot meet demand (and vice versa). Before delving into a discounted cash flow analysis in order to determine the LCOE of China's wind platform, I will first lay out the breakdown for the cost of wind power.

While wind is a capital intensive energy source, like other renewable energy sources, it differs in that its fuel is free. Investment costs, operation and maintenance costs (O&M), capacity factor, economic lifetime, and cost of capital are the most important parameters

for analyzing wind power economics.[61] Unlike other capital intensive renewable sources, wind is among the most cost-efficient with regard to dollar cost per KwH produced. But, as seen in my analysis, often not all of that dollar cost per is delivered.

The capital costs of a wind project should be divided into these major categories: the turbine costs, civil works, grid connection costs, and other capital costs. Turbine costs include blades, tower and transformers, while civil works include site preparation and tower foundation costs. Grid connection costs can include both the transformers and substations as well as the connection to the transmission or distribution grid. Other capital costs can include building construction, control systems etc. Figure 5 demonstrates the capital cost breakdown for a Chinese onshore wind system and turbine. As one can see, almost the entire cost of the wind turbine is upfront. This leaves only future maintenance and financing options going forward. For China, it has been a strategic move to build wind

Figure 5:

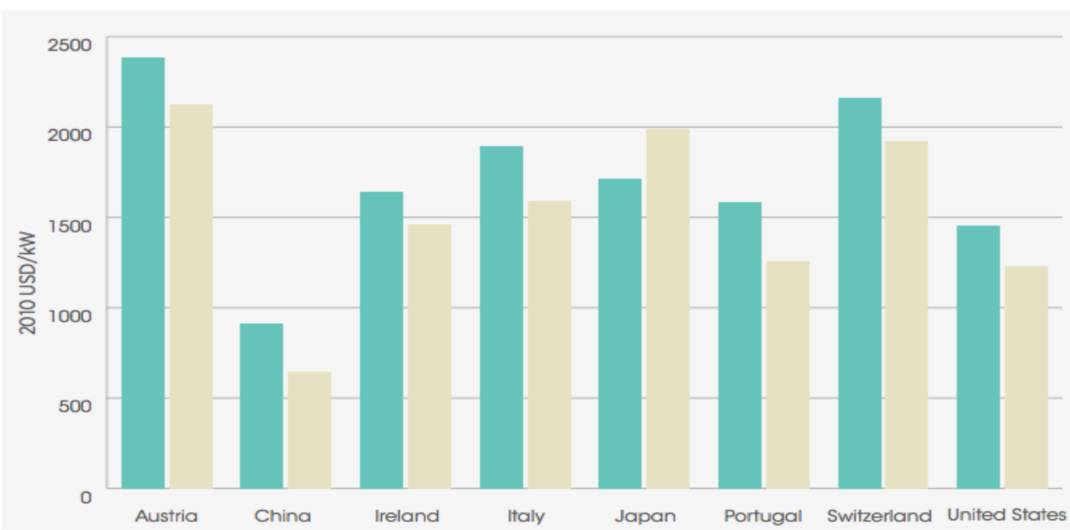


[61] "Renewable Energy Technologies: Cost Analysis Series," International Renewable Energy Agency, June 2012

turbines now, ensuring a cleaner and more cost-effective future. However, as figure 5 and statistics exhibit, 11% of the turbine cost has not been carried out on an estimated 30% to 40% of China's wind fleet. It is likely that by financing 89% of the turbines first, China's grid corporations could end up paying more than 11% per turbine if they continue to struggle with grid curtailment and network transmission.

While the total installed capital costs for an average Chinese wind turbine in 2014 ranged between $1300 and $1450 per KwH, a US turbine faced capital investment costs of between $2000 and $2500 per KwH. The United States actually faced a price hike from 2012 through 2015 because market demand exponentially increased and the global supply chain had difficulty delivering. This caused significant shortages in the US, and thus a price hike, but such price variation was not experienced in China because the CCP controls the entire wind turbine market through its two major utility companies, SGCC and CSPG. In contrast, the approximate 3,700 U.S. utilities are regulated at the state level.[62] For this

Figure 6:



[62] George Leopold, "An Uneven Rollout of a Smarter Grid," August 08, 2013, accessed December 19, 2015, http://electronics360.globalspec.com/article/2141/an-uneven-rollout-of-a-smarter-grid

reason, they do not depend on other countries for supply nor demand, and therefore transportation costs and equipment costs are typically stagnant.

