



VERMONT LAW SCHOOL

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China's Green Glow:

Gambling on Nuclear Power to

Effectively and Efficiently Reduce Climate-Changing Emissions

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### Abstract

China is expected to suffer greatly the consequences of climate change if it is not checked in some way, and that has given the government cause to reassess its energy portfolio to be less dependent on energy sources—namely coal—that contribute to climate change. As part of this effort, the Chinese government is making an unprecedented investment in nuclear power, making it a cornerstone of its climate change policy. While nuclear power has attractive qualities, there are difficult problems that China must address as it moves forward with its investment in nuclear power. This paper will look at those positive and negative qualities related to nuclear power, compare them with competing alternative energy sources, and discuss how China's massive investment in nuclear power will be successful depending on slow technological development for alternative energy technologies.



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## I. Introduction

In June 2009, the Chinese government's National Energy Administration announced that it would strive to have five percent of China's power capacity generated by nuclear power by 2020 and 16 percent by 2030.<sup>1</sup> In order to reach that the five percent goal, China is aiming to achieve a nuclear power generating capacity of 70 gigawatts, nearly a seven-fold increase from current capacity.<sup>2</sup> More than 32 new nuclear reactors are being planned or beginning construction as part of this momentous effort to curb China's climate-changing emissions.<sup>3</sup> This will represent an unprecedented investment in nuclear power, the largest targeted increase in reactor capacity for a ten-year period.

China is investing in nuclear power as part of an effort to diversify its energy portfolio, to gain greater energy independence, and respond to climate change.<sup>4</sup> China depends on coal for most of its energy, approximately seventy percent.<sup>5</sup> Other energy sources such as natural gas, oil, nuclear power, and renewable energy sources fall far behind coal in powering China.<sup>6</sup> This

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<sup>1</sup> *China aims at higher nuclear power capacity*, XINHUA, Nov. 5, 2008, available at [http://news.xinhuanet.com/english/2008-11/05/content\\_10312325.htm](http://news.xinhuanet.com/english/2008-11/05/content_10312325.htm); *China generates over 62 billion kwh of nuclear power in 2007*, XINHUA, Jan. 16, 2008, available at [http://news.xinhuanet.com/english/2008-01/16/content\\_7432786.htm](http://news.xinhuanet.com/english/2008-01/16/content_7432786.htm).

<sup>2</sup> *China nuclear power installed capacity expected to reach 70 GW by 2020, scientists*, XINHUA, Feb. 11, 2009, available at [http://news.xinhuanet.com/english/2009-11/02/content\\_12373871.htm](http://news.xinhuanet.com/english/2009-11/02/content_12373871.htm).

<sup>3</sup> Ariana Eunjung Cha, *China Embraces Nuclear Future*, THE WASHINGTON POST, May 29, 2007, available at <http://www.washingtonpost.com/wp-dyn/content/article/2007/05/28/AR2007052801051.html>.

<sup>4</sup> THE INFORMATION OFFICE OF CHINA'S STATE COUNCIL, CHINA'S POLICIES AND ACTIONS FOR ADDRESSING CLIMATE CHANGE 7, Oct. 29, 2008.

<sup>5</sup> Lin Boqiang, *Understanding the energy challenge*, CHINA DIALOGUE, Sept. 10, 2009, available at <http://www.chinadialogue.net/article/show/single/en/3246-Understanding-the-energy-challenge>.

<sup>6</sup> *Id.*

dependence on coal has led to China being the largest emitter of greenhouse gases, contributing significantly to climate change.<sup>7</sup>

The consequences of climate change in China could be most severe. The State Council characterized the threat as such: “China is one of the countries most susceptible to the adverse effects of climate change, mainly in the fields of agriculture, livestock breeding, forestry, natural ecosystems, water resources, and coastal zones.”<sup>8</sup> Rising sea levels, shifting water resources, increased forest diseases, increased pests, damages to agricultural production, and diminishing bio-diversity are among the many climate change consequences that will affect China.<sup>9</sup>

This problem is exasperated by China’s growing economy and even faster growing energy needs. China has one of the fastest growing economies in the world as the gross domestic rate has grown by ten percent in 2009.<sup>10</sup> This growth is expected to continue, and energy will be critical to keep it going. Unless China’s energy portfolio changes, coal use is going to continue to grow to help meet China’s energy needs and further aggravate the forces causing climate change.<sup>11</sup>

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<sup>7</sup> Keith Bradsher, *China to Pass U.S. in 2009 in Emissions*, N.Y. TIMES, Nov. 7, 2008, available at <http://www.nytimes.com/2006/11/07/business/worldbusiness/07pollute.html>.

<sup>8</sup> THE INFORMATION OFFICE OF CHINA’S STATE COUNCIL, CHINA’S POLICIES AND ACTIONS FOR ADDRESSING CLIMATE CHANGE 5, Oct. 29, 2008.

<sup>9</sup> *Id.* at 5–7.

<sup>10</sup> Dexter Roberts, *More Impressive Economic Numbers for China*, BUSINESSWEEK, Dec. 15, 2009, available at [http://www.businessweek.com/globalbiz/blog/eyeonasia/archives/2009/12/more\\_impressive.html](http://www.businessweek.com/globalbiz/blog/eyeonasia/archives/2009/12/more_impressive.html); this is despite a global recession that has affected trade and investment.

<sup>11</sup> See THE INFORMATION OFFICE OF CHINA’S STATE COUNCIL, CHINA’S POLICIES AND ACTIONS FOR ADDRESSING CLIMATE CHANGE 5–7, Oct. 29, 2008 (discussing the consequences of unmitigated climate change in China).

Investing in nuclear power is part of China's response to this need to diversify. By depending on nuclear power to generate a greater percentage of power, China hopes to become less dependent on coal and reduce its climate change-causing emissions. China will also be investing in renewable energy sources such as solar, wind, and hydroelectric power as well as encouraging greater energy efficiency.<sup>12</sup> However, nuclear is a major component of China's effort to mitigate climate change.<sup>13</sup> Billions of dollars will be poured into further developing nuclear power in China, with both positive and negative consequences. Not to mention, the unresolved issues that come with nuclear power, such as the complex problem of securely storing nuclear waste. All this begs the question of whether nuclear power should play a significant role in China's answer to climate change. This paper will explore the question below.

Part II of the paper will discuss the current state of affairs in China. It will include a discussion of China's contributions to climate change, current efforts to balance the desire for economic growth with the need to reduce climate change emissions, and the future of China's energy needs. Then there will be a discussion of the current efforts to reduce emissions and achieve increased energy security and independence, particular with regard to clean energy sources, such as wind and solar power. Finally, this section will discuss the current state of China's nuclear power infrastructure and how it is managed as well as the details of the plan to invest heavily in nuclear power and to make China the chief nuclear powered country in the world.

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<sup>12</sup> THE INFORMATION OFFICE OF CHINA'S STATE COUNCIL, CHINA'S POLICIES AND ACTIONS FOR ADDRESSING CLIMATE CHANGE 17, Oct. 29, 2008

<sup>13</sup> *Id.* at 17–18.



Part III will explore the issues that come with nuclear power and that give pause to it being a way to meet increasing energy needs without increasing climate-changing emissions. These issues are chiefly increasing costs, safety concerns, management of nuclear waste, and continued access to uranium reserves. While none of these issues preclude investing in nuclear power, they must be considered.

Part IV will discuss the viability of dramatic increases in solar, wind, hydroelectric, and other power sources that are considered cleaner and less risky and which do not have the same long-term cost issues. While they avoid the issues of nuclear power, it remains to be seen whether they could practically generate the same level of power.

Part V will tie these issues together to discuss the question of whether nuclear is the right solution generally and in particular for China. It will discuss the benefits and consequences of nuclear power, even as the Chinese government is investing heavily in nuclear power while still wrestling with resolving these issues.

## II. Climate Change and Nuclear Power in China

China is a leading contributor to climate-changing emissions, because of its great economic growth and dependence on coal for power. Aware of the consequences of climate change for China, the government has developed a strategy to diversify its energy portfolio so that they are less dependent on energy sources that contribute to climate change. Part of this strategy calls for a greater reliance on nuclear power. Given the current status of nuclear power in China, this will require a dramatic investment of resources and will represent a tremendous leap forward in the use of nuclear power.

