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Minimizing the Cost of Innovative Nuclear Technology Through Flexibility: The Case of a Demonstration Accelerator-Driven Subcritical Reactor Park

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We have presented a methodology to analyze the expected deployment cost of a potential future nuclear technology facing significant technological uncertainty, the Accelerator-Driven Subcritcal Reactor (ADSR). We have focused the analysis on recognising potential flexibility in the design of the ADSR's accelerator system as a way to deal pro-actively with uncertainty in accelerator reliability and performance. We have demonstrated that changing the ADSR design such that it is flexible and can adapt during the project as uncertainties are resolved reduces significantly its expected Levelised Cost Of generating Electricity (LCOE).

Recognising uncertainties associated with a project allows for a more realistic economic appraisal. In contrast, not considering uncertainty may lead to severely incorrect assessment and design decision-making. Having identified uncertainties in, for example, technology within the system, it is possible to elicit and incorporate flexibility into its design. Flexibility enables a system to be modified during a project as the uncertainties are resolved. This mitigates the impact of downside scenarios and allows for the design to capitalise on upside opportunities. The net effect in this particular case demonstration is to reduce the expected cost of the project.

Discussed in this paper is a four-step analysis framework to account for uncertainty and flexibility in a demonstration ADSR reactor park. In the first step we developed a basic deterministic economic model to identify its LCOE without considering uncertainty. In the second step

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we identified sources of uncertainty in the design that would affect its LCOE. For simplicity of presentation, our analysis concentrates on one main uncertainty source: the performance of the accelerator system related to its technological reliability. In the third step we identified potential flexibilities in the design of the accelerator system. In this stage we determined that risks due to accelerator reliability uncertainty could be mitigated by enabling the real option to add another accelerator if necessary to improve electricity production, and to phase the system deployment over time as uncertainty is resolved. These considerations are included in the basic economic model in step 1. In the fourth step, we applied decision analysis to the deterministic inflexible and adaptable flexible demonstration ADSR reactor park designs, thus identifing the accelerator system that returns the lowest expected LCOE.

We discuss three possible deployment strategies for the demonstration ADSR reactor park. The first is an inflexible design where the owner commits from the outset to a phased construction of three pairs of reactors and accelerators. When operated each pair is entirely independent of the others, and they are all constructed regardless of the technology performance. The second is a flexible deployment strategy, where the reactor-accelerator pairs are again constructed in phase, but this time a fourth accelerator is planned for as is the ability for each accelerator to deliver its particle beam to any of the existing or planned reactors. This fourth accelerator is built in the second phase, but only if it is deemed economically beneficial to do so. This decision is made based on the better resolved accelerator performance uncertainty, having gained experience building and operating the first accelerator. The third strategy is also flexible and also plans for constructing up to four accelerators. Again all of the accelerators are constructed such that they can deliver their particle beam to any reactor; however, in its first construction phase two accelerators and one reactor are built. If it is determined to be necessary, an accelerator is also constructed in the second and again in the third construction phases along with the two additional reactors. If the accelerator technology has performed well during the first phase, only one more accelerator is constructed between the latter two phases. Our economic analysis of these deployment strategies finds that the cost of enabling the flexibility to construct a fourth accelerator if it is desirable is small compared to the degree to which the flexible strategies reduce the expected LCOE.

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