Figure 6, released by the IEA in 2011, demonstrates China's significant cost advantages in wind as compared to other major wind-friendly nations. The figure's teal bars represent 2008 prices per KwH while the light brown bar shows 2010 prices per KwH, all for a 1.5 MW-sized wind turbine. China's price of a turbine was only $700 per KwH in 2010, and has since decreased to $500 per KwH in 2012.[63] Thus, both total installed costs and manufacturing costs per turbine summed to between about $1900 for a Chinese turbine versus upwards of $3500 for a US turbine. This gives China an absolute advantage in the production of wind power because they're able to produce it at a lower cost than any other nation.

Playing a major role in China's absolute advantage is the government structure which allows for ease of production and financing to the wind sector. Nathaniel Bullard, clean energy and China analyst for Bloomberg New Energy Finance, supported this by explaining "China has very strong renewable energy targets for wind. The countries that really attract large private finance or have high growth investment are the ones with stable energy policies." Bullard's point is valid, though it is worth noting that in 2013, of the $923 million worth of wind energy goods and services traded between the USA and China, the USA held a net trade surplus of roughly $150 million.[64] This can be seen in two lights. First, the US still has a strong hold on the renewables sector and China values American made

[63] Liu, Zhang, Zhao, Yuan, "The Economics of Wind Power in China and Policy Implications," Energies 2015 8(2), 1529-1546; doi: 10.3390/en8021529, February 17, 2015

[64] Lan Lan, "Energy Trade Surplus for U.S.," China Daily, March 07, 2013, accessed February 12, 2016, http://europe.chinadaily.com.cn/world/2013-03/07/content_16286180.htm

energy sector goods more than the USA values Chinese-made energy goods. Or second, China is more concerned with the domestic future of their wind programs, and therefore only imports US products to fill the gap in its technology and manufacturing services. The differences in the success of these nation's wind programs ultimately lies on their government's policies. Ren Dongming, deputy director for the center for the NDRC, noted that "policy choices will determine the direction of the clean energy industry in the months and years ahead."[65]

Notwithstanding, while the prices of Chinese equipment are much lower than those of other nations, the quality of Chinese energy infrastructure technology and turbine equipment systems is inferior to those of competitors. This leaves the door open for non-Chinese companies to play a role in the metering boom. International powerhouses in the energy market, such as Siemens and General Electric, have their eyes on China's energy market technology weaknesses as a prospective way into the market.

In a conversation with a GE China Renewables Wind financial manager, Florence Xu, she made two points to me regarding GE's penetration into the Chinese market. First, since China's energy market is primarily state owned, GE Wind as of 2016 only controls about 3% of China's market share. Although wind industry top-three manufacturers GE, Vestas, and Siemens produce superior quality and efficiency products, the CCP, in an effort to protect their self-owned domestic producers, feels that the costs of allowing international market penetration outweigh the benefits of superior efficiency wind generation. In fact, the CCP takes domestic production so seriously that their state-run producers typically will work with China's low-cost vendors so as to obtain massive internal economies of scale for

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[65] Ibid.

both those firms and the China's SOEs. Such a strategy causes future suppliers to the Chinese wind market to face scant profit margins. Second, Florence notes that as generation capacity grows bigger and bigger, cost must be driven lower and lower in order for GE to maintain their comparative advantage in production process.

