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ORIGINAL RESEARCH

Sustainable transition to renewable energy: An integrated MCDM-template analysis approach

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Abstract

This study examines and evaluates renewable energy (RE) supply chain sources to guide practitioners in selecting and investing in viable RE supply chains that drive the transition to RE, sustainability, and value creation for stakeholders. The relative influence of the various sustainability factors on key RE sources was empirically evaluated using multi-criteria decision-making analysis. Supplementary data were also analysed using the same techniques to assess the tacit factors affecting the transition to RE. Interviews with experts were evaluated using template analysis to explore latent factors further to support the transition to RE. The results revealed solar energy as the most economical, environmentally, and socially preferred cleaner energy with fewer barriers to overcome, followed by wind energy, Biomass, geothermal, and hydropower energy, respectively. The AHP and TOPSIS models provide novel rankings for RE sources to guide stakeholders. Energy supply chain participants may embrace the results to make strategic decisions. The study contributed to the literature by proposing original empirical models that facilitate understanding the viability of various RE supply chain sources and how the transition to RE will contribute positively to sustainability performance and assist supply chain practitioners in making strategic decisions.

Keywords Energy transition · Renewable energy · Sustainability · Energy supply chains · MCDM · Template analysis

1 Introduction

Renewable energy (RE) is derived from various clean and sustainable sources (Baloch et al., 2022). The transition to RE is essential in addressing the rapid growth of energy demand and environmental concerns associated with fossil fuels (Ang et al., 2022). The reliance on non-RE sources significantly releases harmful emissions, which is a global worry for energy security and economic growth (Olabi & Abdelkareem, 2022). The primary cause of climate change is the emission of greenhouse gases released by energy production and consumption (Uhunamure & Shale, 2021). The continuous increase in energy demand raises energy

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security concerns, necessitating energy supply diversification (Cergibozan, 2022). The sustainable transition to RE is necessary for economic growth, environmental sustainability, and social progress (Vidadili et al., 2017). The transition to RE is slow globally, and many countries are still in the early stages (Østergaard et al., 2020).

The transition to RE sources deserves more research, considering it could result in significant environmental, social, and financial benefits across the energy supply chain and society (Mondal & Khalil, 2012). The RE supply chain network consists of generating, transmitting, and distributing environmentally friendly energy (Zare et al., 2015). The interconnections in the RE supply chain further highlighted the implications of the viability of RE investments. Multi-criteria decision-making models for viable RE transition that drive sustainable performance will be vital for countries that placed the transition to RE into their developmental agenda, such as Oman, given the highly capital-intensive nature of RE projects (Ullah et al., 2021). Moreover, the outbreak of COVID-19 in 2020 has created significant investment uncertainties and other disruptions globally, which inhibit the transition to RE (Hosseini, 2020). Other studies have established that solutions to improve supply chain performance have embraced multi-criteria modelling techniques (Zubairu et al., 2021). Researchers and practitioners continually explore multi-criteria techniques to improve sustainability across various supply chain networks (Mohammed et al., 2019 and 2023). Indeed, RE networks should ultimately pursue modelling techniques to optimise sustainable transition to RE.

There is a growing urgency to fast-track the transition to RE for energy diversification and sustainability. Countries and corporations are embracing this obligation (Akrofi, 2021). However, the transition is slow generally (Østergaard et al., 2020). Oman aims for energy diversification by exploiting RE to support the country's energy supply and reduce dependence on natural gas (IRENA, 2014). Energy strategies to meet the growing demand, enhance competitiveness, and achieve sustainable advantages should incorporate strategies and decisions for the transition to RE. Strategy formulation embraces critical decision variables, but only a few studies have investigated the viable transition to RE incorporating environmental, social, and economic sustainability dimensions. Existing literature focuses on the physical and natural science features and performance of RE sources (Østergaard et al., 2020). A few studies focus on sustainability or implementation challenges, but not both. Despite the significant focus on the transition to RE, literature searches revealed no single research has proposed recent and updated decision-making models for the viable transition to RE to complement existing literature and support practitioners and policymakers. In addition, RE generation, transition and distribution networks involve several decisions concerning the complex management of activities, including human, material, facilities, and infrastructures (Pietrosemoli & Rodríguez-Monroy, 2019). In 2014, the International Renewable Energy Agency (IRENA) published Oman's RE readiness assessment to pinpoint the drivers and comparative advantages, enabling policies and technical measures to ensure the successful scale-up of RE sources. Although it gave many recommendations on policy and regulatory framework development, target and market implementation, institutional and legal framework, RE sources and research and development mapping, and capacity building development, the strategies for viable transition to RE remained unclear. Yet, no single study has focused on the viable transition to RE conducted in Oman to assist practitioners and policymakers in strategic decision-making, revealing major research gaps.

In this study, issues related to the viable transition to RE are explored and evaluated in the context of Oman RE supply chain as a case study to establish empirical models and promote discourse on the viable transition to RE to assist researchers, practitioners, and policymakers in the development and adoption of viable RE sources that drive sustainable performance. Oman is highly dependent on domestic subsidised oil and gas energy (Al-Sarihi & Mansouri, 2022). However, the country can develop into a leading supplier of RE energy due to its geographical location. Despite increasing efforts, RE constitutes just 1% of Oman's energy mix (Al-Sarihi & Bello, 2019). Given that previous studies have empirically established the sustainable benefits of the transition to RE, there is a potential for Oman to review, manage and fast-track RE transition to improve sustainable performance and competitiveness. Oman has the potential to become a leading player in the RE sector. However, a comprehensive assessment of various RE sources is key to achieving this goal.

Considering the research gaps highlighted above and the significance of the transition to RE for sustainability and value creation in Oman, this study puts forward the following research objectives:

OBJ 1. To evaluate the impacts of sustainability on the transition to RE.

OBJ 2. To access tacit factors affecting the sustainable transition to RE.

OBJ 3. To propose recommendations to support the sustainable transition to RE.

To address the first objective of this research, an analytical hierarchy process (AHP) and technique for order of preference by similarity to ideal solution (TOPSIS) were deployed to empirically evaluate the relative impacts of environmental, economic, and social sustainability factors on key RE sources (Saaty, 1980; Yoon & Hwang, 1995). Although prior studies have linked RE to sustainability from SCSs, different supply chains or networks may have different priorities for embracing the transition. A given sustainable factor may impact RE transition differently in a certain context and is relevant to its supply chains. Thus, the second objective sought to evaluate other tacit factors, such as policies and infrastructure, affecting the sustainable transition to RE. To achieve the last objective, interviews were organised with various RE supply chain specialists to explore and evaluate latent information influencing the transition to RE and suggest improvement recommendations.

The remainder of the paper is presented in the following structure: the literature review is introduced in Sect. 2, which consists of the RE supply chain, energy transition, linkages between RE sources and sustainability, factors affecting the energy transition, and a framework for a sustainable transition to RE. Section 2 ends by discussing research gaps and posing potential research and innovation highlights. Section 3 discusses methodologies deployed to facilitate rigorous examination of the research problem, including AHP, TOPSIS, and template analysis. Section 4 presents the analysis and results. In Sect. 5, we begin with a critical discussion of the findings related to the key connections between the RE transition and the three dimensions of sustainability in Sects. 5.1.1–5.1.5. Latent factors that influence the transition are discussed in Sect. 5.2 and recommendations are presented in Sect. 5.3. Section 6 presents the conclusions drawn from the results, their practical and theoretical implications, and suggested directions for future research.

2 Literature review

2.1 Renewable energy supply chain

The RE supply chain refers to the value chain networks responsible for producing, storing, distributing, and utilising RE resources through the integration of several processes in a sustainable manner (Hmouda et al., 2023; Ivanov, 2022; Zubairu et al., 2024). RE supply ensures the availability of energy resources to sustain energy demand, which is crucial in supporting the economic activities and livelihood of end-users, including, the public, corporations and households (Sarkar & Seo, 2021). The RE energy supply chain is focused on deploying end-to-end sustainable operation practices from source to final consumers (Biswal and Muduli, 2018). The RE supply chain can be divided into three value streams: upstream, midstream, and downstream (Sarkar & Seo, 2021). The upstream segment includes the resource acquisition and manufacturing of components required for RE generation through exploration, extraction and improvement of RE resources (Fontes & Freires, 2018). For instance, manufacturing solar panels, wind turbines, cultivating biomass sources, and batteries (Hmouda et al., 2023). The midstream phase consists of energy generation, storage, and distribution, where the actual production of RE is initiated through the use of renewable resources (Sarkar & Seo, 2021). The produced RE is later distributed via the power generation sites to end-users (Biswal and Muduli, 2018). The downstream value chain includes the distribution of RE for consumption by end-users (Lei et al., 2020). The downstream also involves providing consumption services, such as installation services for RE systems, energy management systems, and energy efficiency and effectiveness consulting (Sarkar & Seo, 2021). The front end of the RE supply chain mainly focuses on the production of RE, including sourcing raw materials, manufacturing necessary equipment, and generating RE (Fontes & Freires, 2018). The front end of the RE supply chain requires significant investments in research and development, facilities and associated infrastructure (Ivanov, 2022). In contrast, the back end of the RE supply chain focuses on the distribution and consumption of RE, as it involves the efficient transportation of generated energy to end users (Hmouda et al., 2023). However, both ends of the RE supply chain are interconnected and dependent on each other for the success of the overall RE network system. Thus, challenges and disruptions on one end can significantly affect the other, for instance, consumption patterns and technological advancements (Ivanov, 2022; Lei et al., 2020).

2.2 Renewable energy transition

As the global population continues to grow, so will the demand for cheap energy. However, reliance on fossil fuels is creating drastic negative changes to the climate, which is unsustainable. Transitioning to RE will improve energy productivity and accessibility, which are key to achieving "affordable and clean energy" (SDG 7) by 2030 (UNDP, 2022). Energy production, distribution, and usage that rely heavily on fossil fuels threaten energy security, damage the environment, and compromise social development hence jeopardising sustainable development strategies (Vidadili et al., 2017). Global concerns directly linked to climate change and human health are focused on reducing carbon emissions (Petinrin & Shaaban, 2015). Building RE supply chains that are economically viable, overcoming greenhouse emissions, and improving community well-being are key to sustainable development (Petinrin & Shaaban, 2015). Oman's energy production depends heavily on fossil fuels because of its oil and gas reserves, making electricity production available and affordable for producers and consumers (Amoatey et al., 2022). However, the ongoing depletion of these reserves, negative impact on the environment, continuous growth of domestic energy consumption, increase in fuel prices, and diminishing oil and gas export potential creates threats to the country's sustainable development (Al-Sarihi & Mansouri, 2022). The increase in natural gas prices from 2018 to 2022 caused electricity costs to increase by an average of 32% (Said et al., 2022). In the same period, electricity consumption increased by 7% (Electricity production, 2022), leading to an increase in CO_2 emissions by 7% yearly (Amoatey et al., 2022). Oman has the second-highest CO_2 emission rate in the Gulf region, therefore, transitioning to RE sources that safeguard energy security and reduce greenhouse gas emissions can contribute substantially to Oman's sustainable development (Amoatey et al., 2022). Investing in infrastructure and technologies to provide clean and more efficient energy will encourage growth in an environmentally friendly manner (UNDP, 2022).

