

CHINA'S RENEWABLE AND NUCLEAR ENERGY AGENDA: A GEOPOLITICAL
STRATEGY?

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Executive Summary

This study is a culmination of research performed during the Master of Science in Energy Policy and Climate Program at Johns Hopkins University. Through questioning, research accumulation, aggregation, analytical review, synopsis, and conclusion, this paper represents my expertise and knowledge gained throughout the program.

The country of China has always been a focus of mine. I have studied the language, lived in the country, and have always pondered the economic, environmental, and civic future of the nation. In a condensed amount of time China has been able to have an enormous impact on the world and its own people, from its trade relationship with the United States and other nations throughout the world, to its unsustainable pollution caused by energy production. When entering this program, I employed an insufficient number of the tools necessary to research, analyze, and ultimately predict the consequences of China's current actions both nationally and geopolitically. Throughout the program, those tools were gradually gained. I am now able to identify key concepts that include why China's pollution has increased so drastically over the past decades, how it has, why it will continue, what actions China's government is taking to decrease pollution, whether these actions are also being used to for geopolitical gain in certain regions of the world, and what are the national security risks caused by these actions?

The research performed throughout the Capstone Project and the program has greatly helped my professional career. While I am interested in all energy policy, my current focus is nuclear energy. Whereas before, I would not be able to describe how a nuclear power plant operates, I am now able to understand the materials and operations

necessary to generate that electricity. This is not only with nuclear power, but also with wind and solar energy, coal, oil and gas. I was able to deploy my knowledge of this throughout this paper. Transmission and the grid is another area where my knowledge has greatly improved, as well as the process of regulation and policy that is an integral component to where the electricity is originating from and what power source. Furthermore, I am able to identify weaknesses and strongpoints throughout the nuclear energy sector both in the U.S. and abroad, and how China's recent push to increase its nuclear energy production could be a cause for concern.

The program also brought to light the national security issues caused by climate change and taught me how to identify climate trends, analyze if these trends will manifest into conflict, and where the National Security community needs to focus. The Capstone Project allowed me to combine aspects of the program along with my professional work into one final report. I was able to combine energy production technology with geopolitical aspects, with a pronounced focus on nuclear energy.

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Methods

This study was performed using reports, news articles, peer-reviewed journals, and publications by government agencies. A hypothesis was formed using skills and knowledge gained throughout the Energy Policy and Climate Program. The goal was to gather relevant, pertinent, applicable data to analyze in order to produce an answer to the hypothesis.

Results

China is far outpacing the United States in production of renewable and nuclear energy. This production drive is due to current and future threats China faces from a changing climate. The United States has limited ability to compete with China's growing energy markets. China's nuclear energy production creates a geopolitical threat through its ability to control foreign energy markets.

Introduction

The purpose of this paper is to first identify current threats to China caused by climate change and key trends of China's energy policy. It is then necessary to recognize the types of fuel China consumes for energy production and why those certain fuels are chosen. The cause and effects of this energy production are then researched, which includes a synopsis of the current threats faced by China due to climate change. There will be a focus on specific environmental effects that are currently or will cause national security threats to China. This will be followed by how those threats are leading to

actions by the Chinese government. This paper will investigate the true intentions of those decisions and whether this creates both an economic and national security threat to the United States.

Policymakers throughout the United States and its allied countries should be aware of China's actions. President Xi, the leader of China's Communist Party, has taken a more aggressive international stance than his predecessors. His One Belt One Road Initiative, announced in 2013, aims to strengthen his country economically and politically. The government's energy policy is shifting in ways that will affect industries throughout the U.S. and abroad.

China's population and GDP have been hurt because of the country's unhealthy addiction to coal. Due to China's large population and increasing wealth, it is necessary for China to use alternative sources of energy, which has caused an influx of government spending to its nuclear and renewable energy sectors. New technology has been developed and production has been accelerated because of this added spending, opening the door for China to export its technology and infrastructure. China's state-owned enterprises will continue to produce energy through renewable and nuclear energy production because of its increased energy demand and transportation issues. This production will expand across its borders, threatening national security and U.S. economic interests.

The Current Energy Situation in China

For the past forty years China's economy has grown rapidly, leading to an increase in demand for energy production. Since 1976, China's gross domestic product

(GDP) growth rate has not dipped into negative territory. Furthermore, from 1991 to 2015, the country's GDP growth rate did not fall below 6%.¹ In 2012, 66% China's energy fuel was coal. Followed by oil at 20%, hydroelectric power at 8%, natural gas at 5%, nuclear at 1% and other renewables at 1%.² Because of its dependency on coal, China is the world's leading emitter of carbon dioxide (CO²), causing harm to both the country's environmental and civic health. A study performed by Tsinghua University, the Health Effects Institute, the Institute for Health Metrics and Evaluation (IHME), and the University of British Columbia found that "coal combustion is the single largest source of air pollution-related health impact, contributing to some 366,000 premature deaths in China in 2013"³ Furthermore, the study warned that the health burdens will grow substantially by 2030 if no action is taken to reduce China's coal production.

