

# Addressing the Social Impact of Renewable Energy Projects

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**Abstract** The social aspect of renewable energy development is a multifaceted issue that involves concepts such as empowerment, acceptance, and inclusion. It is closely related to economic and environmental factors, making it challenging to plan renewable energy projects suitable for individual countries, governments, or communities. To do so, it is necessary to identify the needs of society as a whole and the benefits that renewable energy development can bring. However, social phenomena are complex making them difficult to measure using traditional metrics. This paper examines the different ways in which renewable energy generation affects society. Drawing on relevant literature, we propose four key aspects to emphasize the social benefits and understand their difficulty and impact on energy projects. Our goal is to enhance the understanding of how to measure this impact and its significance in decision-making for renewable energy projects.

**Key words** Renewable energy, measuring social impact, sustainable development, energy power planning.

## 1. Introduction

Electric power is a fundamental enabler for any nation's economic development and social equity. However, a significant percentage of the world's population lacks adequate access to electricity, mainly in developing countries [1]. According to [2], 13% of people in the world do not have modern electricity services, and approximately 80% of them are concentrated in rural and remote areas. On the other hand, more than 38% of people depend on conventional fossil fuel energy sources, such as oil, coal, and gas, which have a considerable negative impact on the environment and human health due to the greenhouse gas emissions produced during their combustion [3]. In addition, the depletion of these conventional sources poses challenges for energy security in balancing demand and future generation. Global energy demand is projected to increase by 30% by 2040, especially due to population growth, estimated at 9 billion by 2050 [4]. In the case of developing countries, it is inferred that energy demand growth will increase similarly due to their development objectives in infrastructure, technology, industry, and transportation, among others [5].

Against this backdrop, sustainable development has been increasingly significant in recent times. As a result, the United Nations has adopted the 2030 Agenda for Sustainable Development, which consists of 17 Sustainable Development Goals (SDGs) that all governments should reach to achieve sustainable human development in harmony with nature. Specifically, the electricity sector faces the challenge of developing solutions that guarantee universal access to affordable, reliable, modern and sustainable energy services, as established in goal 7 of the United Nations 2030 agenda [6], [7].

In recent years, there has been a growing interest in distributed generation technologies, especially those based on renewable energy resources, with solar and wind being the most prominent. The global distributed power generation market is estimated to reach 580 billion of U.S. dollars by 2027 [8]. The projected growth is attributed to several factors, such as the level of maturity achieved by these technologies, current government policies, decreasing costs, and several benefits they offer to the energy sector. These benefits include access to energy in remote locations, the possibility of avoiding or postponing centralized grid upgrades, reduced system losses, lower

environmental impacts, and stimulation of new business models, among others [9], [10].

The implementation of renewable energies goes beyond just meeting needs and incentives. It also requires an efficient and sustainable interaction between multiple technical, economic, environmental, and social factors. This includes involving various stakeholders with different objectives and interests [11], [12]. The social impact of this implementation is complex and subjective, making decision-making difficult. Therefore, it is important to research and develop new planning approaches that can achieve a compromise between all aspects of social impact.

Measuring social impact fosters community engagement and energy project participation. Understanding how renewable generation affects local livelihoods, cultural heritage, and social cohesion will enable developers to incorporate community preferences into project planning, enhancing social acceptance and ownership. However, quantifying social impacts presents technical challenges. Social phenomena are complex and multifaceted, making them difficult to measure using traditional metrics. Additionally, establishing causality between renewable energy projects and social outcomes requires rigorous methodologies and data analysis, considering confounding variables and indirect effects. Due to this complexity, no specific categories are defined to measure the social impact. Still, based on the literature, four aspects are proposed in this paper to highlight the social benefits and encompass their impact on energy projects.

Despite these challenges, measuring social impact is essential in planning electrical projects. It enables developers to identify potential risks and opportunities, anticipate community concerns, and design interventions that maximize social benefits. By integrating social considerations into project planning, renewable energy projects can contribute to sustainable development while fostering positive relationships with local communities.

Understanding renewable energy projects' social impact involves several technical challenges. These include the complexity of social phenomena, establishing cause-and-effect relationships, monitoring long-term effects, integrating social factors into decision-making processes, and addressing data limitations and inclusivity issues. Overcoming these challenges requires collaboration across different fields, innovative methods, and a dedication to engaging with stake-

holders to ensure that renewable energy projects have a positive social impact and contribute to sustainable development.

