SAMA Joint Research Program JRP/2021/06

An Analysis of Renewable Energy Investments in Saudi Arabia: A Hybrid Framework Based on Leontief and Fuzzy Group Decision Support Models

Tarifa Almulhim [1], Mohammed Al Yousif [2]

[1] School of Business, King Faisal University

[2] Saudi Central Bank

April 2022

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Abstract:

Focusing on renewable energy and making serious investments in this field have come into prominence, particularly throughout the last two decades in the Kingdom of Saudi Arabia. This interest is rapidly increasing in line with Saudi Arabia's Vision 2030 that aims at achieving sustainable economic, social, and environmental developments. Owing to the current importance of the renewable energy investments topic, analyzing and evaluating potential future investment plans and criteria that affect this evaluation process are required. This study attempts to make a contribution in offering combined methodology of multi-disciplinary approaches for the first time of studying renewable energy sector and by considering macroeconomic assumptions, historical information as quantitative data, and judgment from a group of decision experts as qualitative data. Another innovation of the study stems from its capability to tackle the uncertainty about the future of renewable energy investments path by applying IFS theory. In the application of the proposed hybrid framework, results of the Leontief's input-output (Leontief's IO) model proposed three main different investment scenarios by 2030, namely: "based scenario" (Investment of 112 billion Saudi Riyals), "alternative scenario 1" (Investment of 75 billion Saudi Riyals) and "alternative scenario 2" (Investment of 25 billion Saudi Riyals). The second phase unveiled five conflicting decision criteria that might affect the process of selection of a best investment scenarios, namely: ''Economic criterion'', ''Environmental criterion'', ''Social criterion'', ''Public preferences criterion'' and ''Risk criterion ''. The results of the Fuzzy Group Decision Support model unfolded "based scenario" and "alternative scenario 1" are always the compromise investment plans and the "alternative scenario 2" is significantly not preferred. This final result was validated by sensitivity analysis.

Keywords: *Renewable Energy Investments, Leontief's input-output model, IFS, VIKOR method, Multiple-Criteria Group Decision-Making (MCGDM)*

JEL: *C67, Q5, Q20, Q29, C43, C44, D81*

* **Authors' contact**: Tarifa Almulhim, Email: talmulhim@kfu.edu.sa ، tarifaalmulhim@gmail.com ; Mohammed Al Yousif, Email: malyousef2@sama.gov.sa , mykfsa@gamil.com

1. Introduction

In recent years, much attention has been globally paid to renewable energy investment for attaining sustainable economic, social, and environmental development policies (Wüstenhagen & Menichetti, 2012; Al Garni et al, 2016; Hashemizadeh et al, 2021). Furthermore, there is a high correlation between energy consumption and development. This was well evident during the industrial revolution where there was a big shift of production technology from human labor to machines and more burning coal for generating steam (Safa, 2017). According to many studies, the nature of the relationship between global growth and demand for energy is significantly positive (AlKhars et al., 2020). Therefore, there is definitely a high expectation for more demand for energy in the future, as the growth in population and economy is continuously increasing. More specifically, Saudi Arabia consumption of energy is the highest compared to the other countries in the Middle East (Krane, 2019). The average oil consumption inside the Kingdom of Saudi was around 4.3 million barrels per day (bpd) by the end of 2019 compared with the average of 4.1 million bdp in 2018 (Ministry of Energy, 2020). Saudi Arabia consumed around 289.9 terawatt-hours (TWh) by the end of 2018, with an annual increase of 0.42 percent compared to 2017. The domestic consumption of energy inside the Kingdom of Saudi Arabia is very high, due to the high rate of non-oil economic growth with an average of 4.5 percent annually during the period 2010-2019, population fertility of 3.2 percent annually during the period 2012-2017, and water desalination (Rambo et al., 2017). Negewo et al. (2012) predicted the number of oil barrels required to fill up the domestic consumption of energy by 2050 would be around 8 million bpd. So far, this high amount of domestic consumption of energy should cut off some of the Saudi government's ability to export more barrels of oil (Sdralevich et al., 2014; Rentschler & Bazilian, 2017; Blazquez et al., 2017). Consequently, it is necessary for the Saudi government to have control over the growth of demand for domestic energy. Renewable energy can be used for recent purposes as additional sources of energy for Saudi Arabia that would reduce the pressure of demand on fossil fuel.