Faced with this reality, the Chinese government has worked to curb its appetite for energy produced by coal. With a limited supply of domestic oil and gas, the country has increased its development of nuclear and renewable energy production to keep up with its energy demand, and reduce its dependency on foreign markets. In the country's most recent Five-Year Plan, the Chinese government outlined its intention to increase and modernize the country's nuclear energy, solar energy, and wind energy production. The modernization of nuclear reactors has led China into new energy markets of exporting nuclear reactors and solar panels to other countries. China has seemed to realize the potential for both economic and national security gains, and is working to increase its

¹ "GDP Growth (annual %)," *The World Bank*, June 17, 2017. <http://data.worldbank.org>.

² "China: International energy data and analysis," *U.S. Energy Information Administration*, May 14, 2015. <https://www.eia.gov>.

³ "Burden of Disease Attributable to Coal-Burning and Other Air Pollution Sources in China," *Health Effects Institute*, August 20, 2016. <https://www.healtheffects.org>.

nuclear energy technology exports as well as solar power exports. China's need to reduce its dependency on coal, combined with its limited supply of oil and gas, has led the country to focus on renewable and nuclear energy production and development.

China's Current Environmental Issues

Climate change caused by anthropogenic greenhouse gas emissions is altering systems that humans have relied on for stability, prosperity, and ultimately survival for generations. According to a report by the Intergovernmental Panel on Climate Change “warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to a millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen.”⁴ China, the country with the world's largest population of 1.4 billion, is especially vulnerable to systematic changes caused by a warming climate.⁵ The country's large population creates added pressure to the state and its people. This pressure has particular ability to cause damage to China's food production, and water security. Additionally, rising sea levels threaten China's eastern coastal cities, where the majority of its population is located and also where its main economic centers are found. Below is an examination of how increasing global temperatures threaten the stability of China's agricultural, economic and social systems.

⁴ IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 2 pp.

⁵ The United Nations, 'World Population Prospects: The 2017 Revision'. <https://www.un.org> November 25, 2017.

How Global Warming Will Affect China's Agricultural Sector and Food Security

China supplies large amounts of food to its citizens. It is a major producer of crops such as corn, wheat, grains and rice. Since the majority of the crops produced go to its citizens, significant alterations to this sector would be harmful to China's food security. For example, the U.S. Department of Agriculture estimated that China produced 145.77 million metric tons (MMT) of rice from 2015-2016.⁶ Of that total number 141.35 MMT is consumed domestically and only .27 MMT is exported to other countries.⁷ Similar ratios are found when reviewing China's wheat and corn production, consumption, and exports. Threats to these food sources has the ability to cause national security implications through resource scarcity, migration, and social unrest.

Consequences of climate change, including an increase in global temperatures, changes in rainfall patterns, and desertification, will affect China's agriculture sector in the future. According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)'s *Climate Change 2014: Impacts, Adaptation, and Vulnerability*, a projection "suggests that there will be insufficient water for agriculture in the 2020s and 2040s due to increases in water demand for non-agricultural uses...⁸ Electricity production has a high potential to consume water resources in China. While warming temperatures have the ability to prolong the growing season for crops such as wheat, rice, and grains, excessive heat will cause greater harm to food production.

⁶ 'World Agricultural Supply and Demand Estimates', United States Department of Agriculture, WASDE 571 19-25, November 2017, <https://www.usda.gov/oce/commodity/wasde/latest.pdf>, accessed November 26, 2017.

⁷ 'World Agricultural Supply and Demand Estimates', United States Department of Agriculture, WASDE 571 24, November 2017, <https://www.usda.gov/oce/commodity/wasde/latest.pdf>, accessed November 26, 2017

⁸ IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. 1338 pp.

A study included in the IPCC 2014 report concluded that "in terms of risks of increasing heat stress, there are parts of Asia where current temperatures are already approaching critical levels during the susceptible states of the rice plant."⁹ China is included as a susceptible area in Asia, which should be a cause of concern for the country. Rice shortages will increase the price of one of the most heavily consumed foods in Asia. This will most likely cause civil unrest in rural or poorer areas, where food scarcity will become a threat to the population's livelihoods. A rice shortage could also cause migration from areas with harder access to food, to areas where it is easier to access, such as cities. As we've seen before with situations such as Syria, when populations move to the cities, there is a higher probability of riots and upheaval because of increased communication the ability to more easily mobilize larger amounts of the population. The tendency of food scarcity to cause civil unrest should incentivize China to implement policies such as food aid in order to avoid the type of conflict that occurred in Syria.

Demand for Water and The Tibetan Plateau

Global warming has the potential to harm the water resources and ecosystems of China and its neighboring countries by negatively affecting the Tibetan Plateau. As its name suggests, the majority of the Tibetan Plateau is located across Tibet, which China claims sovereignty over, but the plateau also covers parts of India, western China, Nepal, Bhutan, Pakistan, and Afghanistan.¹⁰ The Tibetan Plateau has been known as the "Third Pole" because the amount of frozen fresh water located there is only surpassed by the

⁹ IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. 1344 pp.

¹⁰ Pramod Lamsal, Lalit Kumar, Farzin Shabani, Kishor Atreya, " The greening of the Himalayas and Tibetan Plateau under climate change," *ScienceDirect*. (2017): 79.

Arctic and Antarctica. The Tibetan Plateau "supplies water to nearly 2 billion people in Asia as the source of several major rivers, including the Yangze, Mekong, Salween, Indus, Brahmaputra and Yellow Rivers." ¹¹ Any changes to water distribution or flow would be damaging to the stability of these areas. With so many people dependent on the water stored in these glaciers, tension will increase significantly if this resource is threatened.