2.3 Linkages between renewable energy sources and sustainability

Oman has shown great attention toward RE transition as it is endowed with various RE sources including solar, wind, geothermal, biomass, and hydropower energies (Amoatey et al., 2022; Kazem, 2011). First, due to the high sun intensity in the Gulf region, solar energy is considered a vital source of energy that can be harvested using different technological systems to support energy-consuming applications including water heating, heating of buildings, and distillation (Okedu et al., 2019). Second, Oman's prime location includes stretched coastlines with summer and winter monsoonal wind effects, which ensures the continuous availability of wind energy (Sultan et al., 2010). Third, although geothermal energy has limited potential in Oman because of the boreholes' temperatures, it has certain advantages over other RE sources such as the small size of its plant and the ability to sustain base load electricity (Umar, 2018). Fourth, biomass energy production is facing many challenges yet is favourable in multiple environmental measures related to waste management (Basha et al., 2021; Umar, 2017). Lastly, like geothermal and biomass energies, hydropower energy in Oman is limited due to its location in the desert region deprived of permanent water sources that can ultimately be used in the generation of hydropower energy (Okedu & Al Siyabi, 2021). Thus, there is a clear need to empirically assess these main RE sources with multiple economic, environmental, and social driving factors alongside threats facing RE transition.

For many years transition to RE was non-competitive with fossil fuel energy systems, however, with the progress in technology and the inflation in prices, RE systems are showing better economic, environmental, and social benefits (Mondal & Khalil, 2012). Much research focused on the economic factors of RE transition mainly on investment requirement, availability, reliability, cost of energy, feed-in tariff (FiT), and return on investment (ROI). With the reduction in RE technologies cost, Oman's energy sector is driven toward RE utilisation (Elia et al., 2021). The advancement in RE technologies reduced investment costs thus driving the transition towards RE systems (Evans et al., 2012). ROI is a key measure when evaluating the profitability of RE projects and an essential requirement for investment opportunities evaluation (Capellán-Pérez et al., 2019). Long-term power purchase agreements such as FiT must be established to promote investments (Albadi et al., 2009).

Also, Meeting the availability and reliability requirements is essential to avoid energy losses and poor investments in RE systems (Al-Badi et al., 2020).

Oman's 2040 vision stresses the use of RE for its environmental benefits such as reducing greenhouse gas emissions, toxic emissions, water pollution, soil erosion, and deflation of finite natural resources. Fossil fuel energy production directly affects climate change as it emits GHG mostly CO_2 which is responsible for half the global warming issue (Forghani et al., 2023; Pourali et al., 2023). However, it is argued that RE are not yet 100% clean energy as few solar energy systems use toxic substances that may potentially be released into the environment (Pourmoghadam & Kasaeian, 2023). Also, the loss of vegetation due to the use of land for RE facilities directly increases soil loss rates (Panagos et al., 2015). RE energy production will eventually resolve the deflation of finite natural resources (Twidell, 2021). The transition to RE has both positive and negative implications (Vezmar et al., 2014). The social benefits include job creation, business opportunities, energy supply security, and health and well-being. The associated negative effects include costs of endangering wildlife, loss of vegetation, noise pollution, bad odour, and visual intrusion (Sahoo & Sethi, 2021).

The transition to RE is linked with many positive benefits including job creation, business opportunities, energy supply security, and health and well-being. The development of RE systems creates high-value job opportunities that can tremendously assist the resolving the unemployment issue as well as creating business opportunities for investors (Cole & Banks, 2017). RE transition will facilitate long-term energy security (Mondal & Khalil, 2012). The reduction of toxic emissions released by fossil fuel energy systems not only delivers value to the climate and environment but enhances residents' living standards in health and wellbeing well-being (Kasem, 2019). However, it is established that RE production and distribution are also associated with social challenges, such as endangering wildlife and loss of vegetation. For example, wind turbines threaten many bird species in their breeding areas, and solar energy facilities, requiring the clearance of vegetation from the target sites (Charabi et al., 2022; Macknick et al., 2013). They also include the disturbance caused by RE facilities such as solar panels and wind turbines deployed close to residential areas. These facilities cause visual intrusion, bad odour is linked with biomass treatment, and wind turbines cause noise intrusions (Dai et al., 2015; Okudoh et al., 2014; Tsoutsos et al., 2005) (See Table 1).

2.4 Factors affecting the renewable energy transition

The increasing demand for RE transition to support energy security encouraged the investigation of potential tacit factors that may affect the transition progress (Al-Ajmi, 2014). Factors policies and regulations, advanced and cost-effective technologies, subsidy regimes, grid connectivity and capacity, storage capacity, and land availability affect the transition to RE. The assessment of the effect of these factors on the transition to RE is essential (Wee et al., 2012). Many studies argued that efficient policies and subsidy regimes are required to facilitate RE transition (Al Hatmi et al., 2014; Al-Ajmi, 2014; Al-Badi et al., 2009; Al-Sarihi & Bello, 2019; Charabi & Al-Badi, 2015; Mondal & Khalil, 2012). Other studies posited that there are increasing developments in RE technologies at relatively lower costs, which supports the transition (Al-Badi et al., 2009; Al-Sarihi & Bello, 2019; Azam et al., 2018; Charabi & Al-Badi, 2015; Mondal & Khalil, 2012; Umar & Wamuziri, 2016). Extant literature also highlights that the current grid connectivity and capacity restrict the smooth

Table 1 Sustainability factors driving the renewable energy transition

Sources	Sustainability factors		
	Environmental	Social	Economic
Amoatey et al. (2022); Pourali et al. (2023); Forghani et al. (2023)	Greenhouse gas emissions		
Pourmoghadam and Kasaeian (2023); Kasem (2019)	Toxic emissions		
Evans et al. (2012)			Investment requirement, Cost of Energy
Albadi et al. (2009)			Feed in tariff
Capellán-Pérez et al. (2019)			Return of investment
Panagos et al. (2015) Charabi et al., 2022; Macknick et al. (2013)		Vegetation, Wildlife, Noise pollution	
Twidell (2021)	Deflation of finite natural resources		
Cole and Banks (2017)		Job creation	
Mondal and Khalil (2012)		Energy supply security	Availability, Reliability
Tsoutsos et al. (2005); Dai et al. (2015); Okudoh et al. (2014); Sahoo and Sethi (2021)		Visual intrusion, Bad odour	

transition to RE (Keck et al., 2022). Similarly, RE power output requires a certain storage and grid capacity depending on the type of RE source to meet demands (Cárdenas et al., 2021). It is also established that land availability may limit the transition to RE as it competes with the need to preserve natural ecosystems as well as human needs (Capellán-Pérez et al., 2017). In addition to sustainability concerns, these literature findings suggest policies and regulations, advanced and cost-effective technologies, subsidy regimes, grid connectivity and capacity, storage capacity, and land availability as the tacit factors that influence the transition to RE (see Table 2).

2.5 A framework for a sustainable transition to renewable energy

RE is the most sustainable way of meeting the global energy demand (Kumar et al., 2023). RE supply chains allow energy to be environmentally, socially, and economically generated, transmitted, distributed, and consumed (Zare et al., 2015). The growing attention on RE supply networks reflects the increasing demand for RE as an energy source (Fontes & Freires, 2018). The viability of RE supply chains is driven by desires to minimise environmental problems, maximise social benefits, minimise costs, and maximise revenues (Winkler, 2005). However, the availability of RE sources does not guarantee the viability of RE investments because many factors, including policies, technology, infrastructure, and local capacities, need to be addressed (Rövekamp et al., 2021). Energy policies are established to assist the transition to RE and perform an important role towards sustainable development (Sharvini et al., 2018). However, the dearth of RE policies in Oman makes it challenging to develop sustainable long-term RE systems. For RE supply chain participants to realise the benefits of the transition, a range of favourable subsidy regimes must be established, includ-

Table 2 Tacit factors driving the renewable energy transition

Sources	Tacit Factors					
	Policies and regulations	Advanced and cost-effective technologies	Subsidy regimes	Grid connectivity and capacity	Storage capacity	Land availability
Mondal and Khalil (2012)	✓	✓	✓			
Al-Ajmi (2014)	✓		✓			
Al-Badi et al. (2009)	✓	✓	✓			
Al-Sarihi and Bello (2019)	✓	✓	✓			
Charabi and Al-Badi (2015)	✓	✓	✓			
Umar and Wamuziri (2016)	✓	✓	✓			
Al Hatmi et al. (2014)	✓		✓			
Azam et al. (2018)		✓				
Keck et al. (2022)				✓		
Cárdenas et al. (2021)				✓	✓	
Capellán-Pérez et al. (2017)						✓

ing tax holidays, carbon credits, emission trading, and FiT, amongst others, to encourage adoption and returns for investors (Shum, 2017). RE production technologies are essential to realising the economic benefits of the transition, and their continuous improvement is vital towards achieving cost-effective implementation (Amoatey et al., 2022). The need for improved energy storage capacity is increasing as they are required in all value chain networks from generation to consumption (Kebede et al., 2022). Most RE harvesting stations require huge land availability that can only be found in remote areas, which affects grid connectivity and capacity because having a facility away from the existing grid will incur higher costs and energy losses (Al-Sarihi & Mansouri, 2022). This study investigates the viability of RE transition, including the drivers and challenges facing the transition to guide supply chain practitioners to optimise sustainable performance.

2.6 Gaps in renewable energy transition-related research

RE supply chain networks facilitate sustainable energy production and consumption, thereby integrating all value chain participants to optimise environmental effects, social benefits, and financial performance (Wee et al., 2012). This research is a case study of Oman, which aims to increase its RE production from 1 to 30% by 2030, primarily targeting its vast solar resources (Amoatey et al., 2022; Charabi & Gastli, 2011). However, most studies focused on exploring various RE sources, and a few papers investigated the economic, environmental, and social benefits of RE energy sources, solutions to RE challenges, or individual assessments of different RE sources (Al-Yahyai et al., 2012; Charabi Gastli, 2011). Similarly, Malik et al. (2015) assessed solar and wind energy using diverse criteria including economic, technical, environmental, planning, policies, and regulations. Azam et al. (2018) ranked available RE sources in Oman but focused on limited drivers and neglected the adoption barriers. Limited attention is given to the strategic planning toward the sustainable transition to RE. Only one paper investigated viable RE sources and barriers to technology adoption (Al-Sarihi & Mansouri, 2022). No single research has proposed updated and holistic models to facilitate the viable transition to RE in Oman, indicating a major research gap in the literature. The most efficient way to energise the world sustainably is by RE (Owusu & Asumadu-Sarkodie, 2016; Binh et al., 2023). However, there has been no prior study that evaluates RE sources against sustainability dimensions and analyses the factors that have implications for viable transition to RE sources to assist policymakers and practitioners in strategic decision-making, indicating another research gap. This created a need for a holistic analysis of the factors that influence the RE transition to prioritise the RE sources in Oman, to assist in the selection of viable RE sources and to ease and fast-track the transition to RE.

2.7 Research and innovation highlights

In light of the research gaps established, and the importance of transition to RE for energy security and sustainable development, the following are the key research and innovation highlights from this study:

- A novel framework is proposed for assessing the factors influencing the sustainable transition to RE, including variables published in extant RE studies and tacit issues synonymous with RE supply chains (Fig. 1).
- New and updated MCDM models are produced, which empirically measure and prioritise the factors influencing the transition to RE, to guide practitioners and policymakers in strategic decision-making (Sect. 4.1).
- The study divulges methodological rigour. It is the first research to combine template analysis, AHP, and TOPSIS techniques to support RE transition in Oman. Combining these established approaches minimises the limitations of each method (Sects. 3.1; 3.2).
- The theoretical/scientific and managerial/practical implications of the study are provided to support practitioners, policy and researchers to address the identified factors and fast-track RE transition (Sect. 6.1).

