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Economic Analysis of The Contribution of Renewable Energy Sources to the Decarbonization of the Power Systems

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Abstract:
The economic analysis of the contribution of Renewable Energy Sources (RESs) to the decarbonization of power systems involves evaluating the financial implications and overall benefits of transitioning towards cleaner energy sources. As traditional power systems heavily rely on fossil fuels, which contribute to Greenhouse Gas (GHG) emissions, the integration of RESs plays a crucial role in reducing carbon footprints and addressing Climate Change (CC). Economic analysis assesses the costs and benefits associated with the adoption of RESs in power systems. It involves considering factors such as the initial investment required for deploying renewable energy technologies, Operational and Maintenance (O&M) costs, potential revenue generation, and the long-term environmental benefits. This analysis enables policymakers, investors, and stakeholders to evaluate the financial viability of transitioning to cleaner energy systems.

Keyword: Economic Analysis, RESs, Decarbonizing power, CC.

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التحليل الاقتصادي لمساهمة مصادر الطاقة المتجددة في إزالة الكربون من أنظمة القدرة

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الملخص
يتضمن التحليل الاقتصادي لمساهمة مصادر الطاقة المتجددة (RESs) في إزالة الكربون من أنظمة الطاقة تقييم الآثار المالية والفوائد العامة للتحول نحو مصادر طاقة أنظف. نظرًا لأن أنظمة الطاقة التقليدية تعتمد بشكل كبير على الوقود الأحفوري، الذي يساهم في انبعاثات غازات الاحتباس الحراري(GHG) ، يلعب تكامل مصادر الطاقة المتجددة دورًا مهمًا في الحد من آثار الكربون ومعالجة تغير المناخ .(CC) يقيم التحليل الاقتصادي التكاليف والفوائد المرتبطة باعتماد مصادر الطاقة المتجددة في أنظمة الطاقة. وهو يتضمن النظر في عوامل مثل الاستثمار الأولي المطلوب لنشر تقنيات الطاقة

المتجددة، وتكاليف التشغيل والصيانة (O & M) ، وتوليد الإيرادات المحتملة ، والفوائد البيئية طويلة الأجل. يمكّن هذا التحليل صانعي السياسات والمستثمرين وأصحاب المصلحة من تقييم الجدوى المالية للانتقال إلى أنظمة طاقة أنظف.

الكلمة المفتاحية: التحليل الاقتصادي، RESs، قوة إزالة الكربون، CC.

1. Introduction

Renewable Energy Sources (RESs) play a crucial role in the decarbonization of power systems [1]. The RESs contribution to reducing Greenhouse Gas (GHG) emissions and transitioning away from fossil fuel dependency has significant economic implications. Besides, it can be analyzed in several ways such as cost reduction, job creation, energy independence and security, technological innovation and export opportunities, and environmental and health benefits [2]. Decarbonizing power systems through the integration of RESs offers several economic advantages [3]. Firstly, renewable energy technologies have experienced significant cost reductions in recent years, making them increasingly competitive with traditional energy sources [4]. This cost competitiveness combined with the potential for long-term savings as fossil fuel prices rise, makes RESs economically attractive options [2]. Secondly, the deployment of RESs creates new job opportunities in the renewable energy sector, contributing to economic growth and employment [5]. The development, manufacturing, installation, and maintenance of renewable energy infrastructure require a skilled workforce which stimulates local economies and reduces dependence on fossil fuel industries [6].

