Exploring the Nexus of Renewable Energy and Sustainability: A Literature Review

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Abstract. *Approaching sustainability and achieving its objectives are increasingly common organizational approaches. Renewable energy is a global concern and is addressed in most strategies. This paper offers an extensive literature review on the interrelation between green energy and sustainability. With increased worldwide awareness of the issue of climate change and a decline in the transition to renewable energy sources has become an essential component of sustainable development. The assessment addresses major notions, technological developments, environmental considerations, policies, and future directions of the green energy domain with the objective of creating a well-grounded picture of green energy as the instrument of sustainability. This literature review underscores the intricate relationship between renewable energy and sustainability, emphasizing the need for an integrated approach that considers environmental, social, and economic dimensions.*

Keywords: Green energy, sustainability, environmental dimension, economic dimension.

Introduction

In recent years, there has been a growing understanding that humanity confronts major sustainability issues and that a transition to a reliable and sustainable energy system is essential (Al-Shetwi, 2022). The main characteristic of the said transition is green energy, which represents a broad category of renewable sources, energy efficiency and sustainable measures around climate change mitigation, environment degradation and socio-economic development. The competitiveness of the environment is important in the dynamics of global approaches (Busu et al., 2021; Busu, 2019, 2021)

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The quest for green energy is deeply linked with the wider objective of sustainability, encompassing „the ability to fulfill the current needs without undermining the ability of future generations to meet their own needs" (Sarfraz, Ivascu, et al., 2022). By highlighting the connections between ecological wellbeing, social fairness, and economic progress, sustainability is referring to the environmental, social, and economic characteristics of these three pillars of public policy.

To reduce the environment's effects and carbon footprint, green energy generally refers to the use of renewable energy sources such as solar, wind, hydroelectric, geothermal, and biomass to generate electricity, heat, and fuel (Igliński, 2023). Unlike limited fossil fuel reserves, renewable energy sources are abundant, widespread, and inexhaustible thus providing a sustainable substitute to conventional sources of energy.

Transition to green energy offers enormous possibilities to solve several sustainability challenges concurrently (E. M., Curtis et al., 2024). Generating green energy decreases dependability on fossil fuels, which helps mitigate climate change by reducing carbon emissions and producing fresher water and air. In addition, renewable energy technologies support energy independence, ensure energy security, and enrich the economy, spurring inclusive and sustainable development.

Technological creativity does not exhaust itself and at obtaining sustainability more systematic transformations of energy policies, market mechanisms and societal lifestyles are required. Government, business, community, and individual stakeholders are all key participants in green energy agenda through policy support, investment in clean energy infrastructure, adoption of energy efficient practices and promotion of renewable energy understanding (Ivascu et al., 2019).

As stated in (Gunnarsdottir, 2021), the move to a sustainable energy future is by no means smooth sailing. Besides technical hurdles like high upfront costs, grid integration issues, regulatory barriers and socio-economic inequalities represent considerable obstacles to the widespread adoption of green energy technologies. Addressing the stated challenges necessitates coordinated efforts and creative solutions that are technology driven, policy focused, and community focused to give us a more robust and resilient energy system (Sarfraz, Ji, et al., 2022).

In the backdrop of the current critical crossroad that the world is at, holding significant challenges in the environmental and socio-economic fronts has never the need to adopt sustainable and green energy been so clear (Hariram, 2023). Through implementing sustainable practices and tapping into the revolutionary power of green energy, we move towards the golden age of clean, healthy, and socially just future.

The topic of this paper explores the complex relationship between sustainability and green energy, exploring the drivers, challenges, prospects, and effects of the switch to an energy system that is more environmentally friendly. We examine the economic, social, and environmental elements of green energy from an interdisciplinary standpoint. We also talk about how it promotes global development by helping to achieve sustainability goals.

Methodology

Bibliometric coupling is a method found in bibliometrics, the field that deals with the quantitative analysis of scientific literature. Bibliometric coupling is the relationship between two documents (scientific papers or articles typically) due to similarity in their citation patterns. This method examines the assumption that documents bearing the same references are also most probable to be relevant in content. To carry out the present research bibliometric analysis of key concepts and qualitative evaluation of the implications of renewable energy using reports and public data were used.

The bibliometric results are shown in Figure 1, where each circle is a sustainable subdomain.