Currently, making the right investments in renewable energy has become even more important, especially for countries with oil-based economies such as Saudi Arabia, which is the largest economy in the Gulf Cooperation Council (GCC) region and one of the world's largest producers and exporters of petroleum products (Amran et al., 2020; Callen et al., 2014). The Saudi government desires to be transform away from an oil-based economy to a diversified economy for many reasons. Firstly, using fossil fuels heavily for domestic consumption might build obstacle limitation to the country's oil export capability as much of Saudi production has been consumed inside the country given the limitation of production for the country due to Saudi Arabia being a part of the OPEC group. Secondly, having a single commodity economic structure, which relies on producing and exporting one commodity (such as oil and refined products), is not a stable and sustainable economic structure. Thirdly, crises and epidemics may affect oil prices negatively. The recent COVID-19 crisis is a good example to show how high fluctuation is in the oil market. For instance, according to the recently published data from the General Authority of Statistic (GSTAT, 2020), the oil GDP represented more than 40 percent of the total Saudi GDP, and around 60 percent of total government revenue. Thus, Saudi Vision 2030 aims at increasing the level of diversification of the Saudi economy. Based on relevant literature, renewable energy projects are highly diversified and are enhancing development in the local economic activities (Al Yousif, 2018). Fourthly, using less carbon emission for the local economy will help supporting a healthy local environment and increase Saudi contribution to the global effort to save the globe from climate change. As long as the health system is highly funded by the Saudi government, maintaining the social healthy condition would reduce the healthcare bills on the Saudi government. So far, investment in renewable energy is a promising strategy for transforming the Saudi economy into one that is more dynamic, sustainable, and stable.

Over the last few years, Saudi Arabia has been eager to accelerate the development of renewable energy resources and investment in renewable energy (Taher & Hajjar, 2014; Ramli & Twaha, 2015; Alyahya & Irfan, 2016; Tlili, 2015; Al Yousif, 2020). Saudi Vision 2030 sets a target to achieve a renewable and sustainable energy supply of 9.5 GW by 2030 (Kingdom of Saudi Arabia, Saudi Vision 2030, 2016; Amran et al., 2020). Although there is no specific scenario on renewable energy investment in Saudi Arabia, the Saudi government introduced several initiatives for investment in the renewable energy sector (Mosly & Makki, 2018; Amran et al., 2020). It has a high potential in terms of renewable energy sources, while scientific research for examining and analyzing the Saudi renewable energy sector in terms of benefits and risk criteria that impact the future investment in that sector is largely absent in the literature. Moreover, despite the potential availability of several renewable energy investment scenarios and alternatives, it is difficult to make decisions regarding the optimal investment scenario in Saudi Arabia for the upcoming years. This is because there is no specific best initiative or alternative for investing in renewable energy, especially with the economic fluctuations and uncertainty before, during, and after the COVID-19 pandemic. Thus, there is a need for an appropriate process of analysis and selecting the most appropriate renewable energy investment potential scenario that can aid Saudi policymakers to achieve the economic, social, and environmental development objectives.

In the renewable energy investment context, a key challenge in selecting the optimal scenario is to know and understand future contributions and opportunities of available alternative investment scenarios. Understanding these contributions and opportunities and their implications for all renewable energy alternatives are important for policymakers to make the right decision. As a result, for the research under review, this challenge can be addressed by simulating different investment scenarios in renewable energy in Saudi Arabia in terms of their future contributions and opportunities. The estimated investment scenarios should be appropriate to the potentials and capabilities of Saudi Arabia. They should be also well matched with the Saudi Vision 2030. Macroeconomic analysis is a capable tool to handle that process by calculating future outputs, such as the number of jobs that might be generated as a result of the investment in renewable energy, and the expected contribution of this sector to the local gross domestic product (GDP) over the additional expanding in the production scheme (Ferroukhi et al., 2016; Kammen, Kapadia & Fripp, 2004). The Leontief's IO, is one suitable macroeconomic analysis method (Leontief, 1936; Martínez ,1998). It provides detailed information about the interaction between internal and external sectors of production and change in any GDP elements, such as government spending, household consumption, investments, and net export (Davar, 2020; Albqami, 2004). Consequently, different future alternative investment scenarios in renewable energy in Saudi Arabia will be simulated via the Leontief's IO model in this current research.