Furthermore, the economic analysis of RESs also considers the potential savings from reducing GHG emissions and avoiding the adverse effects of climate change [7], [8]. By transitioning to cleaner energy sources, societies can mitigate the economic costs associated with environmental damages, public health impacts, and the need for costly adaptation measures [9]. Global fuel combustion-related CO2 emissions increased by around 6% in 2021, approaching levels seen before the Covid-19 epidemic [10]. Oil accounted for over 30% of all fossil fuels used in The World's Energy Supply (TES), followed by coal (27%), Natural Gas (24%), and natural gas (30%) [11]. Coal accounted for 44% of all fuel-related emissions globally, with oil (32%) and natural gas (22%), respectively, coming in second and third [12]. The European Union, India, the Russian Federation, China, and the United States combined were responsible for 45% of the emissions from fuel burning worldwide [13]–[16]. It is essential to conduct specific economic analysis tailored to individual regions and scenarios to better understand the unique contributions of RESs to decarbonization [17], [18]. Nonetheless, the overall consensus is that the economic benefits of transitioning to RESs far outweigh the costs in the long run [19].

The contribution to the knowledge in this article by statistically examines the contribution of EV considering economic analysis. the rest of the article is organized as follows: methods and materials are placed in Section 2. The case study of this article and proposed model is positioned in Section 3. The obtained results and its discussion are presented in Section 4. Finally, the summary conclusion and list of references cited articles related to the mentioned topic.

2. Methods and materials

The economic analysis of the contribution of renewables to the decarbonization of power systems typically involves several methods and materials [20], [21]. Furthermore, economic analysis of the contribution of renewables to power system decarbonization combines various quantitative and qualitative methodologies to assess the financial, investment, and policy implications of transitioning to clean energy sources [22].

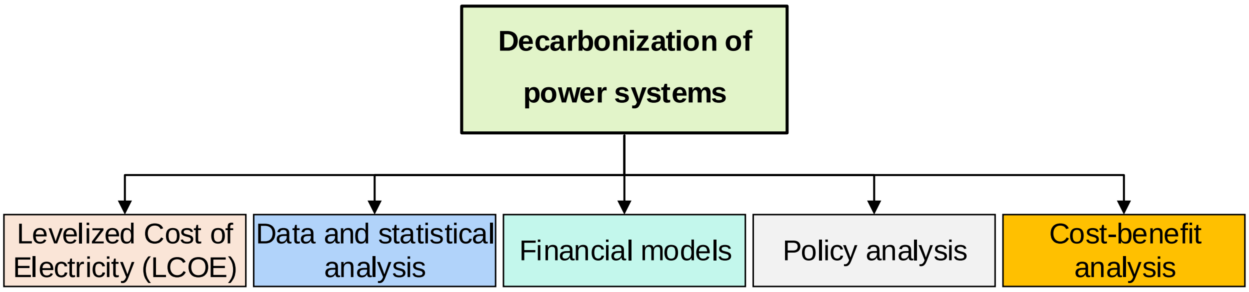


Figure 1. Materials and Methods for decarbonization of power systems

- Levelized Cost of Electricity (LCOE): LCOE is a commonly used metric to estimate the lifetime costs of electricity generation from different sources [23]. It includes factors like capital costs, operating expenses, fuel costs, and the lifetime energy output. Comparing the LCOE of renewable energy sources with traditional ones helps in understanding their economic competitiveness [24].

- Data and statistical analysis: Economic analysis relies on data related to energy generation, consumption patterns, market prices, and technology costs [25]. Statistical techniques are used to analyze historical data, project future scenarios, and quantify uncertainties associated with renewable energy investments [26].
- Financial models: Economic analysis often employs financial models to evaluate the financing aspects of renewable projects. These models include cash flow analysis, return on investment calculations, and considerations of subsidies, tax incentives, and capital structure [27].
- Policy analysis: Assessing the effectiveness of policies and regulations in promoting renewable energy deployment is essential. Economic analysis incorporates the evaluation of policy instruments like feed-in tariffs, tax credits, carbon pricing mechanisms, and renewable portfolio standards. This helps understand the impact of such policies on the economics of renewable energy adoption [28].
- Cost-benefit analysis: This method compares the costs associated with renewable energy technologies, such as installation, operation, and maintenance, with the benefits of reducing carbon emissions and other environmental impacts. It assesses the overall economic viability of renewables against conventional fossil fuel-based power generation [29].