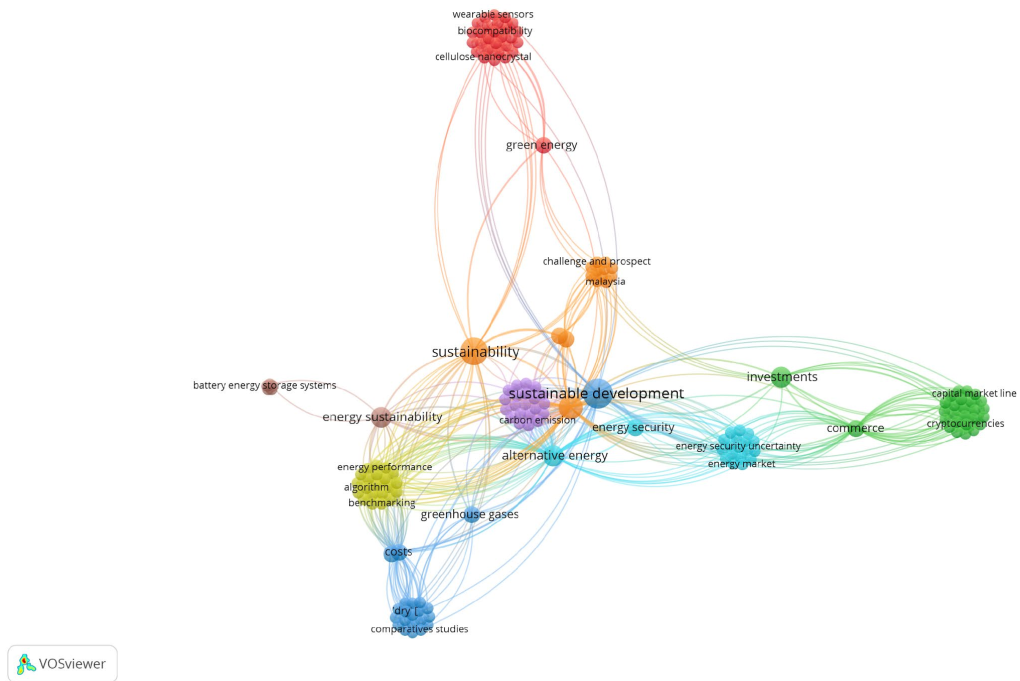

Figure 1. Bibliometric coupling of renewable energy in sustainability

Source: Authors' own research.

Renewable Energy as a Pillar of Sustainability

Carbon Mitigation

Renewable energy has a very central part to the tackling of the carbon emissions and the challenges the climate poses (Dhanda et al., 2022). A less polluting option to the usual fossil fuels, the renewable energy sources provide a much cleaner as well as also a more sustainable solution to the global increasing energy needs.

The main advantage of renewable energy is its ability to displace fossil fuels in electricity production, heat and transport thus resulting into dramatically decreased greenhouse gas emissions (Sarfraz, Hafeez, et al., 2022).

The sustainability and low carbon future are among the global endeavors which renewable energy significantly contributes to through fighting against climate change by offsetting carbon emission (Sovacool, 2022). Continued investments, technological innovations and supportive policies are key to achieve further impact of renewables on carbon reduction.

Comparative assessments of carbon footprints between renewable and conventional energy sources

Comparative considerations of carbon footprints of renewable and conventional energies are required for the comprehensive understanding of environmental impact of various energy alternatives. Carbon footprint is the total greenhouse gas emissions, quoted in CO_2 equivalent emissions, associated with a particular activity, product, or energy source.

Though most types of renewable energy have lower CO_2 emissions during their operational phase than conventional sources, lifecycle analyses are necessities to capture their environmental impact in full. A transformation to more sustainable energy systems, together with technological improvements and supportive policies is critical for realization of deep carbon reductions in the energy sector.

Impacts on global climate change and the potential for achieving sustainability goals.
There exist intricate connections between the implications of global warming and the potential for attaining sustainable objectives. There is a major risk to the climate, ecosystems, and human societies from warning, which is mostly brought about by human actions such the burning of fossil fuels and deforestation. Sustainability is about three aspects: social, economic, and environmental, and is important for the mechanism to respond to and mitigate the pressures of climate change.