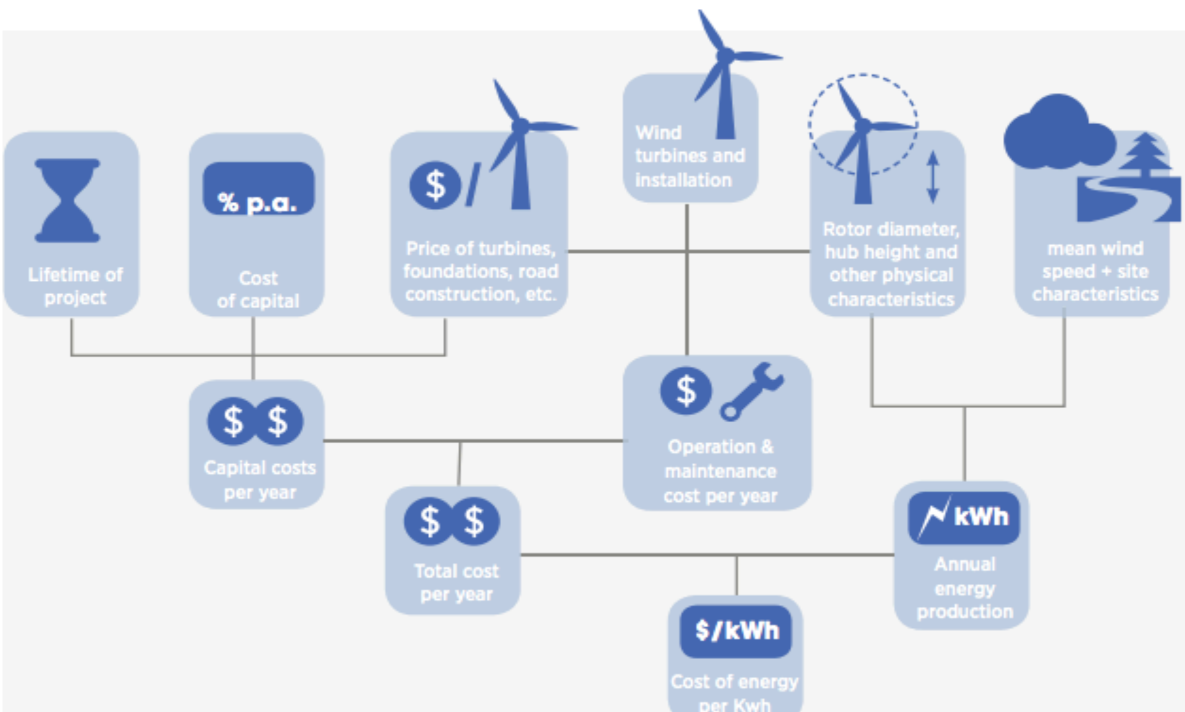
However, channeling back to chapter 4 with the explanation of China's energy policies, Ren Dongming's analysis is supported by a 2015 study by Liu *et al.* which uses a LCOE model to investigate the effectiveness of the 2009 FIT, and other attractive public subsidies, on China's wind program. While several in-place wind policies have been instrumental in causing a positive increase in domestic production and capacity installation of wind, the CCP and SGCC's focus on boosting installed capacity in place of power generation, their attention to production scale rather than quality of a wind turbine, and lastly their decision to focus on economic growth by industry policy instead of environmental policy to promote renewable (especially wind) generation has been disconcerting to the energy sector as well as the general public. Notwithstanding, the 2015 study using analytical framework for the LCOE has brought forth opposing evidence regarding China's success.

Yet, before delving into the study's results, one must understand the levelized cost of energy model and why it's most often used to assess the economic practicality of renewable power generation. For a wind project, the LCOE constitutes the sum of all costs of a functional wind power system over the entire life of the project, with financial flows discounted to a common year. As image 4 demonstrates, the main elements that make up

the LCOE for wind power includes costs of capital, O&M costs, and the projected yearly electricity production amount.[66]

This model employs techniques from the E3 model which essentially measures the value of wind power through a representation of generator's cash flows including technology and fuel, O&M, emissions control and cost, as well as incurred taxes from pollutants. This model is used to evaluate the Chinese energy market for coal and other fossil-fuel generation systems. This is useful because it allows comparisons between the economic feasibility of wind versus coal in China.

Image 4:



[66] "Renewable Energy Technologies: Cost Analysis Series," International Renewable Energy Agency, June 2012

All costs and revenues in the future are accounted for in the model by using the present time value of money. Utilizing a discounted cash flow analysis, where r equals the discount rate, the LCOE is most accurately measured when the present value of the discounted revenues sum is equal to the discounted value of the sum of the costs during the entire economic lifetime of the wind system (measured in N years):[67]

$$\sum_{n=0}^{N} \frac{\mathrm{Re}\,venues_n}{(1+r)^n} = \sum_{n=0}^{N} \frac{Cost_n}{(1+r)^n}$$

