# Nuclear Power and China's Energy Future: Limited Options原子力発電と中国の将来––限られた選択肢

Augustin Boey

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### Nuclear power after Fukushima

In the aftermath of the Fukushima disaster, the fate of nuclear power appeared to hang in the balance as generating states scrambled to conduct safety checks on their existing nuclear reactors and newly-restarted nuclear programmes. A number of these states have since elected to phase out their nuclear power plants.

While it is clear that full extent of the political, social and environmental impacts of the nuclear disaster have yet to be seen at both the national and transnational levels, it is nonetheless apparent that the official responses by various countries have stabilized for now into a fairly coherent pattern. Many OECD nuclear power generating states have officially decided to continue their nuclear energy programmes. However, Belgium, Germany and Switzerland have thus far chosen to abandon nuclear power.[1] These European states together produced 8 percent of total electricity generated from nuclear power in 2009. The potential loss of worldwide nuclear power generating capacity is therefore considerable.

In marked contrast to these countries, all non-OECD countries with operating nuclear power plants (NPPs) or nuclear programmes underway have thus far given no indication that they are likely to abandon them. India has not announced any material change to its nuclear energy plans to boost generating capacity to 63 GW by 2032. Likewise, Russia's nuclear energy policy was endorsed by PM Vladimir Putin in April 2011 as part of a balanced energy mix. The nuclear status quo for many of these developing countries thus remains despite the impacts of the Fukushima nuclear disaster.

This difference in nuclear energy stances reflects critical changes since the Three Mile Island and Chernobyl disasters in the 1970s and 1980s. Nuclear power has increasingly become a key component of electricity diversification strategies throughout the developing world. More significantly, it has entered the realm of the attainable for many developing countries. Nuclear power was not initially a credible energy policy option for these countries as they did not possess the necessary capital and capacity to develop the complex infrastructural, technical and financial arrangements necessary for the successful operation of a civilian nuclear energy programme. However, many of these countries have experienced economic take-offs in the decades since the two major pre-Fukushima nuclear disasters, namely, Three Mile Island and Chernobyl. They have consequently been faced with a commensurate growth in energy demand and this has served to enhance the appeal of nuclear power.

**Mainland China in 2010 had 16 nuclear power reactors in operation, 7 under construction, and 34 planned. China's existing and planned nuclear power sites (IAEA map based on July 2010 data.)**

Prior to Fukushima, China had been pursuing the world's most ambitious nuclear power program. Following Fukushima, this is still the case. Its nuclear expansion goals are primarily driven by closely related energy security and carbon emission concerns and, relative to its other power generating options, the fact that it is arguably a relatively environmentally friendly and efficient source of electricity.[2] This underscores the significance of China's decision to forge ahead with its 12th Five Year Plan target to install 40 additional gigawatts of nuclear capacity by 2015.

This article argues that China will proceed with its nuclear power expansion, despite Fukushima, due firstly to its energy policy imperatives and secondly because it is relatively more efficient and produces less emissions than its other power generating options. In the next section, a brief account of the reasons behind China's continued pursuit of nuclear energy is given. China's current and future energy needs are put in perspective in the following section where projections for China's electricity generation mix and carbon emissions up till 2030 will be discussed. On the assumption that the projections are reasonably accurate, the penultimate section will briefly consider the environmental implications of China's projected power generation demands. Given China's energy policy imperatives, the final section compares the nuclear power, fossil fuels and renewables non-environmental trade-offs. Some observations and policy recommendations conclude the article.

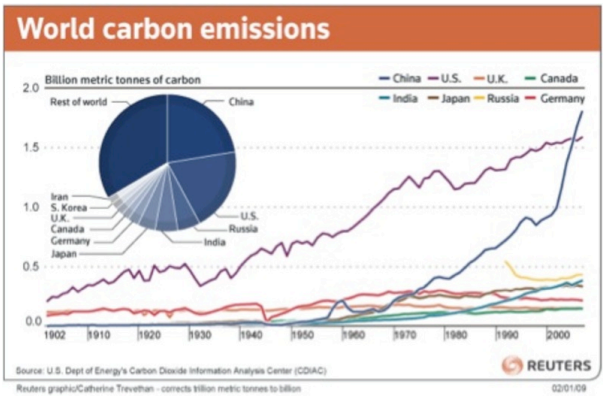
## China's energy needs, climate change and nuclear power

As a growing superpower, China has been making its presence felt in a variety of international arenas. It has long been the world's most populous country, with over 1.3 billion people. China's burgeoning economy, with annual GDP growth around ten percent since the 1980s, allowed it to surpass Japan in 2010 to become the world's second largest economy after the US. As the "world's factory," China has become the world's largest emitter of carbon dioxide since overtaking the US in 2006 in annual volume of emissions, although China's carbon dioxide emitted per capita remains significantly lower than that in the US.