3 Methodology

The study adopted the case study approach to investigate the subject (Yin, 2017). A case study approach is chosen for its perspicuity and subjectivity to establish a clear guide for practitioners in selecting and investing in viable RE supply chains (Pu & Lam, 2023). A case study provides in-depth data collection from various information sources including reports, observations, questionnaires, and interviews (Creswell & Poth, 2016). Data collection is planned to determine multiple RE sources' adaptability based on sustainability dimensions. To achieve the research objectives, this study deploys multiple methods of data gathering and evaluation to fully apprehend practitioners' insights relevant to sustainable transition to RE within the Oman RE supply chain network as the case study. Both quantitative and

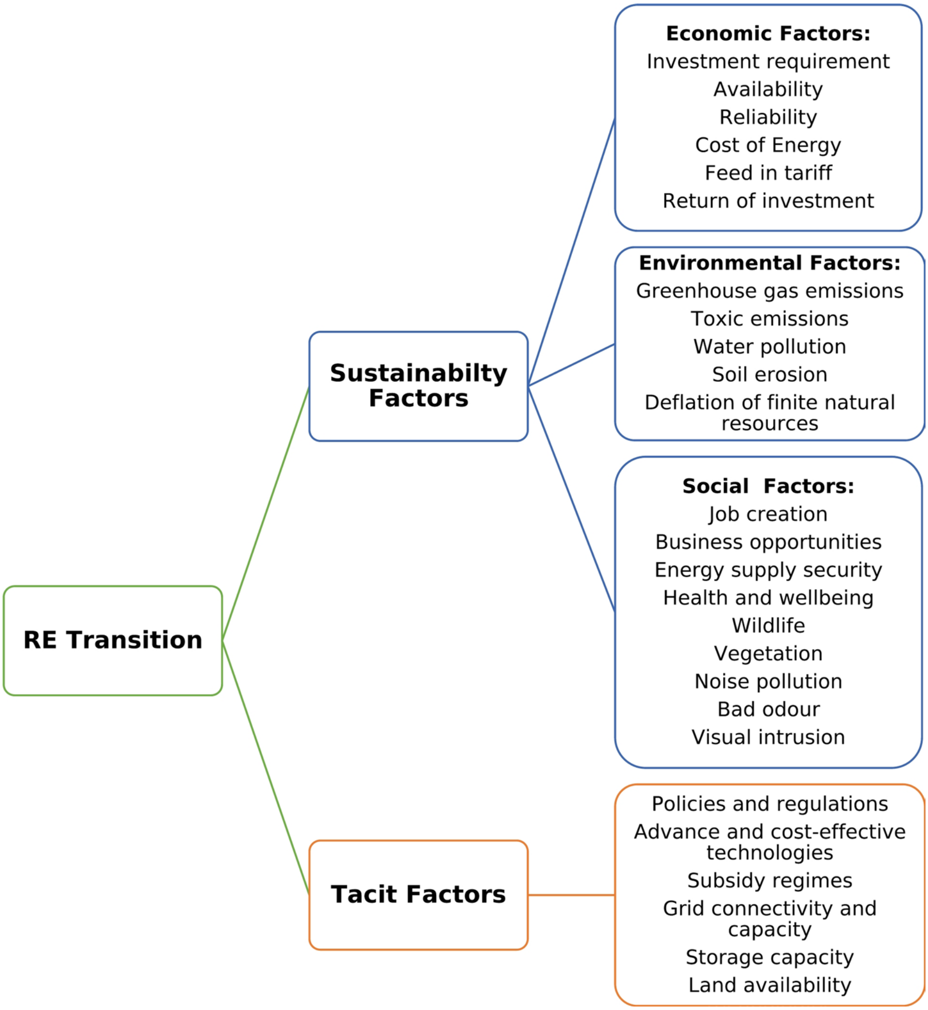


Fig. 1 Framework for a sustainable transition to renewable energy

qualitative approaches are utilised to capture experts' opinions concerning the influence of sustainability dimensions and other factors on RE transition. RE sources, sustainability dimensions, and related variables are selected through a literature review, which was further validated by experts (Zubairu et al., 2021). The quantitative survey data was analysed using AHP and TOPSIS as a hybrid multi-criteria decision-making (MCDM) method (Choudhary & Shankar, 2012; Mohammed et al., 2021). For the qualitative part of this study, interviews were conducted with RE experts which were analysed using template analysis (Brooks et al., 2015). Synthesising qualitative and quantitative approaches supports credibility and validity and assists in minimising bias and risk in research (Creswell & Poth, 2018). Combining AHP and TOPSIS as MCDM methods with template analysis enhances the nobility of this study as the first that synthesised these three methods to study the transition to RE.

3.1 Multi-criteria decision-making techniques: AHP and TOPSIS

The prioritisation of RE sources for the sustainable transition to RE is a decision-making problem. In this study, MCDM methods are utilised in the quantitative part, because of their suitability to use multiple preferences to resolve different conflicting criteria using mathematical equations, resulting in specific criteria preferences (Sindhu et al., 2017). Different MCDM methods, including ELECTRE, AHP, TOPSIS, Rough sets theory, and ANP were analysed in comparison to each other, and the analysis revealed the superiority of combining AHP and TOPSIS methods in evaluating and ranking related alternatives (Choudhary & Shankar, 2012). Hence, hybrid MCDM techniques consisting of AHP and TOPSIS are adopted to aid in the prioritisation of the various RE sources based on their implications on sustainability and other tacit variables.

AHP is an MCDM method that performs pairwise comparisons of selected variables using experts' perspectives as decision support systems (Listyaningsih and Utami, 2018). This approach uses decision-makers judgment based on their knowledge and experience to assess the alternatives (Joshi et al., 2020). AHP allows the evaluation of multiple factors and achieves weights of each factor resulting in the prioritisation of each of the economic, environmental, and social sustainability factors along with other variables affecting the RE transition. Four sequential steps are carried out to use AHP analysis (Wu et al., 2021):

First, multiple pairwise comparisons of various sustainability factors were carried out based on a standardised comparison scale of nine levels to determine the relative importance of each factor against other factors, from one being equally important to nine as absolutely more important (Saaty, 1980). Second, geometric mean is used to group participants' opinions to synthesise the individual experts' preferences and establish a single matrix comparing different RE sustainability factors. The advantage of the geometric mean over the average mean is the consideration of the compound occurring between decision-makers (Saaty, 1989). Third, the normalised matrix of AHP pairwise comparison is reached by dividing each column entry with the total column entries summation and taking the average of each raw. Normalised weights of RE sustainability factors support the identification of the importance of each factor in the sustainable transition to RE. Fourth, consistency is established to prove the fairness of experts' perspectives in allocating the importance of RE sustainability factors. A consistency ratio (CR) of 0.1 or less is acceptable and indicates acceptable results. CR is calculated by dividing the consistency index (CI) by the random index (RI). The consistency index is calculated $CI=(\lambda max–N)/(N-1)$ where λmax is the average of weighted sum values divided by criteria weight and the random index (RI) for the seven-criteria matrix according to Saaty (2008) developed table is 1.32.

TOPSIS is a prioritisation method that ranks alternatives according to their geometric distance from the positive-ideal and negative-ideal solutions. It aggregates experts' opinions and selects the highest-performing alternative that is the closest to the ideal solution and farthest from the negative ideal solution (Joshi et al., 2020). In this study, RE sources were ranked according to their economic, environmental, and social considerations, as well as other factors such as Policies and regulations, subsidy regimes, and land availability that affect the transition to RE using the TOPSIS method. TOPSIS requires the use of weighted criteria that, in this study, are established from the AHP analysis.

First, creating a comparison matrix illustrates the effectiveness of economic, social, environmental, and restricting factors on the adaption of various RE sources to accelerate the transition to RE in Oman. TOPSIS method uses a 9-point rating scale similar to t AHP to rank RE sources based on sustainability factors. Second, similar to AHP analysis, geometric mean is used to cumulate interviewees' results into an individual representative matrix making it easier to analyse in upcoming steps. Third, to achieve a normalised comparison matrix, each column value is divided by the square root of column entries' square summation. Fourth, AHP analysis results in distinct sustainability factors weights utilised in TOPSIS analysis. The weighted normalised decision matrix is accomplished by multiplying column values with weights resulting from AHP analysis. Fifth, this study aims to evaluate the impacts of sustainability on various RE sources to support the transition to RE including factors such as ROI and investment requirements. The best ideal solution is to have the highest ROI and lowest investment requirement. Hence ROI's largest value illustrates the positive ideal solution while the investment requirement's largest value presents the negative ideal solution. Sixth, different RE sources' distances from the ideal best solution are computed by summing entries subtracted from the ideal best solution than the square root of the value. Similarly, the distance from the ideal worst solution is calculated with the same formula. The last step gives the preference of RE sources in transitioning to RE. The performance score is found by dividing the ideal best distance by the summation of both the ideal best and ideal worst distances found in the previous step. The highest rank is given to the RE source with the highest performance score.

Considering the MCDM analyses, AHP and TOPSIS, were conducted based on the factors derived from reviews of prior literature (see Fig. 1). To avoid bias and improve the validity of findings, interviews were conducted and analysed using template analysis to explore tacit variables and expert opinions to gain a better understanding of key factors relevant to improving sustainable transition to RE, which is discussed in Sect. 3.2. Deploying this hybrid of multi-mixed methods approach consisting of surveys and interviews, which are analysed using AHP, TOPSIS and template analysis, enhances the study's contextual relevance and minimises subjectivity in research findings. The latent factors influencing the transition to RE are established by analysing stakeholders' insights to enrich the analytical framework and offer a comprehensive understanding (Zubairu et al., 2021).

3.2 Template analysis of interviews

Template analysis is a qualitative approach used to complete the deficiencies in quantitative approaches (Brooks & King, 2014). Template Analysis is a component of thematic analysis that uses a structured process to analyse data using hierarchical coding (Brooks et al., 2015). Template analysis was chosen as it provides a strong and systematic process yet offers flexibility to data analysis (Brooks & King, 2012). It is particularly advantageous for studies aiming to analyse text materials focusing on discovering themes and prioritising similarities without offering any pre-estimated fixed sequence of coding classes (Anderson-Ingstrup & Ridder, 2020). Relatively, it enables the researcher to establish theme order depending on data richness (Waring & Wainwright, 2008). It captures major themes in the primary analysis and further identifies additional sub-themes with analysis progression (Johnson, 2019). Interview questions are designed to augment AHP and TOPSIS results. Data collected from experts' interviews were analysed using template analysis to access latent information, gain a better understanding, and improve the objectivity and validity of the results. Findings from template analysis enable this paper to suggest recommendations to support the sustainable transition to RE. Template analysis in this study is carried out through the following steps (Brooks et al., 2015).

First, familiarisation in this study has been done by first scanning data collected, followed by the selection of five participants as a subset for initial analysis. Second, five interview transcripts are randomly selected and coded, highlighting items in the text relevant to addressing the questions to develop a priori themes. Third, after analysing selected data in hand, grouping is used to establish the links between major themes and related narrow themes creating hierarchical relationships. Fourth, the initial template is now created using clustered themes from the interview data. Fifth, an analysis of the remaining interview data is carried out to update themes established previously, by adding new themes or restructuring existing themes' orders. Last, with the evaluation of all data, the final template is established with higher, second, and third-order themes to achieve study objectives.

3.3 Sample of respondent

A quantitative survey and qualitative interview questionnaires provide a unique entry to experts' understanding and opinions (Shen et al., 2017). To achieve study objectives, structured interviews with experts are required. The study used a purposive sampling approach to select the RE experts. Purposive sampling is the recruitment of specific participants possessing the necessary experience and knowledge (Campbell et al., 2020). RE field in Oman is in its initial development stages providing limited evidence on RE systems sustainability (Amoatey et al., 2022). Therefore, expert sampling is the best method to choose as part of purposive sampling (Etikan et al., 2016). Purposive expert sampling is employed to select RE experts with the essential knowledge needed to investigate the study objective. RE experts with diverse experience and qualifications working in both local and international organisations, as well as public and private sectors are selected for this study. For data collection, 18 professionals who are involved in the RE decision-making from different RE value chains in Oman participated in the interviews and 20 completed the AHP and TOPSIS surveys. All responses were analysed to derive useful and valid findings.

