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Economic Viability of Small Modular Reactors under a Net Zero Policy

Gianna Guan*

Department of Business Administration, University of the Aegean, Michalon 8, Greece

Introduction

The transition to a net-zero economy has intensified the search for clean, reliable, and cost-effective energy sources. Among the various options, Small Modular Reactors (SMRs) have emerged as a promising solution due to their potential to provide low-carbon electricity with greater flexibility and affordability than traditional nuclear reactors. As governments worldwide commit to net-zero policies, evaluating the economic viability of SMRs becomes crucial to understanding their role in the future energy mix. This report examines the cost factors, market potential, and financial challenges associated with SMRs while considering their competitiveness in a net-zero framework. SMRs are a new generation of nuclear reactors designed to be smaller, more flexible, and more cost-effective than conventional large-scale nuclear power plants. Their modular nature allows them to be factory-built and assembled on-site, reducing construction time and associated costs. Unlike traditional nuclear plants, which require billions of dollars in investment and several years to complete, SMRs are designed for scalability and lower initial capital costs. This makes them particularly attractive to countries and industries seeking to decarbonize their energy systems while minimizing financial risks.

Description

One of the main factors influencing the economic viability of SMRs is their capital cost compared to conventional nuclear reactors and other low-carbon energy sources. Large nuclear power plants require significant upfront investment, often exceeding $10 billion, and are subject to long construction timelines and cost overruns. In contrast, SMRs have a lower capital cost due to their modular design, with estimated costs ranging between $1 billion and $3 billion per unit, depending on size and technology. Additionally, the shorter construction period of SMRs reduces financial risks associated with delays and budget overruns, which have historically plagued nuclear projects. Operating and maintenance costs are also critical in determining the economic feasibility of SMRs. These reactors are designed for higher efficiency, automated operation, and improved safety features, which can reduce operational costs over time. Traditional nuclear power plants require large workforces for maintenance, security, and regulatory compliance, whereas SMRs are expected to need fewer personnel due to advanced automation and standardized designs. However, the long-term cost savings will depend on the ability of SMRs to achieve economies of scale, as early deployments may still face higher per-unit costs due to limited production [1].

Compared to renewable energy sources like solar and wind, SMRs offer the advantage of continuous power generation without dependence on weather conditions. This reliability makes them a strong contender in the energy transition, as net-zero policies require stable baseload power to complement intermittent renewables. However, the Levelized Cost Of Electricity (LCOE) for SMRs must be competitive with other low-carbon energy sources. While solar and wind have seen significant cost reductions over the past decade, nuclear energy remains relatively expensive. Estimates suggest that the LCOE of SMRs could range from $50 to $100 per Megawatt-hour (MWh), depending on deployment scale, technological advancements, and regulatory factors. If SMRs can achieve cost reductions through standardization and mass production, they may become more competitive with renewables and battery storage solutions. Market demand and policy incentives play a significant role in determining the economic success of SMRs. Many countries, including the United States, Canada, the United Kingdom, and China, have invested in SMR research and development to support their net-zero goals [2].

Governments are providing financial incentives, loan guarantees, and research funding to accelerate the commercialization of SMRs. In addition, carbon pricing policies and emissions reduction targets make low-carbon energy sources more attractive, further enhancing the market potential for SMRs. However, the economic case for SMRs will depend on the regulatory landscape, licensing processes, and public perception of nuclear energy safety. One of the challenges facing SMRs is the cost of regulatory compliance and licensing. Nuclear power is heavily regulated to ensure safety, and each new reactor design must undergo extensive approval processes before deployment. These regulatory hurdles can increase costs and delay projects, making it difficult for SMRs to achieve widespread adoption quickly. Standardizing regulatory processes across countries could help streamline approvals and reduce costs, but this remains a challenge due to differences in national nuclear policies and safety standards. Financing is another critical consideration for SMRs. Despite their lower capital costs compared to traditional reactors, securing investment for nuclear projects remains challenging due to perceived financial risks and long payback periods [3].

Investors often favor renewable energy projects, which have shorter development timelines and lower regulatory barriers. To attract investment, SMR developers must demonstrate cost competitiveness, reliability, and long-term economic benefits. Public-private partnerships, government-backed financing, and innovative business models could help overcome these financial barriers and accelerate SMR deployment. The potential applications of SMRs extend beyond electricity generation. These reactors can be used for industrial heat production, hydrogen generation, and desalination, offering additional economic opportunities. In sectors such as mining, manufacturing, and chemical production, SMRs can provide a stable, low-carbon energy source to replace fossil fuels. Additionally, remote communities and islands with limited access to grid electricity could benefit from SMRs as an alternative to expensive diesel generators. Expanding the market for SMRs beyond traditional power generation could enhance their economic viability and attract a broader range of investors and stakeholders [4].

Decommissioning costs and waste management are important economic considerations for any nuclear technology. While SMRs produce less nuclear waste than large reactors due to their smaller size and improved fuel efficiency, long-term waste disposal solutions remain a concern. Effective waste management strategies, including recycling and advanced fuel technologies, could reduce costs and enhance the sustainability of SMRs. Additionally, designing SMRs for extended operational lifespans and modular replacement of components can improve their overall cost-effectiveness. The geopolitical landscape and supply chain considerations also influence the economic viability of SMRs. Nuclear fuel supply, component manufacturing, and skilled workforce availability are critical factors in ensuring cost-effective deployment. Some countries may seek to develop domestic SMR supply chains to reduce dependence on foreign suppliers, while others may rely on international

***Address for Correspondence:** *Gianna Guan, Department of Business Administration, University of the Aegean, Michalon 8, Greece, E-mail: guangianna@gmail.com*

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partnerships for technology development. Ensuring a stable and secure supply chain will be essential for the long-term success of SMRs in a net-zero energy system [5].

Conclusion

Public perception and social acceptance of nuclear energy can impact the economic feasibility of SMRs. While SMRs are designed with enhanced safety features, concerns about nuclear accidents, radiation risks, and waste disposal remain barriers to widespread adoption. Building public trust through transparent communication, community engagement, and demonstration projects can improve acceptance and support for SMR deployment. Governments and industry leaders must address public concerns while highlighting the role of SMRs in achieving net-zero targets. In conclusion, the economic viability of SMRs in a net-zero policy framework depends on various factors, including capital costs, operating efficiency, market demand, regulatory processes, financing availability, and technological advancements. While SMRs offer potential cost advantages over traditional nuclear reactors and provide reliable low-carbon energy, their competitiveness with renewable energy sources will determine their long-term success. Governments and industry stakeholders must collaborate to address financial, regulatory, and public perception challenges to unlock the full potential of SMRs in the global transition to a net-zero economy. If deployed effectively, SMRs could play a significant role in decarbonizing power generation, supporting industrial applications, and providing clean energy solutions for diverse markets.

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Conflict of Interest

None.

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