## 2. Preliminaries

### 2.1 Renewable Energy

The adoption of renewable energy plays a significant role in advancing sustainable development by addressing multiple dimensions of sustainability. Environmentally, renewable energy reduces carbon emissions, air pollution, and ecosystem degradation, contributing to climate change mitigation and biodiversity conservation. By harnessing abundant and clean energy sources, people can minimize their reliance on finite fossil fuels and transition towards a more sustainable and resilient energy system.

Moreover, renewable energy is closely linked to the Sustainable Development Goals (SDGs) outlined by the United Nations, particularly Goal 7 (Affordable and Clean Energy) and Goal 13 (Climate Action). By expanding access to affordable and clean energy services, renewable energy helps eradicate energy poverty, improve health and well-being, and promote inclusive economic growth. Furthermore, by mitigating climate change and reducing our carbon footprint, renewable energy contributes to achieving the broader set of SDGs, including poverty reduction, food security, gender equality, and sustainable cities and communities.

In the context of Society 5.0, renewable energy technologies play a transformative role in shaping a human-centered society that leverages advanced technologies to address social challenges and enhance quality of life. Society 5.0 envisions a future where technological innovations, such as artificial intelligence, the Internet of Things, and renewable energy, are harnessed to create sustainable and inclusive societies. Renewable energy enables the development of smart grids, energy storage systems, and decentralized energy solutions, empowering individuals and communities to participate actively in energy production, consumption, and management. By embracing renewable energy within the framework of Society 5.0, innovation, resilience, and social cohesion can be fostered while advancing towards a more sustainable and equitable future.

### 2.2 Addressing Social Impact

Determining the social impact of renewable energy is crucial for successfully planning and implementing any energy project. Social impacts encompass various factors, including community acceptance, equitable access to benefits, and the potential for social change. Understanding and integrating these social dimensions ensures that renewable energy projects achieve technical and environmental goals and contribute positively to the communities in which they are situated.

One critical aspect of addressing social impacts is gaining community acceptance and support. Renewable energy projects can significantly alter the local landscape, economy, and daily life. For example, installing wind turbines or solar farms can affect land use, property values, and local aesthetics. Engaging with the community early in the planning process through consultations and participatory decision-making can help address concerns, dispel myths, and build trust. When communities feel heard and involved, they are more likely to support the project and participate actively in its development and maintenance, leading to smoother implementation and long-term success [13].

Equitable access to the benefits of renewable energy projects is another vital consideration. These projects can provide significant economic benefits, such as job creation, increased local revenue, and lower energy costs. However, these benefits may only be distributed fairly with careful planning, potentially exacerbating existing social inequalities. For instance, job opportunities might primarily benefit those with specific technical skills, leaving out unskilled or

marginalized workers. Ensuring that training programs and employment opportunities are inclusive and accessible to all community members can help mitigate this risk. Additionally, policies should ensure that renewable energy's financial benefits, such as reduced energy bills, are equitably shared among all residents, including low-income households.

Renewable energy projects also have the potential to drive social change and foster sustainability at the community level. By promoting local ownership and control of energy resources, these projects can empower communities and enhance their resilience. For instance, community-owned solar or wind projects can provide a stable source of income that can be reinvested in local infrastructure, education, or health services. Moreover, the transition to renewable energy can inspire broader environmental awareness and stewardship, encouraging communities to adopt more sustainable practices in other areas of life.

### 2.3 Technical Challenge

Measuring the social impact of renewable energy projects presents a unique set of technical challenges that require careful consideration and innovative approaches. One primary challenge lies in the complexity and variability of social phenomena. Unlike physical parameters such as energy output or environmental emissions, social impacts are multifaceted and context-specific, making them difficult to quantify and compare across different projects and regions. Additionally, establishing causal relationships between renewable energy projects and social outcomes can be challenging due to confounding variables and indirect effects. For example, while a wind farm may create job opportunities in a local community, determining whether these jobs are directly attributable to the project or influenced by factors such as government policies or market conditions requires rigorous analysis.

Moreover, social impacts often manifest over long timeframes and may evolve unexpectedly, posing challenges for monitoring and evaluation. For instance, changes in community dynamics, cultural practices, or social cohesion may unfold gradually and require sustained engagement and data collection efforts to capture accurately.