Table 1. Impacts of climate change for achieving sustainability goals

Impacts of Global Climate Change	***Impact***
Temperature Rise	The global temperatures continue to get hotter causing more and intensive heat waves which contribute to an imbalance in ecosystems bringing negative effects in agriculture and human health
Sea Level Rise	Melt-off of glaciers and icecaps; together with the thermal expansion of seawater, causes sea-level rise which subsequently affects coastlines, biodiversity, and infrastructure
Extreme Weather Events	Extreme weather occurrence rate as well as its magnitude for example, cyclones, flooding, droughts, and fires intensification create an important level of damage, displacement, and economic loss
Biodiversity Loss	Predictable consequence of global warming is acute habitat loss which, besides being detrimental to ecosystems, includes the increase in species extinctions leading to the decrease in biological diversity
Ocean Acidification	Atmospheric CO_2 levels increase resulting in carbon dioxide absorption by oceans and they incur ocean acidification with adverse effects on the marine life, more particularly on coral reefs and catalysts of calcium carbonate
Changes in Precipitation Patterns	Unusual precipitation causes the change in weather and rainfall which further impact on the availability of water, agriculture, and ecosystems
Food and Water Insecurity	Trends in temperature and precipitation in addition to extreme weather events result to food and water scarcity which consequently pose a threat to global food security
Health Risks	With climate change, vector-borne diseases transmission is also increased, heat related illnesses occur and they are burdened with the existing health problems, for the most vulnerable parties

Source: Authors' own research.

Table 2. The potential for achieving sustainability goals

Potential for Achieving Sustainability Goals	*Goal*	*Potential*
Mitigation of Greenhouse Gas Emissions	Have a low carbon, net zero emission economy	Reducing climate change is aided by the use of renewable energy sources, increased energy efficiency, and sustainable land-use techniques
Renewable Energy Transition	Raise renewable energy's share in the global energy balance	Investment in and enlargement of renewable energy resources inclusive of solar, wind, and hydropower, substitutes fossil fuels and lessens the greenhouse gas emissions
Conservation and Sustainable Land Use	Protect and restore the ecosystems, sustainably develop agriculture and forestry	Sustaining forests, practicing sustainable agriculture measures as well as restoration of degraded lands provides both biodiversity conservation and carbon sequestration
Circular Economy and Waste Reduction	Change to a circular economy which reduces waste and maximizes the efficiency of resource use	Circular economy principles implementation leads to reduced resource usage, less waste produced and a more sustainable economic system
Adaptation and Resilience Building	Adapt to changing conditions and increase resilience to climate challenges	Climate proof infrastructure, building early warning systems and including climate into urban management increase resilience to climate change
Sustainable Transportation	Renewable and climate-neutral transport system	Development of public transport, electrification of vehicles and finance in sustainable mobility help to tackle emissions from the transportation sector
Global Collaboration and Policy Alignment	Promote international cooperation and have harmonized policies tackling the issue collectively	Global accords, for instance the Paris Agreement, provide a foundation for countries to collaborate, set emission reduction goals and share information and resources
Climate Finance and Investment	Mobilize financing for climate for sustainable endeavors and projects	The ability to adapt to climate change is increased by funding initiatives in the fields of renewable energy, environmentally friendly infrastructure, and climate resilience
Adequate and Inclusive Development	Make social equity and inclusivity the focus of sustainability initiatives	Implementing policies that focus on vulnerable communities, seek social justice and care for future generations enables sustainable development
Green Technologies and Innovation	Green technologies research, development, and demonstration should be encouraged	Technological improvements like carbon capture and storage, sustainable farming methods and innovations in renewable energy drive the fulfilment of sustainability targets

Source: Authors' own research.

Energy Security

By broadening the energy mix, preventing reliance on fossil fuels, and providing a more robust and sustainable energy infrastructure, renewable energy may improve energy security (Cergibozan, 2022).

Renewable energy both ensures energy security as well as deals with the economy, environment, and social problems. Ranging from postindustrial to developed countries, the application of renewable energy technologies is vital towards ensuring the stability of the global energy system that will be resilient.

Decentralized renewable energy systems are essential in promoting energy supply resilience since they offer a more spread, flexible, and sustainable manner of electricity generation.