To select an optimal investment future scenario of renewable energy from a list of available alternative investment scenarios, it becomes essential to consider multiple conflicting criteria might effect the selection process that should be taken into consideration by a group of decision experts (DEs). Actually, those criteria are called evaluation decision criteria. The evaluation decision criteria might have positive impact (e.g. creation of new jobs) or negative impact (e.g. risk). Generally, those evaluation decision criteria are divided into positive (benefit) criteria and negative (risk) criteria. Thus, a framework that is capable to define the multiple criteria and influence the decision of selecting the most proper alternative investment scenario for renewable energy sector for upcoming years in accordance with the Kingdom's vision 2030, is required to be designed. Indeed, Multiple-Criteria Group Decision-Making (MCGDM) techniques are the suitable methodologies for determining the most appropriate alternative since being developed in the early 1970s (Büyüközkan et. al., 2019). The main principle of MCGDM is ranking a set of feasible alternatives based on quantitative data and/or qualitative judgments collected from a group of DEs. The Višekriter- ijumsko kompromisno rangiranje (VIKOR) method is one of the most appropriate MCGDM methods to focus on prioritizing and selecting from a set of alternatives in the presence of non-commensurable and conflicting criteria (Opricovic, 1998; Opricovic and Tzeng, 2004). It determines the compromise-ranking list and the compromise solution (a feasible solution) that is based on "closeness to ideal solution and mutual agreement through concessions" (Opricovic and Tzeng, 2004). Moreover, the VIKOR method is appropriate for decision-making situations wherein the DEs desires to have maximum benefit from the positive criteria and minimize risk from the negative criteria (Park et al., 2013). In a decision-making process, the evaluation decision criteria used for selecting the best alternative often relies on fuzzy information due to uncertainty in the human judgments. Furthermore, evaluating each alternative about the risk and benefits of investment in Saudi renewable energy sector is a relatively fuzzy process, and there is no absolute most important criterion in selection of the best alternative. Intuitionistic Fuzzy Set (IFS) proposed by Atanassov (1987) has advantages for adequately identifying DEs' judgments and handling the fuzzy environment in the decision-making process (Büyüközkan et al., 2019). Accordingly, MCGDM based on integrated IFS and VIKOR is a suitable technique to facilitate government, policy makers and economists to prioritize future investment estimated scenarios with respect to conflicting evaluation decision criteria and then select the optimal one .

In this paper, the purpose is studying the future investments of renewable energy sector in Saudi Arabia. Consequently, this paper offers a research methodology that stems from its strength in offering a hybrid framework that has not been employed in any renewable energy research under uncertainty. The hybrid framework is based on two primary models: Macroeconomic analysis by using the Leontief's IO model, and the Fuzzy Group Decision Support model, based on integrated IFS and VIKOR method under uncertainty. The proposed methodology in this paper mainly aims at dealing with uncertainty in the process of decision made for selecting renewable energy investment scenario. Eventually, the current research aims to draw recommendations and implementations to help policy makers and government make optimal decisions related to energy in forthcoming years in line with the Kingdom's Vision 2030. The innovation of this paper stems from its strength in presenting combined methodology of multi-disciplinary approaches in terms of studying renewable energy sector and considering macroeconomic assumptions, historical information as quantitative data, and DEs' judgments as qualitative data. Therefore, this study enriches research in this field by providing an integration framework for the first time for a real renewable energy problem under uncertainty to assess the investments selection process in Saudi Arabia

This paper is outlined as follows: Section 2 introduces a review of the renewable energy sector and its investments in Saudi Arabia. Section 3 presents a systematic description of both methods and the process of the proposed research methodology. In Section 4, the proposed methodology is applied to analyze renewable energy investments in Saudi Arabia. Finally, conclusions and limitations of this study and potential further research topics are given in Section 5.

2. Literature Reviews

Recently, the global focus, at all levels of academia and politics, is on the negative consequences of climate change such as hurricanes, earthquakes, and global warming. The world community arrived at a point that the international community should save the environment through necessary quick steps. There are many reasons for global warming, but the increasing level of carbon emission could be the major one. Therefore, there are significant global movements toward reducing global warming by using a clean and friendly source of energy-less carbon emission. The Climate Coalition group claimed that renewable energy, as a clean and sustainable energy source, can be the new source of energy replacing the existing fossil fuel energy. However, there are two obstacles to this optimistic proposal; the efficiency of renewable energy is still very low compared to other conventional sources of energy, and the initial cost of investing in renewable energy is still high (Baras et al., 2012; Sung & Park, 2018). Nevertheless, the speed of the global transition from using fossil fuel to sustainable (zero carbon emission) energy sources could cause different types of environmental and economic disasters. The widespread production of renewable energy devices, such as solar PV, causes an excess demand on a long list of minerals. Increasing mining for these minerals needs a massive amount of water while it also causes the destruction of many mountains, which overall shall cause considerable damage to the environment. In addition, this rapid transition into a sustainable energy source (expensive energy source) would generate an additional cost on the final goods and services. Many producers could not carry these additional costs of energy and might decide to shut down their businesses, thereby leading to job loss. In contrast, various studies have investigated the economic, social, and environmental benefits of investment in renewables. Investment in renewable energy was found as a promising strategy for promoting domestic economic activities and generating new job opportunities for a wide list of occupations and skills. Using renewable energy for local energy consumption will reduce the carbon emission growth locally (Kammen, Kapadia & Fripp, 2004).

A paper by El-Nakla et al. (2017), which handles the recent development in renewable energy for the GCC countries, raised the concern of a high increase in energy demand related to growth, as mentioned earlier, given that more than 80 percent of used energy worldwide comes from natural sources of energy such as coal, oil, and natural gas. Thus, more demand for energy means more carbon emission and the future risk on the economy from relying on unsustainable sources of energy. This paper suggested that creating a supplementary energy source such as renewable energy is a necessary step, besides increasing the level of efficiency of domestic consumption of energy. Furthermore, Saudi Arabia is the highest energy consumer in the Middle East (around 4 million of oil a day in 2019) as fossil fuel is the primary source for electricity generation for industries, government, and people. Due to the high domestic consumption of energy, Saudi Arabia considered seriously investing in a sustainable energy source (Al-Saleh, 2009).