3. Case study and proposed model

The proposed system is examined in a North African country that known as Libya as illustrated the Libyan geographical map in Figure 2 [30]. Libya is positioned between five countries and its capital is Tripoli. Tripoli is located in the norther side of the country with almost 3.5 million population and Mediterranean climate. The collected data of the study is analyzed in order to present the various levels of changes throughout the year. The load demand is presented in Figure 3 and the climatology collected data of the country are shown in Figure 4 [23].

Figure 2. Libyan map

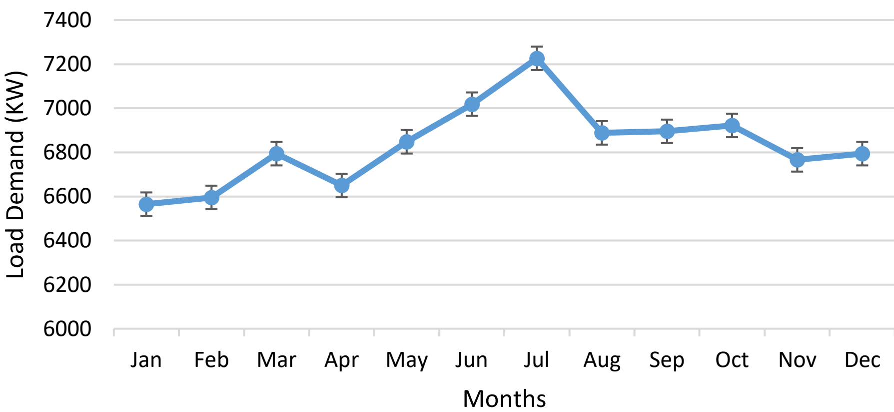
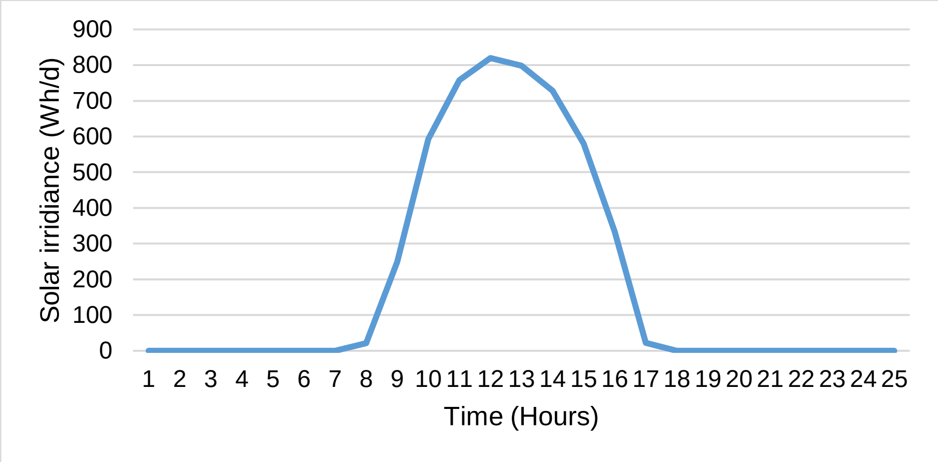
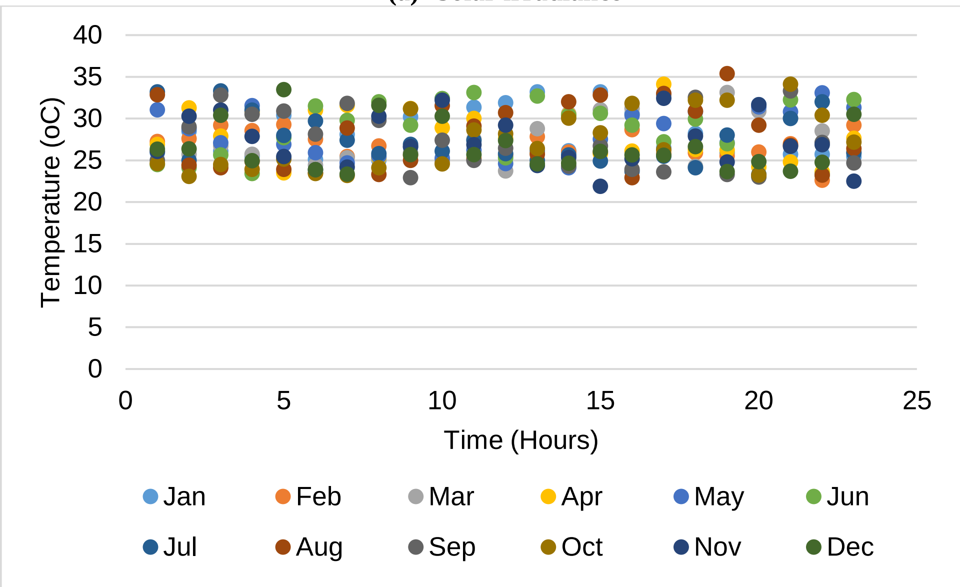