Since China's economic opening and reform program in the 1970s, the demographic, economic and environmental shift that has occurred has necessarily built upon a commensurate growth in electricity demand. Most of the electricity produced in China has thus far been supplied by coal, which provided 2,940,525 GWh of electricity in 2009 and constituted almost 80 percent of the total electricity generation mix.[3] However, the combustion of coal also produces a large quantity of greenhouse gases and other pollutants and is as such a distinctly environmentally-unfriendly fuel, particularly as it is used in conventional coal-burning power plants. With climate change becoming an increasingly important issue on environmental and political fronts, China's energy policy must therefore simultaneously

confront the twin challenges of ensuring energy security and climate change mitigation.

Amongst China's energy security issues is the pressing need to ensure that domestic power demands are met. China's power generation capacity has increased rapidly, as has its electricity infrastructure, but this growth in supply has only unevenly met the growing demands for electricity.[4] This growth is predicted to continue in coming decades – the International Energy Agency has projected that China's total electricity generation will increase by a compound annual growth rate (CAGR) of 3.9 percent from 2009 to 2035.[5] Of this total, coal is projected to increase by a CAGR of 2.5 percent while nuclear power, which has a much smaller base, is projected to increase by a CAGR of 10.6 percent in the same period.[6]




The need to meet the sustained increase in electricity demand is unlikely to let up as China's economy continues to grow. This represents a perennial energy policy challenge.[7] Recent reports indicate that China's power supply in 2012 will again be strained by the low capacity additions relative to growth in power consumption.[8] China's unrelenting consumption of electricity is complicated by its quest for energy self-sufficiency. While China does possess substantial fossil fuel reserves, and indeed used to export oil and coal, it has become a net importer of fossil fuels and has extended its geopolitical reach in part to feed its growing power demands.[9] The government's decision to continue its nuclear power programme can thus be seen as a combination of realism about the growing requirements of its electricity grid and belief that the viability and safety of nuclear power technology has not been seriously compromised by the Fukushima nuclear disaster which, unlike Chernobyl or Three Mile Island, was triggered by natural disaster rather than human error.[10]

Nuclear power has also been legitimized in China's public policy due to its favourable greenhouse gas profile. Nuclear power produces almost zero carbon directly and its substitution for fossil fuel plants reduces the net greenhouse gas emissions emanating from electricity production.[11] Greenhouse gas emissions in China are largely produced by the power sector due to its heavy use of coal.[12] China's need to quickly reduce carbon emissions in power generation is highlighted by the government's objective to reduce the ratio of GDP to carbon dioxide emissions by 40-45 percent between 2005 and 2020.[13] Furthermore, the heavy reliance upon coal fired power generation causes immediate local health and environmental problems. Pollutants released from coal combustion have been identified as causing the rise of respiratory illnesses and has precipitated increased occurrences of acid rain and a consequent degradation in soil quality.[14] These factors enhance nuclear power's appeal as a means to reduce greenhouse gas emissions and improve environmental quality.

## Nuclear power in China's electricity generation mix

China's first nuclear power reactor was connected to the grid in 1991. Since 1993, nuclear generation has grown rapidly, especially since 2001. By 2004, ten commercial power reactors were on the grid and in 2009, 70,134 gigawatt hours of electricity were produced from nuclear power.[15] China's nuclear expansion is continuing

apace. The 25 reactors currently being constructed represent around half of all current worldwide new build projects. According to the International Energy Agency (IEA), 89 percent of China's electricity in 2009 was produced from coal, with hydropower producing six percent or the second highest amount.[16] Nuclear power produced a comparatively paltry 2 percent of the electricity generation portfolio in the same year.

As highlighted above, however, China's nuclear capacity is projected to increase substantially due to exploding energy demands. The IEA predicts that China's energy demand will more than double from 920 Mtoe in 2009 to 1,867 in 2030.[17] This represents a Compound Annual Growth Rate (CAGR) of 3.43 percent, which outstrips the predicted global increase in energy demand in the same period by a CAGR of 1.85 percent. Over the period 2009 to 2035, the IEA predicts that the share of coal power in total electricity production will be reduced by 25 percent, with a projected 64 percent of electricity in China coming from coal in 2035.[18] This reduced role of coal in China accords with the predicted worldwide trend of decreasing reliance upon coal for power generation. The share of nuclear power, on the other hand, is expected to increase in China from its current 2 percent to 12 percent in 2035. This represents a CAGR of 12.68 percent. The IEA's projections roughly correspond with the United States Energy Information Administration's reference case projections in the 2011 edition of its International Energy Outlook, which states that China's nuclear energy consumption will increase by 10.3 percent from 2008 to 2035, while the worldwide and the United States growth rate figures are 2.4 percent and 0.3 percent, respectively.[19]