3.4 Research rigour

Energy specialists with extensive experience are recruited for this study (Zubairu et al., 2021). The RE experts are recruited from nine different energy corporations and work across diverse supply chain networks having both similarities and differences in terms of experiences regarding the sustainable transition to RE. This assisted in generating rich insights that are all-encompassing to improve the validity of findings and minimise bias (Yamini & Gajanand, 2022; Clottey and Benton Jr, 2020). In addition, multiple-mixed methods, including AHP, TOPSIS, and template analysis approaches, are deployed in this work to benefit from the three techniques' analytical and empirical strengths. This assists in addressing potential methodological shortcomings (Olsen, 2022).

To minimise ambiguity, the specialists who participated in the MCDM surveys and interviews were given definitions of key terms, instructions, and demonstrations on completing the MCDM questionnaire (Flynn et al., 2018). Research validity and applicability are paramount for the grant that funded this work, which requires the research team to present the practical and policy implications of the study. Consequently, two researchers with extensive expertise met in person to discuss key research findings. The reliability of the research elements was ensured by producing and continuously updating the project database to record all documents, notes, and meeting details while maintaining strict confidentiality (Alsmadi et al., 2023).

4 Analysis and results

4.1 Analysis of the impact of sustainability on renewable energy transition

To validate and substantiate whether the sustainability variables identified from existing literature influence the RE transition, prior literature was conducted with RE supply chain specialists in Oman. The exercise confirms the literature results that solar (A1), wind (A2), biomass (A3), geothermal (A4), and hydropower (A5) are the key sustainable RE energy sources in Oman. The study also corroborates that all three sustainability dimensions, environmental, economic, and social, are considered in RE decision-making. The study further confirms that the economic considerations include investment requirement (F1), availability (F2), reliability (F3), cost of energy (F4), FiT (F5), and ROI (F6). Greenhouse gas emissions (E1), toxic emissions (E2), water pollution (E3), soil erosion (E4), and deflation of finite natural resources (E5) are the environmental factors influencing the transition to RE sources. Social factors include job creation (S1), business opportunities (S2), energy supply security (S3), health and wellbeing (S4), Wildlife (S5), vegetation (S6), noise pollution (S7), bad odour (S8), and visual intrusion (S9). These factors are analysed empirically using AHP and TOPSIS to determine the relative impacts on the RE transition (Objective 1).

Assessment of sustainability factors makes it possible to evaluate the different RE sources' potential in Oman. AHP is a flexible and comprehensive decision-making process that helps in prioritising multiple alternatives and making an optimal decision. The process consists of a hierarchy structure that starts from the objective, followed by an assessment of set criteria, and is finalised with RE alternatives comparison (Malik et al., 2015). It is used to assess RE economic, environmental, and social considerations by using RE expert judgments. Geometric mean later combines the pairwise comparison as it is an easy extension in fuzzy sets and guarantees a unique solution (Yu et al., 2022).

4.1.1 Evaluation of the impacts of economic criteria on the renewable energy transition

Economic criteria were rated by experts from 1–9, with 9 showing extreme importance, and the geometric mean of each criterion was calculated. The weights and ranks of each economic criterion are developed (see Table 3 & Appendix 1-A). AHP findings revealed that ROI is the most important factor to consider when economically assessing RE sources. Cost of energy and FiT scored second and third most important respectively. System availability scored the lowest importance (see Table 3 & Appendix 1-A). TOPSIS analysis of paired comparison of RE sources concerning economic factors revealed solar energy is the most economical RE alternative investors and energy stakeholders should seek to harvest. Biomass energy is found to be the third best alternative after wind energy. Hydropower energy

Table 3 Impacts of economic criteria on the renewable energy transition

Order of preference for economic factors			The relative influence of economic factors on key RE sources		
Factors	Weight	Priority	RE sources	Score	Rank
F1	0.111	4th	**A1**	0.876	1st
F2	0.069	6th	**A2**	0.732	2nd
F3	0.108	5th	**A3**	0.286	3rd
F4	0.229	2nd	**A4**	0.099	5th
F5	0.160	3rd	**A5**	0.217	4th
F6	0.322	1st			

Table 4 Impacts of environmental criteria on the RE transition

Order of preference for environmental factors			The relative influence of environmental factors on key RE sources		
Factors	Weight	Priority	RE sources	Score	Rank
E1	0.185	3rd	**A1**	0.742	1st
E2	0.194	2nd	**A2**	0.711	2nd
E3	0.310	1st	**A3**	0.294	5th
E4	0.140	5th	**A4**	0.354	4th
E5	0.172	4th	**A5**	0.392	3rd

was shown to be better economically than geothermal which scored lowest (see Table 3 & Appendix 1-B).

4.1.2 Evaluation of the impacts of environmental criteria on the renewable energy transition

The group pairwise comparison matrix of each environmental criterion against the other is performed, and their relative weights are established. Water pollution is found to have extreme importance, followed by toxic and greenhouse gas emissions, while deflation of finite natural resources and soil erosion scored the lowest (see Table 4 & Appendix 2-A). Expectedly, solar energy was found to be the best RE alternative in terms of environmental performance. Wind energy remained second while the third best alternative is hydropower energy. geothermal energy environmental evaluation showed it is in fourth place with biomass scoring lowest (see Table 4 & Appendix 2-B).

4.1.3 Evaluation of the impacts of social criteria on the RE transition

Nine social considerations influencing RE transition are established. Health and well-being, energy supply security and job creation score the top three most important criteria respectively, followed by business opportunities, vegetation, and wildlife preservation. Noise pollution, bad odour, and visual intrusion showed the least importance (see Table 5 & Appendix 3-A). Social evaluation of RE alternatives revealed solar as the most socially preferred with wind being the second-best alternative. Hydropower energy scored third followed by biomass energy. Geothermal energy is socially lowest preferred (see Table 5 & Appendix 3-B).

Table 5 impacts of social criteria on the renewable energy transition

Order of preference for social factors			The relative influence of social factors on key RE sources		
Factors	Weight	Priority	RE sources	Score	Rank
S1	0.148	3rd	**A1**	0.865	1st
S2	0.102	4th	**A2**	0.591	2nd
S3	0.191	2nd	**A3**	0.262	4th
S4	0.221	1st	**A4**	0.254	5th
S5	0.074	6th	**A5**	0.393	3rd
S6	0.101	5th			
S7	0.062	7th			
S8	0.054	8th			
S9	0.048	9th			

Table 6 Impact of factors affecting the transition to sustainable renewable energy

Order of preference for factors			The relative influence of factors on key RE sources		
Factors	Weight	Priority	RE sources	Score	Rank
C1	0.227	1st	**A1**	0.868	1st
C2	0.159	4th	**A2**	0.680	2nd
C3	0.194	2nd	**A3**	0.223	3rd
C4	0.175	3rd	**A4**	0.117	5th
C5	0.109	6th	**A5**	0.176	4th
C6	0.136	5th			

4.2 Assessment of tacit factors affecting the transition to sustainable renewable energy

The literature review revealed that policies and regulations (C1), advanced and cost-effective technologies (C2), subsidy regimes (C3), grid connectivity and capacity (C4), storage capacity (C5), and land availability (C6) as are the key factors affecting the transition to RE, which are later confirmed by experts' opinions during the interviews. To achieve objective two of this study, an AHP group pairwise comparison matrix of different factors that affect the RE transition is developed showing their relative weights (see Table 6 & Appendix 4-A). Findings concluded policies and regulations are the most important factors to consider in facilitating the transition to RE. Subsidy regimes and grid connectivity and capacity scored second and third, respectively, while storage capacity scored the lowest importance. TOPSIS results of paired comparison of the impacts of these latent factors on the key RE sources revealed that more priority should be given to solar and wind energies, due to their high ranks as first and second, respectively. Biomass energy is found to be the third best alternative followed by hydropower energy. Geothermal energy is the least favourite due to the availability of several restrictions (see Table 6 & Appendix 4-B).

4.3 Template analysis for the sustainable transition to renewable energy

To address the third objective of this research, interviews were conducted individually with 18 RE supply chain specialists and decision-makers to explore and evaluate latent information that influences the transition to RE and to suggest recommendations for improvement.

The interviews were analysed using template analysis validated some earlier findings and identified other latent factors specific to the transition to RE in Oman.

4.3.1 Initial template development

As directed by Brooks et al. (2015), five experts' responses were analysed to obtain the initial template. Initial template themes selected highlight RE sources and sustainability factors recognised from the literature review. Initial higher-order themes involve solar energy, wind energy, financial sustainability and considerations, environmental awareness and considerations, policies and regulations, transition to RE benefits, and recommendations. Each theme included a few second-order themes that are highly linked to literature yet require more development and analysis to realise alignment with study factors further used in AHP and TOPSIS analysis (Brooks & King, 2014).

4.3.2 Final template and results

Advance analysis of the additional experts' interviews is conducted to develop the final template and compare it to the initial template as advised by King et al. (2018). The final template is redefined and simplified into 4 categories: RE sources, sustainability factors, RE transition drawbacks, and recommendations almost similar to the initial template. The high-order theme includes solar energy, wind energy, and other sources as RE sources. These themes validate literature findings of the various sources of RE as well as TOPSIS analysis revealing the preferred adoptability of solar and wind energies. Sustainability factors' high-order theme involves financial, environmental, and social considerations confirming literature findings further used in AHP and TOPSIS analysis. Financial sustainability considerations include ROI, investment cost, and energy cost criteria realised from the literature. Similarly, environmental awareness and consideration include all criteria analysed in this study: air, water and soil pollution, as well as deflation of finite natural resources. Although second-order themes related to social consideration were limited to energy supply security, job creation, and business opportunities, these factors are found to be top-ranked in AHP analysis. RE transition drawbacks included all factors found in the literature review except for land availability which was briefly mentioned in one interview as difficulty in choosing a suitable location.

5 Discussion

5.1 Renewable energy as a catalyst for sustainability

The transition to RE is associated with economic, environmental, and social dimensions of sustainability. Template analysis of experts' interviews confirmed the importance of these three sustainability pillars in transitioning to RE.

5.1.1 Economic considerations

Economic consideration is established as a higher-order theme in template analysis, which conforms with the literature findings that revealed that economic factors as key drivers for

RE investments (Kilinc-Ata & Dolmatov, 2023; Martínez et al., 2023). AHP analysis identified ROI and energy cost as having the highest in RE financing. This is further validated by template analysis that placed both ROI and energy cost as second-order themes. It is argued that fossil fuels will be greatly replaced by RE due to long-term cost benefits and ROI (Li, 2023; Capellán-Pérez et al., 2019). FiT is established as the third most important economic factor from AHP analysis and is confirmed by the template analysis as participants discussed the lack of government regulations supporting investing in RE projects. Unclear policies are bottlenecks for RE investments (Albadi et al., 2009). Investment requirements are found to be the fourth most important economic factor. One respondent lamented the high initial cost required to establish RE projects, the dearth of infrastructure, and the lack of governmental support. RE systems availability and reliability are prioritised as the least important economic factors in the qualitative analysis. Template analysis further confirmed these results showing availability and reliability as a secondary theme.

