Tabbre
Research
Report

Why is renewable energy expensive?

Date: 20240726

Version: 1.0

Contents

Summary

Renewable energy, while critical for addressing climate change and achieving sustainable development, often comes with high costs that can hinder its widespread adoption. This article explores the various factors contributing to the expense of renewable energy, including financial, market, regulatory, and technological challenges, and the role of geographic and environmental considerations. Financing renewable energy projects is a significant hurdle, especially in emerging and developing economies where higher perceived risks lead to elevated borrowing costs[1].
This financial burden often makes renewable projects less competitive compared to fossil fuels, despite the long-term cost benefits of renewables like wind and utility-scale solar, which are among the least expensive energy sources when considering their total lifecycle costs[2]. Uncertainties in cost projections, driven by factors such as capital costs, operating expenses, and the cost of financing, add another layer of complexity[3]. Market dynamics also play a crucial role. The competitiveness of renewable energy is often influenced by systemic distortions favouring established fossil fuel technologies and challenges within supply chains, including the procurement of raw materials and scaling manufacturing capacities[4]. Variations in the cost of capital, influenced by country-specific risks and macroeconomic factors, further complicate the financial landscape for renewable energy investments[5]. Regulatory and policy frameworks significantly impact the development and deployment of renewable energy. Effective policies can mitigate investment risks and stimulate market growth, but inconsistent regulations and government support can introduce additional costs and delays[5]. Federal and state incentives, such as those introduced by the Inflation Reduction Act of 2022, aim to make renewable energy more competitive, though they often face resistance from stakeholders[6][8]. Finally, technological challenges, including the integration of variable energy sources into the power grid and the need for advancements in storage solutions, are critical barriers. Government initiatives and investments, such as those supported by the President's Bipartisan Infrastructure Law, are essential for overcoming these hurdles and facilitating the transition to a renewable energy future[9]. The high costs of renewable energy are multifaceted, encompassing financial, market, regulatory, and technological aspects that must be addressed to enable a sustainable and economically viable energy transition.

Factors Contributing to High Costs

Financing costs for clean energy projects represent a significant barrier, particularly in emerging and developing economies where the cost of capital is considerably higher. Financiers and investors demand higher returns in these regions due to perceived risks, exacerbated by the recent worldwide rise in borrowing costs [1]. This financial challenge can lock developing economies into using polluting technologies, which might be less expensive initially but result in long-term fuel and environmental costs[1]. Therefore, enhanced international efforts to increase the availability and lower the cost of capital for these economies are crucial for facilitating affordable transitions to clean energy[1]. In addition to financing issues, there are systemic distortions favouring incumbent fuels, making it harder for renewable energy projects to compete on a level playing field[1]. Higher construction costs also contribute to the perceived riskiness of renewables, leading financial institutions to lend money at higher rates[2]. This, in turn, makes it more challenging for utilities or developers to justify investment in renewable projects[2]. While the upfront costs of fossil fuel power plants may be offset by passing fuel costs onto consumers, the overall cost of renewables over their lifespan can be lower. For instance, wind and utility-scale solar are often the least expensive energy-generating sources when considering the total costs over the project's duration[2]. The uncertainty in cost projections for renewable energy also plays a role. While experts predict a possibility of substantial cost reductions – more than 40% by 2030 and more than 50% by 2050 under a 'low cost' scenario – there is significant uncertainty, with a 'high cost' scenario where reductions are modest or non-existent[3]. Multiple drivers influence these costs, including up-front capital costs (CapEx), ongoing operating costs (OpEx), cost of financing (WACC), performance (capacity factor), and project design life. Recent years have seen reductions in the upfront costs of wind projects and improvements in their performance[3]. Continued improvements in these areas, along with reduced operating costs, longer project design lives, and reductions in financing costs, are anticipated[3].

