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Hedging Against Technology Risks of the Accelerator System of a First-of-a-Kind Accelerator-Driven Subcritical Reactor

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Accelerator-Driven Subcritical Reactor (ADSR) technology promises to generate electricity while emitting minimal amounts of carbon dioxide, ensuring a very high level of safety, significantly reducing or even consuming high-level radioactive waste and improving the sustainability of the world nuclear fuel resources by multiple orders of magnitude. Inevitably a technology that promises so much has its challenges. For ADSRs one of the biggest is its required particle accelerator system. Contemporary accelerators are neither powerful nor reliable enough for ADSR purposes. The large amount of research and development required to improve them will result in a significant uncertainty in the realised performance of the first ADSR accelerator. This uncertainty will create an operational risk to the capital invested in demonstrating the first-of-a-kind ADSR. A further general concern is that the construction of an accelerator system along with a reactor may untenably increase the cost of generating electricity.

The presented analysis quantitatively determines the cost of generating electricity with an ADSR for a wide range of realised reliabilities of particle accelerators. This is carried out for linear accelerators and for two different designs of the accelerator system, one with a single accelerator and one with a redundant second accelerator.

Following the initial analysis of the "Single" and "Dual" accelerator systems the Real Options analysis technique is applied, eliciting flexibilities in ADSR design. This has identified two further designs. One is an "Expandable" accelerator system, where a redundant

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL accelerator is planned for from the outset but not constructed. This gives the owner the option, not the obligation, to build it later should it be determined to be economically beneficial to do so. The second flexible design, named the “Accelerator Test”, initially constructs only an accelerator; this allows for its reliability to be tested. If its reliability is determined to be high enough the reactor is then constructed, possibly along with a second accelerator.

The “Single” accelerator ADSR is found to be very sensitive to the reliability performance of the realised accelerator. If high reliability is achieved this design generates electricity for a lower unit cost than the others. Because the "Dual" accelerator ADSR benefits from redundancy the performance of its individual accelerators is less important; a constant unit cost of electricity is returned for the whole range of considered reliabilities. The premium for constructing the redundant accelerator, however, makes that unit cost large. The “Expandable” design matches the benefits of the "Single" accelerator ADSR, while also reasonably keeping down the unit cost of electricity if reliability is found to be poor. The delay in constructing the redundant accelerator means it doesn't cope with poor accelerator reliability as well as the "Dual" design does. The “Accelerator Test” design performs poorly both in terms of its unit cost of electricity and the amount of capital placed at risk before the first revenue is made. Its key benefit is that less capital is committed to resolving uncertainty in accelerator performance, but this is less unique than it first appears. The “Dual” accelerator ADSR, with its very high tolerance of poor reliability, effectively achieves this as it (nearly) guarantees electricity sales, offsetting the extra capital committed. To a lesser extent the "Expandable" design also does this.

Finally, the concept of an integrated reactor park is introduced. In a reactor park multiple reactor cores are constructed at one geographical site. Uniquely to ADSRs, rather than simply share site utilities, economic value can be improved by integrating all of the accelerators into a single beam transport network, such that they can each drive any of the reactors. This concept allows for sharing one redundant accelerator between all of the reactors, thus sharing the cost of improving reliability. The park lends itself to being constructed in a series of phases, minimising the capital committed to the project at any given time and economically efficiently demonstrating ADSRs as electricity generators. Its success hinges on developing a swift and efficient beam re-direction system during its transport.

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