Next the net present value (NPV) is set equal to zero. Here, the LCOE is the mean energy price necessary for a NPV equal to zero, resulting in an investor return proportionate to the investment's discount rate, r. Accordingly, the total of the present values of $LCOE_n$ multiplied by the electricity produced yearly, E_n, will equal the total of the present values of the costs of the project. But after division, the LCOE will equal the sum of discounted costs over the project's life divided by the amount of discounted energy generated. Following this final calculation, the initial cost for the lifetime of the project is annualized below:

$$LCOE = \left(\sum_{n=1}^{N} \frac{(CAPEX_n + OPEX_n + TAX_n)}{(1+r)^n} \right) \Bigg/ \left(\sum_{n=1}^{N} \frac{(C \times H \times (1-o_u))_n}{(1+r)^n} \right)$$

The above equation demonstrates that LCOEs costs can be broken down further into $CAPEX_n$ as the the yearly value of the initial capital expenditure; $OPEX_n$ as the yearly operation expenditure; TAX_n for the annual tax; C for the installed capacity measure; H being the annual usage hours; o_u as the operational usage rate; N as the service life of the plant; finally, r as the discount rate.

[67] "Renewable Energy Technologies: Cost Analysis Series," International Renewable Energy Agency, June 2012

With the E3 DCF model empirically explained above, it is now appropriate to observe the findings of Liu, Zhang, Zhao, and Yuan's analysis and determine what the outcomes of China's FIT wind subsidy have been on recent wind production costs and overall system development. The study's results, exhibited in table 2, present five numerical scenarios for a typical wind farm in 2009 and 2013 with year to year decreasing unit investment, variable annual operation hours, and alternating service life, depreciation, and maintenance rate.

Table 2 reveals that a 2009 wind farm in the category I zone, consisting of the Inner Mongolia region, with only 1900 operation hours and a lessened service life of 15 years, on top of an unusually high maintenance rate of 4%, results in a LCOE of ¥0.73 per KwH. Because the category I region has a government mandated FIT of ¥0.51 per KwH, this wind farm is technically posting a net loss because the LCOE is well above the FIT. On the other hand, observing the same situation but for 2013, one can see that the LCOE is only ¥0.48 per KwH, which bolsters the FIT's principal goal that decreasing capital expenditure, despite serious grid curtailment issues, can still lead to posted profitable returns.

Because China's wind FIT amount is determined based upon the desulfurized coal power price plus a specific subsidy, which is essentially the real value of cleaned-up coal,

Table 2:

Parameters/Results	2009					2013				
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
Unit investment (yuan/KW)	8000	8000	8000	8000	8000	4900	4900	4900	4900	4900
Annual operation (hours)	2500	2300	2100	1900	1900	2500	2300	2100	1900	1900
Service life (years)	20	20	20	20	15	20	20	20	20	15
Depreciation (years)	15	15	15	15	10	15	15	15	15	10
Maintenance rate	2%	2%	2%	2%	4%	2%	2%	2%	2%	4%
Wind power LCOE (yuan/KWh)	0.45	0.49	0.53	0.59	0.73	0.31	0.33	0.36	0.40	0.48
Benchmarking desulfurized coal power price (yuan/KWh)	0.25–0.3	0.31–0.43	0.41	0.45–0.49	-	0.254–0.3	0.35–0.4	0.4	0.44–0.46	-

the value is included on the bottom row of table 2. In order to allow for comparative analysis, each of the power prices displayed is the true price calculated for coal plants located in the same wind resource region as the numerical wind data above. One can observe in all five scenarios in 2009, the wind power LCOE with the subsidy for the FIT still exceeds the coal power price from ¥0.2 per KwH through ¥0.06 KwH.[68] Because producers will rationally choose the lower cost mechanism, this exact cost divergence has been China's biggest struggle in attempting to transition to renewable energy systems. Yet, as can be observed by observing the 2013, 2015, and 2020 numbers (in both tables 2 and 3), the days of coal being dollars cheaper than renewable energy are over. As demonstrated earlier in figure 3, China's absolute cost advantage in production of wind turbines coupled with the industry's FIT have resulted in LCOEs of wind power which are either nearing or considerably less than coal power prices. Table 3 contains predictions of LCOEs in 2015 and 2020 using a reduced learning-by-doing rate from 6% to only 4%, and highlights that capital investment amounts will likely no longer play a chief role in calculating LCOEs going forward, but rather that the length of service life, number of annual operation hours, and the percentage of maintenance costs will continue to be significant factors.

