INVENTION, INNOVATION, AND DIFFUSION OF NUCLEAR REACTOR TECHNOLOGIES: A MULTI-LEVEL ANALYSIS APPLIED TO THE NUCLEAR SECTOR OF THE UNITED STATES

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Overview

This paper analyzes innovation processes in the nuclear sector that is sometimes considered to play a role in the combat against climate change (IPCC 2018). The paper focusses on non-conventional, i.e. non light-water cooled reactors, sometimes also referred to as "advanced" reactors (EPRI 2018), or "Gen IV" reactors (WNA 2020); these are in the focus of development again with hopes of producing clean, safer, and affordable energy. The United States, amongst the leading countries in this innovation race, has launched the "advanced reactor demonstration program" as a big funding opportunity to push the development of nuclear reactor technology seeking global technological leadership (Rothwell 2022). At the same time its nuclear fleet is with an average age of 40,2 the oldest in the world and they had just one new build in the last decade (Schneider et al. 2021). The aim of this paper is to apply the multi-level analysis framework to the US innovation of nuclear technology with focus on the development of non-conventional reactor concepts. It is analyzed how the different dimensions of landscape, regime and technological niche intertwine and have changed over time. From here implications for the future pathways can be drawn, and comparisons with other countries can be developed.

Methods

In this paper a multi-level analysis is conducted. It is an analytical framework to study innovation dynamics with insights from evolutionary economics (Geels 2002; Berkhout, Smith, and Stirling 2004; Geels and Schot 2007). This framework already has been applied by several authors for example to the coal sector in China (Zhang, Zhang, and Yuan 2020) or the Dutch electricity system (Verbong and Geels 2007). In this paper, this analysis is applied to the nuclear sector in the US to describe the innovation and development of the so-called new and advanced reactor designs. It describes three dimension: the landscape, the socio-technical system, and technological niches. It especially highlights that developing innovations is as a non-linear process driven by the interactions between the three levels.

Results

In the context of innovation and energy transformation, nuclear power displays two conflicting roles. On the one hand, so-called new designs are expected to be breakthrough technology in the energy transformation; on the other hand, the nuclear power sector is seen as part of the incumbent regime for the development of renewable energy. Whereas the niche technology underlies a techno-optimistic assumption it is viewed in a reserve way for nuclear power development: Because the reactor design under the advanced program can be traced back to the beginning of nuclear power itself, the ongoing energy transformation is a window of risk to spend billions of dollar on a technology without diffusion perspectives. First analyses of this research suggest that while inventions are plentiful, innovation and diffusion are slow compared to conventional nuclear power, although non-conventional nuclear power has received strong funding. Therefore, it can be seen as product of the incumbent regime that hinders the development of alternative energies. Why the effort then? The US are trying to revive technical leadership as other nuclear superpowers such as Russia and China gain market share in nuclear power after 1995 (Rothwell 2022).

Conclusions

Invention, innovation, and diffusion processes in the nuclear industry are complex, and the United States has been at the forefront of this process for a long time. In this context, current attempts to launch non-conventional rectors is an attempt to recover the technological leadership, in particular against other nuclear superpowers such as Russia and China. However, at present, companies struggle to finance the projects, and markets that demand such innovations are hard to identify. Therefore, it is doubtful whether the attempts to develop non-conventional reactors will succeed in moving the US nuclear industry from invention to diffusion.

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