Two methods of altering river flows are depletion of the water sources and dams that are built in order to divert water to a certain area. The melting of the region's glaciers threatens the livelihoods of everyone who depends on the rivers that are sourced from the region. The Intergovernmental Panel on Climate Change predicts that annual temperatures will continue to rise in the region. ¹² Additionally, there have been news reports stating that the plateau's temperature has already increased by 1.3C. ¹³ This has led to China's glaciers retreating by about 7,600 square meters since the 1950s, equating to around 18%. Furthermore, an average of 247 square kilometers of glacial ice has been estimated as disappearing every year. ¹⁴ Short-term, it would be advisable for China to prepare for flooding of rivers that are sourced by these glaciers, as the increased melting will release more water. However, China and the other nations whose citizens rely on river tributaries must prepare for water shortages.

¹¹ Yeshi Dorje. "Researchers: Tibetan Glacial Melt Threatens Billions." Voice of America [Asia]. November 28, 2015. Web 27 Nov. 2017

¹² IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1370-1371 pp

¹³ Yeshi Dorje. "Researchers: Tibetan Glacial Melt Threatens Billions."

¹⁴ Chinese Academy of Sciences. http://english.cas.cn/newsroom/china_research/201504/t20150423_146594.shtml. April 23, 2015. Accessed on November 27, 2017

Increasing global temperatures are expected to intensify dryness in regions throughout China that are already arid. For years, China's deserts have been spreading at an annual rate of more than 1,300 square miles.¹⁵ Among the causes of the spread are increased temperatures, overgrazing by herded animals, and deforestation. It is estimated that nearly 20% of China is desert, encompassing areas across the country's northern and northwest regions.¹⁶ In order to bring freshwater to these areas, China will use the "Water Towers of Asia" located on the Tibetan Plateau as resources.¹⁷ China will also use these water resources for hydropower production and the country is building dams at an accelerated pace. Currently, China has 7 dams completed in the upper basin of the Mekong River and 20 more are either being built or planned.¹⁸ The river is a source of livelihood for 60 million people living in the 6 countries through which the river flows. China, Myanmar, Laos, Thailand, Cambodia, and Vietnam all have populations who depend on the river and its tributaries for its ecosystems, local economies, and fisheries.¹⁹ These livelihoods are threatened by China's dams that have the potential to divert the flow of water to its own territories. Tensions between countries or mass migration should be a cause for concern for China, and its recent push for renewable energy implies that it is.

¹⁵ Josh Haner, Edward Wong, Derek Watkins, and Jeremy White. "Living in China's Expanding Deserts," *New York Times*, October 24, 2016. https://www.nytimes.com/interactive/2016/10/24/world/asia/living-in-chinas-expanding-deserts.html?_r=0

¹⁶ Josh Haner, Edward Wong, Derek Watkins, and Jeremy White. "Living in China's Expanding Deserts."

¹⁷ Daniel Rechtschaffen. "China's Huge Dam Projects Will Threaten Southeast Asia As Water Scarcity Builds Downstream." *Forbes*. May 3, 2017 <https://www.forbes.com>

¹⁸ Daniel Rechtschaffen. "China's Huge Dam Projects Will Threaten Southeast Asia As Water Scarcity Builds Downstream"

¹⁹ Daniel Rechtschaffen. "China's Huge Dam Projects Will Threaten Southeast Asia As Water Scarcity Builds Downstream."

Sea Level Rise Threatens China's Coastal Cities

China's current population of 1.4 billion people is the largest of any country in the world. Furthermore, a large percentage of China's population resides in its eastern coastal provinces which are the country's economic hubs. Fourteen of China's administrative units are located along its mainland coast with their lands occupying 16.8% of China's total land mass but is where 41.9% of its population lives.²⁰ Any flooding due to sea level rise in this area would be harmful for the livelihood of those citizens living in the area, and would produce high economic and infrastructure costs. A study published by Climate Central titled *Mapping Choices: Carbon, Climate, and Rising Seas - Our Global Legacy* argues that China has the most to lose from a warming climate of 4 degrees Celsius, as 145 million of its citizens live on land threatened by sea level rise.²¹

China's population would not only be affected by a rising sea level. China's GDP would be negatively affected because a "1 meter rise in sea level would submerge an area the size of Portugal along China's eastern seaboard; the majority of Shanghai - China's largest city - is less than 2 meters above sea level. China's twelve coastal provinces...contribute 73 percent of its GDP.²² Any flooding to this region would cause significant harm to China's people, infrastructure, and economy.

As the previous scenarios illustrated, a warming climate will affect China in many ways and is on a trajectory to cause harmful changes to China's agriculture, economic and

²⁰ Fan Daidu and Li Congxian, 'Complexities of China's coast in response to climate change', *Advances in Climate Change Research 2*, 2006, pp.54-58.

²¹ Strauss, B. H., Kulp, S. and Levermann, A. 2015. Mapping Choices: Carbon, Climate, and Rising Seas, Our Global Legacy. Climate Central Research Report. pp. 1-38.

