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Viewpoint

A comparison of the nuclear options for greenhouse gas mitigation in China and in the United States

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ABSTRACT

China is quickly building up its nuclear power capacity while the hailed nuclear renaissance in the United States has been largely stagnant. The political and industrial structures explain the divergent paths. This paper draws lessons from the French experiences in deploying nuclear power and uses the lessons in comparing Chinese and U.S. policies. An authoritative political system and state-owned utility industry allow China to emulate the French approaches such as government-backed financing and broad-scale deployment with standardized design. The democratic political system and fragmented utility industry, and the laissez-faire ideology in the United States, on the other hand, are unfavorable to a nuclear renaissance. The prospect of a nuclear revival in the United States remains highly uncertain.

As China builds up its nuclear industry, it will be able to reduce carbon emissions without a carbon price through a national plan to deploy low-carbon nuclear electricity, while the United States cannot implement a climate policy without a carbon price. American politicians should stop using China's lack of carbon cap as an excuse for postponing the legislation of a carbon price.

1. Introduction

In the early 2000s, many in the United States were expecting a revival of nuclear power. The hailed nuclear renaissance in the United States, however, proceeded very slowly, if at all. China, on the other hand, is quickly moving forward to scale up its nuclear power deployment. The recent diverge between the Chinese and the U.S. nuclear power development mirrors the historical divide between the France and the United States in the 1980s.

As shown in Fig. 1, the U.S. nuclear reactor market collapsed in 1974–1975. Overburdened by cost overruns, construction delays, and faced with lowered electricity demand outlook, the U.S. utilities canceled over a hundred of previously ordered nuclear reactors in the late 1970s and throughout the 1980s (Bupp and Derian, 1978; Campbell, 1988). Although the Three-Mile-Island (TMI) accident is commonly misperceived as the main cause of the collapse of the U.S. nuclear market, the perception is not true. TMI cannot account for the collapse because the accident happened in 1979, which was several years after the collapse. The main causes for the collapse of nuclear industry in the United States were economic and institutional factors.

In 1974, the French government decided to greatly buildup its nuclear power capacity. Unlike the United States, France has a national utility, Electricité de France, in charge of power supply for the entire country. The French nuclear power program was led by technocratic elites and funded with government-allocated capitals (Campbell, 1986; Schneider, 2008; Kidd, 2009; Sovacool and Valentine, 2010). France adopted the U.S. pressurized water reactor (PWR) design in its national plan and eventually built 58 reactors with a standardized design (Jasper, 1990). A single responsible authority and one standard design allowed the best practice to be replicated. Thanks to economies of scale and technological learning, French nuclear power turned out to be significantly cheaper than its U.S. counterparts (Valenti, 1991). A French nuclear power plant cost roughly the same as the cheapest American plant or half the cost of the average American plant (Jasper, 1990). In the United States, the fragmented utility industry and the lack of standardization prevented economies of scale and deterred technological learning. The best-practice costs in the United States were as good as the French ones, but the average was by far worse.

Other factors also contributed to achieving the French nuclear power buildup (Collingridge, 1984; Campbell, 1986; Lester and McCabe, 1993; Schneider, 2008; Sovacool and Valentine, 2010). The EDF enjoys state-backed finance, which the U.S. utilities typically lack. A nuclear power project is a tremendous financial undertaking. State-backing enables EDF to shoulder the financial risk. In addition to standard reactor design, national planning also has the advantage of site consolidation. A typical French nuclear power site accommodates four reactors, compared to typically

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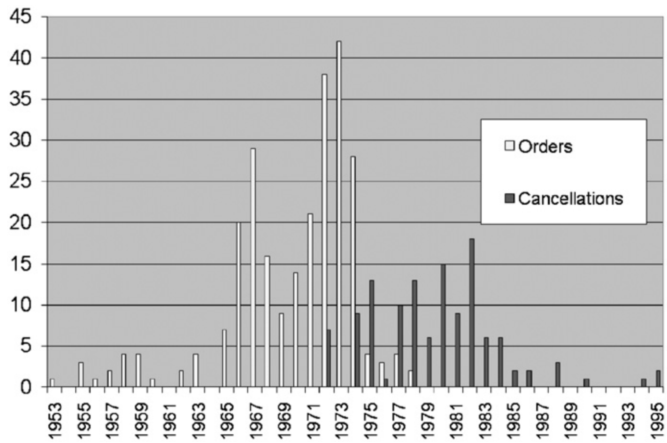

Fig. 1. Orders and cancellations of civilian nuclear reactors in the United States.

two reactors per site in the United States. More reactors per site contribute to lower costs in permitting and site preparation. A typical U.S. utility company serves a much smaller area than France. It is more difficult to achieve the economies of scale in the United States. To summarize, the French secrets in building up a nuclear-dominant electricity system include centralized planning, state-backed finance, standardized design and site consolidation. Government and industry structure largely explained the divergence between the French nuclear power buildup and the U.S. collapse in the past. A similar divergence exists today between China and the United States.

