An Extensive Analysis of Renewable Energy Project Financing Costs, Expenses, and Environmental Impacts of Alternative Energy Sources

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Abstract:

Energy production based on the usage of fossil fuels contributes significantly to global climate change, accounting for about 75% of all greenhouse gas emissions and over 90% of all carbon dioxide emissions. Renewable energy alternatives are essential for decarbonizing the energy sector. However, the adverse consequences of climate change, such as increasing temperatures, high winds, rising sea levels, and diminishing precipitation, may have an influence on renewable energies. In this article, we examine the history of renewable energy, concentrating on how these sources have evolved and their impact on the environment, the economy, and global decarbonization. Our concentration is on the sun, the wind, the biomass, the water, and the ground. The price of solar photovoltaic power is predicted to fall to \$0.048/kWh by 2021, from \$0.417/kWh in 2010. There has been a 68% drop in the price of concentrated solar power, a 60% drop in the price of onshore wind energy, and a 14% drop in the price of biomass energy. Solar energy appears to be the least affected by climate change, whereas wind energy and hydropower might see decreases of up to 40 percent in some regions. Climate change may have an impact on biomass production, plant development, chemical composition, and the microbial communities in soil. Hydroelectric power facilities are the most destructive, thus careful installation of solar photovoltaics is crucial. Wind turbines and biomass power plants, two examples of renewable energy sources, should be widely employed because of their minimal environmental impact. By 2050, renewable energy may power 90 percent of the electrical sector, significantly reducing carbon emissions and helping the cause against climate change. If the zero carbon emission decarbonization concept is achieved, renewable energy in the future has the potential to completely replace energy generated from fossil fuels and keep the global temperature rise to 1.5 °C by 2050.

Keywords:*Climate change, Renewable Energy, Cost Estimation, Financing, Environment*

Introduction

Fossil fuels are the most widely used type of energy because of their high energy density; nevertheless, their burning results in the release of greenhouse gases, with current power plants responsible for emitting around 35% of these gases. As a result, China's coal-fired power plants are responsible for an additional 40% of the heat-trapping greenhouse gases that contribute to an increase in world temperature (Yang et al., 2020). In 2018, climate change was directly responsible for over 300 natural disasters that impacted over 68 million people and generated over \$131.7 billion in economic damages; the most majority of these catastrophes were the result of storms, wildfires, floods, and droughts. The wildfre'sfnancial losses in 2018 are roughly equal to the losses of the entire decade, which is quite worrisome.

Climate change also threatens human health and well-being, food production, agricultural yields, water supplies, the spread of disease, and the stability of communities, buildings, and natural ecosystems.

It is anticipated that by the year 2040, energy consumption would have climbed by 56%. If energy demand continues to grow and the existing approach of depending on fossil fuels is not adjusted, greenhouse gas emissions will increase. Consequently, without working to slow global warming's effects, these outcomes are inevitable. The utilization of renewable energy sources is crucial to achieving carbon neutrality, reducing climate change, and keeping global temperatures below 2 degrees Celsius, as stipulated in the Paris Agreements. Renewable energy is not only inexpensive but also sustainable and good for the environment. Decarbonizing the energy sector and combating climate change require the use of renewable energy sources like solar, hydro, and wind power; yet, these resources are vulnerable to both present and future weather patterns and climatic shifts. Fewer considerations have been given to how using renewable energy sources can affect the environment. This review was conducted to have a conversation about (i) the most well-known renewable energy sources, (ii) the needs and costs of renewable energy, (iii) the impacts of climate change on renewable energy sources and their potential future under climate change scenarios, (iv) the potential environmental impacts caused by renewable energy sources, and (v) the most eco-friendly renewable energy sources.

The importance of renewable energy:

Nearly eighty percent of the world's population resides in nations that are net importers of fossil fuels (IRENAd, 2022). Roughly six billion people are at risk from geopolitical shocks and crises because of their reliance on imported fossil fuels (AaH et al., 2021). Renewable energy sources, on the other hand, are available everywhere but have not been used to their full potential. According to IRENA's projections, 90% of the world's energy needs can and should be met by renewables by 2050.

In this age of global environmental deterioration, the necessity to battle climate change and achieve sustainable development has strengthened the worldwide renewable energy transition momentum. Green buildings, green energy and power use in industry, green transportation, reduced prices of renewable energy, better energy efficiency and continuous technology breakthroughs, and informed policymaking are all contributing to a future where sustainable energy is a reality. This transition is gathering momentum, but it has to speed up if it's going to aid in the sustainable growth of the world as a whole. Renewable energy is crucial to the continued success of the building sector. Policies, finances, technology, and culture all act as roadblocks to the expansion of renewable energy. It was also shown that there is an immediate need for legislation in India to encourage the use of renewable energy in the building sector. Studies show that switching to renewable energy in manufacturing may save costs and prevent damage to the environment caused by emissions from fossil fuels. However, energy conservation significance efforts at the government level are necessary.