China's carbon emissions from power generation are expected to increase at a CAGR of 2.15 percent from 3,324 Mt in 2009 to 5,200 Mt in 2030, while worldwide emissions are expected to increase at a CAGR of 1.02 percent from 11,760 Mt to 14,556 Mt over the same period.[20] It is important to note that this growth in nuclear power will not occur in isolation from growth in renewable power. Renewables are projected to increase from 56 Mtoe in 2009 to 264 Mtoe in 2030, growing with a CAGR of 7.66 percent in that period. This is a rapid projected growth rate by global standards, but it accompanies, not replaces, substantial growth in nuclear power. Chinese government plans call for having 20 percent of electricity produced by renewable power sources by 2020.[21]

## China's energy mix and its environmental implications

The environmental consequences, both international and domestic, of China's heavy reliance on coal for electricity generation renders more attractive the use of nuclear power. The government's latest climate change assessment has projected an increase in floods and droughts attributable to increased greenhouse gas induced warming, with knock-on effects on agriculture and economic growth.[22]

While worldwide carbon dioxide emissions from coal generation are expected by the IEA to be stable at around 72 percent of total carbon emissions from 2009 to 2035, China is expected to cut carbon emissions from coal-fired power generation from 98 percent in 2009 to the still very high level of 93 percent in 2035.[23] This is against a background of increasing total carbon emissions, with China's carbon emissions expected to increase by a CAGR of 7.66 percent over this period. According to some analysts, improvements in efficiency and widespread carbon dioxide capture and storage deployment will not be sufficient to offset the huge increases in energy consumption and thus will only slow but not stop China's rapidly increasing carbon dioxide emissions.[24]

Such environmental effects will not be confined within China's national borders. As the largest emitter of carbon dioxide in the world, there will

inevitably be global problems issuing from China's growing pollution. A study by Levy et al. published in the journal Climate Change has predicted that future global environmental changes resulting from changes in climate, carbon dioxide concentrations and land use patterns will harm the terrestrial biosphere Amazonia, the Sahel, South Central USA and Central America regions most.[25] Therefore, while nuclear power costs significantly more than that produced from the fossil fuels, nuclear power capacity is expanding as a key strategy to reduce China's emissions.[26] Indeed, the low carbon profile of nuclear power and its high capacity factor has led some, such as the scientist James Lovelock and Patrick Moore, co-founder of Greenpeace, to embrace nuclear power as a critical climate change mitigation technology.

However, as the Fukushima nuclear disaster has so vividly demonstrated, nuclear power poses its own set of environmental problems. Indeed, it might be said that substituting fossil fuel-generating capacity with nuclear power is to risk incurring one kind of global catastrophe for another. Chinese planners argue, however, that the risks of nuclear power can be mitigated by judicious planning, utilizing advanced nuclear reactor technologies, appropriate site selection and good construction and operating practices.[27]

Perhaps the most vexing environmental issue associated with China's nuclear power programme is the issue of spent fuel disposal. The World Nuclear Association (WNA) estimates that China's nuclear power industry produced about 600 tonnes of used fuel in 2010 and will produce 1000 tonnes in 2020.[28] Since the inception of the nuclear power program, the government has envisioned a closed fuel cycle as the program's long-term plan for its nuclear program. A number of facilities and projects have been created towards that end. One of them is the Lanzhou Nuclear Fuel Complex, a centralised fuel storage facility constructed in Gansu province. It has a pilot nuclear reprocessing plant that can annually process 50 tonnes of spent fuel using the PUREX process. The Complex itself is in its initial stages and will ultimately have a storage capacity of 550 tonnes. In November 2010, the China National Nuclear Corporation (CNNC) signed an agreement with French nuclear giant Areva to build a reprocessing plant in Jinta (Gansu Province) to be operated by Areva using advanced French technology. It is slated to begin operation from 2025.

The push towards closing the nuclear fuel cycle was furthered in November 2011, with the creation of CNNC Ruineng Technology Co Ltd to industrialise used fuel reprocessing technology and mixed-oxide fuel production. CNNC Ruineng will also be tasked with the storage and management of spent fuel. Currently, most of the used fuel is stored at the reactor sites, with all the attendant risks associated with doing so, rather than in permanent deep geological storage or being reprocessed. The issue is hardly unique to China. The permanent disposal of nuclear power waste has long been the bugbear of the nuclear power industry worldwide and no nuclear power producing state has yet to find a solution to it.