The role of government in helping the transition into renewable energy was found to be very significant (Sung, 2018). On the other hand, Sung (2018) concluded that keeping the cost of traditional energy very low would negatively affect the development of this promising sustainable energy sector. He discussed the interaction between all economic sectors in the process of transition into a more sustainable energy source. Therefore, the decision of adopting a new source of energy such as renewable energy required the involvement of multi-sectors of economic activities to avoid any resistance in the pathway of establishing a new source of energy. Sung (2018) insisted that the transition to a renewable energy economy is a collective (including government, non-profit sector, and traditional energy industry), complex, and a long-term process.

There are many obstacles that impede further development in renewable energy. The technological issues and the low level of efficiency of silicon cells, and the cost of installation of this sustainable source of energy are the main obstacle for this energy source to spread above the conventional source of energy.

In addition, there is a lack of proper infrastructure inside the cities for many countries and a shortage of skilled laborers familiar with this new source of energy (Durganjali et al., 2020; Sen & Ganguly, 2017).

A recent very interesting research paper by Ivanovski & Smyth (2021) found that the impact of renewable energy consumption on economic growth is not clearly significant across OECD countries. However, renewable and non-renewable energy consumption promote economic growth in non-OECD countries. Therefore, this paper shows that the developing countries are most likely to play a major role in the transition process toward renewable energy, taking into account the expected lack of technical progress.

Other research papers discussed the opportunities and challenges of investment in renewable energy for Saudi Arabia (Baras et al., 2012). Investment in Solar energy in Saudi Arabia is a very promising strategy since it has one of the highest direct average irradiation (DNI) globally, and more than 40 percent of the total Saudi Arabia size is desert, which could host solar arrays. The average size of Saudi's houses is big with empty roofs, which could be used to install solar PV panels. In addition, it is more rational for Saudi Arabia to establish an energy mix as renewable energy is the supplementary energy source used to reduce the domestic energy demand. However, the conventional energy source is still more efficient than all types of renewable energy, which makes renewable energy more expensive (Halkos & Tzeremes, 2013). Renewable energy technology is still in the early stage of development, and the level of uncertainty around investment in renewable energy is very high. Finally, Halkos & Tzeremes (2013) recommended that Saudi Arabia starts investing in other energy sources and contributes to the technological development of renewable energy for two reasons: one is to reduce the pressure of the domestic demand on fossil fuel and have a well developed sustainable source of energy. Making investments in renewable energy is part of Saudi efforts toward increasing the level of diversification, which is in line with Vision 2030. In addition, according to a paper by Amran (2020), the Kingdom of Saudi Arabia could generate its domestic consumption of energy totally from renewable energy in the coming 50 years. This optimistic projection was based on the number of factors that would help Saudi Arabia enhance renewable energy development inside the Kingdom—It is located in the sunbelt and has significant renewable energy initiatives as a part of Vision 2030.

Mosly and Makki (2018), investigated the social responses to the purchase and use of renewable energy by conducting questionnaires to a group of people. The main factor influencing the decision to adopt renewable energy is the economic factor. From the questionnaires, the class of people aged between 18 to 29 were found more willing to adopt alternative energy sources, such as renewable energy early. This could be related to the level of awareness of this group compared to other groups. Thus, the government has to spend more effort educating people about this new technology.

AlKhars et al. (2020) studied the relationship between economic growth and energy consumption using questionnaires in GCC countries. These questionnaires have four hypotheses: the relationship goes from economic growth and energy consumption (growth hypothesis), from energy consumption to economic growth (conservation hypothesis), and the third hypothesis assumes that there is a bidirectional causality between economic growth and energy consumption (feedback hypothesis). The authors concluded that there is no causality between economic growth and energy consumption (neutral hypothesis). From the questionnaire, 18 percent of observations supported the growth hypothesis, 26 percent supported the conservation hypothesis, 43 percent supported the feedback hypothesis, and 13 percent supported the neutral hypothesis. Based on these questionnaires, there still is a strong relationship between energy consumption and economic growth.

In addition, some particular factors can be the reason for increasing the domestic consumption of energy in Saudi Arabia, including heavy use of air conditioners during a long hot summer, water desalination as the country suffers from a shortage of fresh water, less developed public transportation, and petroleum products are highly subsidized. Today, Saudi Arabia seeks to reduce the domestic consumption of energy by improving the efficiency of domestic consumption of energy and encouraging local citizens to be self-producers of energy. This matter needs the Saudi government to amplify efforts to solve some structural problems, such as further development in public transport, forcing buildings to be designed in a way using less energy (greenhouses), and providing financial support to the local companies working in renewable energy services.