Integrating social considerations into traditional engineering and economic models is a crucial step. Renewable energy projects are typically evaluated based on their technical feasibility, financial viability, and environmental impact, with social factors often treated as secondary considerations. However, to ensure a holistic approach, it is essential to incorporate social metrics into project appraisal frameworks. This requires the development of new methodologies and indicators that can capture the diverse range of social impacts and translate them into quantifiable terms.

Data availability and quality also pose significant challenges in measuring social impact. Compared to readily available data on energy production or environmental parameters, collecting robust social data requires investment in surveys, interviews, participatory methods, and collaboration with local communities and stakeholders to ensure data accuracy and relevance.

## 3. Identifying Aspects of Social Impact

### 3.1 Research Goal and Approach

Addressing the social impact of renewable generation is crucial for energy project planning due to its significant implications for local communities and stakeholders. Incorporating social considerations into renewable energy projects can help minimize resistance and conflict, enhance community acceptance, and foster long-term sustainability. By proactively engaging with local residents, indigenous groups, and other relevant stakeholders, energy project planners can better understand and address social concerns, ultimately leading to more successful and sustainable renewable energy initiatives. In

addition, considering the social impact can contribute to the overall positive image of the project and enhance its long-term viability.

This paper examines the different ways in which renewable energy generation affects society. Drawing on relevant literature, we identify four key aspects to emphasize the social benefits and understand their impact on energy projects. Our goal is to enhance the understanding of how to measure this impact and its significance in decision-making for renewable energy projects.

## **3.2 Proposed Aspects of Social Impact**

### **3.2.1 Overview**

The analysis of the social aspect is complex as it encompasses various broad concepts such as empowerment, acceptance, and inclusion and is closely interrelated and influenced by economic and environmental development [14], [15]. In the context of renewable energy, there is a crucial connection between energy services and human well-being, which requires the expression of the key social aspects of this relationship, such as the participation and acceptance of end-users and the promotion of equity in access to reliable and quality energy. These can boost economic development and improve people's living standards through the diversification of productive activities and the creation of local employment [16]. Evaluating social aspects is challenging due to the difficulty of obtaining operational data [17]. However, many authors highlight the level of social acceptability, the potential for job creation, the health impact, and the professional development to assess the social impact of implementing renewable energies.

Understanding the social impact of renewable energy generation is a complex task due to its multifaceted and context-dependent nature. The benefits and drawbacks of renewable energy projects can vary significantly across different communities and regions, influenced by local socioeconomic, cultural, and environmental conditions. As a result, no specific categories are defined to measure this impact. However, based on the literature, we propose four aspects to highlight the social benefits and encompass their impact on developing energy projects. While these aspects are not mutually exclusive and are related to economic and environmental factors, they could help in optimal planning and decision-making. A general overview of the four proposed aspects is shown in Table 1

### **3.2.2 Acceptance**

Despite renewable energies' numerous benefits, various challenges hinder their widespread acceptance. These challenges include technological limitations, regulatory barriers, vested interests in the fossil fuel industry, and public perception issues such as intermittency, visual impact, and land use. Addressing these challenges requires concerted efforts from policymakers, industry stakeholders, and civil society to promote education, awareness, and policy support for renewable energies.

Considering the perceived acceptability of renewable energies among the target community is important. This helps build an honest and trustworthy relationship with the community, preventing possible failure risks due to end-user dissatisfaction. Various factors, such as land requirements, visual intrusion, noise, and health and safety concerns, influence the community's perception of the project. These factors are closely associated with different generation technologies; hence, it is crucial to assess the social perception associated with each [18].

According to [19], social acceptance can be divided into socio-political, community, and market acceptance. These 3 areas are not standalone but interact between them and can even be opposite [20]. For example, high market acceptance can reduce community acceptance; this suggests that social acceptance is a complex and ever-changing concept that involves various dimensions [21], [22]. Therefore, to measure this acceptance, researchers have attempted combining methods and approaches that analyze behavior, partici-

pation, and commitment [23].

Surveys and questionnaires are commonly used to measure public opinion and attitudes towards renewable energy. These methods can help researchers understand the level of awareness people have about renewable energy technologies, their perceived benefits and drawbacks, their willingness to pay for renewable energy, and their support for renewable energy policies [24]–[27]. In addition to these methods, focus group discussions can provide qualitative insights into public perceptions and opinions regarding renewable energy. By convening small groups of diverse participants, researchers can explore attitudes, values, concerns, and underlying motivations in depth.