Several Chinese and European studies have found that using a high share of renewable energy in power plants results in low capacity utilization and significant monthly variations in renewable energy, which in turn results in seasonal or even interannual structural imbalances in energy supply. Using the study's findings, Ireland may expect to have effectively adopted a 15% share of renewable energy in transportation by 2020. Denmark may achieve sustainable bioenergy consumption if the transportation sector adopts 100% renewable energy systems. Since the price is comparable to other non-fossil energy options, this is physically feasible. While in principle renewable energy might replace fossil fuels in these four key sectors, the actual transition to this type of energy depends on factors such as legislation and culture. There will be a growing demand in the future for government and relevant authority support for the use of renewable energy, as well as increased promotion of energy saving and adoption of renewable energy.

Alternative power sources

The term "renewable energy" refers to power that comes from non-exhaustible sources. It is estimated that the worldwide proportion of renewable energy will expand from 14% in 2018 to around 74% in 2050, which is an eightfold increase on an annual basis in order to attain carbon neutrality. Sustainability and technical qualities like as compatibility with other resources, energy efficiency, and running costs can be used to assess the viability of renewable energy. These considerations guide policymakers toward the best renewable energy option for satisfying consumer needs. It is crucial to define the renewable energy resource in order to choose the most practical renewable energy source.

Cost of renewable energies

The price of solar energy dropped by 88% between 2010 and 2021 (IRENAa, 2022). Offshore wind energy prices declined by 60%, while onshore costs reduced by 68%. The bulk of the world's future energy consumption will come from poor and middle-income nations, so it's no surprise that these regions are seeing a surge in interest in renewable energy. Since their costs have been going down, low-carbon sources are likely to provide the bulk of the world's future electricity needs. Renewable energy has the potential to significantly reduce carbon emissions and aid in climate change mitigation by providing as much as 65% of the world's total electricity supply by 2030 and as much as 90% of the electrical sector by 2050. The International Energy Agency estimates that the sharper rises in gas and coal prices would boost the competitiveness of solar and wind power, even if their costs are likely to be higher in 2022 and 2023 compared to pre-epidemic levels.Bioenergy power generation increased by 10.3 GW in 2021, up from 9.1 GW the previous year. Outside of these areas, the increase of geothermal power was minimal in 2021, and the addition of concentrated solar power capacity to the networks was just 110 megawatts. This means a rising percentage of overall power coming from renewable sources.

Cost of solar energy

Between 2010 and 2021, solar energy production increased by 21-fold, with over 843 gigawatts deployed globally. In 2021, 133 GW of new systems went live, a 13% increase from the previous year. Accurate cost estimates are crucial for promoting the benefits and future of renewable energies. Research comparing crystalline silicon and amorphous silicon panels in four climatic zones showed crystalline silicon panels have the lowest deterioration rates. To make solar energy more cost-effective, researchers recommend using photovoltaic panels.

Hybrid energy systems are essential to reduce the overall cost of renewable energy sources. Iran's solar-wind hybrid system found a potential of 87-100%, with the cheapest solar system costing $0.592/kilowatt-hour. A hybrid system for heating and cooling buildings could save 64.2% on energy expenses, with further research needed to lower solar energy expenses. The global weighted average levelized cost of power from solar photovoltaic projects reduced by almost 88% annually from 2010 to 2021.

Cost of wind energy

Between 2010 and 2021, solar energy production increased by 21-fold, with over 843 gigawatts deployed globally. In 2021, 133 GW of new systems went live, a 13% increase from the previous year. Accurate cost estimates are crucial for promoting the benefits and future of renewable energies. Research comparing crystalline silicon and amorphous silicon panels in four climatic zones showed crystalline silicon panels have the lowest deterioration rates. To make solar energy more cost-effective, researchers recommend using photovoltaic panels.

To bring down the overall price of renewable energy sources, hybrid energy systems are crucial. The cheapest solar system in Iran costs only $0.592/kilowatt-hour, while the country's hybrid solar-wind system has a potential of 87-100%. Further investigation is required to reduce the price of solar energy, but a hybrid system for heating and cooling buildings might reduce energy costs by 64.2%. There was an annual decline of over 88% in the levelized cost of electricity from solar photovoltaic installations throughout the world between 2010 and 2021.