Table 3:

Parameters/Results	2015					2020				
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
Unit investment (yuan/KW)	4600	4600	4600	4600	4600	4400	4400	4400	4400	4400
Annual operation (hours)	2500	2300	2100	1900	1900	2500	2300	2100	1900	1900
Service life (years)	20	20	20	20	15	20	20	20	20	15
Depreciation (years)	15	15	15	15	10	15	15	15	15	10
Maintenance rate	2%	2%	2%	2%	4%	2%	2%	2%	2%	4%
Wind power LCOE (yuan/KWh)	0.29	0.32	0.35	0.38	0.46	0.29	0.31	0.34	0.37	0.45

[68] "China's 2016 FIT Rates Lower than Expectation, Energy Trend of Trendforce Corp., December 17, 2015, accessed January 25, 2016, http://pv.energytrend.com/news/China_2016_FiT_Rates_Lower_than_Expectation.html

The important takeaway is that even though wind power has always been cleaner and healthier than coal-fired power, it is now cost competitive with coal. This is the fundamental reason that China is switching to a low-carbon renewable based energy program.

The study presents supporting evidence for the successful progress to date of China's FIT policy. It displays the importance of the FIT which effectively triggers wind power capital investment, the success of the CCP's industrial policy which stimulates wind turbine manufacturing domestically, and finally the mutual benefit of the integration between technological advancements and capacity installation. Each of the above developmental elements have worked cohesively to diminish China's LCOE to the point where wind, a free low-carbon clean energy fuel, has become a cost-competitive energy market option alongside coal power. With regard to this paper's contention that grid curtailment and integration represent China's greatest bottlenecks to wind energy success, the results of this study support my analysis by highlighting the importance of such issues in long-run sustainable development of wind generation, but expand on it by proposing that, in the early stages of wind farm development, both technological learning and cost reduction are of utmost priority.[69] In using both Morthorst's 1999 report, which highlighted the significance of measuring efficiency and administrative demands to evaluate wind power growth, in addition to the 2013 paper by Hu *et al.*, which conveys that technology and administration are the two most important indicators of wind progress, one can conclude wind power policy has, until 2013, been instrumental in the substantial

[69] Hu, Wang, Byrne, Kurdgelashvili, "Review of wind power tariff policies in China," University of Delaware, August 21, 2012, accessed January 14, 2016, http://ceep.udel.edu/wp-content/uploads/2013/08/2013_es_EP_wind-energy_China_hu+wang+byrne+lado_2.pdf

decreasing of the LCOE for wind.[70] This therefore indicates the clear presence of economies of scale.

The above DCF framework for LCOE brings to light how crucial it is for the CCP and NEA to work cohesively so as to enact brand new protocols which will ensure a sustainable future for China's wind program. Because the contemporary wind power subsidy is funded by a combination of the CCP's internal endowment and a surtax on the nationwide retail tariff for energy, such funding is vulnerable to potential annual budget cuts as well as Chinese energy consumer's pockets.

China's surcharge on customer energy tariffs began with the enactment of the Renewable Energy Law in 2006, a law which asserted the importance of promoting renewable energy system development in China. Though the surcharge began at ¥0.1 per KwH, record breaking increases in installed capacity have driven the aggregate subsidy through the roof. The CCP augmented the surcharge three times until it reached ¥2 per KwH, whereafter the government and energy sector realized the problem was getting out of hand. By 2008, the gap between the subsidy supply and demand was ¥1.3 billion and by 2011, the gap had exceeded ¥10 billion.[71] During the 12th five-year-plan in late last year the gap had surpassed the ¥100 billion mark. What is the CCP and Chinese energy sector to do; they can either decide to increase the surtax exponentially and face the wrath of revolted citizens, or they can maintain the level of the surcharge and gamble with the chances of a wind deployment downtrend. In other words, much of what seems to be an economies of scale is actually a concealed increasingly larger subsidy.