### *A. Chinese Emissions and the Impacts of Climate Change on China*

In November 2009, China became the world's largest emitter of carbon dioxide, the gas considered most responsible for climate change, and surpassing the United States.<sup>14</sup> China is projected to have emitted close to seven billion tons of carbon dioxide, among tons of other greenhouse gases.<sup>15</sup> This growth in emissions is attributed to China's consistently strong economic growth and dependence on coal for energy.

In 2006, about 70 percent of China's power was generated by coal.<sup>16</sup> China is the world's largest consumer of coal in the world.<sup>17</sup> Oil is a distant second, producing 20 percent of China's power.<sup>18</sup> This is compared to nuclear power at around two percent, hydroelectric power at six percent, and "other renewables" at .06 percent, combining to produce less than nine percent of China's power in 2006.<sup>19</sup> This dependence on coal is not expected to slow. Despite price increases in 2008, Chinese coal consumption increased seven percent.<sup>20</sup>

This increase in coal use can be attributed to the amazing economic growth that China has experienced over the last few decades. Between 1961 and 2008, China's gross domestic

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<sup>14</sup> Keith Bradsher, *China to Pass U.S. in 2009 in Emissions*, N.Y. TIMES, Nov. 7, 2008, available at <http://www.nytimes.com/2006/11/07/business/worldbusiness/07pollute.html>.

<sup>15</sup> *Id.*

<sup>16</sup> NATIONAL DEVELOPMENT AND REFORM COMMISSION, CHINA'S NATIONAL CLIMATE CHANGE PROGRAMME 10, June 2007.

<sup>17</sup> U.S. ENERGY INFORMATION ADMINISTRATION, U.S. DEPARTMENT OF ENERGY, COUNTRY ANALYSIS BRIEFS: CHINA, updated July 2009, available at <http://www.eia.doe.gov/emeu/cabs/China/Full.html>. In addition to consumption, China is also the largest producer of coal. *Id.*

<sup>18</sup> *Id.*

<sup>19</sup> *Id.*

<sup>20</sup> Terry Macalister, *China leads escalation of coal consumption*, GUARDIAN, June, 10, 2009, available at <http://www.guardian.co.uk/business/2009/jun/10/coal-usage-global-energy-survey>

product has grown by an average of nine percent each year;<sup>21</sup> and 2009 has stayed well within that growth trend despite a global recession.<sup>22</sup> There are some estimates that China's economy will surpass the United States' economy, currently the world's largest, by 2025, if not sooner.<sup>23</sup> This will likely further push China towards increased use of coal for energy, at least in absolute terms, even if not relative to other energy sources.<sup>24</sup>

All of this suggests that if nothing changes, China is going to continue to lead in emitting gases that contribute to climate change for the foreseeable future. This does not bode well for China's or the world's ability to mitigate climate change and its expected impacts. This could be particularly devastating to China which is expected to experience some of the worst consequences of climate change.<sup>25</sup>

In June 2007, the State Council for China released a report discussing the consequences of climate change for China and an emerging strategy for reducing China's dependence on energy sources that contribute to climate change.<sup>26</sup> The report, entitled "China's National Climate Change Programme," discussed the impacts of climate change on China in a range of

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<sup>21</sup> THE WORLD BANK, WORLD DEVELOPMENT INDICATORS: CHINA, available at <http://databank.worldbank.org>.

<sup>22</sup> Dexter Roberts, *More Impressive Economic Numbers for China*, BUSINESSWEEK, Dec. 15, 2009, available at [http://www.businessweek.com/globalbiz/blog/eyeonasia/archives/2009/12/more\\_impressive.html](http://www.businessweek.com/globalbiz/blog/eyeonasia/archives/2009/12/more_impressive.html); this is despite a global recession that has affected trade and investment.

<sup>23</sup> CONGRESSIONAL RESEARCH SERVICE, IS CHINA A THREAT TO THE U.S. ECONOMY? 15, Jan. 23, 2007, available at <http://www.fas.org/sgp/crs/row/RL33604.pdf>.

<sup>24</sup> See C.S. Kiang and Feng Chaoling, *Developing China's low-carbon economy*, CHINA DIALOGUE, Aug. 22, 2008, available at <http://www.chinadialogue.net/article/show/single/en/2330-Developing-China-s-low-carbon-economy> (discussion of the Kaya formula).

<sup>25</sup> See generally THE INFORMATION OFFICE OF CHINA'S STATE COUNCIL, CHINA'S POLICIES AND ACTIONS FOR ADDRESSING CLIMATE CHANGE 5–7, Oct. 29, 2008 (discussing the affects of climate change on China).

<sup>26</sup> NATIONAL DEVELOPMENT AND REFORM COMMISSION, CHINA'S NATIONAL CLIMATE CHANGE PROGRAMME 16–19, June 2007.

areas, from agriculture to industry.<sup>27</sup> These consequences could in particular adversely impact China's goals for continued growth.

In agriculture, climate change could limit China's ability to feed itself.<sup>28</sup> High temperatures and drought could damage crops and interfere with livestock in certain parts of the country.<sup>29</sup> Climate change could also lead to increased tsunamis and seasonal disruptions, which would further disrupt food production.<sup>30</sup> In particular, grasslands, which livestock depend upon, are expected to be severely diminished.<sup>31</sup> Desertification is expected as well, aggravated by the potential loss of grasslands.<sup>32</sup>

Forest and other natural ecosystems are also projected to be adversely affected by climate change.<sup>33</sup> Shifting subtropical and temperate zones could be particularly dramatic.<sup>34</sup> Climate change is expected to also increase the frequency of plant and animal diseases and pests, and their traditional ranges could expand.<sup>35</sup> Already fragile ecosystems are expected to decrease and be subject to more fires.<sup>36</sup>

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<sup>27</sup> *Id.*

<sup>28</sup> *Id.* at 16

<sup>29</sup> *Id.*; THE INFORMATION OFFICE OF CHINA'S STATE COUNCIL, CHINA'S POLICIES AND ACTIONS FOR ADDRESSING CLIMATE CHANGE 5, Oct. 29, 2008

<sup>30</sup> THE INFORMATION OFFICE OF CHINA'S STATE COUNCIL, CHINA'S POLICIES AND ACTIONS FOR ADDRESSING CLIMATE CHANGE 6, Oct. 29, 2008

<sup>31</sup> NATIONAL DEVELOPMENT AND REFORM COMMISSION, CHINA'S NATIONAL CLIMATE CHANGE PROGRAMME 16, June 2007.

<sup>32</sup> *Id.* at 17.

<sup>33</sup> *Id.*

<sup>34</sup> *Id.*; THE INFORMATION OFFICE OF CHINA'S STATE COUNCIL, CHINA'S POLICIES AND ACTIONS FOR ADDRESSING CLIMATE CHANGE 8, Oct. 29, 2008

<sup>35</sup> NATIONAL DEVELOPMENT AND REFORM COMMISSION, CHINA'S NATIONAL CLIMATE CHANGE PROGRAMME 17, June 2007.

<sup>36</sup> *Id.*

Climate change is expected to worsen the current trends of decreasing gross water flow in the Yellow, Huaihe, Haihe, and Liaohe rivers.<sup>37</sup> Concurrently, flooding is projected to worsen in southern China, both in terms of frequency and severity.<sup>38</sup> Water resources are expected to shift as well, causing infrastructure and agricultural issues, and overall scarcity is expected to worsen.<sup>39</sup> Diminishing glacier ice reserves could also affect rivers and runoffs, another consequence of climate change.<sup>40</sup>

This is to say nothing of the harms that raising sea-level could cause in China. China has already had to address soil salinization, coastal erosion, damage to coastal wetlands, swamps, and reefs, and declining eco-services because of climate change.<sup>41</sup> Marine fisheries are also being harmed by temperature increases and acidification.<sup>42</sup> This will also undoubtedly affect endangered marine species.<sup>43</sup>

In addition to particular ecological impacts, the State Council acknowledged in this report and in a subsequent report, “China's Policies and Actions for Addressing Climate Change,” that social and economic instability could be among the consequences of climate change, and was of great concern to the council.<sup>44</sup> The follow-up report stated:

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<sup>37</sup> *Id.* at 16 –17.

<sup>38</sup> *Id.* at 17; THE INFORMATION OFFICE OF CHINA'S STATE COUNCIL, CHINA'S POLICIES AND ACTIONS FOR ADDRESSING CLIMATE CHANGE 9, Oct. 29, 2008.