The distributed renewable energy systems constitute an alternative to centralized energy production with higher resilience. The function of microgrids to mitigate liabilities of disruptions, increase the reliability of the grid as well as give local communities some sense of control over their energy supply therefore makes them an integral part of a system designed to achieve a more robust, sustainable, and secure energy infrastructure (Lv et al., 2022).

Sustainable Technologies and Innovations

Smart Grids and Energy Storage

In order to boost the energy efficiency of the power systems, the main approach is the integration of smart grid technology. Smart grids draw on advanced digital communication and control technologies to ensure balanced production, delivery, and consumption of electricity (Lamnatou et al., 2022).

Smart grid technologies integration provides a comprehensive solution for energy systems optimization, grid resilience enhancement and building of a more sustainable and efficient energy regime. The role of smart grids in overcoming the challenges of modernizing the electricity infrastructure and fulfilling the needs of an ever-changing energy system is realized by utilizing digital technologies and data-driven intelligence (Judge et al., 2022).

The effect of storage to improving the quantity of intermittent energy from sustainable sources

The significance of storing energy lies in allowing for a greater absorption of intermittent natural resources, such as wind and solar power, in the balance of energy sources. Intermittent renewables experience oscillations in the production which is because of varying weather conditions, so, the integration of them into the system is not so easy (Jordaan et al., 2022).

The addition of storage systems for energy is critical for achieving the full capacity of fluctuating renewable sources, ensuring a reliable and dependable energy supply, and pushing the transition of the energy system toward a cleaner, more sustainable future. With the advance of the various storage technologies their role to enable a greater share of intermittent renewables will become even more important (Ruhnau et al., 2022).

Green Building and Sustainable Infrastructure

The connection between renewable energy and green building techniques constitutes the core of Green Construction. This alliance aims at enhancing the overall energy efficiency, curb environmental pollution and promote sustainable practices in building construction. The most important key features of the synergy between renewable energy and green building practices are efficiency and conservation, built-in onsite renewables generate net zero positive buildings: storage has integration, carbon reduction etc. (Lombardía, 2023).

Green building refers to the idea that high performance from energy efficiency should be considered throughout all aspects of design and construction, including but not limited to areas such as insulation; energy-efficient windows/doors, HVAC systems etc. (Dadzie, 2022). Technologies for renewable energy, such as wind farms and photovoltaic panels, balance the need for electricity, reducing reliance on the main grid and increasing the use of green energy sources.

Incorporation of renewable energy systems with green buildings enables on-site generation of the necessary amount for consumption reducing dependence on nonrenewable sources. Solar photovoltaic (PV) panels, wind turbines and other on-site renewable technology reduce the building's energy consumption which brings about resilient decentralized power infrastructure.

Application of green building concepts together combined with renewable energy generation will result in net-zero energy buildings. The interconnections that remain can function as sources to absorb any surplus energy from on-site renewables energies and contribute towards positive net balance of the system making it smarter than before.

Energy storage solutions, particularly advanced battery technologies, are common in green building practices. Storage systems serve as a platform to facilitate optimal use of the generated energy from renewables, store extra produced during peak generation surplus times when it is higher than demand for later consumption when there are instances whereby demands on electricity exceed its production.

The combined implementation of green building practices and renewable energy solutions results in substantial carbon reductions associated with the consumption. Also, the use of low-carbon materials or carbon neutral really matches with goals for sustainability.

There are life cycle assessments, green building Practices and renewable energy projects performed to check their environmental footprint. It is ensured that there is a comprehensive approach to environmental sustainability in building development and the generation of wasteful energy by taking into account the entire process, through material extraction to end-of-life disposal.

The partnership between renewable energy and green building practices results in an integrative approach to sustainable development, fostering the implementation of energy efficiency measures as well as environmental responsibility while mitigating against climate change (Meena, 2022). This comprehensive approach is fundamental in the construction of buildings and communities that are environmentally sustainable as well as energy efficient.

Life cycle assessments of renewable energy infrastructure

One important technique for evaluating the environmental impact of renewable energy infrastructure is life cycle assessment, or LCA. A technology or system's life cycle is fully analyzed by life cycle assessments (LCAs), which begin with the extraction of raw materials and conclude with the disposal of the system at the end of its useful life. This includes production stages like transportation and manufacture as well as operational stages like upkeep and operation. Such a comprehensive approach allows for identifying environmental hotspots, evaluating resource use as well assisting decision makers in achieving the highest level of sustainability within renewable energy projects (da Silva Lima, 2021).