5.1.2 Environmental considerations

Results from template analysis revealed environmental considerations as a higher-order theme. A respondent confirmed that the environmental factors are major considerations toward RE transition while another added it is a moderate factor only. “The environmental consequences of non-RE sources are obvious and widespread. Recent tragic floods and famines in certain areas are simply a warning of what is to come” in justification of the importance of environmental factors in RE transition. Low-carbon supply chains are required to reduce greenhouse gases which were identified as an environmental factor in the literature (Hren et al., 2023). It was expected for GHG emissions reduction to be the most important environmental concern toward RE transition due to the enormous number of studies considering RE systems as a critical element of a low GHG energy economy (Forghani et al., 2023; Mukhtarov et al., 2023; Pourali et al., 2023). However, GHG was found as the third most important environmental factor in AHP analysis. The most and second important environmental factors in the study were found to be water pollution and toxic emissions which are third-order themes in template analysis results. Majeed and Luni's (2019) study revealed the negative effect of renewable energy on the environment due to the inefficient use of water causing underground water pollution. The deflation of finite resources has been identified as an environmental factor in prior studies (Twidell, 2021). However, AHP analysis ranked it low, and interview results also confirmed this position revealing limited interest in resource depletion. This is surprising as many studies demand the need to transition to RE to overcome the challenge of finite resources depletion.

5.1.3 Social considerations

The literature review identifies social measures as an important sustainability pillar to consider when transitioning to RE, and this is echoed by the results of the template analysis. Health and well-being are found to be the most important social criteria. The environment has a strong impact on health and well-being. Energy supply security is found to be the second most important social factor driving the transition to RE. Template analysis further supports this finding as this energy supply security is a third-order theme. Similarly, numerous studies have posited that energy supply is a key driver toward RE transition (Amoatey et al., 2022; Cergibozan, 2022; Olabi & Abdelkareem, 2022; Vidadili et al., 2017). The third most important factor found in AHP analysis is job creation, and interview analysis confirmed this by ranking it as a second-order theme. It is argued that RE systems require higher manpower and hence create more jobs than fossil fuel operations (Bulavskaya and Reynès, 2018). AHP analysis ranked business opportunity as the fourth most important social factor. Similarly, the template analysis established this factor as a third-order theme. Most of the interview respondents argued that RE transition drives business opportunities. The business opportunities created by the RE transition include research, local manufacturing, and logistics (Maradin et al., 2017). Noise pollution, bad odour, and visual intrusion showed the least importance in the AHP-TOPSIS analysis. These findings are validated by template analysis due to the non-existing of these factors in the high-order themes.

5.2 Factors affecting the viable transition to renewable energy

The analysis concluded that policies and regulations are the most important barriers to overcoming when transitioning to RE. When the respondents were asked to identify RE transition drawbacks, their responses were focused on policies and regulations, technological advancement, subsidy regimes, grid connectivity, and complex RE plants. Template analysis further identified a lack of legal framework, cross-border carbon policy regionally, and tax incentives as the main policy barriers. Subsidy regimes and grid connectivity scored second and third on their influence on sustainable transition to RE. Template analysis confirmed these superior effects, ranking both second-order themes. Effective policies and regulations, along with subsidy regimes, facilitate investments toward RE transition (Al Hatmi et al., 2014; Al-Ajmi, 2014; Al-Badi et al., 2009; Al-Sarihi & Bello, 2019; Charabi & Al-Badi, 2015; Lu et al., 2020; Mondal & Khalil, 2012). It is argued that there should be potent policies in place to promote RE transition (Siram et al., 2022). Storage capacity and land availability scored the lowest importance in the AHP analysis. Similarly, it was not a major theme under template analysis. A study also argues storage systems have been developed in recent years to increase efficiency (Abdalla et al., 2021). Results suggest that RE plants should be considered due to their complex design, installation, and maintenance.

5.3 Recommendations

The analysis of expert opinions suggests that policies and regulations, subsidy regimes, training, awareness, and research need to be strengthened. This study proposed that policymakers should review and revise RE policies and regulations to establish a support system for investors to attract investments into the RE sector. The policies suggested by RE experts are related to wheeling as compensation for excess energy, incentives to attract foreign investment, national frameworks for foreign direct investment, incentivising the acquisition of RE, carbon credits, and tax exemption. Subsidy regimes are key to the RE transition. Thus, government and other relevant stakeholders should consider providing the required support to make RE competitive against conventional fossil energy. The support could be grants, low-cost financing for investors, and higher subsidies for low-income households, among other initiatives. It is also established that the lack of trained and licensed employees is slowing down the transition to RE, which can be addressed through structured training and licensing programs. It is also important to increase people's awareness about different

RE systems and the associated advantages of RE utilisation. More support should be given to RE sources and supply chain-related research to facilitate more findings, insights and recommendations to support practitioners and policymakers in making informed strategic decisions and to fast-track the transition to RE.

6 Conclusion

Oman aims for energy diversification by exploiting RE to support the country's energy supply and reduce dependence on natural gas. Energy strategies to meet the growing demand, enhance competitiveness, and achieve sustainable advantages should incorporate strategies and decisions for the transition to RE. This study has investigated the sustainable transition to RE incorporating environmental, social, and economic sustainability dimensions along with drivers and challenges for the transition. AHP was used to determine the relative influence of sustainability factors and other tacit variables influencing the sustainable transition to RE. Similarly, RE sources were evaluated using TOPSIS to evaluate the impacts of sustainability dimensions on key RE sources. ROI and cost of energy are the most important economic criteria to consider when analysing RE sources. Likewise, water pollution, toxic emissions, and greenhouse gas emissions are the most important criteria to consider when evaluating the environmental impact of RE. Health and well-being, energy supply security, and job creation are the most important social factors to focus on when analysing the social implications of RE sources. The analysis also concluded it is policies and regulations, subsidy regimes, and grid connectivity and capacity affect the sustainable transition to RE. It is concluded that solar and wind energies represent the best RE sources to utilise and harvest in Oman. Finally, recommendations for policymakers and investors were proposed for the sustainable transition to RE.

6.1 Study implications

6.1.1 Managerial/practical implications

The study develops decision-making tools and promotes discourse on the sustainable transition to RE in the transition to RE sources to drive sustainable performance. The paper suggested that more emphasis and support investment and incentives should be given to solar and wind energies. Solar and wind energies have the potential to support Oman's energy vision of growing RE to 40% of its energy mix by 2040. It is recommended that solar energy should be prioritised ahead of other RE sources to increase RE in Oman's energy mix due to its economic, environmental, and social advantages over the rest of RE sources. Quantitative AHP modelling suggests solar energy has the highest potential as it has more developed policies and regulations, more advances and cost-effective technologies, and higher storage capacity and the lowest challenges to overcome, such as land availability, as it can be installed in various places such as house roofs.

In this study, factors related to the sustainable transition to RE are explored and evaluated in the context of the Oman RE supply chain as a case study. The high impact of solar and wind energies in energy diversification and RE transition may be specific to Oman given its geographical location and socio-political factors. Yet the results of this research might be expanded to present Gulf countries due to their geographical and socio-political similarity (Basha et al., 2021; Praveen et al., 2020). The execution of the study proposition provides the best economic, environmental, and social RE transition options.

6.1.2 Theoretical/scientific implications

This research contributes to RE supply chain literature by incorporating sustainability dimensions in RE transition. This paper develops a framework for sustainability dimensions including economic, environmental, and social factors affecting RE sources selection for sustainable RE transition. Quantitative and qualitative approaches, including AHP, TOPSIS, and template analysis, were applied to this study methodology. AHP as an MCDM method was confirmed in this study to be appropriate in evaluating the relative importance of economic, environmental, and social factors toward RE transition. AHP ranks these sustainability factors independently to further be used in ranking different RE sources. This work illustrates TOPSIS's suitability as an MCDM technique in prioritising various RE sources according to their sustainability performance. TOPSIS deploys AHP results in ranking RE sources depending on economic, environmental, and social criteria independently. In this study template, an analysis of experts' interviews captures latent information and obtains a better understanding. Template analysis information is compared to Literature, AHP, and TOPSIS analysis confirming their conclusions and enhancing the validity of results. It also provides managerial recommendations and implications for practitioners' decision-making. The incorporation of AHP, TOPSIS, and template analysis enhances the original of this research.

6.2 Future research directions

This research is centred on the assessment of viable RE sources of sustainability leading toward RE transition. The study review and analysis are focused on Oman RE transition adoption, which creates a limitation when applying study results to different geographical locations and socio-political factors. Hence, future work is required to use the methodology developed in this research for case studies with different geographical locations, socio-political factors, and economies.

The quantitative and qualitative methods used in this study include limitations; hence, different methods of compilation should be considered. AHP analysis limitation is that answer intuitiveness depends on the size of the matrix (Hartwich, 1999). In this study, four multi-dimensional matrices are designed, which is considered extremely lengthy and time-consuming; thus, experts tend to lose interest at a certain time. For future work, fewer data collection methods, such as the Best–Worst Method (BWM), could be adopted to ensure a focus on more accurate results.

Study framework construction highly depends on literature; hence, RE sources and sustainability factors that are not studied in previous literature are not included. For future research, it might be required to add new sustainability factors in the RE transition field including factors recommended by experts in this study. Additionally, it will be interesting for future studies to deploy machine learning techniques such as decision trees, random forests, and support vector machines to identify factors for RE transition objectively, and to build updated frameworks and typologies. Similarly, machine learning can be integrated with AHP and TOPSIS models to select variables for MCDM analysis strategically. This will enable predictive modelling and forecasting of future trends to proactively offer valuable insights into the future trends of RE transition.

Appendix 1:

Part A: See Table 7.

Part B: See Table 8.

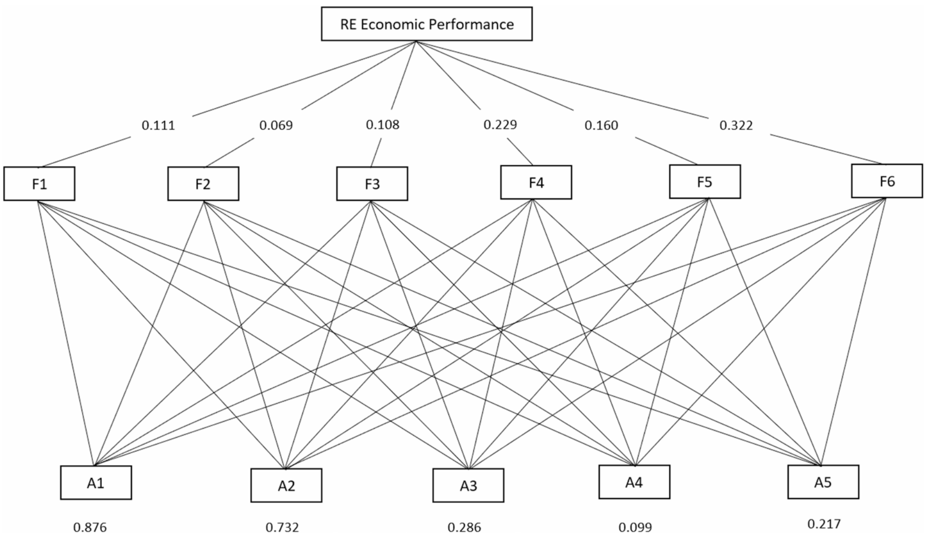
Part C:

Table 7 Order of preference for economic factors affecting the transition to renewable energy

Criteria	F1	F2	F3	F4	F5	F6	Weight	Priority
F1	0.10	0.14	0.11	0.14	0.08	0.09	0.111	4th
F2	0.05	0.07	0.08	0.07	0.08	0.06	0.069	6th
F3	0.10	0.10	0.11	0.09	0.09	0.15	0.108	5th
F4	0.17	0.22	0.27	0.23	0.28	0.21	0.229	2nd
F5	0.19	0.13	0.19	0.13	0.16	0.17	0.160	3rd
F6	0.38	0.34	0.24	0.35	0.30	0.32	0.322	1st

Table 8 Relative influence of various economic factors on key renewable energy sources

Criteria	F1	F2	F3	F4	F5	F6	Score	Rank
A1	4.91	5.09	6.16	5.25	5.16	6.94	0.876	1st
A2	6.57	5.73	5.23	5.91	5.30	7.17	0.732	2nd
A3	5.71	4.10	5.09	4.97	3.94	4.82	0.286	3rd
A4	6.54	4.14	4.56	6.16	3.79	5.01	0.099	5th
A5	7.23	4.25	5.31	5.73	4.39	5.14	0.217	4th



Appendix 2:

Part A: See Table 9.

