Siting Nuclear Power Plants Incorporating Strategic Flexibility

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Abstract Nuclear power is an important energy source for generating electricity in consideration of CO_2 emissions and global warming. Siting nuclear power plants is a challenging issue nowadays due to the volatility of long-term electricity demand, as well as public acceptance of nuclear technology. In the aftermath of the Fukushima Daiichi disaster, it is understood that public acceptance of nuclear technology plays a central role in the decision-making process regarding systems operations and capacity deployment policies, even outside of the country where the incident occurred. For example, Germany decided to close half of its plants after the catastrophic events of March 2011, and will close the remainder by 2022. Other countries, however, depend on nuclear technology, or a considering it as a viable alternative for sustainable power generation. Typical efforts on capacity deployment and siting of nuclear power systems in the literature do not account well for long-term (e.g., 40+ years) uncertain drivers. This work introduces a novel approach to nuclear power systems design and capacity deployment under uncertainty that exploits the idea of flexibility and managerial decision rules. Flexibility in engineering design—also referred as real option in design—is promoted as a means to deal pro-actively with uncertainty, and has been shown in many contexts to improve life cycle performance significantly as compared to standard design and systems evaluation methods. Decision rules can be described as "IF-THEN-ELSE" statements, and are captured in the model via non-anticipative constraints. New design and deployment strategies are developed and analyzed through a multi-stage stochastic programming framework based on sample average approximation. The proposed solution considers flexibility in terms of phased capacity deployment, in-site capacity expansion, and life extension, subject to demand and public

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acceptance uncertainty. The numerical analysis shows that the flexible design benefits from life extension flexibility most significantly. Flexible phased deployment and capacity expansion are also important when electricity demand is the main uncertainty driver considered.