On the other hand, conducting interviews with various stakeholders, including community members, policymakers, industry representatives, and advocacy groups, provides a platform to gather diverse perspectives on renewable energy projects. Understanding their interests, concerns, and priorities is essential to assess social acceptance. In addition, involving the public in participatory processes such as town hall meetings, workshops, and public hearings provides an opportunity for direct interaction and dialogue between project developers and communities. These processes facilitate the exchange of information, build trust, and address concerns. [28], [29]

### **3.2.3 Employment**

Renewable energies, including solar, wind, hydroelectric, geothermal, and biomass, offer diverse energy sources for businesses. Entrepreneurs can invest in solar photovoltaic installations for commercial and residential properties, develop wind farms to harness the power of the wind or explore opportunities in bioenergy production from organic waste materials. The versatility of renewable energy technologies enables businesses to adapt to local conditions and market demands, fostering innovation and entrepreneurship.

As renewable energy sources such as solar and wind are inherently intermittent, integrating energy storage solutions is essential for grid stability and reliability. This presents a burgeoning market for businesses specializing in battery storage, pumped hydro storage, compressed air energy storage, and other innovative storage technologies. Moreover, companies that develop smart grid solutions and grid management software play a crucial role in optimizing the integration of renewable energies into existing energy infrastructure, unlocking new revenue streams and business opportunities.

The electrification of transportation represents another lucrative business opportunity for renewable energy stakeholders. Electric vehicles (EVs) are gaining popularity worldwide, driven by advancements in battery technology, government incentives, and growing consumer awareness of environmental issues. Businesses involved in EV manufacturing, charging infrastructure deployment, and renewable energy-powered transportation services stand to benefit from the transition towards sustainable mobility. Additionally, developing renewable energy-powered hydrogen fuel cells for transportation applications presents an exciting avenue for innovation and investment.

The growing demand for renewable energy projects has catalyzed the emergence of green finance and investment opportunities. Renewable energy developers require capital to finance project development, construction, and operation. As a result, financial institutions, venture capitalists, and impact investors are increasingly channeling funds into renewable energy projects, offering debt, equity, and other financial instruments tailored to the needs of clean energy entrepreneurs. Moreover, the rise of green bonds, renewable energy investment funds, and crowdfunding platforms democratizes access to capital and stimulates entrepreneurship in the renewable energy sector.

The expansion of renewable energy businesses contributes to job creation and economic development across diverse sectors of the

Table 1 Overview of proposed aspects

Aspect	Description	Benefit	Challenge
Acceptance	The target community's perceived acceptability of renewable energies. Factors such as land requirements, visual intrusion, noise, and safety concerns influence the community's perception of the project.	Build an honest and trustworthy relationship with the community, preventing possible failure risks due to end-user dissatisfaction.	Geographic, cultural, and economic factors make it difficult to generalize findings and apply them universally. Changes in demographics can affect previously obtained results and long-term studies.
Employment	Jobs generated due to research, planning, manufacture, installation, maintenance, economic activities and new opportunities created by the usage of renewable generation.	Boost economic development and improve people's living standards through the diversification of productive activities and the creation of local employment.	Calculating the indirect jobs and determining new job opportunities or economic activities derived solely from renewable generation are difficult to measure with certainty.
Health	Health benefits perceived from renewable energy development. Factors such as air and water contamination, food and water insecurity, displacement, and increased risks of infectious diseases affect community health outcomes.	Increase life expectancy, quality of life, and social development.	Renewable generation's impact on health requires long-term studies and empirical evidence. Current approaches to health benefits are based on environmental and political factors.
Education	The level of community involvement in understanding the effects of renewable generation. Increasing knowledge to innovate, implement sustainable technologies, and develop policies ensures the inclusion of individuals in renewable energy generation projects.	Promoting environmental awareness and sustainable development. Encourage responsible behavior and reduce pollution. Increase interest in the development and usage of renewable generation.	Measuring the level of involvement requires long-term studies and depends on cultural, economic, and political factors.

economy. From manufacturing and construction to research and development, renewable energy projects generate employment opportunities at every value chain stage. Local communities benefit from increased economic activity, tax revenue, and infrastructure investment associated with renewable energy development, fostering inclusive growth and prosperity.