<sup>39</sup> NATIONAL DEVELOPMENT AND REFORM COMMISSION, CHINA'S NATIONAL CLIMATE CHANGE PROGRAMME 17, June 2007.

<sup>40</sup> *Id.*

<sup>41</sup> *Id.* at 18.

<sup>42</sup> *Id.*

<sup>43</sup> *Id.*

<sup>44</sup> THE INFORMATION OFFICE OF CHINA'S STATE COUNCIL, CHINA'S POLICIES AND ACTIONS FOR ADDRESSING CLIMATE CHANGE 7, Oct. 29, 2008.

Climate change will also produce far-reaching impacts on society, economy and other fields, and cause huge losses to the national economy. Corresponding economic and social costs will have to be paid for addressing climate change. In addition, there will be increased chances of disease occurrence and spread, ensuing dangers to human health, rising possibilities of geological and meteorological disasters and consequent threats to the security of major projects. The eco-environment and bio-diversity of nature reserves and national parks will be affected, accompanied by adverse effects on natural and cultural tourism resources, and augmented threats to the safety of life and property, and to the normal order and stability of social life.<sup>45</sup>

Clearly, the State Council is aware of the potential harms that climate change could cause to China, and consequently drafted a plan to diversify China's energy portfolio.

### *B. Turning China Green*

In October 2008, the State Council released "China's Policies and Actions for Addressing Climate Change," detailing China's strategies for mitigating and adapting to climate change.<sup>46</sup> The council declared that China would use the following guidelines to combat climate change:

To give full effect to the Scientific Outlook on Development, adhere to the fundamental state policy of resources conservation and environmental protection, control greenhouse gas emissions and enhance the country's capacity for sustainable development, center on securing economic development and accelerate the transformation of the pattern of economic development, focus on

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<sup>45</sup> *Id.*

<sup>46</sup> THE INFORMATION OFFICE OF CHINA'S STATE COUNCIL, CHINA'S POLICIES AND ACTIONS FOR ADDRESSING CLIMATE CHANGE 1. 3–4, Oct. 29, 2008.

conserving energy, optimizing the energy structure and strengthening eco-preservation and construction, and rely on the advancement of science and technology, increase international cooperation, constantly enhance the capability in coping with climate change, and make new contribution in protecting the world environment.<sup>47</sup>

The report also continued to espouse core principles for China's climate change policies, chief among them a reliance on technology and international cooperation.<sup>48</sup> The State Council committed in the report to reducing China's use of power sources that release climate-changing emissions by "developing renewable energy, boosting nuclear power plant construction and speeding up the development and utilization of coal-bed gas."<sup>49</sup>

With that goal in mind, the State Council stated China would enthusiastically develop nuclear power.<sup>50</sup> The report said:

[China] is working hard to reform the nuclear power system and spur mechanism innovation in an attempt to establish a market-oriented nuclear power development mechanism. It will strengthen its capacity for developing and manufacturing nuclear power equipment, and raise its ability to absorb imported technology and make new innovations on this basis. It will strengthen the construction of nuclear power transmission and related technical services, as well as the training of qualified personnel. It will implement preferential policies on taxation and investment that will promote the development of nuclear power, improve nuclear power safety, and quicken the enactment of laws and

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<sup>47</sup> *Id.* at 7.

<sup>48</sup> *Id.* at 7–9.

<sup>49</sup> *Id.* at 10.

<sup>50</sup> *Id.* at 18.

regulations in this field.<sup>51</sup>

From that initial goal, China has set an even higher aim for nuclear power by 2020, increasing it recently to 70 gigawatts.<sup>52</sup> To reach that goal, 32 new nuclear reactors have been approved for construction or have begun construction.<sup>53</sup> As such, China is the world's leader in nuclear-energy capacity under construction.<sup>54</sup> China is also investing in developing a self-sustaining nuclear industry,<sup>55</sup> currently it depends on foreign businesses for design and construction expertise.<sup>56</sup> The ultimate goal is to have five percent of China's power needs met by nuclear power by 2020 based largely on Chinese technology and Chinese designs.<sup>57</sup> It is an ambitious goal that will push China's nuclear development forward several fold, though it is not clear that the goal will be met on time.

### C. Chinese Nuclear Power

To better understand the future of Chinese nuclear power, it is best to understand the current state of Chinese nuclear power. China's nuclear industry is relatively young, its first

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<sup>51</sup> *Id.*

<sup>52</sup> *China nuclear power installed capacity expected to reach 70 GW by 2020, scientists*, XINHUA, Feb. 11, 2009, available at [http://news.xinhuanet.com/english/2009-11/02/content\\_12373871.htm](http://news.xinhuanet.com/english/2009-11/02/content_12373871.htm).

<sup>53</sup> NATIONAL DEVELOPMENT AND REFORM COMMISSION, CHINA'S POLICIES AND ACTIONS FOR ADDRESSING CLIMATE CHANGE: THE PROGRESS REPORT 2009 at 22, Nov. 2009; Ariana Eunjung Cha, *China Embraces Nuclear Future*, THE WASHINGTON POST, May 29, 2007, available at <http://www.washingtonpost.com/wp-dyn/content/article/2007/05/28/AR2007052801051.html>.

<sup>54</sup> NATIONAL DEVELOPMENT AND REFORM COMMISSION, CHINA'S POLICIES AND ACTIONS FOR ADDRESSING CLIMATE CHANGE: THE PROGRESS REPORT 2009 at 22, Nov. 2009.

<sup>55</sup> *Official: China to speed up nuclear power development*, CCTV.COM, June 2, 2009, available at <http://english.cctv.com/20090602/101150.shtml>; *China's nuclear power giant buys from private businesses*, XINHUA, Nov. 2, 2009, available at [http://news.xinhuanet.com/english/2009-11/02/content\\_12373613.htm](http://news.xinhuanet.com/english/2009-11/02/content_12373613.htm).

<sup>56</sup> *Official: China to speed up nuclear power development*, CCTV.COM, June 2, 2009, available at <http://english.cctv.com/20090602/101150.shtml>; *China's nuclear power giant buys from private businesses*, XINHUA, Nov. 2, 2009, available at [http://news.xinhuanet.com/english/2009-11/02/content\\_12373613.htm](http://news.xinhuanet.com/english/2009-11/02/content_12373613.htm).

<sup>57</sup> *China aims at higher nuclear power capacity*, XINHUA, Nov. 5, 2008, available at [http://news.xinhuanet.com/english/2008-11/05/content\\_10312325.htm](http://news.xinhuanet.com/english/2008-11/05/content_10312325.htm).



reactor coming online in 1991,<sup>58</sup> and its nuclear plants are owned by government-backed corporations.<sup>59</sup>

China currently has 11 active nuclear power plants, scattered predominately along eastern portions of the country.<sup>60</sup> In 2007, these reactors combined to produce 62.6 billion kilowatt hours of electricity, providing China with 2.3 percent of its energy needs.<sup>61</sup> Most of China's nuclear power technology is imported from other nuclear powers: Russia (two facilities), France (four facilities), and Canada (two facilities).<sup>62</sup> Three of China's current reactors are based on domestic designs.<sup>63</sup>

China's energy and nuclear power decision-making and organizational structure is surprisingly complex and fractured. While the Chinese government is a centralized or unitary system,<sup>64</sup> local government plays a critical role in energy development and investment.<sup>65</sup> China's nuclear power industry is controlled by the government through two state-owned corporations that compete against each other: the China National Nuclear Corporation, which

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<sup>58</sup> U.S. ENERGY INFORMATION ADMINISTRATION, U.S. DEPARTMENT OF ENERGY, TIMELINE OF THE CHINESE NUCLEAR INDUSTRY, 1970 TO 2020, *available at* [http://www.eia.doe.gov/cneaf/nuclear/page/nuc\\_reactors/china/timeline.html](http://www.eia.doe.gov/cneaf/nuclear/page/nuc_reactors/china/timeline.html).

<sup>59</sup> MASSACHUSETTS INSTITUTE OF TECHNOLOGY, THE FUTURE OF COAL: OPTIONS FOR A CARBON-CONSTRAINED WORLD 68, 2007.

<sup>60</sup> *China generates over 62 billion kwh of nuclear power in 2007*, XINHUA, Jan. 16, 2008, *available at* [http://news.xinhuanet.com/english/2008-01/16/content\\_7432786.htm](http://news.xinhuanet.com/english/2008-01/16/content_7432786.htm).