Market Dynamics

To enhance the comparability of costs between regions and markets, it was necessary to harmonise certain assumptions. Therefore, in the base cases of various analyses, an 85% capacity factor is assumed for nuclear, coal, and Combined Cycle Gas Turbine (CCGT) plants, as well as a 7% discount rate. These parameters can differ significantly based on the existing technology mix and market environment[10]. For instance, not all units are dispatched equally across technologies and markets, and revenues in many markets are determined by fluctuating prices rather than by a stable price over a technology's lifetime[10]. A key determinant of competitiveness in energy markets is the discount rate, which corresponds to the cost of capital. A uniform discount rate of 7% is often assumed for all technologies and countries in theoretical models. In practice, the discount rate reflects opportunity costs of investment and various kinds of risk and uncertainty, including political and regulatory developments, market design, system development, and future investment and fuel costs[10]. Additionally, government support, such as price guarantees, can shift the risk from the investor to the public, making investments cheaper from an investor's perspective[10]. Developers face supply chain challenges that include securing access to raw materials and rare earth metals at stable prices, scaling manufacturing capacity to meet regional demand, and getting creative with vertical integration[4]. The commodity squeeze challenging the wind and solar industries will only tighten as demand increases from global decarbonization efforts. Rare earth metals like neodymium and praseodymium, crucial for high-power magnets in wind turbine generators and electric vehicles, are estimated to face a 50-60% shortage by 2030, with recycling meeting only

10% of total demand[4]. Moreover, scaling manufacturing capacity is complicated by volatile market conditions and fluctuating regulations. For example, Japan's offshore wind market is currently paused as the government revises auction rules, leading to cancellations of planned production facilities[4]. To build resilient supply chains and meet ambitious expansion targets, sourcing needs to become a strategic priority[4]. Broad country-related risks and macroeconomic factors also explain country-by-country variations in the cost of capital. These include the rule of law, sanctity of contracts, and concerns about currency fluctuations and convertibility. As energy investments shift from globally traded commodities like oil to clean energy projects that rely on domestically generated revenues, the quality and predictability of the domestic business environment become increasingly crucial for investors[5]. Mechanisms to mitigate these risks include guarantees against expropriation and facilities to reduce the cost of currency hedging, although strengthening national institutions and deepening local capital markets offer longer-term solutions[5].

Regulatory and Policy Challenges

The successful development and deployment of renewable energy technologies are significantly influenced by regulatory and policy frameworks. Governments play a critical role in shaping these frameworks, which encompass a range of activities from funding research and development (R&D) to setting regulatory standards and providing financial incentives. Effective regulatory and policy measures can reduce investment risks and stimulate market growth, but they also pose certain challenges that can impact the cost and pace of renewable energy adoption.

Government Support and Regulatory Frameworks

For industries to advance quickly in renewable energy and export opportunities, governments need to support infrastructure roll-out and mitigate investment risks. This includes evaluating supply chain risks, supporting bilateral agreements, and developing European Union (EU) rules like the Carbon Border Adjustment Mechanism, hydrogen certification, and a framework for CO_2 transportation and storage, as well as rules for negative emissions[11]. The essential justification for public intervention in innovation is to address the market's undersupply of new ideas and technologies, a phenomenon known as public goods market failure. Radical new concepts, or “disruptive” technologies, often arise from basic scientific research and are rarely supplied by incumbent companies, which focus more on incremental improvements to their existing technology portfolio[12].

Impact of Policy and Regulatory Quality

The quality of energy institutions, policies, and regulations plays a crucial role in determining the cost of capital and the feasibility of clean energy projects. Reliable policies and a clear vision for energy transitions are essential. These should be backed by robust data and support for project preparation, as seen in the experiences of various emerging markets and developing economies (EMDEs). Effective policies must be technically sound, clear, and predictable, especially in new areas like energy storage or privately financed grids[5]. For instance, South Africa's well-designed procurement programs for renewables have successfully catalyzed battery storage investment and deployment[5].

Federal and State Incentives

Various incentives and policies at federal, state, and local levels influence renewable energy development. The Inflation Reduction Act of 2022 introduced significant federal incentives for energy communities, aiming to support renewable energy installations on potentially contaminated lands[6]. Governments have also begun to give subsidies and tax incentives to green energy developers, similar to how fossil fuel subsidies historically made oil, gas, and coal more affordable and competitive[7]. Explicit subsidies, such as tax breaks, direct payments, grants, and price controls, aim to reduce the financial burden associated with fossil fuel production and use, but similar support mechanisms are increasingly being adopted for renewable energy[7].