Cost of biomass energy

Between 2010 and 2021, solar energy production increased by 21-fold, with over 843 gigawatts deployed globally. In 2021, 133 GW of new systems went live, a 13% increase from the previous year. Accurate cost estimates are crucial for promoting the benefits and future of renewable energies. Research comparing crystalline silicon and amorphous silicon panels in four climatic zones showed crystalline silicon panels have the lowest deterioration rates. To make solar energy more cost-effective, researchers recommend using photovoltaic panels.

The overall cost of renewable energy sources may be greatly reduced via the use of hybrid energy systems. 87-100% potential was discovered for Iran's solar-wind hybrid system, with the lowest solar system costing only $0.592/kWh. With more study, we can reduce the high cost of solar energy and realize savings of 64.2% by switching to a hybrid system for heating and cooling buildings. From 2010 to 2021, the annualized global weighted average levelized cost of electricity from solar photovoltaic plants decreased by over 88%.

Cost of hydropower energy

The price tag for generating electricity using hydropower is very variable, depending on set-up, gear, running, and upkeep costs. Access to energy in rural and undeveloped regions is impossible without microhydropower plants. The expense of setting up a microhydropower plant that uses components made in the country. Nearly half of all sub-system costs in a hydroelectric plant are associated with the generator, penstock, and turbine. Compared to solar and wind power plants, which cost 10 and 7 cents/hour to set up, micro-hydropower plants only cost around 6 cents/hour. Another research evaluated the costs of a hydropower project using the enhanced Hydropower's Environmental expenditures Analysis Model (HECAM II), and they used the Bakhtiari dam in Iran as a case study. With a benefit-to-cost ratio of 2.57, the total cost per megawatt hour (MWh) was $79.13, while revenue was $203. Another study on the costs of hydropower plants in Ecuador found that the most recent projects, such as Coca Codo Sinclair, Sopladora, Minas San Francisco, Delsintagua, and Manduriacu, had prices that were 79%, 34%, 21%, 12%, and 119% higher than the IRENA's norms.In conclusion, hydropower projects need to be managed efficiently from the get-go if they are to be profitable due to the high initial expenses of construction compared to operation and maintenance expenditures.

Geothermal energy costs

Heating buildings and water with geothermal energy is common practice. In Geneva, Switzerland, the cost of installing a geothermal district heating system was analyzed. The LCOE for geothermal energy alone varied from 59 to 553 Swiss Francs/MWh, depending on the options selected. The lowest LCOE was achieved with a linear heat density of 8 MWh/m2 and a geothermal coverage of 40% in a centralized system, with an annual heat demand of 400 TWh. The greatest LCOE was achieved with a heat demand of 100 TWh/yr, a geothermal coverage of 10%, and a geothermal flow rate of less than 20 L/s. The lowest cost for a 150 MW plant was determined to be €2.8/kWh in another study done in Bangladesh, where it was observed that the price of geothermal energy declined with both capacity and duration. The price of constructing a power plant, which includes buying land, building it, and buying the necessary machinery, begins at $2,500,000. It is estimated that operating and maintenance costs amount to $0.01-0.03 per kilowatt-hour, with an uptime of 90%. Since geothermal power plants have varied initial costs, it is important to carefully consider how to price the energy they produce.

The effects of global warming on alternative energy sources

Use of fossil fuels in the generation of energy is the primary cause of climate change and global warming. Clean, renewable power is crucial for mitigating climate change and lowering emissions of greenhouse gases. Changes in the weather and climate can have an impact on the production of hydropower, solar electricity, and other renewable energy sources. The potential for a low-carbon and sustainable energy system may be evaluated with more certainty by analyzing the impact of future climate and estimating the variability of renewable energy sources. Climate change, which includes things like warmer temperatures, stronger winds, higher sea levels, and less precipitation, will be one of the most pressing societal challenges of the 21st century. Below, we'll talk about how global warming affects various renewable energy options.

Economic impact of renewable energy

Explicit subsidies, tax exemptions, and unaccounted for health and environmental damages brought the total amount of subsidy to the fossil fuel sector in 2020 to a whopping $5.9 trillion. In order to attain zero carbon emissions by 2030, it will be necessary to spend almost $4 trillion year on renewable energy. This figure includes investments in both technology and infrastructure. Many countries will need financial and technical aid to make the shift since the initial cost may be too high. However, spending money on renewable energy sources will provide a profit. By 2030, the yearly savings from reducing pollution and climate consequences might amount to $4,2 trillion. Energy resilience and security may be improved by diversifying power supply sources, and efficient, reliable renewable technologies may help create a system that is less vulnerable to market shocks. Investing in renewable energy sources helps the economy expand, creates millions of new jobs, and enhances the standard of living for everybody.