<sup>61</sup> *Id.*

<sup>62</sup> *Id.*

<sup>63</sup> *Id.*

<sup>64</sup> As opposed to a federal system.

<sup>65</sup> MASSACHUSETTS INSTITUTE OF TECHNOLOGY, THE FUTURE OF COAL: OPTIONS FOR A CARBON-CONSTRAINED WORLD 68, 2007.

operates nuclear reactors in northeastern China, and the China Guangdong Nuclear Power Group, which operates nuclear reactors in southeastern China.<sup>66</sup>

While the central Chinese government, through the State Council, sets strategic goals and creates energy policy, local governments greatly impact energy development, whether it pertains to nuclear power or other sources.<sup>67</sup> As MIT found:

[I]t is a mistake to attribute China’s aggregate energy demand growth—or even the actions of the state-owned energy companies—to central government agendas or geopolitical strategy. What many outsiders see as the deliberate result of Chinese national ‘energy strategy’ is in fact better understood as an agglomeration of ad hoc decisions by local governments, local power producers, and local industrial concerns.<sup>68</sup>

These actors are motivated more by a desire to promote economic growth than out of any sense of obligation to the national interest.<sup>69</sup> This has been attributed in part to the Chinese government not developing a “coherent national-level energy strategy”;<sup>70</sup> this may change as China develops and enforces its policies responding to climate change and encourage mitigation strategies such as expanding nuclear power capacity.

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<sup>66</sup> *Id.*; Keith Bradsher, *Nuclear Power Expansion in China Stirs Concerns*, N.Y. TIMES, Dec. 15, 2009, available at <http://www.nytimes.com/2009/12/16/business/global/16chinanuke.html>.

<sup>67</sup> MASSACHUSETTS INSTITUTE OF TECHNOLOGY, *THE FUTURE OF COAL: OPTIONS FOR A CARBON-CONSTRAINED WORLD* 65, 2007.

<sup>68</sup> *Id.*

<sup>69</sup> *Id.*

<sup>70</sup> *Id.*

Local governments also play an important role in providing capital for developing energy projects, even nuclear power plants.<sup>71</sup> State-owned energy corporations provide only a small portion of capital for new energy projects:

[N]ational energy corporations provide only about 25% of the capital required for new power plant investment. Much of the remainder comes in the form of loans from the municipal branches of state-owned banks. These banks in theory answer to a headquarters in Beijing, but in practice are likely to respond to the wishes of local governmental officials . . . .<sup>72</sup>

Local governments are major players in energy development of China, and any coherent energy policy, nuclear or otherwise, would have to acknowledge that feature either by integrating it or limiting its influence.

### III. The Costs and Concerns of Going Nuclear

Though China's State Council has committed to a significant increase in nuclear power capacity, some issues have not been resolved. There are four main areas of concern that need to be addressed in some manner as China moves to increase its nuclear facilities: Cost, safety and proliferation, nuclear waste, and access to fuel.<sup>73</sup> If these issues are neglected, in either the

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<sup>71</sup> *Id.* at 68.

<sup>72</sup> *Id.*

<sup>73</sup> Cost, safety, proliferation, and nuclear waste concerns were the issues focused on by MIT when it evaluated nuclear power; access to nuclear fuel was raised by Professor ZhongXiang Zhang. *See* MASSACHUSETTS INSTITUTE OF TECHNOLOGY, THE FUTURE OF NUCLEAR POWER 2, 2003 (discussing that the report would analyze cost, safety, proliferation, and waste issues, among others, as they relate to nuclear power); ZHONGXIANG ZHANG, THE ECONOMICS OF ENERGY POLICY IN CHINA: IMPLICATIONS FOR GLOBAL CLIMATE CHANGE 51–52, 1998 (discussing concerns of whether China had adequate domestic reserves of uranium to support a large nuclear power industry).

short- or long-term, then the long-term health of China's nuclear power industry and its ability to provide large amounts of emission-free energy could suffer.

#### *A. Cost*

The construction cost<sup>74</sup> of a single nuclear power plant requires a significant upfront investment over a number of years. It is also a difficult investment to plan for in a budget. The projected costs of a nuclear plant often fall short, and subsequently these projects require more capital than initially expected. However, the price per kilowatt hour is among the cheapest compared to other sources, which is one of the major initial draws of nuclear power in the first place.

The estimated cost of constructing a nuclear power plant is about eight to 14 billion dollars.<sup>75</sup> However, there is a great deal of variation between plant types and, subsequently, costs as well.<sup>76</sup> A common factor is that the actual costs of construction have far exceeded the projected costs of construction;<sup>77</sup> this was especially the case in the United States and Europe during the 1960s on through the 1980s.<sup>78</sup> The reasons for the difference between actual and projected costs are not clear, but a combination of regulatory delays, redesign requirements, management problems, and quality control issues are considered leading culprits.<sup>79</sup> The four to

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<sup>74</sup> This is as opposed to the costs of fuel, waste storage, plant decommissioning, and others.

<sup>75</sup> See WORLD NUCLEAR ASSOCIATION, THE ECONOMICS OF NUCLEAR POWER, April 2010, available at <http://www.world-nuclear.org/info/inf02.html> (discussing the estimated construction costs of various nuclear power plants that were recently proposed).

<sup>76</sup> See MARK COOPER, INSTITUTE FOR ENERGY AND THE ENVIRONMENT, VERMONT LAW SCHOOL, THE ECONOMICS OF NUCLEAR REACTORS: RENAISSANCE OR RELAPSE? 41, June 2009 (“Reactor design is . . . non-standardized.”).

<sup>77</sup> *Id.* at 36.

<sup>78</sup> *Id.* at 33.

<sup>79</sup> *Id.*

five year construction period has also contributed to cost overruns.<sup>80</sup> What is certain is that the current projected costs of constructing these new Chinese nuclear power plants will fall far short of the final construction cost.

This trend in construction costs would suggest that China is not going to meet its nuclear ambitions without a major financial commitment, either from the government or through incentivizing private investors. Based on China's most recently completed nuclear plant and the current plans, China's is committing to a multi-billion dollar project. China's most recently completed plant, the Yangjiang Nuclear Power Plant, had a total construction cost of 10.1 billion dollars.<sup>81</sup> Assuming that is representative of the costs of building additional plants, the cost of constructing the 32 nuclear power plants approved for construction or under construction already would cost no less than 323.2 billion dollars.<sup>82</sup> That figure is setting aside inflation, all but certain cost overruns, and ignoring the other costs of nuclear power.<sup>83</sup> For a point of reference, a coal fire plant costs between one and three billion dollars.<sup>84</sup>

While constructing a nuclear power plant requires a large upfront investment, nuclear power is relatively inexpensive when comparing cost of kilowatts produced. Nuclear power on

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<sup>80</sup> *Id.* at 30–31. MIT has proposed that a construction period of four years rather than five years would reduce costs substantially. MASSACHUSETTS INSTITUTE OF TECHNOLOGY, THE FUTURE OF NUCLEAR POWER 7, 2003.

<sup>81</sup> WORLD NUCLEAR ASSOCIATION, NUCLEAR POWER IN CHINA, April 22, 2010, available at <http://www.world-nuclear.org/info/inf63.html>.

<sup>82</sup> Ariana Eunjung Cha, *China Embraces Nuclear Future*, THE WASHINGTON POST, May 29, 2007, available at <http://www.washingtonpost.com/wp-dyn/content/article/2007/05/28/AR2007052801051.html>. Thirty-two nuclear facilities multiplied by 10.1 billion dollars would equal 323.2 billiondollars.

<sup>83</sup> Such as the costs of securely storing nuclear waste and fuel costs.

<sup>84</sup> Tobin Hack, *Building more coal-fired power plants: Big mistake?*, PLENTY, April 2008, available at <http://www.mnn.com/earth-matters/energy/stories/building-more-coal-fired-power-plants-big-mistake> (interview with Professor Michael Dworkin, director of Vermont Law School's Institute for Energy and the Environment).

average costs seven cents per kilowatt per hour.<sup>85</sup> Solar power, in contrast, costs between 20 to 30 cents per kilowatt per hour.<sup>86</sup> This suggests the true advantage of nuclear power over other alternatives: it produces a lot of power per unit over its lifetime. This high capacity may give nuclear power the edge over solar or wind power, but it also requires that large initial investment.