Challenges in Implementation

Federal agencies have been crafting regulations to fulfil legal requirements and reduce emissions, but these efforts often face pushback from various stakeholders. For example, the EPA's proposal to regulate greenhouse gas emissions from fossil fuel-fired electricity has been met with resistance from power suppliers and regional grid operators, who argue that the proposal could impact reliability and depend on unavailable technology[8]. Similarly, the U.S. Treasury Department's guidance on the 45V Hydrogen Production Tax Credit sets stringent standards for obtaining tax credits, aiming to encourage clean production pathways[8].

Geographic and Environmental Considerations

Geographic and environmental factors play a significant role in the cost and feasibility of renewable energy projects. The distribution of renewable energy resources such as wind, solar, and hydropower is highly uneven across different regions, leading to varied costs and benefits associated with their development.

Environmental Impact

The environmental pillar comprises the impact of human activities on the natural environment, both as a source for raw materials and as a sink for pollutants. Human activities have dramatic effects on the functioning of Earth's ecosystems, including landscape destruction, climate change, and biodiversity decline. Notably, climate change has been an important impetus for rethinking traditional forms of energy production and use[13]. As these negative environmental impacts often materialise as external effects not fully accounted for by market mechanisms, policymakers have increasingly regulated energy systems to reduce these impacts, aligning with many stakeholders and creating economic incentives to promote sustainable practices[13].

Policy and Community Response

Geographic considerations are deeply intertwined with community values and local planning practices, which significantly influence decisions about renewable energy development. For example, communities may react to renewable energy proposals either in real-time or proactively by incorporating their values into comprehensive plans that address natural resources, land use, and energy[14]. These planning practices ensure that renewable energy projects align with the overall goals and priorities of the communities they affect.

Specific Regional Initiatives

Different regions in the United States have undertaken specific initiatives to address their unique geographic and environmental contexts. In Utah, for example, $75 million has been allocated to various measures, including expanding electric vehicles and reducing methane emissions from oil and gas production[15]. In Oregon, nearly $200 million will be used to reduce climate pollution across major sectors like buildings and transportation[15]. On the East Coast, a coalition of states led by North Carolina will invest over $400 million to store carbon in agricultural lands and natural places such as wetlands[15].

Hydropower Potential

Hydropower resources are categorized based on their technological characteristics and analytical needs. One significant category is Non-Powered Dams (NPD), which are existing dams that do not currently generate hydropower. Studies have estimated up to 12 GW of technical potential for NPDs in the U.S., based on historical flow rates and design parameters. However, recent development activity suggests that the economic potential may be lower than initially estimated due to current technologies16. Most of the economic potential (approximately 5 GW) is associated with fewer than 700 dams, and further cost reductions are being explored through detailed cost analyses and future projections16. Understanding the geographic and environmental considerations is crucial for effectively planning and implementing renewable energy projects. These factors not only influence the costs and feasibility but also determine the long-term sustainability and acceptance of renewable energy initiatives.