3. Research Methodology

A hybrid framework methodology based on three phases is used in this study. The first phase involves simulation scenarios with different investment hypotheses in renewable energy in Saudi Arabia by applying a macroeconomic analysis. The macroeconomic analysis is conducted using the Leontief’s IO model. In this first phase, the contribution of future investment in renewable energy will be estimated during the period between 2020 to 2030 with three scenarios based on historical data. The second phase involves the identification of decision criteria that are expected to influence the process of selecting the optimal scenario that achieves sustainable investment in renewable energy in Saudi Arabia. This phase will be achieved on the basis of literature review and experts’ opinion. The third phase involves selecting and ranking the optimal renewable energy investment scenario in Saudi Arabia. A Fuzzy Group Decision Support model, based on integrated IFS and VIKOR method, is used in this phase. A three-phase methodology is presented in Figure 1. Each of these phases is discussed below:

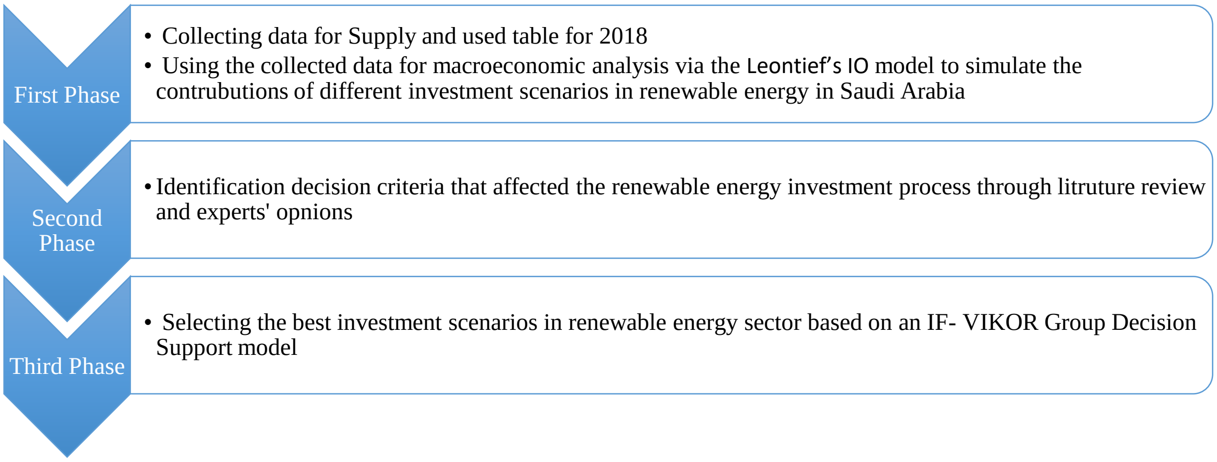

Figure 1: The Chart of Proposed Methodology for Analysis of Renewable Energy Investments in Saudi Arabia

3.1 First Phase: Data for Simulation and Analysis

This phase consists in estimating the economic contributions of investment in renewable energy inside the Kingdom. These simulation scenarios utilize a macroeconomic analysis for different investment hypotheses in Saudi Arabia during the period between 2020 to 2030. The macroeconomic analysis is conducted using the Leontief's IO model based on the supply and used table for 2018. This estimation would calculate the amount of contribution of this new investment in renewable energy inside the Kingdom into the gross domestic product, local labor market, carbon emission reduction, and the amount of renewable electricity (GW). There are many reasons for using the Leontief's IO for this research. The first reason is that this macroeconomic model has the capability of calculating the direct, indirect, and induce effects of investment in renewable energy for the local economy. The second reason, Leontief's IO can calculate the number of new occupations in the market and the new value added generated by investment in renewable energy (Al Yousif, 2019). The third reason, Leontief's IO model is capable of estimating changes (expansion/ mitigation) in the production system resulting from any exogenous shock, such as new government spending, increase in the local consumption, or new flow of investments. Hence, all sectors of local production are estimated to be interacted at different degrees based on the coefficient, which means that the model is dynamic in term of distribution of shocks among all sectors of production. For instance, a specific expansion in the Saudi investment in the local renewable energy sector should carry over to both local and primary departments due to the new demand for goods and services from the new employees in renewable energy. Later on, there is an expected expansion in the entire production system, which will take place gradually that is associated with employing more workers and purchasing more capital.