### *B. Safety and Proliferation*

Safety concerns are perhaps the issue most associated with opposition to nuclear power in the United States.<sup>87</sup> The potential harm that could arise from an accident at or attack on a nuclear power plant is great, and not without precedent. Safety concerns have focused on the following issues: reactor safety, staff quality, nuclear fuel-cycle safety, and threats from direct attack. There are also special concerns regarding proliferation of nuclear technology, particularly any that could contribute to building a nuclear weapon.

Reactor safety concerns have focused on the physical mechanics of nuclear power plants.<sup>88</sup> This includes avoiding failure of safeguards, ensuring functional cooling systems, and

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<sup>85</sup> MASSACHUSETTS INSTITUTE OF TECHNOLOGY, THE FUTURE OF NUCLEAR POWER 42, 2003.

<sup>86</sup> *Solar Energy Costs/Prices*, SOLARBUZZ, available at <http://www.solarbuzz.com/statsCosts.htm>. However, these numbers are coming down and becoming more competitive with conventional energy sources. *Id.*

<sup>87</sup> MASSACHUSETTS INSTITUTE OF TECHNOLOGY, THE FUTURE OF NUCLEAR POWER 12, 2003; *see, e.g.*, MARYLAND PIRG FOUNDATION, THE HIGH COST OF NUCLEAR POWER: WHY AMERICA SHOULD CHOOSE A CLEAN ENERGY FUTURE OVER NEW NUCLEAR REACTORS, 2009 (discussing the safety and cost concerns of a proposed nuclear power plant in Maryland).

<sup>88</sup> MASSACHUSETTS INSTITUTE OF TECHNOLOGY, THE FUTURE OF NUCLEAR POWER 48, 2003.

preventing damage to the core.<sup>89</sup> Staff quality concerns focus on preventing human error.<sup>90</sup> As an interdisciplinary MIT study put it:

[T]raining and qualification of people competent to manage and operate the plants safely, including the supporting infrastructure necessary for maintenance, repair, refueling, and spent fuel management [is important to maintain safety]. Development of competent managers and identification of effective management processes is a critical element in achieving safe and economic nuclear power plant operations.<sup>91</sup>

Fuel-cycle safety issues essentially concern of how to safely and securely store nuclear material after it has been used.<sup>92</sup>

Of special concern is what steps should be taken to prevent a terrorist attack on a civilian nuclear facility.<sup>93</sup> While even civilian nuclear power plants are very secure, especially in terms of physical structures (to prevent accidents stemming from natural disasters), the concern is that nuclear power plants are too tempting a potential target.<sup>94</sup>

China has a good safety record with regards to large-scale nuclear energy production.<sup>95</sup> There has not been one serious accident in China's 15 year nuclear history.<sup>96</sup> And to maintain that record, in October 2009, Prime Minister Wen Jiabao expanded China's corps of nuclear

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<sup>89</sup> U.S. NUCLEAR REGULATORY COMMISSION, NUCLEAR REACTOR SAFETY RESEARCH, July 23, 2009, *available at* <http://www.nrc.gov/about-nrc/regulatory/research/reactor-rsch.html>.

<sup>90</sup> MASSACHUSETTS INSTITUTE OF TECHNOLOGY, THE FUTURE OF NUCLEAR POWER 49, 2003.

<sup>91</sup> *Id.*

<sup>92</sup> *Id.* at 53.

<sup>93</sup> *Id.* at 21–22.

<sup>94</sup> *Id.*

<sup>95</sup> Keith Bradsher, *Nuclear Power Expansion in China Stirs Concerns*, N.Y. TIMES, Dec. 15, 2009, *available at* <http://www.nytimes.com/2009/12/16/business/global/16chinanuke.html>.

<sup>96</sup> *Id.*

inspectors to 1,000, aiming for that goal by late 2010.<sup>97</sup> Foreign inspectors have even been invited to help ensure that China's nuclear expansion is safely executed.<sup>98</sup>

However, a recent event has undermined the confidence that China once had in the safety of its nuclear industry.<sup>99</sup> In August 2009, Kang Rixin was dismissed as president of the China National Nuclear Corporation and charged in a 260 million dollar corruption case, where he is alleged to have rigged bids for constructing nuclear power plants.<sup>100</sup> While it does not appear that Rixin's alleged activities have directly compromised safety at nuclear facilities, it does bring into question to what extent the executives of China's nuclear power industry are making safety a priority.<sup>101</sup> Furthermore, China has charged "whistleblowers"—someone who reveals wrongdoing to authorities or to the public—with causing a public disturbance, raising additional safety and good-governance concerns.<sup>102</sup>

Proliferation of nuclear technology has been a particularly relevant issue as of late (with regard to developments in Iran and North Korea).<sup>103</sup> Because some nuclear technology can be used for both civil energy and for developing a nuclear weapon, the international community has developed mechanism such as the Nuclear Non-Proliferation Treaty<sup>104</sup> and the International

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<sup>97</sup> *Id.*

<sup>98</sup> *Id.*

<sup>99</sup> *Id.*

<sup>100</sup> *Id.*

<sup>101</sup> Keith Bradsher, *Nuclear Power Expansion in China Stirs Concerns*, N.Y. TIMES, Dec. 15, 2009, available at <http://www.nytimes.com/2009/12/16/business/global/16chinanuke.html>.

<sup>102</sup> See, e.g., Malcolm Moore, *China puts father of "toxic milk" child on trial*, TELEGRAPH, Mar. 30, 2010 available at <http://www.telegraph.co.uk/news/worldnews/asia/china/7537822/China-puts-father-of-toxic-milk-child-on-trial.html>; *Tougher and tougher: Dissent becomes even more dangerous*, THE ECONOMIST, Feb. 11, 2010, available at [http://www.economist.com/world/asia/displaystory.cfm?story\\_id=15500663](http://www.economist.com/world/asia/displaystory.cfm?story_id=15500663).

<sup>103</sup> MASSACHUSETTS INSTITUTE OF TECHNOLOGY, *THE FUTURE OF NUCLEAR POWER* 65, 2003.

<sup>104</sup> *Treaty on the Non-Proliferation of Nuclear Weapons* (NPT), 729 UNTC 168 (1970) (ascended 1992).



Atomic Energy Agency to monitor and limit the spread of this technology.<sup>105</sup> While China is a party to the Nuclear Non-Proliferation Treaty, the proliferation issue is otherwise moot to China's investment in advancing its nuclear power industry since it already has both nuclear weapons and civil technology.<sup>106</sup>

### *C. Nuclear Waste*

The question of what to do with high-level nuclear waste is a major issue plaguing all countries that have developed nuclear power. Nuclear waste is highly toxic, difficult to contain, and stays that way for thousands of years.<sup>107</sup> Any proper nuclear waste management plan must store the waste so that it is safely contained and not a health risk and so that it cannot be misused, for example, by terrorists or some other malevolent group.<sup>108</sup> China, like others, has yet to completely address this issue, though efforts are underway.

Properly managing nuclear waste is quite difficult because it is highly toxic for thousands of years.<sup>109</sup> As a result, containment technology must not only be effective at storing the material so that there is no leakage, but also must do so for a very long time.<sup>110</sup> Aside from

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<sup>105</sup> INTERNATIONAL ATOMIC ENERGY AGENCY, THE "ATOMS FOR PEACE" AGENCY, *available at* <http://www.iaea.org/About/index.html>.

<sup>106</sup> PROJECT OF THE NUCLEAR AGE PEACE FOUNDATION, CHINA, *available at* <http://www.nuclearfiles.org/menu/key-issues/nuclearweapons/issues/proliferation/china/index.htm>.

<sup>107</sup> MASSACHUSETTS INSTITUTE OF TECHNOLOGY, THE FUTURE OF NUCLEAR POWER 53, 2003.

<sup>108</sup> *Id.* at 21–22.

<sup>109</sup> *Id.* at 22.