²² Lewis, Joanna I. *Climate change and security: examining China's challenges in a warming world*. International Affairs. 2009.

social systems. China's government must begin work now on mitigating the negative impacts of a warming climate. Particular focus must be made to China's agricultural sector, water resources, and rising sea levels that threaten the country's heavily populated coastal cities. The warming climate will offer many challenges for China in the future. However, it is evident that the Chinese government is working to identify its most vulnerable areas and institute plans to mitigate potential damage, most notably described in the communist party's recently submitted Intended Nationally Determined Contributions and its most recent Five Year Plan.

A Look Ahead: China's Submitted INDC and Most Recent Five-Year Plan

In 2015, China submitted its Intended Nationally Determined Contributions (INDC) for enhanced actions on climate change to the Secretariat of the United Nations Framework Convention on Climate Change. In its INDC, the Chinese government made clear that the country is working to curb its carbon dioxide emissions significantly. Specifically, goals outlined in the INDC include: 1) achieving the "peaking of carbon dioxide emissions around 2030 and making best efforts to peak early;" 2) lowering CO² emissions "per unit of GDP by 60%-65% from the 2005 level;" and 3) increasing the "share of non-fossil fuels in primary energy consumption to around 20%."²³ China can meet its goal of lowering its CO² emissions by cutting back the country's energy production of coal. Additionally, China's goal of increasing its share of non-fossil fuels in its primary energy consumption creates an incentive for the country to invest in renewable and nuclear energy.

²³ "Full Text: Enhanced Actions on Climate Change: China's Intended Nationally Determined Contributions." *Xinhuanet*. June 30, 2015. <http://www.news.xinhuanet.com>.

Reducing energy production through coal coincides with China's plan to increase its renewable energy sources and consumption described in the INDC. Included in the INDC is the plan to scale up its development of nuclear power in a "safe and efficient manner," and also to accelerate wind, solar, and geothermal power development.²⁴ Specific goals include achieving "the installed capacity of wind power reaching 200 gigawatts, the installed capacity of solar power reaching around 100 gigawatts and the utilization of thermal energy reaching 50 million tons coal equivalent by 2020."²⁵ This report demonstrates China's efforts to increase its renewable power production in order to reduce its dependency on coal.

China also offers transparency of its energy production and consumption goals in its most recent Five-Year Plan. The Chinese government publishes these plans in order to outline its economic and social development initiatives. China's 13th Five-Year Plan (2016-2020) lists both renewable energy and nuclear power under the country's Energy Development Projects. Listed under this section are plans to "coordinate the development of end-use markets and power transmission routes; take ordered steps to optimize the development of wind energy and photovoltaic energy in northern, northeastern, and northwestern regions and in coastal areas; accelerate the development of dispersed wind power and distributed photovoltaic power in central, eastern, and southern regions; carry out solar thermal energy demonstration projects."²⁶ Furthermore, listed under the 13th Five Year Plan's Key Technology and Equipment objectives are offshore wind energy,

²⁴ "Full Text: Enhanced Actions on Climate Change: China's Intended Nationally Determined Contributions." *Xinhuanet*. June 30, 2015. <http://www.news.xinhuanet.com>.

²⁵ "Full Text: Enhanced Actions on Climate Change: China's Intended Nationally Determined Contributions." *Xinhuanet*. June 30, 2015. <http://www.news.xinhuanet.com>.

²⁶ "The 13th Five-Year Plan For Economic and Social Development of the People's Republic of China 2016-2020." November 5, 2015. <http://www.en.ndrc.gov.cn>

solar thermal power generation, and notably to “make breakthroughs in the manufacturing of and applied technologies for key components and materials such as high-power electric and electronic equipment and high-temperature superconductors.”²⁷ China’s increased manufacturing and technology of both renewable and nuclear energy materials will be discussed later in the report. However, China’s push for increased renewable energy is clearly shown in this Five Year Plan.

The Plan also clarifies China’s nuclear energy production strategy. For development, China lists the completion of the Sanmen and Haiyang AP1000 projects as one of its goals. Additionally, the Five-Year Plan's Energy Development Projects includes plans to "develop demonstration projects for Hualong-1 nuclear technology" in two of its cities, and begin construction on the CAP1400 demonstration project, and also on a "number of coastal nuclear power plants." Furthermore, the Plan includes working on inland nuclear power plant projects, accelerating feasibility studies and large commercial reprocessing plant development, increasing nuclear power plants installed capacity to 58 gigawatts, and strengthening systems that ensure nuclear fuel.²⁸ The nuclear power projects will be outlined later in this report.

The 13th Five-Year Plan offers clarity into the Chinese government's goals of nuclear power production. Other objectives included in the plan are to increase China's scale of natural uranium reserves, most likely by diverting more government resources to exploratory missions, and also to accelerate research and development of Generation IV

²⁷ "The 13th Five-Year Plan For Economic and Social Development of the People's Republic of China 2016-2020." November 5, 2015. <http://www.en.ndrc.gov.cn>

²⁸ "The 13th Five-Year Plan For Economic and Social Development of the People's Republic of China 2016-2020." November 5, 2015. <http://www.en.ndrc.gov.cn>

nuclear energy, and improve the capacity to manufacture Generation III nuclear power reactors.²⁹ It is clear that China is working to reduce its CO² emissions and diversify its energy production sector through the development of its nuclear energy industry.