With a complete life cycle assessment, the stakeholders can make informed choices concerning the renewable energy infrastructure and identifying many improvement opportunities, and certification of the environmental sustainability. The incorporation of LCA results to the decision making ensures the progress of the integration of the renewable energy technologies pursuant to the broader sustainable goals.

Technological innovations for energy-efficient buildings and infrastructure

Technological changes are very core to the advancements of the energy efficiency in the buildings and infrastructure too. Current sustainability and environmental issues to our world have generated many smart, energy-efficient technology solutions (Shabalov, 2021).

The following represent a few significant technology advancements that support energy-efficient infrastructure and buildings: Building energy management systems, or BEMS, integrate lighting, security, HVAC (heating, ventilation, and air conditioning), and other building systems; energy-efficient lighting technologies, such as LEDs and smart lighting systems, offer more energy-efficient lighting options than traditional lighting. Daylight harvesting technologies help in adjusting the artificial lighting according to the availability of natural light, thus in the process reducing energy consumption; Building Information Modeling (BIM) – BIM technology helps in creating detailed digital models that replicate the energy performance of a building; blockchain technology for energy management: Peer-to-peer energy exchanges and reliable energy markets are made possible by accessible and safe energy transactions made possible by blockchain technology.

These technological advancements lead into the development of the energy efficient buildings and infrastructure, hence, enhancing sustainability, reducing carbon footprints, and promoting resilience to the emerging energy challenges. Further research and application of these technologies is very much needed to meet the challenging energy efficiency and environmental targets.

Circular Economy Approaches

Applying circular economy principles to the renewable energy sector

Alignment of renewable energy initiatives with SDGs of the United Nations is critical in bringing about global sustainable development. Renewable energy plays an important part in addressing the aspects of SDGs that cover environmental, social, and economic points. Initiatives pertaining to renewable energy are in line with the following SDGs: SDG 7: Affordable and Clean Energy: By expanding access to reasonably priced, dependable, and clean energy sources, renewable energy projects directly support SDG 7. SDG 13: Climate Action: One of the most crucial tactics in reducing the effects of climate change is the shift towards alternative sources of energy.

Innovation is encouraged and sustainable infrastructure is advanced through the development and application of renewable energy technologies; these initiatives also lower greenhouse gas emissions, which aids in the global effort to control global temperature rise and adapt to the effects of climate change; SDG 9: Infrastructure, Innovation, and Industry. Infrastructure investments for renewable energy stimulate economic expansion and job generation; Cities that include renewable energy into their planning are resilient and sustainable, as outlined in SDG 11 Sustainable Cities and Communities. Less emissions as an objective indicator will enhance the general state of the urban setting when renewable energy is used for development and transportation. eleven-sustainable towns and cities, with a portion of energy generated from renewable sources as a part of the duties of 12-Consumption and production that are accountable.

The measures for reducing the negative effects of energy production and use include the life cycle evaluations of renewable energy technology; SDG 1: No Poverty - By improving livelihoods and providing accessibility to electricity to the impoverished, a connection to clean, reliable electricity helps to reduce poverty. In order to combat poverty, renewable energy projects typically include social components like community development and employment creation; SDG 3: Good Health and Well-Being - Public health is enhanced by less air pollution resulting from the burning of fossil fuels. SDG 3: Good Health and Well-Being - Access to electricity in healthcare facilities enhances patient outcomes and lowers indoor air pollution. This is made possible by clean and sustainable energy; SDG 4 Quality Education – Energy projects provide access to electricity to schools for improved educational opportunities and resources. - Educational programs on renewable energy create consciousness and individual skill; SDG 5: Gender Equality - Through employment opportunities, increased opportunities for electricity, and improved living conditions, women can gain from renewable energy projects. Gender equality is promoted by participatory decision-making procedures in the energy from renewable sources sector; SDG 8: Decent Work and Economic Growth - By employing people, the renewable energy industry promotes economic growth. Contributions in green energy initiatives support the growth of a sustainable economy; SDG 15 Life on Land - Renewable energy projects help fight climate change and this contributes to the preservation of terrestrial ecosystems and biodiversity.