<sup>110</sup> *Id.*

this technical challenge, there is also the issue of siting the storage facility for the nuclear waste. These facilities should not be sited near population centers, aquifers, agricultural areas, or any location where leakage would threaten public health. The often turned to choice is isolated geologic storage sites, which are geologically stable, and ideally underground locations surrounded by nearly impenetrable granite deposits.<sup>111</sup> Storing nuclear waste at isolated geologic areas meets the twin goals of preventing adverse health risks and, if properly secured, deterring misuse. However, public perceptions<sup>112</sup> of nuclear waste have led to local opposition to having such dangerous materials stored in the vicinity of even small communities. This says nothing of the tremendous costs of storing the waste for an extended period. In the United States, the estimated costs of storing nuclear waste at about \$500 million per year, and the cost of storage during 100 years ranging between \$20 and \$97 billion.<sup>113</sup> Even if China could avoid the higher end of these estimates, storing nuclear waste would constitute quite a long-term financial commitment.

China has taken steps to establish a geologic storage area.<sup>114</sup> The leading potential site is in the Gobi Desert portion of Gansu province.<sup>115</sup> The listed benefits of the site are that it “is sparsely populated, has a low precipitation rate, a high evaporation rate, and a shallow water

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<sup>111</sup> *Id.* at 158–59.

<sup>112</sup> *See, e.g.*, MARYLAND PIRG FOUNDATION, THE HIGH COST OF NUCLEAR POWER: WHY AMERICA SHOULD CHOOSE A CLEAN ENERGY FUTURE OVER NEW NUCLEAR REACTORS, 2009 (discussing the cost and safety issues regarding nuclear waste).

<sup>113</sup> U.S. GENERAL ACCOUNTING OFFICE, NUCLEAR WASTE MANAGEMENT: KEY ATTRIBUTES, CHALLENGES, AND COSTS FOR THE YUCCA MOUNTAIN REPOSITORY AND TWO POTENTIAL ALTERNATIVES - SUMMARY, Nov. 4, 2009, available at <http://www.gao.gov/products/GAO-10-48>; *see also*, Brian Kemp, *Storing nuclear waste a \$24-billion problem*, CBC NEWS, Aug. 18, 2009, available at <http://www.cbc.ca/canada/story/2009/08/18/f-nuclear-waste-storage.html> (discussing the costs of storing nuclear waste that the Canadian government is bearing).

<sup>114</sup> OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT, U.S. DEPARTMENT OF ENERGY, CHINA’S RADIOACTIVE WASTE MANAGEMENT PROGRAM, available at <http://www.ocrwm.doe.gov/factsheets/doeymp0409.shtml>.

<sup>115</sup> *Id.*

table.”<sup>116</sup> However, Gansu province has a history of geologic instability, making it a questionable choice of long-term high-level nuclear waste storage.<sup>117</sup> Also, the current Chinese plan states that the “[r]epository operation will begin no earlier than 2040.”<sup>118</sup> As such, even if the site in Gansu province proves to be a sound selection in geologic terms, there seems to be no centralized and secure storage facility for nuclear waste in the short-term.

#### *D. Access to Fuel*

Uranium is required for nuclear power; it is the fuel for the reactors.<sup>119</sup> It is also, like most minerals, is a scarce natural resource. Without access to uranium, China’s, or any nation’s, nuclear power infrastructure would begin to grind to a halt.<sup>120</sup> Securing access to nuclear fuel, whether through reprocessing of used fuel or by exploiting new mineral resources, is a requirement for the long-term success of China’s investment in nuclear power.

While uranium is finite, the planet seems to have a great deal of it. At marketable prices, it is estimated that there are three to four million tons of uranium.<sup>121</sup> At current fuel use for

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<sup>116</sup> *Id.*

<sup>117</sup> See *China earthquakes: timeline of deadly disasters*, TELEGRAPH, April 14, 2010, available at <http://www.telegraph.co.uk/news/worldnews/asia/china/7589265/China-earthquakes-timeline-of-deadly-disasters.html> (discussing the history of geologic instability in Northwestern China, in particular Gansu province and surround provinces).

<sup>118</sup> OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT, U.S. DEPARTMENT OF ENERGY, CHINA’S RADIOACTIVE WASTE MANAGEMENT PROGRAM, available at <http://www.ocrwm.doe.gov/factsheets/doeymp0409.shtml>.

<sup>119</sup> MASSACHUSETTS INSTITUTE OF TECHNOLOGY, THE FUTURE OF NUCLEAR POWER 53, 2003.

<sup>120</sup> Assuming that reprocessing facilities and other infrastructure have not been developed.

<sup>121</sup> MASSACHUSETTS INSTITUTE OF TECHNOLOGY, THE FUTURE OF NUCLEAR POWER 34, 2003.

nuclear reactors, there are adequate uranium reserves to last for roughly the next one hundred years;<sup>122</sup> more efficient reactors have led to speculation that these reserves could last up to about 2,500 years.<sup>123</sup> These numbers are not based on the use of breeder reactors,<sup>124</sup> which can be used to create nuclear fuel from spent fuel.<sup>125</sup>

China has access adequate uranium resources in the near-term and is making efforts to secure long-term access to uranium reserves. China is estimated to have 38,000 assured tons of uranium,<sup>126</sup> and an estimated 21,700 tons of uranium they could potentially mine.<sup>127</sup> With these reserves, the Chinese State Environment Protection Administration estimates that China has adequate domestic uranium reserves to support the expanded nuclear power program until 2020.<sup>128</sup>

To protect long-term fuel needs, China has set up a strategic uranium reserve to store and preserve uranium and has expanded exploration efforts in western China and in Outer Mongolia.<sup>129</sup> China is also searching for foreign sources of uranium. It has already signed strategic cooperation agreements for uranium with Australia, Kazakhstan, Uzbekistan, Namibia,

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<sup>122</sup> NUCLEAR ENERGY AGENCY, URANIUM RESOURCES SUFFICIENT TO MEET PROJECTED NUCLEAR ENERGY REQUIREMENTS LONG INTO THE FUTURE, June 3, 2008, available at <http://www.nea.fr/press/2008/2008-02.html>.

<sup>123</sup> *Id.*

<sup>124</sup> MASSACHUSETTS INSTITUTE OF TECHNOLOGY, THE FUTURE OF NUCLEAR POWER 29–30, 2003.

<sup>125</sup> *Id.*

<sup>126</sup> ENERGY STATISTICS DATABASE, UNITED NATIONS STATISTICS DIVISION, CHINA – URANIUM, available at <http://data.un.org/Data.aspx?q=China+Uranium&d=EDATA&f=cmID%3aUR%3bcrID%3a156>

<sup>127</sup> *Id.*

<sup>128</sup> *China nuclear body says uranium reserves sufficient for power development*, XINHUA, Feb. 27, 2008, available at [http://news.xinhuanet.com/english/2008-02/27/content\\_7681721.htm](http://news.xinhuanet.com/english/2008-02/27/content_7681721.htm).

<sup>129</sup> Robert J. Saiget, *China To Set Up Strategic Uranium Reserve*, ENERGY DAILY, April 18, 2007, available at [http://www.energy-daily.com/reports/China\\_To\\_Set\\_Up\\_Strategic\\_Uranium\\_Reserve\\_999.html](http://www.energy-daily.com/reports/China_To_Set_Up_Strategic_Uranium_Reserve_999.html).

South Africa, Central African Republic, and Senegal;<sup>130</sup> similar agreements are being pursued with Kazakhstan (expanding operations), Niger, Jordan, and Mongolia.<sup>131</sup> China is also investing in technology that would allow for uranium to be extracted from coal ash, which is a byproduct of coal power plants.<sup>132</sup> These agreements and research efforts could guarantee the longevity of China's nuclear power industry.

#### IV. The Alternatives

Before discussing the merits of China's investment in nuclear power, a brief look at the other investments China is making that achieve the same goals would be appropriate. In addition to nuclear power, China is also expanding other clean energy sources and exploring how to limit the emissions of existing coal power plants.<sup>133</sup> Most of these investments achieve the same emission goals as nuclear power, and without the same long-term costs, but it is not clear that these alternatives could provide either adequate amounts of power in the aggregate to sustain China's economic growth or transmittable power in a practical or flexible manner to China's industrial or urban centers.

China relies on coal to power its industries, with coal power plants providing China roughly 70 percent of its energy.<sup>134</sup> If China could modify its existing predominantly coal-based power infrastructure so that it emitted less climate-changing emissions, it could save a great

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<sup>130</sup> George Miller, *China's Uranium Supply: Securing Foreign Resources*, DYNABOND POWERTECH SERVICE, Nov. 11, 2009, available at <http://www.dynabondpowertech.com/en/topic-of-the-month/2423-chinas-uranium-supply-securing-foreign-resources>.