Miller & Blair book has a good explanation for the Leontief's model (2009). Let us say that a certain economy has three sectors of production: A, B, and C. The total output of sector (A) is supposed to be consumed by the sector itself and by the other sectors of production, such as (B) and (C). In addition, the total production of goods and services from the other sectors (B) and (C) should be consumed among themselves, and some of these goods and services might be input for the sector of production (A). The supply and used table has detailed information about the flows of goods and services between internal sectors of production and the final demand sector (government, investors, household consumption, trade) during 2018 in our case (Miller, 1998). There are two primary methods for changing the structure of production: changing the level of technology and the final demand. For the sake of simplicity, the level of technology (A) for different sectors of production is assumed to be unchangeable. As a result, the coefficients between different production sectors are fixed in the medium term (three to five years). However, the final demand might change (increase or decrease) due to some exogenous variables. For instance, if the local investors decided to pump new investments in renewable energy. This increase in the level of investment would enhance expansion throughout the entire sectors of production.

Juan Carlos Ciscar Martinez (1998) wrote a paper, "Quantification of the Socio-Economic Effects of Renewable Energy Technologies in Southern Mediterranean Countries: An Input-Output Evaluation." This study concluded that investment in renewable energy is a promising policy for enhancing economic growth, generating new local jobs, and promoting trade. The Leontief's IO model is the quantitative methodology for estimating the expected impact of investment in renewables, including wind, biomass, and PV electricity on the Southern Mediterranean Countries such as Turkey, Tunisia, and Morocco. Let us shed light on the significant findings, the wind and biomass projects on average create at least 90 jobs per year for every one million dollars invested in these technologies. Also, this paper found that PV rural electrification projects create approximately 45 new jobs per year for every million dollars. The author referred to the reason for the lower number of jobs created by investment in PV projects in a rural area for these countries in the sample due to most of the PV panels and electrical cycles not being domestically produced. In addition, the cost of these imported parts is accounting for 47 percent of the total project cost. Finally, this paper insisted that Leontief's IO model is a beneficial tool for evaluating macroeconomic policy.

In general, the Leontief's IO model classifies the economy into $N + 1$ sectors: N here indicates the number of production sectors (demand of other producing sectors i.e., petroleum refining sector, agriculture and forestry sector) and the final demand (demand of the open sector).

For the final demand sector, Leontief's model handles its demand in the aggregate level as the final demand sector is determined by some exogenous factors. For instance, each sector of production produces goods and services; part of this production would be consumed by the production sectors, while the final demand sector would consume the rest of the output. Therefore, the total goods and services, which a particular production sector creates, shall be consumed by N sectors of production and the final demand sector FD_z. The following equations simplified the Leontief's IO models (Davar, 2020; Albqami, 2004; Al Yousif & Al Backer, 2017; Al Yousif, 2018, 2019):

$$X_z = h_{11}X_1 + h_{12}X_2 + \cdots + h_{zy}X_Z + FD_z \quad (1)$$

where X_z is the total output of any production sector z, and $z = 1,2, \dots N$. $h_{zy}X_Z$ is a portion of X_Z's output used as an input to the X_Z sector; $y = 1,2, \dots N$ and c_{z1} is a percentage calculated as ($h_{z1} = {}^{h_{zy}}\!/_{X_z}$). FD_z denotes the aggregate level of final use section, which includes the government, households, investors, and exports, consumes the rest of the produced output as outside entities from the production scheme. We are interested in solving the following linear system, which is called the Leontief production equation:

$$X = HX + FD \quad (2)$$

In the above equation, X is a $z \times 1$ matrix-vector. H is a $z \times y$ matrix and contains the percentage of distribution of output to each sector of production. The final demand users FD_z would consume the rest of the output for all production sectors. So for a given H and FD we need to solve the following liner system to figure out how much each sector should produce:

$$(I - H)X = FD \quad (3)$$

Equation (3) adds all the X's on the left side, which represents the domestic sector, while the right-hand side represents the distribution of X's to the final users FD. The following equation, which is derived from equation (3), shows a direct relationship between these main sectors:

$$X = (I - H)^{-1}FD \quad (4)$$

Hence, $(I - H)^{-1}$ is Leontief's inverse matrix, which displays the kind of relationship between the production sector and the final demand sector. Having Leontief's inverse matrix is the final step needed to calculate the relationship between ΔFD_z and ΔX_z (Albqami, 2004; Rose & Miernyk, 1989).

3.2 Second Phase: Finalization of the Decision Criteria

Through an extensive review of previous studies and using experts' opinions, the decision criteria that affect the process of selection of the optimal renewable energy investment are finalized. The expert opinion, which is based on knowledge in the field of renewable energy investment, is obtained.

