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EcoSMR - Ecosystem for Small Modular Reactors

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ABSTRACT

This paper introduces a Business Finland funded project EcoSMR dedicated to small modular reactor research. Project work and some results are shortly presented and a short overview on the status of SMR deployment for some of the most prominent designs is given.

1 INTRODUCTION

During recent years, small modular reactors (SMR) have been gaining more and more popularity in Finland and all around the world. Practically all traditional large LWR reactor vendors such as GE-Hitachi Nuclear Energy, EDF, Rosatom and Westinghouse have developed their own SMR concepts [1]-[4]. Additionally, new players have emerged introducing new SMR designs. Some of these have experience from naval reactors such as Rolls Royce [5], some have previously planned advanced reactor designs such as Terrapower [6] and some are completely new companies built around a new SMR design such as NuScale [7], Terrestrial Energy [8] and USNC [9]. In Finland two different SMR concepts dedicated to district heating have been designed at VTT [10] and LUT university [11]. The afore mentioned SMR designs and companies are by far not the only ones. Around 70 different designs including 31 LWRs and several HTGR, FR and MSR designs are described in the IAEA SMR book from 2020 [12].

Many of the planned designs have in addition to private investments, secured large financial support from governments. Some examples are the LWR SMR NuScale, and SFR and HTGR SMRs Natrium and Xe-100 that have received generous funding from the US Department of Energy (DOE) in the recent years [13],[14]. Also UK SMR in Britain and NUWARD in France have secured governmental support for the deployment of their designs [15],[16].

In Finland such large scale financial support from governmental sources has not yet been seen. Some currently ongoing or recently accepted research projects where Finland is part of are e.g. EU projects McSAFER, ELSMOR and TANDEM. These projects include among other things studies related to safety and modelling tools, licensing and techno economic modelling. Some small-scale studies have also been funded in the KYT research programme for SMR waste management during 2021 and 2022.

The most recent governmental funding instrument for SMR research in Finland is Business Finland. In 2020 EcoSMR project received funding from Business Finland as the second project ever (in the best knowledge of the authors) to secure Business Finland funding for nuclear energy related research. This paper presents the contents of EcoSMR project, its research topics and lessons learned about the global situation in SMR deployment.

2 ECOSMR PROJECT

EcoSMR is a Business Finland co-innovation project coordinated by VTT. Funding is distributed between Business Finland (70 %), participating companies and VTT. EcoSMR partners comprise two research institutions, VTT and LUT university, who are responsible for carrying out the research project and 10 companies. In addition, three out of the total 10 participating companies have their own research projects according to the graph presented in Figure 1. The project began in August 2020 and will continue until the end of 2022.

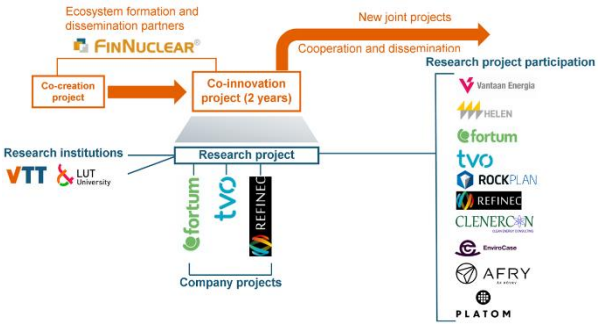

Figure 1: EcoSMR project and partners.

The main goal of EcoSMR is to enable Finnish companies to participate in the emerging SMR markets. The goal is pursued by enhancing Finnish expertise in several key research areas and actively networking Finnish actors with each other and with foreign SMR actors. Work in EcoSMR is devided in seven work packages presented in Table 1. The content of the work packages and some results are presented in chapter 3.

Table 1: EcoSMR work packages.

WP number	WP description
WP1	Licensing and regulations
WP2	Heat use of SMRs
WP3	SMR case studies
WP4	Business models
WP5	Ecosystems
WP6	Dissemination
WP7	Coordination and management

3 PROJECT WORK AND RESULTS

This chapter introduces the work done in EcoSMR work packages. Work in work packages 3-5 is introduced in one section, section 3.3, since the work in these work packages is strongly linked with each other.

3.1 Licensing and regulations

In this work package we examine ways for streamlining the licensing processes of SMRs. Needed safety analysis specific to SMRs and the applicability of existing modelling tools are also studied. One of the major questions related to licensing of heating reactors or reactors providing combined heat and power concerns siting. Cost efficient district heating production requires siting of the SMR close to end users since in district heating, costs considerably increase with distance. Close proximity in urban areas raises questions for example on the size of emergency planning zone (EPZ). These issues have been studied in the EcoSMR project. EPZ sizes have been suggested by several SMR vendors, but no clear rules for determining the size has been set by regulators [17]. In essence, more studies and justification is needed.