## Tradeoffs and policy choices

Other considerations shape China's decision to continue its nuclear power programme. Coal power is especially egregious with regard to safety. From 2000 to 2010, 47,676 Chinese miners died in coal mining accidents.[29] This puts nuclear power in an especially good light.[30] Coal combustion also releases more radioactivity than nuclear power per unit of electricity generated due to the concentrating effect of combustion on otherwise trace amounts of uranium and thorium present in coal.[31]

While China has announced ambitious targets for renewable power deployment, it cannot presently rely exclusively upon renewable power to fulfill rapidly growing energy demads. One

reason for this is the substantial distances between the urban centres of electricity demand and the rural sites of renewable power potential.

This problem is especially stark in the case wind power. Wind power potential is concentrated mainly in China's north and west, while the primary centres of electricity demand are located in the eastern coastal areas.[32] Electricity demand in Chinese cities has been increasing exponentially due to high rates of rural-urban migration.[33] The construction of nuclear power stations near urban demand centres will probably be less costly than the transmission and infrastructural costs to connect them to distant wind power sources.[34] Secondly, solar and wind power are both intermittent sources of electricity and have low capacity factors, limiting their ability to provide the immense baseload electricity requirements. Thus, they do not obviate the need for conventional sources of electricity. As for hydropower, it does produce large amounts of electricity reliably when operating under normal weather patterns, but has been affected by recent droughts.

Thirdly, even increasing renewable power capacity does not eliminate deleterious environmental effects. The rare earths crucial for producing renewable power sources, such as neodymium for the magnets in wind turbines, are mined unsustainably and toxic tailings are often irresponsibly dumped to the detriment of local communities and the environment.[35] Likewise, negative impacts from some of China's large hydropower projects, such as the Three Gorges Dam and those on the Mekong River, have been extensively discussed and need not be rehearsed here.[36]

Nevertheless, a plausible case for a dramatic expansion of renewable power sources in preference to nuclear power may be made in anticipation of infrastructural and technological improvements and to mitigate the path-dependent "lock-in" of less sustainable forms of power generation. In the latest edition of the World Energy Outlook, the IEA has highlighted the urgent need for countries to make the right energy policy decisions as investment in high-carbon infrastructure – such as conventional coal-fired power plants – instead of cleaner alternatives would lock-in future emissions and make mitigating climate change progressively costlier and more difficult.[37] Nuclear power should therefore be scrutinized according to this decision-making criterion as it is not the only possible means to mitigate climate change and is not exempt from competition with other power generation options on grounds both of cost-effectiveness and political acceptability.[38] But these long-term considerations should not obscure the realities of China's overburdened grid. Even with its current coal-dominant electricity generation mix, China still faces severe power shortages. This is due in part to the fact that coal production is insufficient to meet demand. Nuclear power is thus an important energy source in China.[39]

Energy security concerns combined with a desire for a greater degree of energy independence are important reasons for China's continued use of nuclear power. China's long-term energy policy objective is to ensure that domestic resources and generating capacity can supply 90 percent of national energy demand.[40] The fact that indigenous coal reserves will be depleted within the next half century is another factor supporting the need for other electricity production sources to be quickly developed.[41] It is with these policy considerations in mind that the chief of the Chinese National Energy Board proclaimed that "only nuclear power can substitute [for] fossil energy on a large scale at the present time".[42]

China has an impressive track record of mobilizing massive investment, expertise and resources to support government policy objectives. From the Three Gorges Dam to its aggressive deployment of wind generation capacity, and from its gargantuan reforestation

efforts to its ambitious nuclear program, it has shown ability to take swift and decisive action. The question is whether the same abilities will be manifest in tackling problems of growing carbon emissions and energy security in environmentally-friendly and cost-efficient ways.

The Chinese government remains committed to the expansion of its nuclear power program together with development of other clean electricity sources such as renewables. Feed-in Tariffs for renewable power need to be expanded to serve a complex and growing electricity situation,[43] in order to sustain renewable power development and avoid locking-in unsustainable sources of electricity generation. By the same token, current efforts to promote energy conservation and efficiency are crucial and market and institutional barriers to such efforts must be met with sound policies. It is unlikely that the Chinese government will cease its support for nuclear power in the foreseeable future even as it seeks to expand the supply of renewables. With stringent regulation and monitoring by both national and international nuclear bodies to ensure its continued safety, this should not be a cause for alarm. Rather, continued full reliance on fossil fuels most certainly would be.

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## Notes

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