China's Production of Coal and Its GDP

China's Intended Nationally Determined Contributions and 13th Five Year Plan portrays the country's efforts to reduce pollution and slow the impacts of climate change. A source of these shifts in both state funding and collective conscious of the Chinese Communist Party is likely the effect of coal production on the country's GDP. China is a country rich in coal reserves, but the large amount of coal consumption has led to detrimental effects on both the country's population and GDP. As stated previously, China's use of coal for energy production led to 366,000 premature deaths in 2013, and this number is only expected to rise if no action is taken to reduce the country's use of coal. Coal consumption has a detrimental effect on the country's GDP as well. According to a study performed by the RAND Corporation, health impacts and a loss of labor production due to coal cost China 6.5% of its GDP each year between 2000 and 2010. If that figure is applied to China's 2012 GDP of \$8,227 billion, the RAND Corporation estimates that reducing China's air pollution to levels deemed acceptable by the World Health Organization (WHO) would give China the annual benefit of \$535 billion.³⁰ In order to reach WHO's level of acceptable pollution the authors recommend

²⁹ "The 13th Five-Year Plan For Economic and Social Development of the People's Republic of China 2016-2020." November 5, 2015. <http://www.en.ndrc.gov.cn>

³⁰ Keith Crane, Zhimin Mao. *Costs of Selected Policies to Address Air Pollution in China* (Santa Monica: Rand Corporation, 2015), 3.

substituting natural gas or propane for coal for both commercial and residential use, and also to replace coal with nuclear and renewable fuels in order to generate electricity.

The Geography of Coal Production Versus Consumption

The transportation of coal provides another issue for China. The majority of China's coal mines are located in the western part of the country. However, most of the energy demand is located in the more populated eastern cities. The U.S. Central Intelligence Agency (CIA) states that an "overwhelming majority of the population is found in the eastern half of the country; the west, with its vast mountainous and desert areas, remains sparsely populated."³¹ However, the western mountainous region of the country, located far from China's industrial centers and coastal regions which are highly populated, are where approximately 80% of China's coal resources are located.³² China's Shaanxi, Shanxi and Inner Mongolia provinces contribute more than 50% of China's total coal output and are the three largest coal-producing provinces. However, China's cities of Shanghai, Zhejiang, Guangdong, and Fujian consume the majority of energy produced from coal.³³ Please see Figure 1 at the end of this report for a map of China. Therefore, China's coal consumption is heavily dependent on the country's railways and issues arise when access to these routes is impeded by weather, technological issues, or congestion. China would benefit from diversifying its energy production capacity through both technology and geography.

³¹ "The World Factbook." *Central Intelligence Agency*. June 15, 2017. <https://www.cia.gov>.

³² Yun Zhou. *Why is China Going Nuclear?* (2010): 3,756-3,757

³³ Zhou, p. 3,757

China's Natural Gas Production

Due to the previously examined issue with coal production and consumption in China, the country is working to diversify its energy sector. In 2015, natural gas accounted for 5% of China's total energy consumption.³⁴ Natural gas is a cleaner energy source when compared to coal, and faced with pollution issues, the country has focused more resources for prospecting natural gas reserves. Due to government funding, the cost to drill a shale gas well in China's Sichuan basin has dropped from just over \$14 million in 2013 to just under \$11 million in 2015. In June 2016, China's Ministry of Land and Resources announced that the country's natural gas reserves increased by 42% since 2007. The ministry estimates that China has 90 trillion cubic meters of natural gas, of which 50 trillion can be extracted and used for energy.³⁵ While this is positive news for China's domestic energy production, natural gas faces hurdles in China's energy market and one hurdle is the cost of fuel. Fuel costs account for 60% of the total generating costs for liquefied natural gas plants, meaning that LNG power generation is very sensitive to gas prices. This creates instability in the market and leads to increased prices.³⁶ This could facilitate the need for additional subsidies in order for the sector to compete with coal-fired plants.

Another issue attributing to the high cost of natural gas is that China purchases a portion the energy fuel internationally. This means that China does not control the cost of natural gas and typically pays a higher price for the resource when compared to what it

³⁴ "China: International energy data and analysis," *U.S. Energy Information Administration*, May 14, 2015. <https://www.eia.gov>.

³⁵ "China's potential oil, natural gas reserves rise: official data." *China Daily*. June 14, 2016. <https://www.chinadaily.com.cn>

³⁶ Zhou, p. 3,758

would cost to produce domestically. It also creates a national security threat if those imports are threatened through sanctions or hostility. China is heavily dependent on the South China Sea for its key shipping routes, but the area is currently heavily disputed. China argues for territory using its “nine-dash line” map, which originated decades ago and is the source of China’s sovereign claim to the region. The claim has been rejected by the United Nation’s Convention Law of the Sea and by surrounding nations, but tensions are still high. Any conflict in the region could drastically affect the price of natural gas imports for China, creating an unstable economic situation. Another challenge of China’s natural gas production is, similar to coal, the majority of its natural gas reserves are found in the western part of the country. This raises the issue of transportation infrastructure. China’s LNG production can help the country meet its increased energy demand. However, there are still many hurdles for the industry which China must face.