Part B: See Table 10.

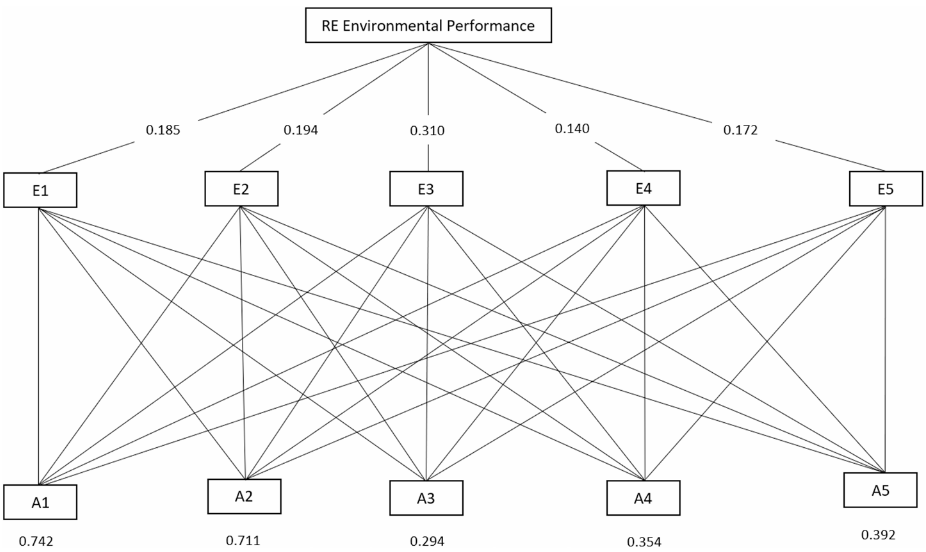
Part C:

Table 9 Order of preference for environmental factors affecting the transition to renewable energy

Criteria	E1	E2	E3	E4	E5	Weight	Priority
E1	0.19	0.20	0.21	0.13	0.20	0.185	3rd
E2	0.18	0.19	0.19	0.22	0.19	0.194	2nd
E3	0.28	0.32	0.31	0.34	0.30	0.310	1st
E4	0.19	0.12	0.12	0.13	0.13	0.140	5th
E5	0.16	0.18	0.18	0.17	0.17	0.172	4th

Table 10 Relative influence of various environmental factors on key renewable energy sources

Criteria	E1	E2	E3	E4	E5	Score	Rank
A1	2.83	2.56	2.00	2.21	2.63	0.742	1st
A2	2.62	2.70	2.06	2.01	2.87	0.711	2nd
A3	4.51	5.38	4.12	3.77	2.71	0.294	5th
A4	3.79	4.02	3.62	3.81	3.21	0.354	4th
A5	2.84	2.84	4.00	2.98	3.37	0.392	3rd



Appendix 3:

Part A: See Table 11.

Part B: See Table 12.

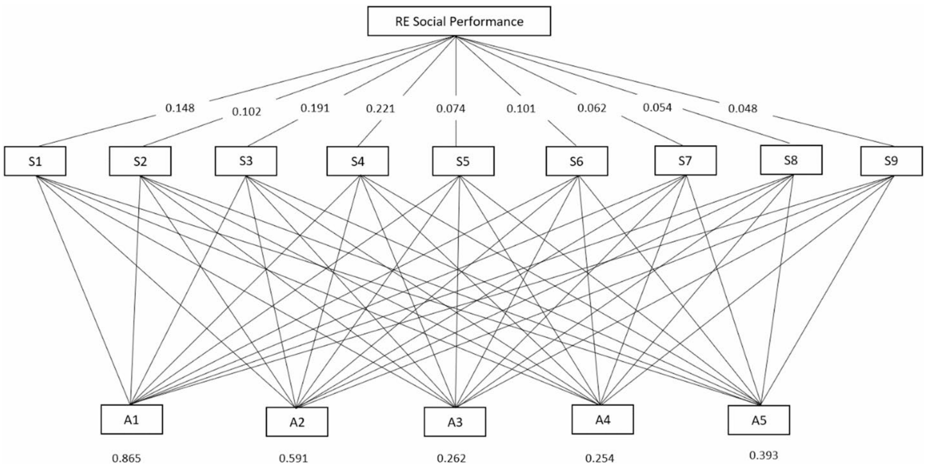
Part C:

Table 11 Order of preference for social factors affecting the transition to renewable energy

Criteria	S1	S2	S3	S4	S5	S6	S7	S8	S9	Weight	Priority
S1	0.137	0.096	0.115	0.126	0.208	0.204	0.161	0.163	0.123	0.148	3rd
S2	0.122	0.086	0.071	0.061	0.091	0.098	0.147	0.115	0.126	0.102	4th
S3	0.227	0.230	0.191	0.168	0.178	0.155	0.169	0.187	0.214	0.191	2nd
S4	0.249	0.326	0.261	0.230	0.213	0.252	0.173	0.137	0.144	0.221	1st
S5	0.047	0.068	0.077	0.077	0.072	0.071	0.072	0.097	0.084	0.074	6th
S6	0.063	0.082	0.115	0.085	0.094	0.094	0.137	0.132	0.103	0.101	5th
S7	0.052	0.036	0.069	0.081	0.061	0.042	0.061	0.073	0.087	0.062	7th
S8	0.046	0.041	0.056	0.092	0.040	0.039	0.046	0.055	0.068	0.054	8th
S9	0.056	0.034	0.045	0.080	0.043	0.046	0.035	0.041	0.050	0.048	9th

Table 12 Relative influence of various social factors on key renewable energy sources

Criteria	S1	S2	S3	S4	S5	S6	S7	S8	S9	Score	Rank
A1	5.91	7.08	6.48	6.08	4.55	3.34	1.78	1.88	4.39	0.865	1st
A2	4.21	5.83	5.96	5.78	4.68	3.39	4.34	1.77	4.66	0.591	2nd
A3	4.56	4.43	3.65	4.74	4.61	3.97	2.93	4.72	3.32	0.262	4th
A4	3.42	3.24	3.73	4.60	4.14	3.44	2.48	3.03	2.71	0.254	5th
A5	4.19	3.45	4.39	5.39	3.81	2.82	3.13	2.04	3.81	0.393	3rd



Appendix 4:

Part A: See Table 13.

Part B: See Table 14.

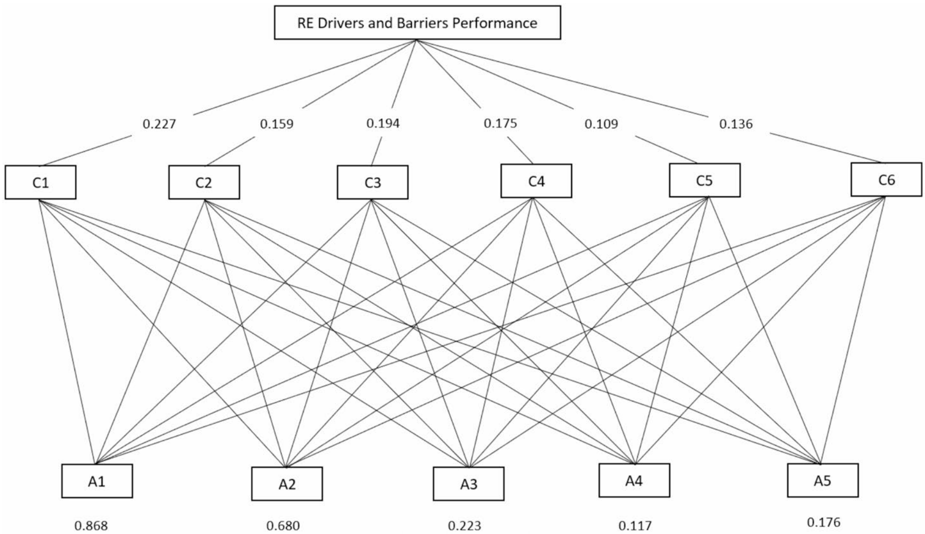
Part C:

Table 13 Order of preference for factors affecting the transition to renewable energy

Criteria	C1	C2	C3	C4	C5	C6	Weight	Priority
C1	0.22	0.36	0.17	0.22	0.14	0.26	0.227	1st
C2	0.08	0.14	0.17	0.16	0.23	0.16	0.159	4th
C3	0.25	0.16	0.20	0.23	0.20	0.12	0.194	2nd
C4	0.18	0.16	0.15	0.18	0.21	0.19	0.175	3rd
C5	0.16	0.06	0.10	0.09	0.11	0.13	0.109	6th
C6	0.11	0.12	0.21	0.13	0.11	0.14	0.136	5th

Table 14 Relative influence of various barriers factors on key renewable energy sources

Alternatives	C1	C2	C3	C4	C5	C6	Score	Rank
A1	4.488	5.590	4.924	4.507	3.825	4.840	0.868	1st
A2	3.200	5.475	4.488	4.824	4.343	5.782	0.680	2nd
A3	2.644	4.127	2.903	3.044	2.795	4.089	0.223	3rd
A4	2.360	3.571	2.611	2.881	2.819	3.618	0.117	5th
A5	2.805	4.320	2.360	3.382	3.159	2.690	0.176	4th



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Declarations

Conflict of interest No conflicts of interest in the development of this research.

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References

Abdalla, A. N., Nazir, M. S., Tao, H., Cao, S., Ji, R., Jiang, M., & Yao, L. (2021). Integration of energy storage system and renewable energy sources based on artificial intelligence: An overview. *Journal of Energy Storage, 40*, Article 102811.

Akrofi, M. M. (2021). An analysis of energy diversification and transition trends in Africa. *International Journal of Energy and Water Resources, 5*(1), 1–12.

Al Hatmi, Y., Tan, C. S., Al Badi, A., & Charabi, Y. (2014). Assessment of the consciousness levels on renewable energy resources in the Sultanate of Oman. *Renewable and Sustainable Energy Reviews, 40*, 1081–1089.

Al-Ajmi, M. Z. (2014). Assessment of Renewable Energy Resources Potential in Oman: An Overview. In: 13th Research Seminar Series Workshop.

Al-Badi, A. H., Ahshan, R., Hosseinzadeh, N., Ghorbani, R., & Hossain, E. (2020). Survey of smart grid concepts and technological demonstrations worldwide emphasizing on the Oman perspective. *Applied System Innovation, 3*(1), 5.

Al-Badi, A. H., Malik, A., & Gastli, A. (2009). Assessment of renewable energy resources potential in Oman and identification of barrier to their significant utilization. *Renewable and Sustainable Energy Reviews, 13*(9), 2734–2739.

Albadi, M. H., El-Saadany, E. F., & Albadi, H. A. (2009). Wind to power a new city in Oman. *Energy, 34*(10), 1579–1586.

Alsmadi, A. A., Alrawashdeh, N., Al-Gasaymeh, A., Alhawamdeh, L. N., & Al-Hazimeh, A. M. D. (2023). Adoption of blockchain technology in supply chain. *SAGE Open, 13*(1), Article 21582440231160143.

Al-Sarihi, A., & Bello, H. (2019). Socio-economic and Environmental Implications of Renewable Energy Integrity in Oman: Scenario Modelling Using System Dynamics Approach. In: Climate Change and Energy Dynamics in the Middle East(pp. 17–46).