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[70] E.L. Petersen, "1999 European Wind Energy Conference Wind Energy for the Next Millennium," (Earthscan, New York 1999)
[71] Liu, Zhang, Zhao, Yuan, "The Economics of Wind Power in China and Policy Implications," Energies 2015

The fundamental idea of implementing an FIT is ultimately to lower the initial costs of wind development to competing costs with typically cheap fossil fuels. Sensibly, after a few years of government aid, the operational wind farm will have garnered sufficient scale and technologies, hence allowing for the termination of the FIT so that its funds can be allocated elsewhere.[72] In spite of such economic practicality, China has continued to supply FIT funds to wind farms for far more years than they are needed. Instead, the CCP should have confidence in its own economy and let the invisible hand of the market guide the success of developed wind turbine projects. If China continues to fund so carelessly, there will be several consequences, including numerous unknown costs.

The first, and most obvious downside, would be China's loss of support for renewable energy from its customers. This would once again be a blow to China's international image. Despite the obvious benefits of renewable energy, fewer consumers will elect to support it if it means that tariffs, which will likely increase year-to-year, must be paid out of pocket annually. Furthermore, any allocated funding for other renewable energy systems, such as solar power, will be diminished. Finally, because the CCP subsidizes China's wind industry, hence deeming wind a public good, if its subsidy is being used inefficiently, it is not only a waste of government financial funding but is further a waste of a public good. A relatable equivalent is this: Imagine hearing that a United States public good, say a mass-transit system, had a percentage of its funding allocated to renovating train cars that were created last year. There is no doubt that the general public of the United States would be up in arms over the fact that their hard earned tax dollars are being wasted. While the explicitness of the reactions between U.S. and Chinese citizens

[72] Maddie Stone, "China's Wind and Solar Energy Capacity is Soaring," March 1, 2016, accessed March 4, 2016, http://gizmodo.com/chinas-wind-and-solar-energy-capacity-is-soaring-1762235757

would diverge due to the presence of a Constitutional republic versus a Socialist state, the stigma of repudiation would be commensurate. A great way to ween off of CCP subsidies for wind power projects would be to institute sunset legislation.[73] A sunset provision is a measure within a law or regulation which mandates that the law, or subsidy in this case, will stop taking effect after a specific date in time. With market research on the relationship between wind farm age and prices of energy, such a system, if instituted, could save government funds which can, in turn, be used in the development of additional renewable resources.

In support of the above argument, in late February of 2016, China's NDRC announced that it would cut the onshore wind FIT by $0.02 for type 1 (Inner Mongolia Province), type 2 (Hebei Province), and type 3 (Jilin Province) wind regions. This is the first cut since China's subsidy surcharge issue has gotten out of hand, and is thankfully milder than many had projected. The NDRC's mandate states that two groups will pay for the FIT going forward: The portion of the price of wind that is equal to the regional coal power plant price will be funded by the local provincial grid operators. The remainder, which is roughly 40% or less of the price, will be backed by the CCP's renewable energy development fund.[74]

The takeaway here is that wind power in China is now undeniably cost competitive with fossil fuels. Therefore, as the world's biggest polluter, China now has no excuse to continue generating over 60% of its energy from coal-fired power. In China's 13th five-

[73] Brian Baugus, "Sunset Legislation in the States: Balancing the Legislature and the Executive," August 27, 2015, accessed January 16, 2016, http://mercatus.org/publication/sunset-legislation-states-balancing-legislature-and-executive

[74] Jianxiang Yang, "China Confirms Cut to Onshore Tariff," January 6 2015, accessed January 5, 2016, http://www.windpowermonthly.com/article/1328437/china-confirms-cut-onshore-tariff

year-plan, they acknowledged just that, by aiming for an ambitious 15% non-fossil fuel primary energy target by 2020.[75] Fundamentally, China provides the lowest cost for onshore wind with installed costs of $1300 per KwH, as compared to $1900 per KwH in the US. China's operations and maintenance costs annually are between $35 and $46 per KwH, while coal's O&M cost range from $27 to $53.[76] Additionally, as modeled above, China's FIT has brought the LCOE of wind down to competitive pricing with coal, in some cases boasting cheaper prices. By enacting laws to lower the FIT for three regions, China has provided support for my proposal that by allowing the free market to take its course, as Milton Friedman said, " coordinates the activity of millions of people, each seeking his own interest, in such a way as to make everyone better off."[77] Nevertheless, one must remember that China still must address major structural issues before reaping the benefits of such wind power construction growth. Despite cost successes, China still must allow better conditions for access to the grid, mandate comprehensive and fair transmission rules, and build efficient and reliable UHV transmission lines.