With so many possibilities of impact on society, authors have divided employment into three categories [30]: direct jobs due to manufacture, installation, operation, and maintenance; indirect jobs due to supply chain, processing raw materials, marketing, and regulatory activities; and induced jobs due to economic activities and new opportunities created by the usage of renewable generation. The challenge lies in determining how to measure employment, given this categorization. Surveys are used by authors to estimate direct job effects, but they cannot calculate indirect employment impacts. However, it is necessary to consider both the direct and indirect effects to accurately evaluate the impact of a job [31]. Other methods, like top-down analysis [32], can estimate the impacts of renewable energy on the output and employment by sector, as it estimates both direct and indirect effects while considering interdependencies among sectors [33].

### 3.2.4 Health

Renewable energy sources have a significant advantage over non-renewable energy sources in greatly reducing air pollution. Burning fossil fuels releases harmful pollutants like sulfur dioxide, nitrogen oxides, particulate matter, and carbon monoxide. These pollutants contribute to respiratory diseases such as asthma, bronchitis, and lung cancer. On the other hand, energy sources like wind, solar, and hydroelectric power produce little to no air pollutants during operation. This leads to cleaner air and improved respiratory health [34]–[37].

Renewable energy sources also produce fewer greenhouse gas emissions compared to fossil fuels. Carbon dioxide, methane, and other greenhouse gases trap heat in the atmosphere, leading to global warming and climate change. By transitioning to renewables, we can mitigate the impacts of climate change, such as extreme weather

events. These events indirectly affect human health through food and water insecurity, displacement, and increased risks of infectious diseases. Fossil fuel extraction and combustion can result in water pollution due to oil spills, fracking chemicals, and thermal pollution from power plants. In contrast, renewable energy technologies such as solar and wind power use very little water, reducing the pressure on water resources and preserving water quality for drinking, agriculture, and ecosystem health.

The importance of energy in influencing health outcomes has been recognized, but most studies are qualitative and rely on evidence from specific cases. The literature indicates various connections between energy and health status, emphasizing the necessity for empirical analysis to establish the actual relationship, as there is currently no global evidence available. [36].

### 3.2.5 Education

The renewable energy sector has emerged as a substantial source of employment globally, offering various opportunities across various skill levels and professions [38]. Renewable energy projects create manufacturing, installation, maintenance, management, research, and development jobs. The growth of wind, solar, hydroelectric, geothermal, and biomass energy industries directly generates employment and stimulates ancillary sectors such as transportation, logistics, and finance [39]. Additionally, decentralized renewable energy systems promote local job creation and economic development. Small-scale solar installations, community wind farms, and bioenergy projects often prioritize hiring locally and procurement, contributing to regional prosperity and resilience.

Research and innovation play a critical role in driving advancements in renewable energy technologies and improving the quality of education [40]. Academic institutions, government agencies, and private enterprises invest in research initiatives to enhance renewable energy systems' efficiency, reliability, and affordability. Through interdisciplinary research collaborations, scholars and students contribute to cutting-edge discoveries and technological breakthroughs, shaping the future of sustainable energy production and utilization.

Education plays a crucial role in promoting environmental aware-

ness and sustainable development. By incorporating environmental education into curricula, individuals can better comprehend the impact of their actions on the planet, leading to more environmentally responsible behavior. This knowledge empowers people to make informed decisions that support conservation efforts and sustainable practices, contributing to the health of ecosystems and reducing pollution [40], [41]. Additionally, educational programs focusing on sustainability can equip future generations with the skills and knowledge to innovate and implement sustainable technologies and policies. Therefore, education is critical in driving the transition toward a more sustainable and environmentally conscious society.

To measure the impact of renewable energy initiatives on education development, it is necessary to identify relevant indicators that can capture the effects on students, educators, and educational institutions. Some indicators that can be used are integrating renewable energy topics into the curriculum across different subjects or grade levels and the level of student involvement and enthusiasm in renewable energy-related activities [40], [42]. It is also important to assess how much renewable energy education prepares students for employment opportunities in the renewable energy sector, including internships, apprenticeships, and job placements. Similar to social acceptance, educational development is measured by quantitative and qualitative methodologies such as surveys, interviews, focus groups, and comparative studies using education and training data [42].

## 4. Discussion

### 4.1 Advantages and limitations

Addressing renewable energy's social impact is necessary and a gateway to potential positive change in communities. Social impacts encompass various factors, including community acceptance, equitable access to benefits, and the potential for social change. Understanding and integrating these social dimensions ensures that renewable energy projects achieve technical and environmental goals and contribute positively to the communities in which they are situated.