China’s Renewable Energy Development

The issue of insufficient long-distance transmission occurs throughout China’s renewable energy system as well. China is looking to develop power transmission routes and to also take steps to optimize development of solar and wind power in the country’s central, southern, and eastern regions.³⁷ In 2012, energy consumed in China that was produce by renewable energy was only 1%.³⁸ China’s stated goal is to produce at least 15% of energy from renewable sources by 2020. To achieve this goal, the government

³⁷ "The 13th Five-Year Plan For Economic and Social Development of the People's Republic of China 2016-2020." November 5, 2015. <http://www.en.ndrc.gov.cn>

³⁸ "China: International energy data and analysis," *U.S. Energy Information Administration*, May 14, 2015. <https://www.eia.gov>.

invested \$89 billion in renewable energy projects in 2014.³⁹ This is a 31% increase from 2013 and the country is expected to continue its contribution to the renewable energy sector in order to meet its 2020 goal. The growth of transmission systems has not kept pace with the increase of production and investment in renewable energy however, and more investment must be made.

China has also increased its hydroelectric power production, but large-scale domestic dam projects such as the Three Gorges Dam caused large population displacement and harmed historical and cultural resources. As mentioned previously, dams have the ability to create a great source of tension both domestically and internationally. In this case, the dam construction changed the flow of the Chang Jiang River, and this affected local water quality, climate, and increased biodiversity loss. Additionally, between 1.2 and 1.9 million people were forced to leave their homes as a direct cause of the dam's development.⁴⁰ China would benefit by investing in renewable energy in order to avoid these social and economic problems caused by hydroelectric power. There is no doubt that China is working to increase its supply of renewable energy sources in order to meet its climate and environment goals. China is aiming for a cleaner environment, and both renewable energy and nuclear energy can help the country meet its goals.

³⁹ "China: International energy data and analysis," *U.S. Energy Information Administration*, May 14, 2015. <https://www.eia.gov>.

⁴⁰ Zhou, p. 3,759

Nuclear Power Technology

Fuel from nuclear power is derived from two types of uranium, U-238 and U-235. The two different numbers represent the number of neutrons found in the chemical element. U-238 and U-235 have the same number of protons in each atom, 92, but the nucleus of the U-235 atom contains 143 neutrons, while the nucleus of the U-238 atom contains 146. When the number of neutrons and protons are combined, this equals the atomic mass, hence U-238 and U-235.⁴¹ Uranium found in nature contains the U-235 isotope 0.7% of the time and the other 99.3% is mostly the U-238. Nuclear fuel requires a higher concentration of the U-235 isotope than what exists in nature. When the U-235 is enriched, this means that the isotope is being concentrated, which allows for fission. Fission occurs when a nucleus of an atom splits, producing heat, and also additional neutrons that cause nearby atoms to fission, allowing a nuclear reaction to occur.⁴² The uranium fuel creating the nuclear reaction is contained in ceramic pellets that are packaged into vertical tubes. These tubes are inserted into the reactor, which is constantly produce heat. The heat that is released during the process either boils or pressurizes water to create steam, which turns a turbine to produce electricity.

Uranium must undergo an enrichment process so that it can be used to produce electricity. The enrichment process requires the uranium to be in a gaseous state at a low temperature. In general, uranium oxide, which is mined from the ground, is converted to uranium hexafluoride (UF₆) so that it can be enriched. UF₆ is favorable because the fluorine only has one isotope, so it doesn't affect the atom's weight. Additionally, UF₆

⁴¹ "Uranium Enrichment," *World Nuclear Association*, May 2017. <https://www.world-nuclear.org>.

⁴² "Uranium Enrichment," *United States Nuclear Regulatory Commission*, March 2, 2017. <https://www.nrc.gov>

exists in a gaseous state, which is necessary for enrichment. This conversion process generally occurs at a separate enrichment plant before the uranium is used for nuclear power production.⁴³

China's Nuclear Power Production and Technology

China is becoming increasingly independent in its ability to produce nuclear power. Currently, the country has 36 nuclear power reactors in operation and 21 under construction. More are planned to be built, and China is looking to modernize its nuclear reactor technology.⁴⁴ As noted before, China's most recent Five-Year Plan (2016-2020) includes the development goal of the Sanmen and Haiyan AP1000 projects. The AP1000 is a nuclear reactor designed by the Westinghouse Electric Company. The updated technology is an improvement on established methods including steam generators, digital instrumentation and controls, fuel, pressurizers, and reactor vessels.⁴⁵ Additionally, the new plants are simplified and require less material to function. These features are meant to accelerate construction time of the plants and save money. The AP1000 is an example of a Generation III type reactor included in China's Five-Year Plan. Hualong-1 is another example of this reactor and in May 2017, China successfully completed construction of the Hualong-1 reactor.⁴⁶ The completion of this project signifies another step towards China meeting its nuclear power production goals.

China's increased focus on nuclear energy technology has allowed the country to gain more control throughout the nuclear energy industry. China's government structure

⁴³ "Uranium Enrichment," *World Nuclear Association*, May 2017. <https://www.world-nuclear.org>.

⁴⁴ "Nuclear Power in China," *World Nuclear Association*, May 25, 2017. <https://www.world-nuclear.org>

⁴⁵ "AP1000 Pressurized Water Reactor," *Westinghouse Nuclear*, 2017. <https://westinghousenuclear.com>

⁴⁶ "China Completes Construction of First Hualong One Nuclear Project." *Xinhuanet*. May 25, 2017. <https://www.xinhuanet.com>

is beneficial to nuclear energy development "through its ownership of the companies and its ability to marshal all aspects of the economy especially the financial sector to support its industries." ⁴⁷ This gives China an advantage over nuclear energy companies located in other countries such as the United States, Japan and France. Competitors in those countries, Areva and Toshiba/Westinghouse faced significant financial issues which has created space for China to enter foreign markets. ⁴⁸ The U.S. nuclear energy is in atrophy and unless government subsidies and market mechanics are used, the industry will continue to decline. Japan's nuclear power industry was hit especially hard by the Fukushima Daiichi disaster and it has yet to recover.