3.2 Heat use of SMRs

Research in the second work package revolves around heating reactors. One of the major questions for heating reactors or any other new technology is the economic competitiveness. This is one of the big issues currently concerning investments in large nuclear power reactors and one of the major issues that SMRs aim to solve for nuclear energy. In EcoSMR, investment modelling for heating reactors are done by comparing their profitability to different technologies such as heat pumps and combined heat and power production in different scenarios. In the same context, modelling tools for this kind of calculations are developed. Also load following capabilities of heating reactors are analysed. The present studies indicate that SMRs are more cost competitive than new biomass based units or large heat pumps from ambient heat sources in the Helsinki Metropolitan area [18]. One of the goals of the work package is to collect design requirements for district heating reactors in Finland.

3.3 Ecosystem and business models

SMRs bring new kind of opportunities and challenges in nuclear reactor deployment. Since SMRs are small in size, a greater number of reactors is needed to cover energy needs compared to conventional large reactors. Smaller heating reactors may be owned by conventional power companies with no previous experience in nuclear energy. This creates a potential need for new kind of business models and responsibility allocations. For example, the operation and maintenance of several reactors might be better to outsource to one company instead of dealing with the operations, maintenance, fuel supply etc. for each small plant individually. The same goes with waste management. This kind of potential new ways of creating business models and allocating responsibilities are investigated in these work packages.

For efficient networking in the SMR field, a Finnish SMR ecosystem has been founded within the EcoSMR project. The purpose of the ecosystem is to facilitate discussion and networking for Finnish companies between each other and with foreign actors. The ecosystem welcomes interested members broadly from industry, research and municipal

organizations. The current members include EcoSMR partners, Finnish energy companies, municipalities in Finland and foreign SMR vendors and nuclear component suppliers.

3.4 Dissemination

One of the goals of the project is to disseminate information on SMRs to industry, research organizations, policy makers and the general public. To fulfil this goal, several webinars and seminars have been arranged in the project. These seminars have addressed widely different topics involving SMRs such as investment modelling, supply chain building, licensing, heating reactor designs in Finland and other general SMR related topics [19].

3.5 SMR deployment, current status

One of the activities of the project was to arrange meetings between EcoSMR partners and SMR plant suppliers. In these meetings, the current status of different SMR designs and the range of available solutions has been well clarified. Meetings with several supplier companies were arranged and some conclusions from the meetings with European and North American + Japanese suppliers are drawn in the following. Table 2 summarises some key aspects from the different designs.

Table 2: Some SMR designs investigated in EcoSMR. "Site" indicates the site of the first of a kind reactor and "Year" the anticipated year of commissioning.

Reactor (Supplier)	Type	Site	Year
BWRX-300 (GEH)	BWR	Darlington, Ontario, Canada	2028
UK SMR (Rolls Royce)	PWR	GBR	2029
MMR® (USNC)	HTGR	University of Illinois, USA	2026 (demo)
NuScale (NuScale Power)	PWR	Idaho Falls, Idaho, USA	2029
NUWARD (EDF)	PWR	France	2030s
IMSR (Terrestrial Energy)	MSR	USA	2020s
Natrium (Terrapower)	SFR	Kemmerer, Wyoming, USA	2020s

The power production of the reactors presented in Table 2 ranges from 5-10 MWe of MMR to 470 MWe of UK SMR. The LWR designs are based on conventional well proven technology both in reactor and fuel design. Some of the designs are planned to utilize one reactor unit per plant such as BWRX-300 and UK SMR. Some are designed to comprise a set number of units in one plant such as NuScale which plans to utilize 4, 6 or 12 units inside one plant. However, other sizes can be considered also. NUWARD plant comprises two independent reactor modules for greater flexibility.

The non-LWR designs offer also other applications than conventional electricity production to an existing network and other innovations. The MMR is a so called "fission battery" designed to deliver electricity and heat in remote locations. Natrium reactor is designed to function in connection with a molten salt energy storage system which simplifies load following.

Almost all of the reactor vendors are claiming to start commercial operation or a demo reactor already during this decade. The goals are ambitious, but not necessarily unrealistic. One way to examine the realism of the set goals is to consider the readiness of the technology, available funding, commercial interest and political support.

As LWR based technologies, BWRX-300, NuScale, NUWARD and UK SMR design concepts are mature technologies. BWRX-300 and NuScale already have interested customers and the site of the first of a kind (FOAK) reactor has been decided. NUWARD and UK SMR don't have a dedicated site yet, but on the other hand both companies have secured notable governmental support both politically and financially. MMR, IMSR and Natrium are advanced designs and therefore the technologies are not as mature and proven as in the LWR designs. An additional concern is related to spent fuel management which may pose additional challenges for these designs. On the other hand, IMSR and Natrium have received governmental funding from US Department of Energy which indicates both greater financial security and strong political support.

4 CONCLUSIONS

Presently SMRs are a hot topic in nuclear industry and research. Several SMR design concepts exist and reactor vendors and new SMR companies are investing heavily in the deployment of some of these technologies. Many designs are backed by strong governmental support both financially and politically. EcoSMR project aims to develop Finnish competence in SMR related topics and enable

Finnish companies to participate in the developing international SMR market.

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