Operation and Maintenance Costs

After a wind turbine is erected, the expense of ongoing upkeep must be considered. Wind turbine maintenance expenses usually include frequent inspections, lubrication, and repair of worn or damaged components. While these costs differ based on the model and manufacturer of the turbine, they are usually cheaper than the maintenance costs connected with other energy sources such as fossil fuels[18]. Wind turbine installation and maintenance costs can vary greatly based on region and other variables. For instance, installing a wind machine in an isolated location with limited access to resources may be much more expensive than in an area with excellent infrastructure. Similarly, the expense of maintenance may be higher in regions subject to harsh weather or with restricted access to skilled personnel[18]. Efforts to reduce operations and maintenance costs include improvements in power electronics reliability, as well as the use of data analytics and automated characterization tools to better understand and predict overall maintenance needs[19]. Newer installations, particularly those whose feed-in payments have been determined through auctions, receive little more than the average wholesale power price on the market. However, many older installations are entitled to payments that exceed the market price. This dynamic affects the overall economics of maintaining older turbines, which retain their feed-in priority over conventional power sources and can therefore remain connected to the grid and market their electricity independently[20]. The landscape of operation and maintenance is also influenced by the general trend towards technological innovation. Successful technology concepts typically pass through several stages including prototype, demonstration, early adoption, and maturity. Feedback between these stages means that technology options are always evolving, and the process involves a wide range of participants such as governments, researchers, investors, entrepreneurs, and corporations[12]. The evolution of these technologies, including improvements in efficiency and cost reductions, directly impacts the operational costs of renewable energy projects, including wind energy[12]. Finally, the cost of energy from wind projects is influenced by several key components: up-front capital cost (CapEx), ongoing operating costs (OpEx), cost of financing (WACC), performance (capacity factor), and project design life. Recent years have seen significant reductions in the up-front cost of wind projects as well as increases in wind project performance. Experts anticipate continued improvements in these areas, which will likely lead to reduced operating costs and longer project design lives[3].

Technological Challenges

The transition to renewable energy sources involves several technological challenges that need to be addressed to ensure grid stability and reliability. One of the primary issues is the weather-dependent and volatile nature of renewable energy generation, which necessitates backup from conventional power plants to maintain grid stability[13]. While future storage solutions are expected to significantly mitigate this problem, the current market structure and the restructuring of major energy suppliers play a crucial role in the transition toward renewable energy sources[13]. Technological innovation is essential for the success of renewable energy adoption, but it is a complex and uncertain process. It has taken decades for technologies such as solar photovoltaics and batteries to develop to their current stages, and not every technology that is developed will be successful[12]. Accelerating technological progress is critical at this juncture, and governments and private sector actors must address both the improvement of technology through research and the enhancement of the selection environment through regulations and new business models[12]. The integration of variable energy generators like wind and solar into existing power grids, originally designed for synchronous generators such as hydropower and fossil fuels, poses additional challenges. Studies have shown that significant levels of wind energy (up to 30%) can be integrated without impacting overall system reliability, but this requires measurable experience and innovative solutions[14]. Options to increase grid flexibility include expanding balancing areas, increasing conventional generator ramp rates, and shifting demand of flexible loads[19]. Government initiatives and investments are pivotal in overcoming these technological hurdles. For instance, the President's Bipartisan Infrastructure Law is the largest-ever investment in America's power grid, aiming to build new transmission lines that are critical for unlocking clean energy resources and providing more affordable and reliable electricity[9]. This law supports research, development, and demonstration of next-generation transmission technology, and it seeks to modernise transmission planning and improve permitting processes to facilitate faster grid expansion[9].

Financial Challenges

The cost of financing plays a critical role in the overall expense of renewable energy projects. The cost of debt is the interest rate or yield that a company, project, or purchaser secures from lenders or bond subscribers. In contrast, the cost of equity is the financial return expected by shareholders in exchange for providing capital, often involving higher risks and higher rewards through dividends and capital appreciation[21]. One major challenge is the disparity in financing costs between regions. Emerging and developing economies face financing costs that are often twice as high as those in advanced economies[21]. This discrepancy is primarily due to country-related risks and underdeveloped local financial systems, which can make the financing costs up to seven times higher than in the United States and Europe[21]. Additionally, the financial stability of sponsors is crucial; their revenues ideally should be double the total project capital expenditures to signal stability and attract financiers[22]. Cost inflation also poses significant challenges. Approximately half of the additional USD 200 billion in capital investment in 2022 is likely to be consumed by higher costs, driven by multiple supply chain pressures, tight markets for specialised labour and services, and increased prices for essential construction materials like steel and cement[23]. These cost pressures are notably visible in clean energy technologies such as solar panels and wind turbines, which have seen cost increases of 10% to 20% since 2020[23]. Despite these challenges, sustainable finance remains crucial for clean energy investments. Although financial conditions have been volatile, many listed energy-related businesses entered 2022 with strong balance sheets, signalling a positive environment for energy investment[23]. However, acute financial strains continue to be a problem for many state-owned energy companies in emerging and developing economies[23]. The overall rise in the cost of money is a significant concern for the innovation systems supporting renewable energy. For a decade, cheap capital has lowered barriers to investment, but as financing costs rise, the health of these systems and the level of public support will be vital in determining how quickly new technology ideas continue to emerge[24].