Unfortunately, data for China's Smart Grid infrastructural development has not been publicly disclosed. For this reason, it is difficult to measure the time frame that China must have in order to be able to develop and adapt to its new grid and renewable resources. However, CCP-run agencies, such as the People's Daily News source as well as the NDRC, have announced that it plans to spend at least $320 billion between 2016 and 2020 in

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[75] Martin Feldstein, "China's Latest Five-Year Plan," November 28, 2015, accessed January 28, 2016, https://www.project-syndicate.org/commentary/china-new-five-year-plan-by-martin-feldstein-2015-11?barrier=true

[76] David Milborrow, "Onshore Wind is More Competitive Than Ever," January 30, 2015, accessed February 14, 2016, http://www.windpowermonthly.com/article/1330525/onshore-wind-competitive-ever

[77] Ernest Partridge, "A Dim View of Libertarianism," January 20, 2015, accessed January 29, 2016, http://gadfly.igc.org/libertarian/3-markets.htm

order to rebuild its grid infrastructure.[78] China has already spent roughly $150 billion on Smart Grid infrastructure and transmission line construction. It's clear that the funding for China's energy reconstruction is sizable and further that, with China's current economic slowdown in 2015 and 2016, there is no margin for production errors.

While China has announced ambitious targets for 15% renewable energy output by 2020 and the entire grid infrastructure to be completed by 2025, the evidence presented regarding internal systemic bottlenecks suggests China will not have a completed energy grid and wind program with full operational capacity until at earliest 2030. China is facing issues in transmission development, grid development, uncontrollable energy consumption levels, and an international reputation that is in serious trouble. To worsen the situation, China's strong consistent economic growth rates have dwindled from between 8% and 12% from 2008 through 2013, to 6.8% in 2014 and 2015. Because the slowdown has been largely caused by both an import-export imbalance and structural uncertainty of China, the energy grid infrastructure will likely see its own curtailment in the first half of 2016. China will need to sacrifice some economic growth regardless in favor of bettering the Chinese people's quality of life. I predict that analysts willing to perform data analysis on China's Smart Grid infrastructure funding would get a reading of China's inherent characteristic bottlenecks, driven by their inability to adapt efficiently.

Perhaps China's largest enemy as of right now is time; the Chinese government and population cannot afford to wait until 2030 for their air pollution to begin to subside, because there are serious health, environmental and social costs for China which worsen year over year. A Bloomberg News study estimated China's air pollution to cost China

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[78] "China Targets $300 billion power grid spend over 2015," September 1, 2015, accessed January 14, 2016, http://www.reuters.com/article/china-power-transmission-idUSL4N1171UP20150901

economically about 7% of their GDP, when taking into account both short term and long term health scenarios.[79] MIT research studies have demonstrated that polluted air significantly raises morbidity and mortality rates. They proved that such rates cause increased medical expenses and greater number of missed work days, leading to decreased productivity.[80] China's polluted air also has indirectly affected China's economy in the attraction of foreign investment for the new Shanghai Free Trade Zone as of 2013. Many businesses would rather not operate in an unclean environment, especially considering that such an environment deters tourism. In 2013, foreign tourism was down 5% across China, as well as 10.5% down specifically for Beijing. It is difficult for foreigners to avoid seeing or hearing about China's smoggy air, as media outlets worldwide love to use it as a poster child for the consequences that fossil fuels have brought to the anthropocene.

Two further effects of air pollution are its depletion of natural resources and buildings. Air pollution causes acid rain, which in turn translates to soil acidification, a reduction in the area of China's arable land, and hence lessened productivity. Further, each year that coal-fired power plants remain as China's largest power source, mercury is emitted by coal combustion into Chinese water systems. This polluted water toxifies the water, and in turn mutates or kills fish, rice, vegetables, and fruits. It also emits pollutants in the air which are deleterious to trees and forests. China's battle with air pollution has become so severe that it has caused building structures to deteriorate, including sacred historical monuments such as the temples of Hangzhou.

