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Estimating the cost of Small Modular Reactors

Master Thesis Report

Paul Scherrer Institut (PSI),
Laboratory for Energy Systems Analysis, Technology Assessment Group

Author:
Piotr Dobrzyński (piotr.dobrzynski@phelma.grenoble-inp.fr)

Supervisor:
Dr. **Warren Schenler** (warren.schenler@psi.ch)
Paul Scherrer Institut
Laboratory for Energy Systems Analysis
5232 Villigen PSI, Switzerland

Academic Coordinators:
Dr. **Emilie Ferrié** (emilie.ferrie@simap.grenoble-inp.fr)
Dr. **Luc Salvo** (luc.salvo@phelma.grenoble-inp.fr)
Grenoble INP Phelma
3 Parvis Louis Néel, 38000 Grenoble, France

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Abstract

Small Modular Reactors are a family of new nuclear technologies with the electrical output lower than 300 MWe. This concept is based on simplified designs with inherent passive safety features, that have a shorter and easier construction process. Out of more than 60 such rectors proposed globally, around 20 are believed to be currently under development mostly at the conceptual stage, with 2 reactors being under construction in Argentina and China. Despite a multitude of advantages belonging to these technologies, there are still many questions especially about their safety, manufacturing process, regulatory issues and most importantly economics. Since no such reactor has yet been built, there is not much reliable information related to the costs of these technologies besides the vendor estimates and a few research reports. Moreover, very often such estimations do not provide the methodology and/or assumptions made to calculate the capital costs.

This work analyzes existing capital cost estimation techniques and suggests the way how they can be adjusted for the case of Small Modular Reactors. The base of this analysis is the top-down methodology which uses the costs of a similar reference plant as input data which are then approximately scaled. The analysis consists of two parts each devoted to the different technology group. The first one focuses on the four most developed integral Pressurized Water Reactors: the Chinese ACP100, the Argentinean CAREM, the American NuScale and the Korean SMART with existing PWRs from the same countries used as reference plants. The second, on the other hand, deals with the Chinese High Temperature Gas Reactor HTR-600, being the target version of the currently built HTR-PM reactor, whose project cost data were obtained pursuant to the agreement signed between PSI and the Chinese Institute of Nuclear and New Energy Technology. Due to the significant design and construction differences between the reference PWRs and analyzed iPWRs, in the first analysis, the adjusting coefficients were developed for each design to modify the top-down technique. They reflect the influence of such factors as design simplification, shorter construction time, shared plant equipment and the potential learning factor for subsequent units on the capital cost.

The results show that the cost of the n^{th}-of-a-kind iPWR reactor would be around 15-40% lower than the cost of the referenced PWR reactor scaled to the same electrical output. While the American NuScale reactor can potentially generate the highest percentage savings, the Asian reactors are the cheapest in terms of the absolute overnight capital cost. One of the main findings is that for all reactors besides the NuScale, the estimated cost of the NOAK units are in line with the vendor estimates. Moreover, the analysis shows that regardless of the country, the investment cost of iPWRs seems higher than the cost of existing PWRs of larger capacity.

The second analysis uses the Chinese HTR-PM reactor as the reference one for the cost estimation of its target HTR-600 plant. The results show that the overnight capital cost of the HTR-600 are around 20% higher than for a Chinese PWR (Generation II+ type), which again is in line with the vendor internal estimates. Moreover, the analysis approximates the cost of this reactor in different countries accounting for the different cost of labor. The simplified method assuming proportionality of the labor cost to the average wages in manufacturing results in the overnight capital cost of the HTR-600 plant in Western Europe being on average 4-5 times more expensive than in China.