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Risk Management of Micro Nuclear Reactor Projects

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1. Introduction

The investment risk of projects is concerned with the risk of not being able to recover investment cost. Therefore it is calculated with the loss and the probability of not being able to recover the investment costs. In the project of large-scale light-water nuclear reactors (henthforth LWR), the amount of loss might be large due to default, but the probability of default is relatively very low. The investment cost (net construction cost) of a large-scale LWR (two reactors) project is known for some $11 billion. However, it is a relatively mature technology, the licensing process is well established, the market experience is sufficient, the connection with national or international institutions is well understood. Therefore the risk of default in the decision-making process can be reasonably evaluated and predicted. Micro nuclear reactors (MNRs) are very high in the investment risk but different for the LWR In terms of characteristics of investment risk. In MNR projects, in particular non-LWR MNRs, the amount of loss is relatively small in the event of default, or failure to recover investment cost, but the probability of default is relatively very high. The investment cost (net construction cost) of a SMR project is estimated to be about $30-55 billion. Currently most MNR projects are undergoing early stages of R&Ds. As such, there is high uncertainty of technical success, the licensing process has not been established, and it is very unclear whether profits will be generated in the market. In order to succeed in the MNR project, therefore strategic efforts must be made to overcome the risks linked to supply and demand of MNRs.

2. Risks of Supply

Currently most of MNRs are in the early stages of R&D. Furthermore, as most of MNRs, especially non-LWR types aim at employing radically innovative principles including fully passive cooling and autonomous operation, etc. As a result, It would be very high for them to succeed in design development and technical demonstration. Therefore it is necessary to solve this technical challenges. In order to reduce the technical risk, first of all, it is most important to complete their standard design and detailed design at an early stage. Especially the detailed design should meet the requirements of the Regulatory Authority(NRC), building the initial MNRs and constructing MNR manufacturing facilities.

Most of MNRs are still unlikely to succeed in their commercialization because of huge amount of initial capital investment, long-term payback period, and probably low social acceptance. Without government support, SMR suppliers must be able to afford losses until they sell sufficient enough reactors to make profits. In order to reduce the commercialization risk, first, MNR suppliers should receive government support for the completion of design and licensing. Second, the cost of commercialization should be shared within the initial supply chain with other up- and down- stream suppliers.

MNR licensing is in its infancy worldwide. As of January 2022, only US NuScale reactor received standard design certification. Licensing methods and process for MNR, particularly non-LWR ones, have not yet been established, which is leading to high uncertainty about obtaining MNR licenses. Licensing uncertainty is related to the risks of technical and economic success. Failure or delay in obtaining permits may delay seriously the design, manufacture and construction of MNRs which may result in economic loss. In order to prevent or mitigate the licensing risk, above all, the design should be completed as much as possible before applying for licenses. Second, MNR developers and suppliers should help regulators understand their new designs of MNRs and establish relevant licensing methods and process for the designs.

Although much less expensive than that of large LWR, MNR projects are still costly. The total investment cost (net construction cost) of the SMR project is estimated to be about $30-55 billion. First of all, the capital cost for technology demonstration and commercial deployment of the first unit (FOAK) plays most important role in this risk. As for SMR or MNR vendors, generally the initial capital costs account for 30% of their market capitalization, which can act as a significant financial barrier for their projects. Moreover, it would be very difficult to finance MNR projects in third-party financial markets such as venture capital (not MNR developers or governments) due to market uncertainty and technical risks. Second, the long-term payback period of capital cost is also an obstacle to initial capital raising because practical profit is expected to occur in about 20 years. Securing sufficient markets with reliable contract could be best to address the financing risk and attract investors including private capital as early as possible.

The commercial business of MNRs requires an exclusive production facility for MNR which needs a considerable amount of investment and subsequently pose a major threat to the establishment of the MNR supply chain. It is best as many orders with contract as possible to construct the facility without government financing support. Although there is no subsidy, government policy to create markets for MNRs needs to be drawn out. Accordingto EPIC (2011), at least 18 MNR modules must be manufactured in order to ensure the economic feasibility of NoAK of a MNR.

3. Risks of Demand

No MNR project can succeed without sufficient demand. The MNR project takes at least 10 years from design development to commercial deployment. Therefore it is very difficult to precisely predict the demand of each MNR that will occur 10 years after the start of the project. Besides The predicted demand may change during the project. During the project, MNR developers and suppliers will be likely to face the

change of the demand resulting the change of socio-economic environment in terms of public acceptance and government energy policy, etc. which lead delaying or canceling the project and lowering its economics. First of all, in order to cope with the demand risk, the future demand and market competitiveness of MNR must be predicted as objectively and reasonably as possible. Furthermore, it is required to forecast the future demand on a scenario considering the uncertainty of long-term prediction. The demand of a concerned MNR must be predicted in terms of total size of the demand at a given time and growth potential over time. The market competitiveness of a specific MNR product must be predicted by its market share during the product life cycle over time. In particular forecasting the future demand of MNR needs to predict the requirements to meet the future demand and win the competition in the future markets on the scenario. Second, it is necessary to demonstrate the radical innovations required to meet the future demand and market competition as technically perfect as possible not only in the laboratory but also in commercial environments. In addition, international patents for key technologies must be obtained to protect the commercialization and market profitability of the MNR. Third. like the cases of energy storage and renewable energy. government policies that can create favorable demand and market environments needs to be drawn out, which will help greatly increase the commercialization potential of MNR projects. In particular the government's direct purchase or lease of MNRs helps to stimulate purchasing demand, thereby reducing demand risk and attracting private investment.

First unit (FOAK) of MNRs have low economics which plays negative role in exploiting their markets.In general, because the first new products are produced on a small scale in a new industry, the production cost is higher than the potential production cost saved by the advantage of NOAK in terms of economies of scale and learning effects. The LCOE of LEAD/FOAK MNRs is estimated to be approximately 50-60% higher than that of NOAK. In order to eliminate the risk of the FOAK, some measures should be used in combination. First, risk-based project management should be employed. The FOAK project must be managed focusing on avoiding, mitigating, eliminating risks during the entire life cycle of the project from design development to market victory. Relevant milestones and stages must be set on the basis of risks, which lead project management to focus on overcoming risks and achieving targets. Second it is also need to find precisely future demand and markets and business models to win the markets. Emerging industries must acquire first-time buyers of new products. It should induce the customers replacement of existing products and purchase new ones. MNRs can enter the markets with high electricity prices, where energy security is very important. Third, ensuring social acceptance and government support will help reduce the risk of the FOAK. Technical demonstration that there would no risk of radiation accidents is required to secure social acceptability and policy support

4. Conclusions

The success of MNR projects is very uncertain because of with radical change of both supply and demand sides. In addition, the possible risk of institutions related to supply and demand environments of MNRs increase the project more uncertain. In order to mitigate and address the risks of MNR projects, risk-based project management should be employed. Relevant milestones and stages must be set on the basis of risks, which lead project management to focus on overcoming risks and achieving targets. US DOE and NASA is applying this kind of stage-gated decision-making (down-selection) process to its projects develop advanced technologies. To do this technically, in particular, competition between multiple (at least two) designs should be promoted, not only for detailed design and design certification, but also for commercialization. The University of Chicago Energy Policy Research Institute (EPIC, 2011) proposed multiple competitions should be extended into the construction and operation of the first unit. Secnod, the competition should be processed like funneling step by step (down-selection process). In this approach, the project start with many constestants when each cost little. As the project proceeds, competitive alternatives are narrowed down. Currently the US DOD is competing with three design alternatives for the development of a MNR to be deployed in late 2020s.

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