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[79] "Why Beijing's Air Has Turned Deadly and How It Can Be Reversed," Bloomberg News, December 10, 2015, http://www.bloomberg.com/news/articles/2015-12-11/why-beijing-s-air-has-turned-deadly-and-how-it-can-be-reversed

[80] Joshua S. Graff Zivin, The Impact of Pollution on Worker Productivity, The National Bureay of Economic Research, April 2011, accessed February 14, 2016, http://www.nber.org/papers/w17004

While China's rise to the world's second largest economy has been almost entirely caused by low-price competitive export based manufacturing industries, their recent economic deceleration has been bad news for the industrial sector. Thousands of industry factories have been driven to operate in the red, and the even greater issue is that most of these factories are state owned. Therefore, China's competitive advantage in manufacturing has been diminished, and now China must begin to transition from an export based economy into an internal consumption based economy. However, while China's population certainly is not lacking, reports by Business Insider indicate that China's move from coal-fired power to renewable energy will cause significant job losses for the Chinese population.

The CCP has announced that it plans to lay off 1.8 million workers in the coal industry.[81] Such job losses are indicative of a future issues though. China's transition out of coal will lead to further job losses in the coal industry, which employs roughly 12 million people. While on one hand a transition into renewables means that renewable jobs will be cultivated, on the other hand there will be an uneducated 12 million blue-collar workers out of jobs. Ultimately, these layoffs need to happen at one point or another, and it is better that China tackles them now as opposed to during a domino effect leading to economic collapse. By acting on this now, China is going against the characteristic I used to describe them and actually constructing from the ground up! In addition, there are actually many labor opportunities that will become available for work on the various smart-grid applications.

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[81] Toni Matthews, "China Layoffs: Why 5 Million People Are Set to Love Their Jobs," Inquisitr News, March 2, 2016, accessed March 5, 2016, http://www.inquisitr.com/2846130/china-layoffs-why-5-million-people-are-set-to-lose-their-jobs/

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Chapter 7: Conclusion

China's transition from a developing country into the world's second largest economy has been nothing short of mesmerizing. While China has reached the forefront of the technology sector, industrial sector, and many others, its successes have not come without detrimental consequence. s. China's opening to the world economy in 1979 announced to the world that China was eager to catch up, and that it could do so by developing manufacturing as the heart of China's transition. By offering cheap labor, and hence cheap exports, China has since served as the world's manufacturing hub. However, the Chinese ignored one crucial matter that has since come to hurt them as a nation: the coal-fired power that powered over 90% of China's high energy supply during that time would release greenhouse gas emissions in the area. Furthermore, the majority of the coal plants that were located in the North would have those emissions blown across the nation by wind.

The decades of greenhouse gases that filled China's area, coupled with rising environmental activism, have deemed China as the world's largest polluter – a reputation which no nation wants. While China has since sought to repair its image by becoming the world's leading nation in wind power, it has failed to disclose the truth behind its renewable successes. This paper has intended to point out that China has deceived the global energy sector by reporting their colossal installed capacity of wind turbines, while hiding the amount of wind turbines that genuinely produce electricity. By doing so, China has essentially worked backwards as they've constructed thousands of wind farms before providing them actual functionality by grid-connection. Moreover, this characteristic of working backwards is not an isolated situation.

China has had major issues with grid integration and curtailment, and has sought to fix those issues by building a Smart Grid. China has focused their Smart Grid on featuring the strongest and most efficient UHV long-distance transmission lines, but in doing so has left their lines with only 20% efficiency. In this circumstance, China again worked backwards by attempting to develop strong transmission lines before developing and strengthening the regional grids that could support such lines. Likewise, in developing Smart AMR meters for every household across the mainland, China installed state-of-the-art meters before designing the back office software that could support such a system. The economic analysis portion of the paper has provided evidence that such errors cost China drastically financially, socially, environmentally, and politically.

This thesis is important because it brings light to China's systemic and characteristic issues which must be addressed before China continues to structure its energy system and wind program. Because this paper did not include data analytics, it would be useful for further study to be conducted on ratio between the actual generation percentage of China's wind turbines to the installed capacity of such turbines. It would also be valuable for additional research to be conducted on true efficiency of China's political system, and as I point out in this paper, what could be modified to increase efficiency so as to minimize costs.