Figure 3. Load demand.



(a) Solar irradiance



(b) Temperature

Figure 4. Climatology data, a) solar irradiance and (b) temperature.

Based on the collected data and implemented in the related mathematical equations in order to estimate the output power on the proposed model that presented in Figure 5. Hence, the presented components are the PV and EV integrated through load.

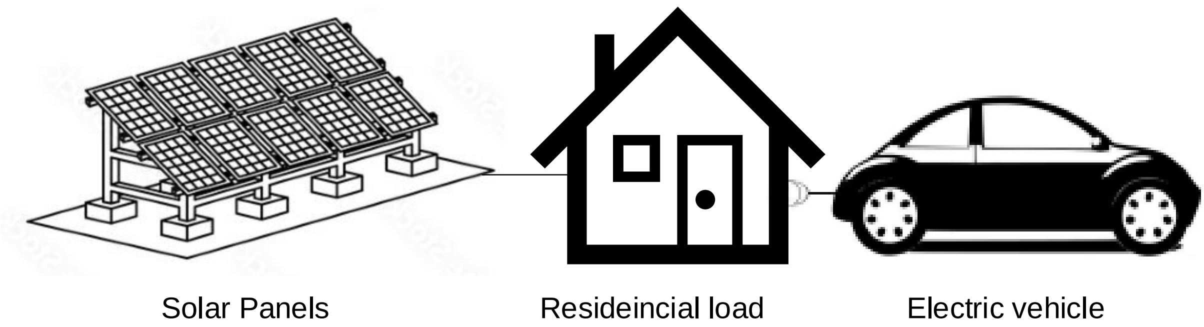


Figure 5. Proposed method.

4. Economic analysis

In terms of charging scenarios considering the PV, there are three types that namely smart charging, V2G, and Random Charge (RC) as mathematically presented in Eq. (1) – Eq. (3), respectively [31].

$$SC_{PV} = \int_{t_{max}}^{t_{max}+\frac{E_d}{\mu P_{EV}}} P_{EV} \times G_{PV}(t)dt \quad (1)$$

$$V2G_{PV} = \int_{t_{max}}^{t_{max}+\frac{C_b}{\mu P_{EV}}} P_{PV}(t)dt \quad (2)$$

$$RC_{PV} = \int_{t}^{t_{max}+\frac{E_d}{\mu P_{EV}}} P_{EV} \times G_{PV}(t)dt \quad (3)$$

Firstly, Eq. (1) represent the smart charge (SC_{PV}) considering PV, P_{EV}, G_{PV}, µ round trip of efficiency of energy. Secondly, Eq. (2) represents the charging operation from the PV to EV ($V2G_{PV}$) as classified under V2G operation, t_{max} starting time of PV generation peak period, and C_b refers to the on-board capacity that measured in (kWh). Eventually, Eq. (3) refers to the random charging utilizing the PV, the t refers to the time of staring charge, Among the presented equations, Eq. (2) is utilized due to their direct of exploiting the solar panels without auxiliaries such as energy batteries.