When renewable energy projects are positioned and planned properly, their impact on the environment and ecosystems is reduced. SDG 16: Peace, Justice, and Robust Institutions: By resolving energy-related problems, access to energy produced from renewable sources helps promote stability and peace. Strong institutions are promoted by inclusive governance in conjunction with open leadership within the renewable energy sector (Mutezo, 2021).

Recycling and sustainable disposal of renewable technology components

Achieving environmental sustainability in the renewable energy sector requires recycling and proper disposal of the components of renewable technologies. As renewable energy technologies proliferate, managing component end-of-life becomes increasingly important to minimizing environmental effect and promoting a circular economy (Efstratiadis, 2022).

Recycling and sustainable disposal techniques are very essential for achieving the complete environmental advantages of renewable energy technologies.

Case studies on minimizing environmental impact throughout the life cycle of renewable projects

The case studies concerning minimization of environmental impact throughout the life cycle of renewable energy projects show the successful strategies and practices implemented by various stakeholders. These cases illustrate a try to react to environmental problems from the beginning of a project to the decommissioning. A few of the cases in point are provided below:

Case Study: Offshore Wind Farm - Horns Rev 3 (Denmark):

Offshore wind power will undoubtedly contribute significantly to European wind energy output in the future given the available wind resources and the industry's expenditures and attempts to lower offshore wind power costs (Sørensen, 2021).

Located in the North Sea, Horns Rev 3 is about 25-40 kilometers from the west coast of Denmark. Horns Rev 3 is a Vattenfall owned and operated wind farm. The wind farm was built as a response to Denmark’s effort to enlarge renewable sources of energy and decrease carbon emissions. Offshore wind farm construction and operation facilities the local economy through job creation, technology development, and renewable energy sector investment attraction.

The objective of the Horns Rev 3 offshore wind farm was to generate clean energy with minimal environmental impact (Sørensen, 2021).

Case Study: Solar PV Recycling - First Solar (United States):
First Solar has employed a closed-loop recycling approach focused on the material reintegration into its manufacturing process, which eliminates the necessity for new raw materials and the generation of waste. The company has made investments in setting up recycling facilities to oversee end of life solar panels. The role of these facilities in the recovery of key materials and minimization of environmental impact is significant. Additionally, First Solar has partnered with industry associates, government, and institutions in developing recycling capabilities and more sustainable practices within the solar industry.

(Curtis et al., 2021) discovered no federal rules or regulations that particularly address recycling-based recovery of PV modules in the US, however, rules driven by the state and industry are starting to take shape in order to solve the end-of-life (EoL) solar energy module management issues. (Curtis et al., 2021) identified four states that may have an impact on domestic resource utilization and U.S. recycling because of their recent adoption of PV module recycling policies. This is a consequence of Washington's EPR regulations, which have an impact on solar module producers. Beginning on July 1, 2023, the law will compel manufacturers of PV modules to provide funding for the recycling, reuse, or takeback of any modules that have been shipped or imported into the territory following the start of 2017 at no additional expense to the final consumer. Additionally, California has passed laws for the treatment of end-of-life photovoltaic modules as regular waste, which will go into effect in January 2021. The universal waste rule in California forbids the use of heat, chemical treatment, and recycling processes, but permits the handling, transportation, and storage of modules meant for recycling under less restrictive guidelines. In order to strengthen future regulations, New Jersey and North Carolina both introduced laws in 2019 tasked with looking at optimal methods concerning EoL solar power system administration in their respective jurisdictions.

Case Study: Hydroelectric Project - Laúca Hydroelectric Plant (Angola):
The vital highland catchments of Angola, which serve as the "Water Towers" for central and southern Africa, play three significant national and international functions. At first, they provide Angola's human population with drinking water. Secondly, they provide Namibia and Angola with the potential energy needed for hydroelectric dam developments. Thirdly, they sustain the incredibly vast natural systems of the Okavango Delta in Botswana, the Bulozi Floodplain in Angola and Zambia, and the Cuvelai Basin in Angola and Namibia. Nonetheless, human activities threaten the stability of these roles (Huntley, 2023).

The project of Laúca was created to grow the capacity of Angola to generate its electricity and to improve its energy infrastructure. The construction of the Laúca Hydroelectric Plant was commenced in 2012 and was opened in 2017. The project was to construct a dam and power station.