3.3 Third Phase: IF- VIKOR Group Decision Support framework

3.1.1 Intuitionistic Fuzzy Sets (IFSs)

After the ordinary fuzzy set proposed by Zadeh (1965) to deal with the uncertainty of human judgments, an extension of fuzzy set to intuitionistic the fuzzy Set (IFS) was proposed by Atanassov (1986). An IFS $\tilde{X}$ in a finite set Z is an object having the form: $\tilde{X} = \{< z, \mu_{\tilde{X}}(z), \nu_{\tilde{X}}(z) > / z \in Z\}$. Where the numbers $\mu_{\tilde{X}}(z)$ and $\nu_{\tilde{X}}(z)$ represent the membership degree and the non-membership degree of $z \in Z$ in the subset $\tilde{X}$ of Z , and $\mu_{\tilde{X}}(z)$ and $\nu_{\tilde{X}}(z)$ satisfy $0 \leq \mu_{\tilde{X}}(z) + \nu_{\tilde{X}}(z) \leq 1$. For any element $z \in Z$, $\pi_{\tilde{X}}(z)$ indicates the hesitancy degree $\pi_{\tilde{X}}(z) = 1 - \mu_{\tilde{X}}(z) - \nu_{\tilde{X}}(z)$. For convenience, an intuitionistic fuzzy number (IFN) α denotes as $\alpha = (\mu_{\alpha}, \nu_{\alpha}, \pi_{\alpha})$. Refer to Büyüközkan et al. (2019), and Çalı and Şebnem (2019) for more details regarding the IFS and its mathematical operations.

3.1.2 Calculation Steps for the IF- VIKOR Group Decision Support

This section proposes an IF- VIKOR Group Decision Support methodology with unknown DEs and criteria weights based on Entropy and VIKOR methods under the IF environment. The proposed methodology mainly consists of 8 steps that are explained in detail in this section.

The notations for the proposed IF- VIKOR Group Decision Support methodology are as follows:

$A = \{a_1, a_2, \ldots, a_m\}$ is a set of m feasible alternatives. In this study, the alternatives are the simulated renewable energy investment scenarios.

$C = \{c_1, c_2, \ldots, c_n\}$ is a finite set of n decision criteria with a weight vector $[w_1, w_2, \ldots, w_i]$, where $w_i > 0, i = 1,2, \ldots n, \sum_{i=1}^{n} w_i = 1$.

$D = \{d_1, d_2, \ldots, d_K\}$ is a set of k DEs, D be associated with a weights vector denoted as $[\lambda_1, \lambda_2, \ldots, \lambda_k]$, where $\lambda_k > 0, k = 1,2, \ldots K, \sum_{k=1}^{K} \lambda_k = 1$.

STEP 1: Structuring a hierarchy for decision-making.

Alternatives and decision criteria obtained from first and second phases are used to structure a decision-making hierarchy. The hierarchy involves three levels. The first level is the goal which is to select the optimal renewable energy investment scenario in Saudi Arabia, the second level are the decision criteria $C = \{c_1, c_2, \ldots, c_n\}$, and the third level are the alternatives which are the simulated renewable energy investment scenarios $A = \{a_1, a_2, \ldots, a_m\}$.

STEP 2: Constructing the individual decision matrices.

This step involves getting DEs' judgments on each alternative. This can be achieved by asking each DE to evaluate the alternatives with reference to each criterion using linguistic variables. The linguistic variables (LVs) allow DEs to evaluate the alternatives on each criterion between 'Extremely Poor' to 'Extremely Good', as given in Table 1. Each individual evaluation on alternatives proposed by each DE are indicated by individual decision matrix $R^k = \left[r_{ij}^{(k)}\right]_{m\times n}$. The evaluation value $r_{ij}^{(k)}$ is represented as an IFN, in the form of $\left(\mu_{r_{ij}^{(k)}}, \nu_{r_{ij}^{(k)}}, \pi_{r_{ij}^{(k)}}\right)$, of the alternative a_j according to the attribute c_i for the DEs, d_k, where $j = 1 \dots m;\ i = 1 \dots n;\ k = 1 \dots K$.

Table 1: LVs and Its IFN (Adapted and Modified from Gao et al., 2021)

For the evaluation of alternatives		**For the importance of DEs**	
LVs	**IFNs**	**Linguistic variables**	**IFNs**
Very Poor (VP)	(0.13,0.81,0.06)	Extremely less important (ELI)	(0.13,0.81,0.06)
Poor (P)	(0.17,0.75,0.08)	Very less important (VLI)	(0.17,0.75,0.08)
Medium Poor (MP)	(0.24,0.66,0.1)	Less important (LI)	(0.24,0.66,0.1)
Moderately (M)	(0.43,0.43,0.14)	Important (I)	(0.43,0.43,0.14)
Medium Good (MG)	(0.66,0.24,0.1)	Very important (VI)	(0.66,0.24,0.1)
Good (G)	(0.75,0.17,0.08)	Very very important (VVI)	(0.75,0.17,0.08)
Very Good (VG)	(0.81,0.13,0.06)	Extremely important (EI)	(0.81,0.13,0.06)

STEP 3: Determining the weights of DEs.