China can use this opportunity to become a leading exporter of nuclear energy technology and infrastructure. A developed economy is showing its willingness to allow China to participate in its nuclear energy development. In the fall of 2016, the United Kingdom's (U.K.) government approved a deal that allowed China General Nuclear Power Group to take a financial stake (33.5%) in a deal to build a nuclear power plant at Hinkley Point in the U.K. The rest will be funded by a French company, Électricité de France.

Additionally, China is hoping to build another nuclear power plant in the U.K. and would own 66.5% of the project.⁴⁹ Allowing foreign governments to control a portion of a country's energy sector could signal a national security threat if relations between the two countries turn negative. A spokesperson for the U.K.'s Department of Business illustrated this issue by stating that the government will take steps to "ensure

⁴⁷ Steve Thomas. *China's Nuclear Export Drive: Trojan Horse or Marshall Plan* (2016): 683

⁴⁸ Thomas, p. 686.

⁴⁹ "China Will Own Part of the New U.K. Nuclear Power Plant." *CNN*. September 15, 2016. <https://www.money.cnn.com>

that the significant stakes cannot be sold without the government's knowledge or consent" and that "there will be reforms to the government's approach to the ownership and control of critical infrastructure..."⁵⁰ These steps highlight the national security concerns that arise when a foreign government controls a portion of a government's energy infrastructure.

China has been signing contracts to build reactors in other countries as well. Argentina has made several agreements with China that allow China some form of control over Argentina's nuclear power sector. Specifically, under the terms of development for a nuclear power plant called Atucha, the Chinese government would transfer its technology to Argentina, which in turn would supply "third countries with nuclear technology incorporating Chinese goods and services."⁵¹ China gains an aspect of control over Argentina's and possibly other countries' energy technology in this scenario, which would give China leverage if a national security dispute ever arose.

Most recently, China announced in June 2017 that it is poised to launch its version of a small modular reactor (SMR). SMR's are small scale reactors that can be used on ships and in isolated regions.⁵² This technology could increase China's international authority in two ways. First, China will have the technology to power areas in the disputed South China Sea region. If China provides power to that area, they will have more authority to claim the territory as their own and increase tension with other nations who rely on resources in that area, including the Philippines, Thailand, Indonesia, and Vietnam. Second, the small scale of the reactor will allow the technology to be

⁵⁰ "Hinkley Point: UK Approves Nuclear Plant Deal." *BBC*. September 15, 2016. <https://www.bbc.com>

⁵¹ "Nuclear Power in Argentina," *World Nuclear Association*. May 22, 2017 <https://www.world-nuclear.org>

⁵² "Analysis - Enter the Nimble Dragon: China Looks to Small Reactors for Nuclear Edge," *Reuters*. June 14, 2017 <https://www.reuters.com>

exported more easily. This could lead to agreements with additional countries and give China a form of control over other countries' energy markets.

Solar Power Technology

A Photovoltaic (PV) cell works when solar radiation on a PV cell creates a current and ultimately power. The sun's light energy hits the solar cell, causing electrons to be knocked loose from atoms in a semiconductor material. The power generated by the device is equal to the net number of freed electrons per second and their energy.⁵³ This energy needs to exit the cell and follow an electrical circuit to do useful work. Therefore, a PV silicon cell needs an electric field to carry electrons away from holes so they don't recombine. The electric field is generated by a voltage difference found in the crystal. This is done through a p-n junction, which is created by inserting the silicon with impurities.⁵⁴ This enables the chemical energy of the band gap energy to be converted to electrical energy.

China's Solar Power Production and Technology

As noted previously, China's government has instituted goals that aim to increase China's solar power production. As early as 2008, the country had created the six biggest solar companies in the world, with a combined value of \$15 billion.⁵⁵ China's production is far outpacing the U.S. From 2015 to 2016, China's PV market grew from 15.2 GW to 34.45 GW for a total capacity of 78 GW. By comparison, the U.S. market grew from 7.3

⁵³ "How Do Solar Panels Work," *LiveScience*. December 6, 2017 <https://www.livescience.com/41995-how-do-solar-panels-work.html>

⁵⁴ "How Do Solar Panels Work," *LiveScience*. December 6, 2017 <https://www.livescience.com/41995-how-do-solar-panels-work.html>

⁵⁵ "China Pioneers Renewable Energy," *People's Daily Online*. September 9, 2008. <http://en.people.cn/90001/90780/91344/6496247.html>

GW to 14.7 GW and has a total capacity of 47.1. ^{56 57} This outpacing has caused tension between U.S. and Chinese manufacturers. China's lower cost materials were being imported into the U.S. and harming domestic solar panel manufacturers. In September, the International Trade Commission voted to "uphold a complaint brought by two domestic solar manufacturers that complained that the low-cost imports had damaged their businesses." ⁵⁸ While beneficial to U.S. solar manufacturers, it is expected to harm the United States' ability to keep pace with its current PV levels, ultimately paving the way for China's power over the industry to grow throughout world markets.