One critical aspect of addressing social impacts is gaining community acceptance and support. Renewable energy projects can significantly alter the local landscape, economy, and daily life. For example, installing wind turbines or solar farms can affect land use, property values, and local aesthetics. Engaging with the community early in the planning process through consultations and participatory decision-making can help address concerns, dispel myths, and build trust. When communities feel heard and involved, they are more likely to support the project and participate actively in its development and maintenance, leading to smoother implementation and long-term success. This underscores the crucial role of stakeholders in the success of renewable energy projects.

One of the primary advantages of studying the societal impact of renewable energy is the potential to enhance community acceptance and support. Researchers can identify factors influencing public perception and acceptance by systematically analyzing how renewable energy projects affect local communities. This knowledge can inform strategies to effectively engage communities, address their concerns, and foster a sense of ownership and involvement. Improved community relations can lead to smoother project implementation, reduced opposition, and greater long-term sustainability of renewable energy initiatives. Another key advantage lies in promoting equitable development, a crucial factor in promoting social justice. Detailed impact assessments can reveal how the benefits of renewable energy projects, such as job creation, economic growth, and lower energy costs, are distributed among different social groups. This information is vital for designing policies and

interventions that ensure all community members, particularly those from disadvantaged backgrounds, share equitably in these benefits. By highlighting disparities and promoting inclusivity, impact studies contribute to social justice and help prevent the exacerbation of existing inequalities, making stakeholders feel included and valued.

Despite these advantages, studying the social impacts of renewable energy has significant limitations. One major challenge is the complexity and variability of social impacts, which can differ widely based on geographic, cultural, and economic contexts. This variability makes it difficult to generalize findings and apply them universally. Moreover, social impacts are often intertwined with other factors, such as economic policies and environmental conditions, complicating isolating the specific effects of renewable energy projects.

Another area for improvement is the methodological challenges associated with measuring social impacts. Quantitative metrics can capture certain aspects, such as job numbers or income levels, but may overlook qualitative dimensions like community cohesion, cultural shifts, or perceived quality of life. These qualitative aspects are often subjective and harder to quantify, requiring comprehensive and often resource-intensive methods such as interviews, focus groups, and long-term ethnographic studies. Finally, there is the issue of temporal dynamics. Social impacts can evolve, with some effects appearing only in the long term. Short-term studies may miss these delayed impacts, leading to incomplete or misleading conclusions. Longitudinal studies, while more informative, require sustained funding and commitment, which are only sometimes feasible.

### 4.2 Including Social Impact in Planning Energy Projects

Understanding the social impact is crucial for making informed decisions when developing energy projects. Energy projects can have far-reaching effects on communities and the environment, so it's essential to consider the social implications alongside the technical and economic aspects. By analyzing the potential impact on local residents decision-makers can ensure that the planning and development of energy projects aligns with the needs and values of the community. Taking a holistic approach to project development that incorporates social impact assessment can lead to more sustainable and socially responsible energy initiatives.

Planning in general terms is defined as a decision-making process aimed at achieving future objectives, taking into account both the present situation and the internal and external factors that may influence the success of a project. In any system or organization, the efficient utilization of resources, the reduction of uncertainty in processes, and the choice of suitable alternatives following a systematic approach to plan development and implementation are crucial aspects for the achievement of the established objectives [43]. This definition of planning can be applied to the development of the electricity system with the purpose of promoting renewable energy projects.

Power system planning has traditionally been approached as an investment decision, where the lowest financial cost is reasonably sought. This is usually contemplated in a financial analysis framework that includes a cost model summarizing the economic need of the system [44]. However, in a context of sustainable development and given the heterogeneous nature of renewable energy, a comprehensive planning must address various multidimensional aspects through a broad analysis that includes technical, economic, environmental and social aspects, as well as the participation of various stakeholders [43].

In the planning of any system, it is essential to achieve an optimal design in terms of selection, sizing and efficient operation of the components involved [45]. In the case of renewable energy, by adopting an optimization strategy, various scenarios can be explored

in order to identify the most suitable combinations and sizes of energy sources, in line with a set of relevant criteria according to the needs and preferences of the stakeholders [46]. This idea should link all the social criteria evaluated throughout the planning process. It is important to note that some of these criteria may conflict with each other, therefore, the optimization approach in planning should seek those alternatives that offer an appropriate balance or compromise between criteria [47]. It is essential to perform a comprehensive assessment to identify and select the alternative that best represents the social impact and the interests of the decision makers (Decision Makers, DM) [48].