5. Results and discussion

Based on the model in Figure 5, the result has been statistically analyzed and provided in Table 1. Further explanation has been plotted in the seasonal and annual forms as in Figure 6 and Figure 7, respectively.

Table 1. Monthly PV contribution in percent.

RESs	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PV	5	7	8	10	11	12	12	10	9	7	5	4

As demonstrated in Figure 6, summer is the highest seasons of generating energy due to the time high solar radiation and temperature, while the scone is Spring, Autumn, then Winter, respectively.

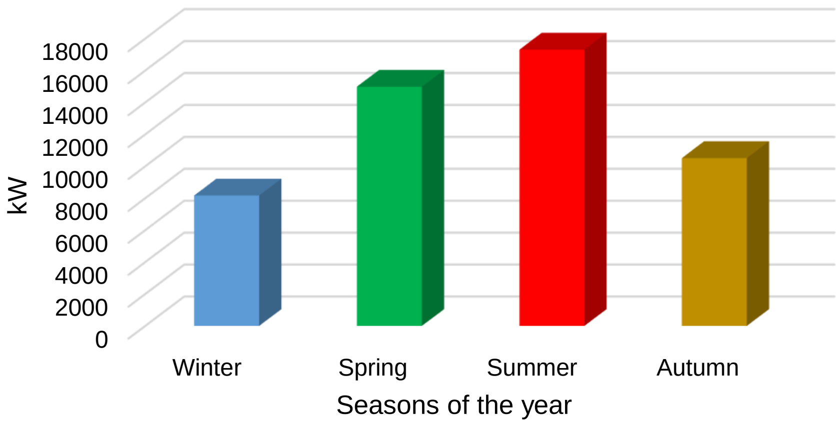


Figure 6. Seasonally contribution.

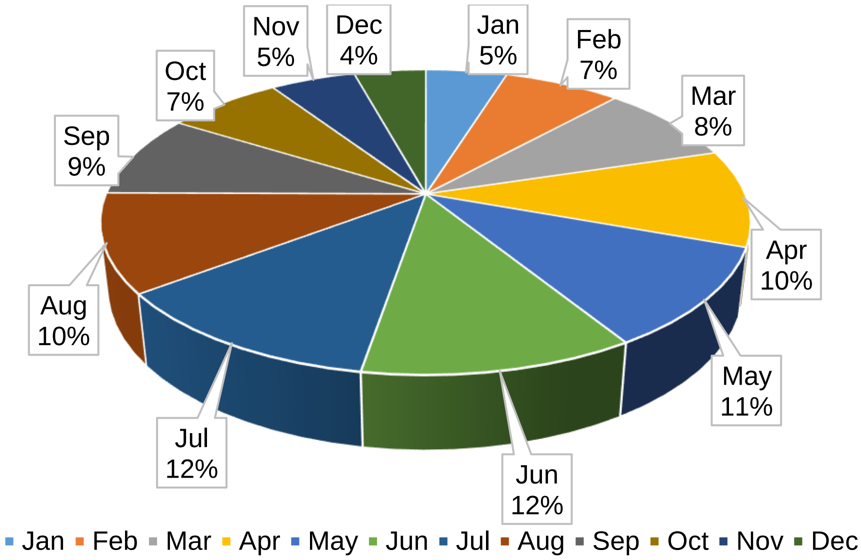


Figure 7. Pie chart of the RESs contribution.

Conclusion

In conclusion, the economic analysis of the contribution of RESs to the decarbonization of power systems provides valuable insights into the financial implications and benefits of transitioning towards cleaner energy sources. It helps inform policymakers, investors, and stakeholders about the economic viability of renewable energy deployment, ensuring sustainable and economically prosperous energy systems for the future. For further direction studies, scholar should pay more attention in exploiting technological Innovation and export opportunities to develop the RESs generation system and reducing the GHG along with pollution from ICEV.

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