The Laúca Hydroelectric Plant is a part of Angola's plans to generate more electricity while using fewer fossil resources. This assists the nation in meeting its goals for energy security and in meeting its needs for electricity to run its economic operations.

Case Study: Geothermal Power Plant - Hellisheiði (Iceland)
One of the primary justifications for geothermal energy's attention is its potential to play a significant part in the carbon reduction of the power generation industry and, subsequently, the transition to a low-carbon economy. This is known as the environmental sustainability perspective (Paulillo, 2021). More precisely, Iceland's geothermal industry is well established, with private enterprises setting the standard for exploration and development. Particularly, the Hellisheidi

Geothermal Power Plant, a CHP-type geothermal plant, has been the focus of numerous research intended to evaluate its numerous natural environmental burdens (Díaz-Ramírez, 2023).

Hellisheiði is geographically positioned in an area rich in geothermal resources. Volcanic activity in the area is a huge renewable energy resource (Cao et al., 2022).

Besides electricity production, the Hellisheiði plant is an important supplier of district heating to Reykjavik and surrounding towns. This district heating system utilizes hot water from the geothermal reservoir to warm the homes and commercial buildings in the region.

The location of Hellisheiði as a carbon collection and storage (CCS) operation is noteworthy. By sequestering greenhouse gas (CO2) emissions generated by geothermal steam, the plant stops the emissions from entering the atmosphere. The CO2 captured is then injected into underground geologic formations for storage.

Case Study: Biomass Power Plant - MGT Teesside (United Kingdom):

With its consumption of almost 14% of the world's oil and 8% of its gas, petrochemical production is the greatest industrial energy user in the world. In petrochemical production operations, slightly over half of these inputs are utilized as material feedstock, and the remaining portion is used as fuel (Geels, 2022). A few key compounds account for around 60% of the 1.5 gigatons of CO2 emissions produced by the chemical industry in 2017: methanol, ammonia, three volatile compounds (benzene, toluene, and xylene), three lubricants (ethylene, propylene, and butadiene), and ammonia. All of these primary chemicals, with the exception of ammonia, are produced by the petrochemical industry, which also directly contributes to global climate change by producing artificial fibers, synthetic rubber, and plastics, among other things (IEA, 2018).

The power plant is in Teesside, which is an industrial area in the northeast of England. The location is favorable for feeding into the grid and potential industrial heating.

The MGT Teesside biomass power plant is supposed to help the UK reach its renewable energy targets and lessen the usage of fossil fuels. Biomass power generation offers a reliable and manageable renewable energy source.

Policy and Regulatory Frameworks

Renewable Portfolio Standards (RPS) and Mandates

Challenges and successes in meeting renewable energy mandates

Meeting renewable energy mandates such as Renewable Portfolio Standards (RPS) (Feldman et al., 2023) or Renewable Energy Targets (RET) is not without challenges yet presents successes also. The guidelines aim to reduce greenhouse gas emissions, increase the share of renewable energy in the energy mix, and support sustainable development.

Table 3. Challenges in meeting renewable energy mandates

Challenges	***Challenge***	***Addressing***
Intermittency and Grid Integration	Several renewable sources including solar, and wind are unpredictable; they create problems of integration and frequency stability of the grid	The impact of intermittency can be lessened by integrating advanced grid technology with demand-side control and energy storage
Technological and Infrastructure Barriers	Several renewable technologies may encounter some hurdles like high capital costs, technological limits, or absence of critical infrastructure	Incentives, research and development investments and infrastructure development are some of the ways to tackle the barriers

Challenges	*Challenge*	*Addressing*
Policy Uncertainty and Changes	Frequent changes in renewable energy policies or lack of stable political support result in the unstable investment environment	Giving long-term policy stability, clear regulatory guidelines, bipartisan political support contribute to the enhancement of investor confidence
Land Use and Environmental Concerns	Renewable energy projects on a large scale will accept a lot of land possibly provoking ecological issues and disputes	Balancing of renewable energy development with environmental conservation, community engagement and sustainable land-use are paramount
Storage Technologies and Energy Transition	In order to solve the intermittent problem when switching to renewable energy, very effective energy storage technologies are needed	Ongoing research and development in energy storage technologies as well as their integration into the energy system
Financing and Investment Risks	The financial viability of renewable projects is threatened by investment risks, unpredictable income streams and lack of available financing	By implementing supportive financial mechanisms like feed-in tariffs, tax incentives and green finance options investment is attracted
Public Acceptance and NIMBYism	Local communities' opposition, often referred to as NIMBY (Not In My Backyard), can delay the development of renewable projects	Engaging communities early in planning, offering economic incentives and providing transparent information can increase public approval
Transmission and Infrastructure Bottlenecks	Lack of suitable transmission system hampers the incorporation of renewable energy resources, particularly in the more distant regions	Extending and improving transmission infrastructure to enhance the transmission of renewable energy to demand centers

Source: Authors' own research.