Previous works have identified the problem of conflicting criteria, where there is the limitation that all of them are reached at the maximum at the same time [49]. Faced with this problem, Multi-Criteria Decision-Making (MCDM) methods emerged with the purpose of finding a balance between the conflicting interests of the parties involved in a structured way [50]. These methods, also known as Multiple-Criteria Decision Analysis (MCDA) methods, can be classified into three general categories [17]: value measurement methods, which assign numerical scores to alternatives to rank them in order of merit, such as MAVT (Multi-Attribute Value Theory) and AHP (Analytic Hierarchy Process); goal, aspirational, and reference level programming methods, which use mathematical algorithms to find the alternatives closest to achieving the predefined objectives for each criterion, such as TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution); and outranking methods, which compare alternatives against each other with respect to each attribute to determine the degree of dominance of one alternative over another, such as ELECTRE-III (Élimination Et Choix Traduisant la REalité).

### 4.3 Future Perspective and Conclusions

Renewable energy generation plays a crucial role in transitioning to a sustainable future. However, its societal impacts extend beyond environmental benefits, affecting community acceptance, employment, health, and education. A comprehensive framework for measuring these impacts is essential to ensure that renewable energy projects contribute positively to society and are effectively integrated into energy planning processes.

Community acceptance is a critical determinant of the success of renewable energy projects. Measuring this acceptance involves both qualitative and quantitative methods. Surveys and questionnaires can be used to gauge public attitudes toward renewable energy, focusing on metrics such as levels of support, perceived benefits, and specific concerns. These instruments can capture demographic variations in attitudes, revealing how different community segments perceive the project.

In addition to surveys, focus groups, and community meetings provide deeper insights into local opinions, allowing for a more nuanced understanding of community sentiment. These discussions help identify specific concerns and areas of resistance, which can be addressed proactively. Social media analysis is another useful tool, offering real-time public sentiment and engagement data. Incorporating these findings into renewable energy planning involves engaging with communities from the early stages of the project. Transparent communication about project goals, benefits, and potential impacts can build trust and foster a sense of ownership among community members. This proactive engagement helps to mitigate opposition and enhance overall project acceptance.

Comprehensive labor market analyses are essential to measuring these impacts. Surveys of employers and employees within the renewable energy sector can provide detailed data on job creation, including the types of jobs, required skills, and wages. Additionally, economic modeling can estimate the multiplier effects of renewable energy projects on local and regional economies. Integrating

employment impact data into renewable energy planning involves designing training and capacity-building programs to equip local workers with the necessary skills. Ensuring job opportunities are accessible to disadvantaged groups can promote inclusive economic growth. Policymakers can also use employment data to tailor incentives and support measures that maximize job creation and economic benefits.

Surveys of schools, teachers, and students can provide data on including renewable energy topics in educational programs. Participation rates and outcomes of community awareness programs can also be tracked. Additionally, partnerships with educational institutions to develop and evaluate renewable energy curricula can provide valuable insights. Including educational impacts in renewable energy planning involves developing community outreach and education programs that raise awareness about renewable energy and its benefits. These programs can foster a knowledgeable and supportive community more likely to embrace renewable energy initiatives.

A structured impact assessment framework should be established to incorporate these measurements effectively into renewable energy planning. This framework should integrate baseline data collection, continuous monitoring, and post-implementation evaluation. Engaging multidisciplinary teams, including sociologists, economists, public health experts, and educators, ensures a comprehensive approach to impact assessment. The findings from these assessments should inform decision-making processes, refine project designs, and develop targeted policies that maximize positive social impacts and mitigate any negative effects. Transparent reporting and regular stakeholder communication are essential to maintaining public trust and support. However, this measurement is complex due to their multidimensionality and coordinating such diverse methodologies is technically challenging.

Balancing quantitative and qualitative measures is another challenge. While quantitative data provide concrete metrics, they may need to capture affected communities' nuanced, subjective experiences fully. Qualitative data offer deeper insights but are harder to standardize and quantify, requiring robust methodologies to integrate both types effectively.

Temporal dynamics also play a crucial role, as social impacts often manifest over extended periods. Short-term studies may miss long-term effects, necessitating longitudinal studies that require sustained funding and methodological consistency. Additionally, geographic and cultural variability means that impacts can differ widely based on local contexts, complicating the development of standardized measurement tools.

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