<sup>131</sup> *Id.*

<sup>132</sup> SPARTON, URANIUM SECONDARY RECOVERY, available at <http://www.spartonres.ca/uraniumsecondary.htm>.

<sup>133</sup> NATIONAL DEVELOPMENT AND REFORM COMMISSION, CHINA'S POLICIES AND ACTIONS FOR ADDRESSING CLIMATE CHANGE: THE PROGRESS REPORT 2009 at 27, Nov. 2009.

<sup>134</sup> Lin Boqiang, *Understanding the energy challenge*, CHINA DIALOGUE, Sept. 10, 2009, available at <http://www.chinadialogue.net/article/show/single/en/3246-Understanding-the-energy-challenge>.

deal of money and ease a potentially difficult transition to a carbon-free or low-carbon economy. As such, China has committed to the “use of clean coal and [to] develop[ing] efficient and clean power generating technology, such as large-scale combined cycle units and poly-generation, and promote technology for carbon dioxide sequestration.”<sup>135</sup> To this end, the government has invested 46 million dollars into the GreenGen project, an effort to build a coal plant with carbon-capture technology.<sup>136</sup> By 2020, the project hopes to have a fully operation plant in place and that captures and stores 80 percent of the carbon emitted; construction began in June 2009.<sup>137</sup> However, the technology remains unproven, could prove costly, and ignores long-term issues about the viability of coal supplies.

China gets six percent of its power from hydroelectric power.<sup>138</sup> While it has adverse environment impacts,<sup>139</sup> it does not significantly contribute to climate change.<sup>140</sup> And accordingly, China has committed to expanding its hydroelectric capacity.<sup>141</sup> However, hydroelectric power has come under increasing attack, with some contending that it contributes more to climate change through indirect impacts than previously thought.<sup>142</sup> Also, climate

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<sup>135</sup> THE INFORMATION OFFICE OF CHINA'S STATE COUNCIL, CHINA'S POLICIES AND ACTIONS FOR ADDRESSING CLIMATE CHANGE 18, Oct. 29, 2008.

<sup>136</sup> MASSACHUSETTS INSTITUTE OF TECHNOLOGY, PROJECT: GREENGEN, April 8, 2010, *available at* <http://sequestration.mit.edu/tools/projects/greengen.html>.

<sup>137</sup> *Id.*

<sup>138</sup> U.S. ENERGY INFORMATION ADMINISTRATION, U.S. DEPARTMENT OF ENERGY, COUNTRY ANALYSIS BRIEFS: CHINA, updated July 2009, *available at* <http://www.eia.doe.gov/emeu/cabs/China/Full.html>.

<sup>139</sup> ALTERNATIVE ENERGY, HYDROELECTRIC POWER, *available at* <http://www.altenergy.org/renewables/hydroelectric.html>.

<sup>140</sup> UNION OF CONCERNED SCIENTISTS, HOW HYDROKINETIC ENERGY WORKS, *available at* [http://www.ucsusa.org/clean\\_energy/technology\\_and\\_impacts/energy\\_technologies/how-hydrokinetic-energy-works.html](http://www.ucsusa.org/clean_energy/technology_and_impacts/energy_technologies/how-hydrokinetic-energy-works.html).

<sup>141</sup> THE INFORMATION OFFICE OF CHINA'S STATE COUNCIL, CHINA'S POLICIES AND ACTIONS FOR ADDRESSING CLIMATE CHANGE 28, Oct. 29, 2008.

<sup>142</sup> *Water power “fuels climate change”*, BBC NEWS, May 31, 2000, *available at* <http://news.bbc.co.uk/2/hi/science/nature/771465.stm>.

change may affect water flows such that expensive hydroelectric systems could be rendered useless in the coming decades.<sup>143</sup>

Solar power plays an important role in China's energy portfolio. China leads in solar energy with more than 110 million square meters of solar energy collectors.<sup>144</sup> Slightly more than 53 percent of this capacity is dedicated to providing for personal domestic use, such as for heating homes in rural China (42.86 million square meters), powering stoves (1.12 million square meters), and providing energy for homes (14.68 million square meters).<sup>145</sup> China is planning to expand this capacity: "China will actively take advantage of solar power to generate electricity and use it for heating . . . ."<sup>146</sup> However, this focus on solar power is targeted towards addressing individual needs and not the industrial-levels of energy required for production and growth.<sup>147</sup>

Of all the renewable energy sources being developed in China, wind power has the most potential to deliver clean industrial-levels of electricity. China currently has six million kilowatts of installed wind power capacity.<sup>148</sup> This capacity is swiftly increasing too: "In 2006 and 2007, some 3.05 million [kilowatts] of installed capacity was added, an average annual increase of 148 percent."<sup>149</sup> China is investing expanding their existing wind-power capacity, seeking to "develop rapidly more of its wind-power potential to the scale that industrialization

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<sup>143</sup> EUROPEAN ENVIRONMENTAL AGENCY, WATER AND HYDROELECTRIC POWER, Nov. 29, 2005, *available at* <http://www.eea.europa.eu/themes/climate/multimedia/water-and-hydroelectric-power/view>.

<sup>144</sup> THE INFORMATION OFFICE OF CHINA'S STATE COUNCIL, CHINA'S POLICIES AND ACTIONS FOR ADDRESSING CLIMATE CHANGE 17, Oct. 29, 2008.

<sup>145</sup> *Id.*

<sup>146</sup> *Id.*

<sup>147</sup> *Id.*

<sup>148</sup> *Id.* at 27.

<sup>149</sup> *Id.*

can be achieved.”<sup>150</sup> The State Council is also pursuing the construction of large wind-power farms, ranging from one to ten million kilowatt generating capacity.<sup>151</sup>

Because of this emerging policy that is pushing wind-power, China is experiencing a boom in the wind industry.<sup>152</sup> In 2009, China became the leading producer of wind turbines.<sup>153</sup> Current projects having China achieving 100 gigawatts of wind-power capacity by 2020;<sup>154</sup> this would surpass anticipated nuclear energy capacity by 30 gigawatts.<sup>155</sup> Despite these advances, wind power has some lingering issues. Wind power is necessarily dependent on the weather, and wind is not necessarily available at all times.<sup>156</sup> As such, while nuclear power is reliably available, wind power is subject to the weather and wind currents.<sup>157</sup> And while technological advances promise to provide a means of storing wind-power, they are not fully developed.<sup>158</sup> Furthermore, wind-power development has led to the additional construction of coal power plants to back up wind farms when they have to shut down (because of a lack of wind or

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<sup>150</sup> THE INFORMATION OFFICE OF CHINA'S STATE COUNCIL, CHINA'S POLICIES AND ACTIONS FOR ADDRESSING CLIMATE CHANGE 28, Oct. 29, 2008.

<sup>151</sup> *Id.*

<sup>152</sup> Rujun Shen and Tom Miles, *China's wind-power boom to outpace nuclear by 2020*, REUTERS, April 20, 2009, available at <http://uk.reuters.com/article/idUKPEK33615120090420>.

<sup>153</sup> David Sassoon, *Heads Up: China To Be #1 Wind Turbine Maker in '09*, SOLVECLIMATE, Jan. 28, 2008, available at <http://solveclimate.com/blog/20080128/heads-china-be-1-wind-turbine-maker-09>.

<sup>154</sup> Rujun Shen and Tom Miles, *China's wind-power boom to outpace nuclear by 2020*, REUTERS, April 20, 2009, available at <http://uk.reuters.com/article/idUKPEK33615120090420>.

<sup>155</sup> *Id.*

<sup>156</sup> Martin LaMonica, *Saving wind power for later*, CNET NEWS, Mar. 27, 2007, available at [http://news.cnet.com/Saving-wind-power-for-later/2100-11392\\_3-6170659.html](http://news.cnet.com/Saving-wind-power-for-later/2100-11392_3-6170659.html).

<sup>157</sup> *Id.*

<sup>158</sup> See Martin LaMonica, *Saving wind power for later*, CNET NEWS, Mar. 27, 2007, available at [http://news.cnet.com/Saving-wind-power-for-later/2100-11392\\_3-6170659.html](http://news.cnet.com/Saving-wind-power-for-later/2100-11392_3-6170659.html) (discussing how wind power could be stored using compressed air); Matthew Knight, *Where to store wind-powered energy? Under water!*, CNN.COM, April 8, 2008, available at <http://www.cnn.com/2008/TECH/science/03/31/windpower/index.html> (discussing how wind power could be stored using ocean or water currents).



because the wind may be too strong to harness).<sup>159</sup> However, wind power has the potential to compete with nuclear power to produce the electricity that China needs to maintain growth, while having the advantage of lacking nuclear power's long-term issues.