Cost of capital indicators for renewables

The investment and financing of renewable energy assets is of interest to researchers in many different areas of economics (including but not limited to energy and environmental economics, energy system modeling, and financial economics), all of which have different perspectives on the cost of capital or discount rates. We briefly discuss financing structures and cost of capital metrics as they are understood in this study, and we highlight recent research on the expected difference in the cost of capital among renewable energy assets.

Methods of Financing Green Energy Projects

Corporate finance structures ("on balance sheet"), as in the case of a utility, or project financing structures ("off balance sheet"), as in the case of a distinct legal entity, can be used to finance power plants and other infrastructure assets. Historically, utilities have realized many fossil fuel-based power plants using corporate financing structures, but in the last two decades, a significantly more diversified variety of sponsors has been driving the boom of renewable energy investments through the use of project finance. The real estate asset is owned by a special purpose vehicle (SPV) that is created by the sponsor and funded by loans and equity. Real estate projects leave equity investors and financing lenders dependent on the project's future cash flows for repayment rather than the sponsor's other assets. This means that the cost of capital and associated level of risk for any given real estate investment project will vary depending on its specifics.

Measures of the cost of capital

Many different definitions exist for the private cost of capital; nevertheless, economists generally agree that it is "the expected rate of return that market participants require in order to attract funds to a particular investment." The cost of capital is a forward-looking word for describing expected returns, and it consists of the time value of money plus a risk premium (and occasionally other aspects, such as taxes or transaction fees). The discount rate is the same as the cost of capital for calculating the value of an investment using techniques like the net present value.

Expected heterogeneity among projects

In financial economics, the time value of money-adjusted expected return is sometimes separated from the risk premium that comes with investing. Although the risk-free rate ought to be the same across all investment choices, the actual cost of capital varies due to the risk premium (in addition to differences in taxes and transaction charges). Numerous studies have examined the dangers of investing in renewable energy assets by surveying financiers. In the following research, we take this into account by segmenting empirical estimates of the cost of capital by geographic region, economic sector, and time period of financing. The impact of interest rate fluctuations on the market is also factored in.

capex costs for renewable energy projects are being analyzed and quantified.

To begin, we create a systematic and repeatable literature foundation of pertinent papers. Then, we classify the research methodologies used to estimate the cost of capital, describe their advantages and disadvantages, and provide an overall assessment of the papers we chose (RQ 2). Finally, we collect empirical data on the cost of capital, normalize it into consistent units by making any additional assumptions that are needed, create a database that can be used in a meta-analysis, and talk about the empirical results using descriptive statistics and charts (RQ 2).

Estimation methods for RE cost of capital

To replicate auction outcomes or analyze financial market data, approaches use readily available data from other areas, such as information about the project itself or the general real estate market for factors other than the cost of capital. After introducing each method in turn, we will discuss its applicability in various contexts.Five methods are discussed: (1) analyzing financial market data, (2) surveying experts for their predictions, (3) replicating auction outcomes, (4) analyzing project finance data, and (5) calculating market return on equity.

Conclusion:

Achieving a sustainable future requires an appreciation of how climate change affects the generation of renewable energy. Solar energy was determined to have the least impact compared to wind, hydropower, biomass, and geothermal energy. When compared to short- and medium-term climatic fluctuations, the effects of long-term climate change are far more significant. To further safeguard the environment from pollution and climate change, as well as lessen dependency on fossil fuels, further decarbonization efforts are required for growing and establishing renewables. Instead of focusing on a single energy source to develop decarbonization methods, future research should aim to increase climate model predictions to analyze the overall energy generating system. The environmental impacts of renewable energy have also been extensively researched for this assessment. Renewable energy options including solar, wind, hydro, geothermal, and biomass are all taken into account. Depending on factors including kind, location, scale, and implementation style, renewable energy sources can have varying degrees of environmental effect. These effects, however, can be lessened by the strategic use of renewable energy. The negative effects of solar energy on the environment may be greatly reduced by concentrating panels on rooftops, for example. Hydroelectric facilities cause the most damage to the environment of any renewable energy source. Once we're no longer reliant on fossil fuels, we can focus on preventing hydroelectric projects and restoring natural rivers. The most eco-friendly energy comes from the wind and biomass.

The purpose of this systematic literature analysis was to provide much-needed information on the cost of capital for renewable energy projects by compiling estimates from 19 studies that calculated WACCs for solar photovoltaic, onshore wind, and offshore wind power in 46 different nations. Capital costs increase from solar PV to onshore wind to offshore wind power in a consistent order for these nations. The average cost of capital in developing nations is far greater than in developed ones, although there is a wide range of variation even within economically similar countries. The article's findings showing a wide range of WACC estimations highlight the need of considering alternative cost of capital assumptions for energy economists and energy system modelers. For example, in RE investment models and energy system models with endogenous investment, the current research provided strong evidence for variations across nations and technologies.

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