Government Policies and Their Impact

Success in the renewable energy sector is not easily achieved and requires significant technological innovation, which can take decades to mature. The evolution of technologies like solar photovoltaics and batteries illustrates the inherently uncertain nature of this progress. Therefore, finding effective ways to innovate is crucial for fostering rapid change [12]. Governments play a central and multifaceted role in this process, which extends beyond merely funding R&D. They set national objectives, determine market expectations, ensure the flow of knowledge, invest in infrastructure, and facilitate major demonstration projects[12]. One prominent example is the continuous cost reduction in solar PV over the past 70 years. Various governments, including those of the United States, Germany, and China, have implemented R&D and market-pull policies, such as targets and revenue guarantees, to encourage investments along the value chain, thus supporting innovation and economies of scale[12]. Similar patterns have been observed in the development of lithium-ion batteries[12]. In Germany, the Renewable Energy Sources Act (EEG), introduced in 2000, significantly impacted the energy companies and facilitated the shift towards renewable energy. Initially, energy companies were resistant to change, continuing to rely on traditional revenue sources despite the growing political will for renewable energy. However, the EEG and subsequent legislative changes promoted grid priority for renewable sources and guaranteed feed-in tariffs, leading to substantial growth in onshore wind, solar PV, and biogas. Today, these renewable sources cover half of the country's electricity consumption20. Further legislative changes are anticipated to promote renewable energy in Germany, including concepts to abolish the renewables surcharge in favor of a budget-neutral financing model, facilitating repowering of existing wind farms, and enhancing conditions for power purchase agreements between renewable operators and private consumers[20]. Additionally, by 2027, the government aims to propose how and when renewable funding via the EEG could be entirely market-driven[20]. The phase-out of nuclear power generation in Germany, initiated in 2002 by the coalition government of the Social Democrats (SPD) and the Green Party, marked another significant policy shift. This led to the ban on constructing new nuclear plants and the decision to decommission the last nuclear plant by 2021. Concurrently, renewable energy development continued, with amendments to the EEG affecting feed-in tariffs for wind turbines[13].

Case Studies

Government Accountability Office (GAO) Assessment

To conduct a thorough technology assessment of renewable energy costs, the Government Accountability Office (GAO) reviewed a wide range of evidence. This included analysing various articles and reports, interviewing stakeholders from government, industry, and academia, conducting site visits, and convening an expert meeting with the National Academies of Sciences, Engineering, and Medicine.

The GAO aimed to identify policy options in their report to address the challenges associated with the high costs of renewable energy[25].

Academic Research

Two significant academic papers provide insights into the economics of renewable energy technologies. The first paper by Rupert Way et al. explores how standard portfolio theory is altered when assets are technologies that follow experience curves. This study is detailed in the Journal of Economic Dynamics and Control [26]. The second paper by J.D. Farmer et al. discusses 'Sensitive intervention points in the post-carbon transition,' highlighting critical points where strategic interventions could significantly impact the cost and adoption of renewable energy. This research was published in the journal Science [26].

International Energy Agency (IEA) Insights

The IEA's World Energy Outlook 2020 provides a comprehensive analysis of electricity's role in the energy transition, including the challenges and costs associated with renewable energy. This outlook is crucial for understanding the broader context in which renewable energy technologies operate and the economic factors influencing their adoption [26].