## V. The Nuclear Gamble

China's decision to expand its nuclear power industry is an investment like any other, it has risks and benefits. However, it is a massive, long-term multi-billion dollar investment that could impact China for centuries. This is balanced against the risk of lost opportunities, public health problems, and the possibility that cheaper, cleaner, and more efficient technology will be developed. In this way, expanding nuclear power is China's big gamble. A gamble whose terms will become clearer as China tackles the issues that come with nuclear power and while alternative technology develops, both to the benefit of nuclear power and competing power sources.

The benefits of nuclear power are straight forward. Nuclear power produces large amounts of power, enough to fuel industrial production and general development, at relatively cheap rates. It produces no direct climate-changing emissions; so while it does impact the environment,<sup>160</sup> it does not contribute to climate change. Uranium fuel is available, and the technology exists<sup>161</sup> that allows for spent fuel to be processed into useable plutonium, further extending availability into the future. And despite the public's safety concerns, there have been

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<sup>159</sup> Louisa Lim, *China's Wind Power Plans Turn On Coal*, NPR, Dec. 10, 2009, available at <http://www.npr.org/templates/story/story.php?storyId=121244275>.

<sup>160</sup> For example, the environmental impacts of uranium mining, cooling water intake and discharge, facility construction, etc.

<sup>161</sup> MASSACHUSETTS INSTITUTE OF TECHNOLOGY, *THE FUTURE OF NUCLEAR POWER* 29–30, 2003.

very few actual significant nuclear power accidents.<sup>162</sup> Quite simply, nuclear power is an available means of mitigating climate change without compromising economic growth or development.

The risks and issues of nuclear power are, however, more complex than the benefits. Nuclear power plants are expensive to construct and maintain, that is just during the lifetime of the power plant. Then there is the storage of the nuclear waste that results from the process. It cannot be stored just anywhere by just any means. The waste must be secured so that it will not leak out and become a risk to human health, either through direct contact or through contamination of resources, i.e. water tables. In addition, the nuclear waste must be secured away from those who would misuse it, namely terrorists. Because of its hazardous nature, nuclear waste could easily be used as a weapon. So the safe and secure storage of nuclear waste is an expensive byproduct of developing nuclear power, and it is a byproduct that must be managed for hundreds of years. The long-term costs of nuclear power are large and difficult to precisely determine, even assuming that there are no intervening incidents.

Perhaps the greatest risk that comes with nuclear power is the risk of lost opportunity. Since nuclear power requires a large upfront capital investment and long-term maintenance and security costs, and because there is only so much money available for capital investments and other government initiatives, investing in nuclear power means not investing in something else. It could mean not investing in healthcare, transportation infrastructure, education, or research and development of clean energy technology. China is sacrificing the possibility of investing in

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<sup>162</sup> *Id.* at 9–10.

those areas so that nuclear power can generate five percent of their power needs by 2020 and 16 percent by 2030. This focused investment on nuclear power could preclude investments in other areas that would further China's development more so than nuclear power itself. However, that is speculative, compared to the certain benefits of nuclear power.

That is what China's gamble on nuclear power comes down to: what technologies or other benefits could emerge if they were invested in to the same degree as this new nuclear power expansion? The speculative sacrifices that China is making could be great, or they could be insignificant compared to the benefits of nuclear power. The only certainty is that the benefits of nuclear power are readily acknowledgeable, while everything else is just guesswork and is currently uncertain.

Since the goal of the nuclear power plant is to mitigate climate change by reducing emissions that seems like the critical rubric by which to analyze possible technologies. Looking at alternative or clean energy technologies, there are possible investments that could challenge the idea that nuclear power is the best investment. These technologies could yield results that could prove more beneficial than those of nuclear power.

A substantial investment in carbon capture and sequestration technology could provide many benefits. China has plentiful coal resources and has developed substantial infrastructure designed to turn that raw coal into electricity. If China is to have substantial success in reducing its emissions, it must either reduce its reliance on coal power or reduce the emissions of those power plants. Carbon capture and sequestration technology could reduce emissions by retrofitting technology to existing coal power plants and by integrating the technology into

future designs. This technology could prevent massive changes in existing infrastructure and would avoid the long-term problems that come with nuclear power.

Similarly, solar power could yield benefits that would surpass those of nuclear power if given an equally large investment. A large investment could expand China's solar power capacity so that it could provide industrial-level amounts of electrical power. It could also resolve the issue of how to store power, since solar power technology does not generate power when sunlight is not available. A multi-billion dollar investment in solar power technology, especially so as to resolve the storage problem, would yield benefits that would certainly be competitive with the benefits of nuclear power and that would certainly compare well against the risks of nuclear power.

Wind power has the same problem of solar power, which is how to store surplus power so that it can be used when wind power is not directly available. An equally large investment for wind power as to nuclear power could resolve that problem. Wind power has already been shown to be able to produce industrial amount of electricity, and it is already projected to surpass the capacity of nuclear power in China by 2020. Also, wind power has more readily evident, but nascent, technology in which to invest. Wind power energy could be stored through compressors or through wave technology.<sup>163</sup> If capital was poured into these technologies, wind power could become a clean, reliable source of power that would very likely be superior to nuclear power.

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<sup>163</sup> Matthew Knight, *Where to store wind-powered energy? Under water!*, CNN.COM, April 8, 2008, available at <http://www.cnn.com/2008/TECH/science/03/31/windpower/index.html> (discussing how wind power could be stored using ocean or water currents); Martin LaMonica, *Saving wind power for later*, CNET NEWS, Mar. 27, 2007, available at [http://news.cnet.com/Saving-wind-power-for-later/2100-11392\\_3-6170659.html](http://news.cnet.com/Saving-wind-power-for-later/2100-11392_3-6170659.html).

The problem is that these potential investments offer no concrete or immediate benefits. Nuclear power technology exists, the problems are clear if not easily resolved, and the benefits are available once the reactors are engaged. Improved solar technology will likely exist, but it does not exist now. Carbon capture and sequestration technology has great potential, but there is no technology that can be put to use today to cut Chinese climate-changing emissions while generating power. Wind power could be harnessed through wave or air compressor technology, but it has yet to be proven. While these and other technologies are probable, they still exist more on paper than in reality.

The Chinese government's gamble may pay off and prove to be the best decision, not just the safest or least speculative. The wisdom of investing in nuclear power will become more evident as time goes by and as new technologies emerge. These technologies may indicate that nuclear power was a waste of money, or they improve the benefits or mitigate the costs of nuclear power. Time and the progress of technological development will tell. Thus, ultimately, it will not be the amount of money spent on nuclear power or the selection of a safe and secure waste storage site that will vindicate the Chinese government's investment in nuclear power, but it will be the success or failure of emerging nuclear and clean energy technologies that will provide the final verdict.

## VI. Conclusion

Nuclear power is neither good nor bad; it is simply a piece of technology to be used for the benefit of humanity. The Chinese government has chosen to invest heavily into that technology to benefit their people. An expanded nuclear power infrastructure will generate large

amounts of energy while not contributing to climate change. Those are concrete results that will benefit China's interests. And while there are unresolved issues with nuclear power, the Chinese government is acting to address them. China is working to maintain their already solid safety record. New domestic and foreign sources of uranium, the fuel for nuclear power, are being secured. And a secure waste site is being planned, although it is far from being completed.

However, the Chinese government is still gambling. Their investment in an increased nuclear power infrastructure means that other technologies that could be invested in and that could prove more beneficial will have to wait. And the consequences could be great for China if this bet falls through. China will be stuck with the major problem inherent to nuclear power, large amounts of a very toxic nuclear waste. Meanwhile, other countries that invested in those clean energy technologies (assuming others will do so) will have significantly mitigated their contributions to climate changes, own potentially exportable and profitable technology which can be sold to other countries that want to mitigate their emissions, and they will not have large amounts of nuclear waste that is expensive to store securely. Those dynamics, if they go against China, could slow down China's economic development to the benefits of others, defeating their overarching policy goal; quite the loss to take gambling on nuclear power.