Al-Sarihi, A., & Mansouri, N. (2022). Renewable energy development in the Gulf Cooperation Council countries: Status, barriers, and policy options. *Energies, 15*(5), 1923.

Al-Yahyai, S., Charabi, Y., Gastli, A., & Al-Badi, A. (2012). Wind farm land suitability indexing using multi-criteria analysis. *Renewable Energy, 44*, 80–87.

Amoatey, P., Al-Hinai, A., Al-Mamun, A., & Baawain, M. S. (2022). A review of recent renewable energy status and potentials in Oman. *Sustainable Energy Technologies and Assessments, 51*, Article 101919.

Anderson-Ingstrup, J., & Ridder, H. M. (2020). A scoping review and template analysis of manual-based complex interventions in dementia care. *Clinical Interventions in Aging, 15*, 363.

Ang, T. Z., Salem, M., Kamarol, M., Das, H. S., Nazari, M. A., & Prabaharan, N. (2022). A comprehensive study of renewable energy sources: Classifications, challenges and suggestions. *Energy Strategy Reviews, 43*, Article 100939.

Azam, M. H., Abushammala, M. F., & Qazi, W. A. (2018). Evaluation of the significant renewable energy resources in Sultanate of Oman using analytical hierarchy process. *International Journal of Renewable Energy Research (IJRER), 8*(3), 1528–1534.

Baloch, Z. A., Tan, Q., Kamran, H. W., Nawaz, M. A., Albashar, G., & Hameed, J. (2022). A multi-perspective assessment approach of renewable energy production: Policy perspective analysis. *Environment, Development and Sustainability, 24*(2), 2164–2192.

Basha, J. S., Jafary, T., Vasudevan, R., Bahadur, J. K., Ajmi, M. A., Neyadi, A. A., ... & Fattah, I. R. (2021). Potential of utilization of renewable energy technologies in gulf countries. Sustainability, 13(18), 10261.

Bilgen, S., Keleş, S., Kaygusuz, A., Sarı, A., & Kaygusuz, K. (2008). Global warming and renewable energy sources for sustainable development: A case study in Turkey. *Renewable and Sustainable Energy Reviews, 12*(2), 372–396.

Binh An, N., Kuo, Y. L., Mabrouk, F., Sanyal, S., Muda, I., Hishan, S. S., & Abdulrehman, N. (2023). Ecological innovation for environmental sustainability and human capital development: The role of environmental regulations and renewable energy in advanced economies. *Economic Research-Ekonomska Istraživanja, 36*(1), 243–263.

Biswal, J. N., Muduli, K., Satapathy, S., & Tripathy, S. (2018). A framework for assessment of SSCM strategies with respect to sustainability performance: An Indian thermal power sector perspective. *International Journal of Procurement Management, 11*(4), 455–547.

Brooks, J., & King, N. (2012). Qualitative psychology in the real world: The utility of template analysis.

Brooks, J., & King, N. (2014). Doing template analysis: evaluating an end of life care service. Sage Research methods cases.

Brooks, J., McCluskey, S., Turley, E., & King, N. (2015). The utility of template analysis in qualitative psychology research. *Qualitative Research in Psychology, 12*(2), 202–222.

Bulavskaya, T. and Reynès, F., 2018. Job creation and economic impact of renewable energy in the Netherlands. Renewable energy, 119, pp.528-538.

Campbell, S., Greenwood, M., Prior, S., Shearer, T., Walkem, K., Young, S., Bywaters, D., & Walker, K. (2020). Purposive sampling: Complex or simple? Research case examples. *Journal of Research in Nursing, 25*(8), 652–661.

Capellán-Pérez, I., De Castro, C., & Arto, I. (2017). Assessing vulnerabilities and limits in the transition to renewable energies: Land requirements under 100% solar energy scenarios. *Renewable and Sustainable Energy Reviews, 77*, 760–782.

Capellán-Pérez, I., De Castro, C., & González, L. J. M. (2019). Dynamic energy return on energy investment (EROI) and material requirements in scenarios of global transition to renewable energies. *Energy Strategy Reviews, 26*, Article 100399.

Cárdenas, B., Swinfen-Styles, L., Rouse, J., Hoskin, A., Xu, W., & Garvey, S. D. (2021). Energy storage capacity vs. renewable penetration: A study for the UK. *Renewable Energy, 171*, 849–867.

Cergibozan, R. (2022). Renewable energy sources as a solution for energy security risk: Empirical evidence from OECD countries. *Renewable Energy, 183*, 617–626.

Charabi, Y., & Al-Badi, A. H. (2015). Creating an enabling environment for renewable energy application in the Sultanate of Oman. *International Journal of Green Energy, 12*(11), 1169–1177.

Charabi, Y., & Gastli, A. (2011). PV site suitability analysis using GIS-based spatial fuzzy multi-criteria evaluation. *Renewable Energy, 36*(9), 2554–2561.

Charabi, Y., Abdul-Wahab, S., Al-Mahruqi, A. M., Osman, S., & Osman, I. (2022). The potential estimation and cost analysis of wind energy production in Oman. *Environment, Development and Sustainability, 24*(4), 5917–5937.

Choudhary, D., & Shankar, R. (2012). An STEEP-fuzzy AHP-TOPSIS framework for evaluation and selection of thermal power plant location: A case study from India. *Energy, 42*(1), 510–521.

Clottey, T., & Benton, W. C., Jr. (2020). Recommendations for assessing unit nonresponse bias in dyadic focused empirical supply chain management research. *Decision Sciences, 51*(2), 423–447.

Cole, P., & Banks, G. (2017). Renewable energy programmes in the South Pacific-Are these a solution to dependency? *Energy Policy, 110*, 500–508.

Creswell, J. W., & Poth, C. N. (2016). *Qualitative inquiry and research design: Choosing among five approaches*. Sage publications.

Creswell, J. W., & Poth, C. N. (2018). *Research Design: Qualitative and Quantitative Approaches* (4th ed.). Sage.

Dai, K., Bergot, A., Liang, C., Xiang, W. N., & Huang, Z. (2015). Environmental issues associated with wind energy–A review. *Renewable Energy, 75*, 911–921.

Electricity production. (2022, February). Retrieved from Trading economics: https://tradingeconomics.com/oman/electricity-production

Elia, A., Kamidelivand, M., Rogan, F., & Gallachóir, B. Ó. (2021). Impacts of innovation on renewable energy technology cost reductions. *Renewable and Sustainable Energy Reviews, 138*, Article 110488.

Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics, 5*(1), 1–4.

Evans, A., Strezov, V., & Evans, T. J. (2012). Assessment of utility energy storage options for increased renewable energy penetration. *Renewable and Sustainable Energy Reviews, 16*(6), 4141–4147.

Flynn, B., Pagell, M., & Fugate, B. (2018). Survey research design in supply chain management: The need for evolution in our expectations. *Journal of Supply Chain Management, 54*(1), 1–15.

Fontes, C. H. D. O., & Freires, F. G. M. (2018). Sustainable and renewable energy supply chain: A system dynamics overview. *Renewable and Sustainable Energy Reviews, 82*, 247–259.

Forghani, K., Kia, R., & Nejatbakhsh, Y. (2023). A multi-period sustainable hydrogen supply chain model considering pipeline routing and carbon emissions: The case study of Oman. *Renewable and Sustainable Energy Reviews, 173*, Article 113051.

Hartwich, F. (1999). Weighting of agricultural research results: Strength and limitations of the analytic hierarchy process (AHP). Universitat Hohenheim.

Hmouda, A. M., Orzes, G., & Sauer, P. C. (2023). Sustainable supply chain management in energy production: A literature review. *Renewable and Sustainable Energy Reviews, 191*, Article 114085.

Hosseini, S. E. (2020). An outlook on the global development of renewable and sustainable energy at the time of COVID-19. *Energy Research & Social Science, 68*, Article 101633.

Hren, R., Vujanović, A., Van Fan, Y., Klemeš, J. J., Krajnc, D., & Čuček, L. (2023). Hydrogen production, storage and transport for renewable energy and chemicals: An environmental footprint assessment. *Renewable and Sustainable Energy Reviews, 173*, Article 113113.

IRENA, I. R. (2014). Sultanate of Oman renewables readiness assessment. Muscat: IRENA.

Ivanov, D. (2022). Blackout and supply chains: Cross-structural ripple effect, performance, resilience and viability impact analysis. *Annals of Operations Research*, 1–17.

Johnson, K. W. (2019). Mama bear conversations: a template analysis of mothers message board discussions of hpv vaccination and weight management for their pre-adolescent and adolescent children.

Joshi, S., Sharma, M. and Singh, R.K., 2020. Performance evaluation of agro-tourism clusters using AHP–TOPSIS. Journal of Operations and Strategic Planning, 3(1), pp.7-30.

Kasem, A. (2019). Exploring the impact of renewable energy on climate change in the GCC countries. *International Journal of Energy Economics and Policy*. https://doi.org/10.32479/ijeep.8477

Kazem, H. A. (2011). Renewable energy in Oman: Status and future prospects. *Renewable and Sustainable Energy Reviews, 15*(8), 3465–3469.

Kebede, A. A., Kalogiannis, T., Van Mierlo, J., & Berecibar, M. (2022). A comprehensive review of stationary energy storage devices for large scale renewable energy sources grid integration. *Renewable and Sustainable Energy Reviews, 159*, Article 112213.

Keck, F., Jütte, S., Lenzen, M., & Li, M. (2022). Assessment of two optimisation methods for renewable energy capacity expansion planning. *Applied Energy, 306*, Article 117988.

Kilinc-Ata, N., & Dolmatov, I. A. (2023). Which factors influence the decisions of renewable energy investors? Empirical evidence from OECD and BRICS countries. *Environmental Science and Pollution Research, 30*(1), 1720–1736.

Kim, K., Park, H., & Kim, H. (2017). Real options analysis for renewable energy investment decisions in developing countries. *Renewable and Sustainable Energy Reviews, 75*, 918–926.

King, N., Brooks, J., & Tabari, S. (2018). Template analysis in business and management research. In Qualitative methodologies in organization studies (pp. 179–206). Palgrave Macmillan, Cham.

Kumar, C. M. S., Singh, S., Gupta, M. K., Nimdeo, Y. M., Raushan, R., Deorankar, A. V., Kumar, T. M. A., Rout, P. K., Chanotiya, C. S., Pakhale, V. D., & Nannaware, A. D. (2023). Solar energy: A promising renewable source for meeting energy demand in Indian agriculture applications. *Sustainable Energy Technologies and Assessments, 55*, Article 102905.

Lei, X., Shiyun, T., Yanfei, D., & Yuan, Y. (2020). Sustainable operation-oriented investment risk evaluation and optimization for renewable energy project: A case study of wind power in China. *Annals of Operations Research, 290*, 223–241.

Liao, C., Erbaugh, J. T., Kelly, A. C., & Agrawal, A. (2021). Clean energy transitions and human well-being outcomes in lower and middle income countries: A systematic review. *Renewable and Sustainable Energy Reviews, 145*, Article 111063.

Listyaningsih, V. and Utami, E., 2018. Decision support system performance-based evaluation of village government using AHP and TOPSIS methods: Secang sub-district of Magelang regency as a case study. International Journal of Intelligent Systems and Applications, 4(18-28).

Lu, Y., Khan, Z. A., Alvarez-Alvarado, M. S., Zhang, Y., Huang, Z., & Imran, M. (2020). A critical review of sustainable energy policies for the promotion of renewable energy sources. *Sustainability, 12*(12), 5078.

Macknick, J., Beatty, B., & Hill, G. (2013). Overview of opportunities for co-location of solar energy technologies and vegetation (No. NREL/TP-6A20–60240). National Renewable Energy Lab.(NREL), Golden, CO (United States).