References

[1]: Executive summary – Strategies for Affordable and Fair Clean Energy ...
https://www.iea.org/reports/strategies-for-affordable-and-fair-clean-energy-transitions/executive-summary
[2]: Barriers to Renewable Energy Technologies - Union of Concerned Scientists
https://www.ucsusa.org/resources/barriers-renewable-energy-technologies
[3]: Wind Power Costs Reduced Dramatically | Energy Analysis & Enviromental ...
https://energyanalysis.lbl.gov/news/wind-power-costs-reduced-dramatically
[4]: Projected Costs of Generating Electricity 2020 – Analysis - IEA
https://www.iea.org/reports/projected-costs-of-generating-electricity-2020
[5]: Renewable-energy development: Disrupted supply chains | McKinsey

https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/renewable-energy-development-in-a-net-zero-world-disrupted-supply-chains
[6]: Executive summary – Reducing the Cost of Capital – Analysis - IEA
https://www.iea.org/reports/reducing-the-cost-of-capital/executive-summary
[7]: Executive summary – Denmark 2023 – Analysis - IEA
https://www.iea.org/reports/denmark-2023/executive-summary
[8]: Clean energy technology innovation and the vital role of governments
https://www.iea.org/reports/clean-energy-innovation/clean-energy-technology-innovation-and-the-vital-role-of-governments
[9]: Incentives and Policies | US EPA
https://www.epa.gov/re-powering/incentives-and-policies
[10]: For decades, governments have subsidised fossil fuels. But why?
https://theconversation.com/for-decades-governments-have-subsidised-fossil-fuels-but-why-213467
[11]: Growth of Renewable Energy in the US | World Resources Institute
https://www.wri.org/insights/clean-energy-progress-united-states
[12]: Causes and effects of the German energy transition in the context of ...
https://energsustainsoc.biomedcentral.com/articles/10.1186/s13705-023-00407-2
[13]: WINDExchange: Wind Energy Economic Guide
https://windexchange.energy.gov/economic-development-guide
[14]: How $4 billion in government money is being spent to reduce ... - NPR
https://www.npr.org/2024/07/23/nx-s1-5046808/heres-how-4-billion-in-government-money-is-being-spent-to-reduce-climate-pollution
[15]: Hydropower | Electricity | 2021 | ATB | NREL
https://atb.nrel.gov/electricity/2021/hydropower
[16]: Hydropower | Electricity | 2023 | ATB | NREL
https://atb.nrel.gov/electricity/2023/hydropower
[17]: Wind Energy Economics 101: Understanding the Costs
https://therenewablerundown.com/wind/wind-energy-economics/
[18]: Solar on the rise: How cost declines and grid integration shape solar's ...
https://www.cambridge.org/core/journals/mrs-energy-and-sustainability/article/solar-on-the-rise-how-cost-declines-and-grid-integration-shape-solars-growth-potential-in-the-united-states/9881673A13F2A13B602C8B3C03D00155
[19]: What's new in Germany's Renewable Energy Act 2021
https://www.cleanenergywire.org/factsheets/whats-new-germanys-renewable-energy-act-2021
[20]: FACT SHEET: Biden-Harris Administration Races to Deploy Clean Energy ...
https://www.whitehouse.gov/briefing-room/statements-releases/2022/01/12/fact-sheet-biden-harris-administration-races-to-deploy-clean-energy-that-creates-jobs-and-lowers-costs/
[21]: The Cost of Capital in Clean Energy Transitions – Analysis - IEA
https://www.iea.org/articles/the-cost-of-capital-in-clean-energy-transitions
[22]: Five Pillars That Determine Commercial Renewables Projects' Bankability
https://www.irena.org/News/expertinsights/2024/Apr/Five-Pillars-That-Determine-Commercial-Renewables-Projects-Bankability

[23]: Overview and key findings – World Energy Investment 2022 – Analysis - IEA
https://www.iea.org/reports/world-energy-investment-2022/overview-and-key-findings
[24]: World Energy Investment 2023 – Analysis - IEA
https://www.iea.org/reports/world-energy-investment-2023/overview-and-key-findings
[25]: Wind Energy: Technologies and Approaches to Help Address Environmental ...
https://www.gao.gov/products/gao-24-106687
[26]: Why did renewables become so cheap so fast? - Our World in Data
https://ourworldindata.org/cheap-renewables-growth