Table 4. Successes in meeting renewable energy mandates

Successes	*Success*	*Factors*
Cost Reduction and Competitiveness	The expense of renewable energy has significantly decreased as a result of technological innovation and economies of scale, making it comparable with traditional sources	Deployment, R&D and supportive policies lead to cost reductions
Capacity Additions and Market Growth	Many regions have seen considerable additions to renewable energy capacity, thus creating a more diverse energy mix	These are supportive policies, market incentives and higher public awareness which have accelerated the growth of the market
The Creation of Jobs and Their Economic Advantages	The renewable energy industry has increased employment and the economy	Investments in renewable projects, manufacturing and ongoing maintenance activities result in jobs creation and local economies stimulation
Global Investment and Technological Innovation	The increasing number of global investments in renewable energy projects as well as constant technological development show that the sector is doing well	The global success is enhanced by the growing public and private sector interests, the enabling policies as well as the advancement in technology
Grid Modernization and Smart Technologies	Developing smart grids in coordination with the smart technologies has effectively enhanced grid flexibility and reliability.	Integration of renewable energy is aided by advancements in demand response resources, grid management techniques, and storage technologies

Successes	*Success*	*Factors*
Reaching Renewable Energy Goals	Apex renewable energy performers in the country include several countries and regions	Articulated goals, proper implementation and continued efforts have been key in attaining and cutting above the set targets
Innovative Financing Models	The advent of innovative financing methods like public-private partnerships and green bonds helped in funding renewable endeavors	Diversifying funding sources and developing financial instruments consistent with the sustainable development goals facilitate achievement
Public Awareness and Support	Rise in public awareness and support of renewable energy promotes its success	The aspects like outreach programs, education campaigns and tangible benefits of renewable energy projects are concrete influences that strengthen public trust

Source: Authors' own research.

Considering the challenges, the accomplishments in meeting renewable energy targets highlight the steps taken in the direction of a more resilient and sustainable energy future. Constant practice in overcoming difficulties and utilizing beneficial methods will be key to the persistence of development in renewable energy adoption across the globe.

Social and Economic Dimensions

Community Engagement

Community involvement in renewable energy projects is crucial for several reasons, reflecting the importance of fostering local support and engagement (Goedkoop et al., 2022).

Communities are more likely to embrace and support renewable energy projects if they actively participate in the decision-making processes associated with these programs. Involving the community from the early planning stages helps address concerns, build trust, and reduce opposition, contributing to smoother project implementation.

Community engagement can lead to a better understanding of local needs, preferences, and concerns, allowing project developers to tailor renewable energy projects to fit the specific context. Aligning the project with community priorities increases its chances of long-term success and viability.

Involving the community is essential to the accomplishment of energy efficiency initiatives because it creates a sense of community support, allows projects to be customized to meet community requirements, and guarantees that the rewards of sustainable energy are distributed fairly, all of which contribute to a more inclusive and sustainable energy transition.

Job Creation and Economic Impact

Participation from the community in energy-saving projects can result in the creation of jobs and other economic opportunities in the area. Providing jobs and training to locals boosts the area's economy and promotes a sense of pride in one's town.

Revenue-sharing models or community benefit agreements can be established, ensuring that a portion of the profits generated by the renewable energy project is reinvested into the local community. Funds can be directed towards education, infrastructure, healthcare, or other community development initiatives.

Conclusion

This overview of the literature highlights the complex interrelationship between sustainability and renewable energy, highlighting the necessity of an integrated strategy that takes social, economic, and environmental factors into account. To fully achieve the promise of green power in creating a reliable and environmentally friendly future, as the world strives to shift in the direction of a more environmentally friendly energy paradigm, comprehensive strategies and continuous research are essential.

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