Majeed, M. T., & Luni, T. (2019). Renewable energy, water, and environmental degradation: A global panel data approach. *Pakistan Journal of Commerce and Social Sciences (PJCSS), 13*(3), 749–778.

Malik, A., Al Badi, M., Al Kahali, A., Al Nabhani, Y., Al Bahri, A., & Al Barhi, H. (2015, December). A methodology of ranking renewable energy alternatives using AHP and their sensitivity with respect to criteria weights. In 2015 Saudi Arabia Smart Grid (SASG) (pp. 1–6). IEEE.

Maradin, D., Cerović, L., & Mjeda, T. (2017). Economic effects of renewable energy technologies. *Naše Gospodarstvo/our Economy, 63*(2), 49–59.

Martínez, L., Dinçer, H., & Yüksel, S. (2023). A hybrid decision making approach for new service development process of renewable energy investment. *Applied Soft Computing, 133*, Article 109897.

Mohammed, A., Govindan, K., Zubairu, N., Pratabaraj, J., & Abideen, A. Z. (2023). Multi-tier supply chain network design: A key towards sustainability and resilience. *Computers & Industrial Engineering, 182*, Article 109396.

Mohammed, A., Harris, I., Soroka, A., & Nujoom, R. (2019). A hybrid MCDM-fuzzy multi-objective programming approach for a G-resilient supply chain network design. *Computers & Industrial Engineering, 127*, 297–312.

Mohammed, A., Harris, I., Soroka, A., Naim, M., Ramjaun, T., & Yazdani, M. (2021). Gresilient supplier assessment and order allocation planning. *Annals of Operations Research, 296*, 335–362.

Mondal, A., & Khalil, H. S. (2012). Renewable energy readiness assessment report: the GCC countries. Masdar, UAE: Masdar Institute.

Mukhtarov, S., Aliyev, F., Aliyev, J., & Ajayi, R. (2023). Renewable energy consumption and carbon emissions: Evidence from an oil-rich economy. *Sustainability, 15*(1), 134.

Okedu, K. E., & Al Siyabi, M. S. (2021). Harnessing Hydropower Potential in Desert Regions: The Case of Wadi Dayqah Dam, Quriyat. *Oman. Frontiers in Water, 68*, 686856.

Okedu, K., Nadabi, H., & Aziz, A. (2019). Prospects of solar energy in Oman: Case of oil and gas industries. *International Journal of Smart Grid-ijSmartGrid, 3*(3), 138–151.

Okudoh, V., Trois, C., Workneh, T., & Schmidt, S. (2014). The potential of cassava biomass and applicable technologies for sustainable biogas production in South Africa: A review. *Renewable and Sustainable Energy Reviews, 39*, 1035–1052.

Olabi, A. G., & Abdelkareem, M. A. (2022). Renewable energy and climate change. *Renewable and Sustainable Energy Reviews, 158*, Article 112111.

Olsen, W. (2022). *Systematic mixed-methods research for social scientists*. Palgrave Macmillan.

Østergaard, P. A., Duic, N., Noorollahi, Y., Mikulcic, H., & Kalogirou, S. (2020). Sustainable development using renewable energy technology. *Renewable Energy, 146*, 2430–2437.

Owusu, P. A., & Asumadu-Sarkodie, S. (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. *Cogent Engineering, 3*(1), 1167990.

Panagos, P., Borrelli, P., Meusburger, K., Alewell, C., Lugato, E., & Montanarella, L. (2015). Estimating the soil erosion cover-management factor at the European scale. *Land Use Policy, 48*, 38–50.

Petinrin, J. O., & Shaaban, M. (2015). Renewable energy for continuous energy sustainability in Malaysia. *Renewable and Sustainable Energy Reviews, 50*, 967–981.

Pietrosemoli, L., & Rodríguez-Monroy, C. (2019). The Venezuelan energy crisis: Renewable energies in the transition towards sustainability. *Renewable and Sustainable Energy Reviews, 105*, 415–426.

Pourali, M., Kavianpour, M. R., Kamranzad, B., & Alizadeh, M. J. (2023). Future variability of wave energy in the Gulf of Oman using a high resolution CMIP6 climate model. *Energy, 262*, Article 125552.

Pourmoghadam, P., & Kasaeian, A. (2023). Economic and energy evaluation of a solar multi-generation system powered by the parabolic trough collectors. *Energy, 262*, Article 125362.

Praveen, R. P., Keloth, V., Abo-Khalil, A. G., Alghamdi, A. S., Eltamaly, A. M., & Tlili, I. (2020). An insight to the energy policy of GCC countries to meet renewable energy targets of 2030. *Energy Policy, 147*, Article 111864.

Pu, S., & Lam, J. S. L. (2023). The benefits of blockchain for digital certificates: A multiple case study analysis. *Technology in Society, 72*, Article 102176.

Rövekamp, P., Schöpf, M., Wagon, F., Weibelzahl, M., & Fridgen, G. (2021). Renewable electricity business models in a post feed-in tariff era. *Energy, 216*, Article 119228.

Saaty, T.L. and Wind, Y., 1980. Marketing applications of the analytic hierarchy process. Management science, 26(7), pp.641-658.

Saaty, T.L., 1989. Group decision making and the AHP. In The analytic hierarchy process: Applications and studies (pp. 59-67). Berlin, Heidelberg: Springer Berlin Heidelberg.

Saaty, T.L., 2008. Decision making with the analytic hierarchy process. International journal of services sciences, 1(1), pp.83-98.

Sahoo, M., & Sethi, N. (2021). The intermittent effects of renewable energy on ecological footprint: Evidence from developing countries. *Environmental Science and Pollution Research, 28*(40), 56401–56417.

Said. A, D. A. (2022). The effect of natural gas prices for energy sectors in the middle east. Universiti Tun Hussein Onn Malaysia.

SAOC, O. P. (2018). OPWP's 7-year statement (2018–2024). Muscat: SAOC.

Sarkar, M., & Seo, Y. W. (2021). Renewable energy supply chain management with flexibility and automation in a production system. *Journal of Cleaner Production, 324*, Article 129149.
Sharvini, S. R., Noor, Z. Z., Chong, C. S., Stringer, L. C., & Yusuf, R. O. (2018). Energy consumption trends and their linkages with renewable energy policies in East and Southeast Asian countries: Challenges and opportunities. *Sustainable Environment Research, 28*(6), 257–266.
Shen, S., Doyle-Thomas, K. A., Beesley, L., Karmali, A., Williams, L., Tanel, N., & McPherson, A. C. (2017). How and why should we engage parents as co-researchers in health research? A scoping review of current practices. *Health Expectations, 20*(4), 543–554.
Shum, K. L. (2017). Renewable energy deployment policy: A transition management perspective. *Renewable and Sustainable Energy Reviews, 73*, 1380–1388.
Sindhu, S., Nehra, V., & Luthra, S. (2017). Investigation of feasibility study of solar farms deployment using hybrid AHP-TOPSIS analysis: Case study of India. *Renewable and Sustainable Energy Reviews, 73*, 496–511.
Siram, O., Sahoo, N., & Saha, U. K. (2022). Changing landscape of India's renewable energy and the contribution of wind energy. *Cleaner Engineering and Technology*. https://doi.org/10.1016/j.clet.2022.100506
Sultan, A. Y., Charabi, Y., Gastli, A., & Al-Alawi, S. (2010). Assessment of wind energy potential locations in Oman using data from existing weather stations. *Renewable and Sustainable Energy Reviews, 14*(5), 1428–1436.
Thabane, L., Thomas, T., Ye, C., & Paul, J. (2009). Posing the research question: Not so simple. *Canadian Journal of Anesthesia/journal Canadien D'anesthésie, 56*(1), 71–79.
Thousand Oaks, CA.
Tsoutsos, T., Frantzeskaki, N., & Gekas, V. (2005). Environmental impacts from the solar energy technologies. *Energy Policy, 33*(3), 289–296.
Twidell, J. (2021). *Renewable energy resources*. Routledge.
Uhunamure, S. E., & Shale, K. (2021). A SWOT analysis approach for a sustainable transition to renewable energy in South Africa. *Sustainability, 13*(7), 3933.
Ullah, Z., Elkadeem, M. R., Kotb, K. M., Taha, I. B., & Wang, S. (2021). Multi-criteria decision-making model for optimal planning of on/off grid hybrid solar, wind, hydro, biomass clean electricity supply. *Renewable Energy, 179*, 885–910.
Umar, T. (2017, July). Briefing: Towards a sustainable energy: the potential of biomass for electricity generation in Oman. In: Proceedings of the institution of civil engineers-engineering Sustainability (Vol. 171, No. 7, pp. 329–333). Thomas Telford Ltd.
Umar, T. (2018). Geothermal energy resources in Oman. *Proceedings of the Institution of Civil Engineers-Energy, 171*(1), 37–43.
Umar, T., & Wamuziri, S. (2016). Briefing: Conventional, wind and solar energy resources in Oman. *Proceedings of the Institution of Civil Engineers-Energy, 169*(4), 143–147.
UNDP (2022), "Goal 7: Affordable and clean energy", available at: https://www.undp.org/sustainable-development-goals#affordable-and-clean-energy (accessed 10 October 2022).
Vezmar, S., Spajić, A., Topić, D., Šljivac, D., & Jozsa, L. (2014). Positive and negative impacts of renewable energy sources. *International Journal of Electrical and Computer Engineering Systems, 5*(2), 47–55.
Vidadili, N., Suleymanov, E., Bulut, C., & Mahmudlu, C. (2017). Transition to renewable energy and sustainable energy development in Azerbaijan. *Renewable and Sustainable Energy Reviews, 80*, 1153–1161.
Waring, T., & Wainwright, D. (2008). Issues and challenges in the use of template analysis: Two comparative case studies from the field. *Electronic Journal of Business Research Methods, 6*(1), 85–94.
Wee, H. M., Yang, W. H., Chou, C. W., & Padilan, M. V. (2012). Renewable energy supply chains, performance, application barriers, and strategies for further development. *Renewable and Sustainable Energy Reviews, 16*(8), 5451–5465.
Winkler, H. (2005). Renewable energy policy in South Africa: Policy options for renewable electricity. *Energy Policy, 33*(1), 27–38.
Wu, Z., Mohammed, A., & Harris, I. (2021). Food waste management in the catering industry: Enablers and interrelationships. *Industrial Marketing Management, 94*, 1–18.
Yamini, S., & Gajanand, M. S. (2022). Inventory decision-making biases: A review and suggestions for future research. *Benchmarking: An International Journal, 29*(6), 1889–1912.
Yin, R. K. (2017). *Case study research and applications: Design and methods*. Sage publications.
Yoon, K., & Hwang, C. L. (1995). *Multiple Attribute Decision Making: An Introduction*. Sage.
Yu, W., Patros, P., Young, B., Klinac, E. and Walmsley, T.G., 2022. Energy digital twin technology for industrial energy management: Classification, challenges and future. Renewable and Sustainable Energy Reviews, 161, p.112407.
Zare, K., Mehri-Tekmeh, J., & Karimi, S. (2015). A SWOT framework for analyzing the electricity supply chain using an integrated AHP methodology combined with fuzzy-TOPSIS. *International Strategic Management Review, 3*(1–2), 66–80.

Zubairu, N., Dinwoodie, J., Govindan, K., Hunter, L., & Roh, S. (2021). Supply chain strategies as drivers of financial performance in liquefied natural gas networks. *Supply Chain Management, an International Journal, 26*(5), 579–591.

Zubairu, N., Mohammed, A., and Zeinab, Z. (2024). Navigating the path to sustainable energy transition in Oman: a systematic literature review and future research opportunities, Management of Environmental Quality,

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