Wind Power Technology

The modern horizontal axis wind turbine faces into the wind. The Yaw mechanism points the nacelle and wind turbine blades into the wind. Kinetic energy is extracted from the wind, causing the turbines to rotate and sending energy to a generator. The wind then slows and expands because it has lost some of its energy.⁵⁹ The process converts a significant fraction of the wind's kinetic energy to work, but no more than 59% due to the Betz limit. ⁶⁰ There are two types of wind turbines, the horizontal axis and the vertical axis. The horizontal wind turbines typically have 2-3 blades that face into the wind. Wind turbines are getting bigger because it enables the turbines to access faster wind speeds which occurs at higher elevations from the Earth's surface due to less

⁵⁶ The International Energy Agency. "2016: Snapshot of Global Photovoltaic Markets." 2016. http://www.iea-pvps.org/fileadmin/dam/public/report/statistics/IEA-PVPS_-_A_Snapshot_of_Global_PV_-_1992-2016__1_.pdf

⁵⁷ "U.S. Solar Market Insight," *Solar Energy Industries Association*. <https://www.seia.org/us-solar-market-insight>

⁵⁸ Wolf, Eric. "Trade decision could devastate U.S. solar market." *Politico*. September 22, 2017. <https://www.politico.com/story/2017/09/22/solar-tariff-trump-china-trade-243021>

⁵⁹ "How Do Wind Turbines Work," *The U.S. Department of Energy*. <https://energy.gov/eere/wind/how-do-wind-turbines-work>

⁶⁰ "The Betz Limit," *Wind Power Program*. <http://www.wind-power-program.com/betz.htm>

surface friction. Additionally, the density of the air decreases as the elevation increases and therefore the velocity of the air can be higher. Furthermore, air moves from high pressure to low pressure, which creates wind. Pressure varies more at higher elevations, creating faster wind speeds.

China's Wind Power Industry

China's wind power capacity has grown significantly since initial demonstrations began in the late 1980s. From 2002 to 2010, China's accumulative capacity for wind power grew from .44 GW to 31 GW.⁶¹ Furthermore, in 2016 China installed 23.4 GW of new capacity, while the U.S. only installed 8.2 GW.⁶² In 2016, China had a cumulative installed wind capacity of 168,731 MW compared to the U.S.'s 82,143 MW.⁶³ This growth and accumulation can be attributed to the government's push for development and its economic support throughout China. The U.S. wind power industry received monetary assistance through the Production Tax Credit, but China still possess the ability and tools to overcome the U.S. wind power industry.

The Future of the United States' and China's Renewable Energy Sectors

It is evident from this analysis that both the United States and China are working to increase their renewable energy industries. Much of the same motivations act as drivers for these actions, including pollution reduction, resource mitigation, and added

⁶¹ The International Energy Agency. "China Wind Energy Development Roadmap," 2011. https://www.iea.org/publications/freepublications/publication/china_wind.pdf

⁶² Frangoul, Anmar. "China and US lead way with wind power installations, says global energy report." *CNBC*. February 13, 2017. <https://www.cnbc.com/2017/02/13/china-and-us-lead-way-with-wind-power-installations-says-global-energy-report.html>

⁶³ The International Energy Agency. "IEA Wind Technology Collaboration Programme, 2016 Annual Report," 2016. <https://community.ieawind.org/publications/ar>

reliance on domestic energy sources. However, there is a staunch difference between the two countries and that is the governments which are in control. The United States' democratic government and capitalist economy create uncertainty for the renewable and nuclear energy industries. The political system guarantees that no same person will remain in control for more than 8 years. Barack Obama's administration focused great efforts towards reducing energy through coal production, and increasing the renewable energy sector. Now, with Donald Trump as president, much of those economic resources have been diverted away from renewable energy.

China, on the other hand, is ruled by a one-party system, whose leaders are allowed more longevity in office. The government also has the power to divert monetary resources to wherever it deems necessary, giving its renewable and nuclear energy sectors a clear advantage over the United States. China will continue to outpace the United States in renewable and nuclear energy production until its government decides not to.

Conclusion

China's domestic threats from climate change have motivated the country's government to act. China's 13th Five-Year Plan publicizes the country's effort to diversify its energy markets. The need to diversify is derived from China's rapid economic growth, causing an increase in energy demand. The pollution caused by this energy demand has detrimental effects on China's population and environment. Therefore, China has increased investments in nuclear energy, renewable energy sources, and oil and gas. The increased investment in China's nuclear and renewable energy development has

modernized the sectors and enhanced the country's capability to export their technology and resources. The United States has limited ability to compete with China's growing energy markets and China's nuclear energy production creates a geopolitical threat through its ability to control foreign energy markets.

Figure 1: China's Administrative Divisions



Source: cia.gov

Curriculum Vita

Alison Ashburn currently works as a policy analyst and program manager at the Howard Baker Forum. The Forum was founded by former Senator Howard Baker in Washington, D.C. in order to provide a platform for examining specific, immediate, critical issues affecting the nation's progress at home and its relations abroad. Previously, Alison worked as a policy analyst at a broker dealer in Washington, D.C. She graduated from the University of Vermont in 2009 with a BA in history.