2. Nuclear buildup in China

China did not have any civilian nuclear power until 1994. China's first nuclear power plant (Daya Bay 1&2) adopted the French PWR design. Meanwhile, China also built a reactor with indigenous PWR (CNP300) design. Combining the experiences from the indigenous CNP300 and technology transfer from France, China developed semi-indigenous PWR (CPR1000) reactors. During the 1990s, standardization was not a high priority in China's nuclear power policy. In addition to the indigenous CNP/CPR reactors and the French reactors, China also built two reactors with Canadian pressurized heavy water design (PHWR or CANDU) and two with the Russian PWR (VVER) design. In the early 2000s, Chinese technocrats called for standardization. There was a debate over the choice between the semi-indigenous CPR1000 and the more advanced AP1000 designs (Xu, 2008; Lu, 2009). The National Development and Reform Commission (NDRC) eventually chose AP1000 as the official standard for the future nuclear buildup. Critics of this choice argued that AP1000 lacks proven construction record, and China would be the first to try building one. CPR1000, on the other hand, has a track record of construction experiences. Large-scale deployment of an untried design is risky. Therefore, China has to postpone its nuclear power deployment until its first (also the world's first) four AP1000 reactors are completed. However, faced with increasing international pressure to reduce greenhouse gas (GHG) emissions, China cannot wait until the AP1000 design is fully proven to deploy nuclear power. Therefore, China is not abandoning its CPR1000 design in the near term. It is currently building 16–20 CPR1000 reactors. AP1000 remains the official choice for the long term. More than 50 AP1000 reactors have been proposed.

The Chinese government established the State Nuclear Power Technology Corporation (SNPTC) to be responsible for the technology transfer and indigenization of AP1000. SNPTC is also charged with the development of CAP1400 design, which would be an indigenized and enlarged version of AP1000. If the first four AP1000 reactors perform satisfactorily, China could scale up the AP1000 deployment in the mid-term and follow up with CAP1400 reactors in the long term. The Chinese nuclear power program is on a path to become the biggest nuclear power deployment in human history. Some Chinese researchers are concerned with the potential high costs of AP1000 and argue for wider deployment of CPR1000, which already has a satisfactory cost record (Table 1; NDRC, 2008; Pan, 2009; Zhou et al., 2009). Due to such concerns, the CPR1000 design has continued to be deployed and developed in the near term.

The NDRC is the authority in charge of approving nuclear projects and administratively set the wholesale generation price (RAP, 2008). A nuclear power plant sells electricity at a price that is determined according to the levelized cost plus allowed return of this particular plant (Liu, 2009; Li, 2009). Such pricing scheme guarantees profitability for every nuclear power plant. Therefore, Chinese nuclear utilities do not need a carbon price to be profitable. The state-owned corporations will build as many nuclear power plants as the NDRC instruct/allow them to.

China National Nuclear Corporation (CNNC) is the owner of the first two AP1000 reactors currently under construction at the Sanmen site. China Guangdong Nuclear Power Holding Company (CGNPC) owns the CPR1000 design and operates most of the existing plants with French PWR and the CPR1000 designs. It is also the primary owner of most CPR1000 projects currently under construction. Before 2006, only these two specialized nuclear power companies (i.e. CNNC and CGNPC) were authorized to build and operate nuclear power plants in China. In 2006, one of the conventional power corporations, China Power Investment Corporation, broke the duopoly and obtained the license to become the primary owner of the nuclear power station at Haiyang site with two AP1000 units (Pan, 2009). Other state-owned conventional power companies have also expressed interests in entering the nuclear business. The NDRC has so far been cautious about further opening the market.

China's nuclear power development and deployment are nationally planned (Sovacool and Valentine, 2010). The state-owned banking system provides state-backed finance for nuclear projects. The administratively set tariffs guarantee profit. National planners dictate technology choice to insure standardization. Rapid demand growth allows large-scale deployment. A typical Chinese nuclear power plant site is designed to accommodate 8 reactors or more. Unlike the national monopoly in France, China's nuclear power industry is a state-owned oligopoly. Each of the two major designs (CPR1000 and AP1000) will be repeated at least in tens of projects.

Other features of the Chinese government also help to reduce costs of nuclear power. The Chinese constitution disallows private land ownership, which greatly eases the difficulty in siting. Legal challenges to nuclear projects, like those in the United States, are impossible in China, where the communist leadership openly rejects the very idea of judicial independence.

Table 1
Costs of nuclear plants in China.

CPR1000			AP1000		
Project	Cost/kW	Completion	Project	Estimated cost/kW	Expected completion
Lingao #1	$1800	2002	Sanmen #1, Haiyang #1	$1938	2013–2014
Lingao #2	$1550	2010	Sanmen #2, Haiyang #2	$1680	2014–2015