

# NEXT-GENERATION NUCLEAR TECHNOLOGIES FOR NET-ZERO EMISSIONS: AN INTERDISCIPLINARY EVALUATION OF NUCLEAR FUSION

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## Abstract

At this point, the global energy sector has to address the challenges of both meeting more energy demands and addressing the danger posed by climate change. As the Paris Agreement and subsequent international agreements require, we must significantly change our energy systems to achieve net-zero emissions by mid-century (IAEA, 2024a). The process needs the fast introduction of renewable energy technologies as well as the growth and addition of various low-carbon energy sources that can supplement the variability of solar and wind power (World Economic Forum, 2024).

Within this field, advanced nuclear technologies appear to be vital for a sustainable energy system. Importantly, nuclear energy can bring many benefits when used in a carbon-free energy mix. Nuclear power causes little pollution while operating, runs reliably all the time with a large capacity, takes up less land than many other renewable sources and does not depend on weather to work (Abou-Jaoude et al., 2024). Nuclear power plants are especially helpful because they provide electricity without putting air pollutants such as sulfur dioxide, nitrogen oxides and particulate matter into the air.

Many aspects have limited the development of large-scale nuclear power such as expensive construction costs, long construction periods, concern over nuclear safety following accidents in previous years, difficulties in handling nuclear waste and difficult regulations for the industry (Ramana et al., 2023). Because of these challenges, countries like North America and Western Europe have not built many large reactors over the past few decades (Holdsworth & Ireland, 2024).

Despite these issues, the attention of researchers, policymakers and industry leaders is turning to the advancement of two innovative nuclear technologies, one of which is fusion. Research on nuclear fusion is being done currently. Fusion use unique techniques to produce nuclear energy, helping to manage most of the issues that come with traditional nuclear power plants. Nuclear fusion tries to produce energy by joining together light atomic nuclei, much like what occurs in stars and offers nearly unlimited energy sources, produces very little radioactive waste and is naturally safer (IAEA, 2024c).

I have reviewed this next-generation nuclear technologies from different fields and examined it's technological design, economics, effects on nature, safety aspects and the impact of policies. With the help of expertise in nuclear engineering, economics, environmental science and policy studies, the paper aims to understand nuclear fusion may facilitate lowering carbon emissions.