The level of importance of each of the DE might not be equal due to their different level of experience and knowledge that influence the overall decision-making process. Thus, the relative importance for each DE, d_k should be determined, which denoted as a weights vector $[\lambda_1, \lambda_2, \dots, \lambda_k]$. Linguistic variables and its IFNs are used for determining the weight of each DE, as shown in Table 1. LVs allow estimating the importance on each DE between 'Extremely Unimportant' and 'Extremely Important' based on their experience, responsibilities and knowledge. Assuming that $Q_k = (\mu_k, \nu_k, \pi_k)$ is representing the importance level of the k-th DE in a form of IFN, the weight, λ_k, can be calculated by following equation (Boran et al., 2009):

$$\lambda_k = \frac{\left[\mu_k + \pi_k\left[\frac{\mu_k}{1-\pi_k}\right]\right]}{\sum_{k=1}^{K}\left[\mu_k + \pi_k\left[\frac{\mu_k}{1-\pi_k}\right]\right]}, \text{ Where } \sum_{k=1}^{K}\lambda_k = 1 \quad (5)$$

STEP 4: Constructing a group decision matrix

All of DEs' opinions will be combined into one group opinion so that the group decision matrix for alternatives can be formed. As the next action, all individual decision matrices $R^k = \left[r_{ij}^{(k)}\right]_{m\times n}$ are aggregated into a group decision matrix $R = \left[r_{ij}\right]_{m\times n}$ using the IF weighted averaging (IFWA) operator as following (Xu, 2014):

$$(6) r_{ij} = \left[1 - \prod_{k=1}^{K}\left(1-\mu_{ij}^{(k)}\right)^{\lambda_k}, \prod_{k=1}^{K}\left(\nu_{ij}^{(k)}\right)^{\lambda_k}, \prod_{k=1}^{K}\left(1-\mu_{ij}^{(k)}\right)^{\lambda_k} - \prod_{k=1}^{K}\left(\nu_{ij}^{(k)}\right)^{\lambda_k}\right]$$

Where $r_{ij} = (\mu_{ij}, \nu_{ij}, \pi_{ij})$ denotes the evaluation value of the alternative a_j according to the criteria c_i according to group evaluation, where $j = 1 \dots m;\ i = 1 \dots n$.

STEP 5: Computing the weights of criteria.

The weights of criteria have a significant effect on solving of MCGDM problems (Çalı and Şebnem, 2019). Thus, the process of deriving criteria weights is critical in MCGDM problems. Form the group decision matrix, the weight vector of criteria, $[w_1, w_2, \dots w_i]$ can be computed by utilizing IF entropy method as following equations (Büyüközkan et al., 2019):

$$E(x_i) = -\frac{1}{m\ ln2}\sum_{j=1}^{m}\left[\mu_{ij}\ln\mu_{ij} + \nu_{ij}\ln\nu_{ij} - \left(1-\pi_{ij}\right)\ln\left(1-\pi_{ij}\right) - \pi_{ij}\ln 2\right] \quad (7)$$

$$w_i = \frac{1-E(x_i)}{\sum_{i=1}^{n} 1-E(x_i)} \quad (8)$$

Where $E(x_i)$ indicates the entropy of the criteria c_i where $i = 1 \dots n\ ; \sum_{i=1}^{n} w_i = 1$.

STEP 6: Finding the IF-positive ideal solution (IFPIS) and IF-negative ideal solution (IFNIS).

Here, decision criteria are categorized into benefit criteria set and cost criteria set. That can be done by determining the best $f_i^{+} = (\mu_i^{+}, \nu_i^{+}, \pi_i^{+})$ (denoted as IFPIS) and the worst $f_i^{-} = (\mu_i^{-}, \nu_i^{-}, \pi_i^{-})$ (denoted as IFNIS) values of evaluations of alternatives j $(j = 1, \dots, m)$ by each criterion i $(i = 1, \dots, n)$ (Krishankumar et al., 2020).

$$f_i^{+} = \begin{cases} \max\limits_j r_{ij} & \text{, for the benefit criteria} \\ \min\limits_j r_{ij} & \text{, for the cost criteria} \end{cases} ;\ f_i^{-} = \begin{cases} \min\limits_j r_{ij} & \text{, for the benefit criteria} \\ \max\limits_j r_{ij} & \text{, for the cost criteria} \end{cases} \quad (9)$$

STEP 7: Calculating the individual regret value, group utility value, and rank coefficient for each alternative.

Here, group utility (S_j) and individual regret (R_j) for alternative a_j is calculated according to following equations (Xu, 2014):

$$S_j = \sum_{i=1}^{m} w_i \frac{\sqrt{\frac{1}{2}\left[\left(\mu_i^{+}-\mu_{ij}\right)^2+\left(\nu_i^{+}-\nu_{ij}\right)^2+\left(\pi_i^{+}-\pi_{ij}\right)^2\right]}}{\sqrt{\frac{1}{2}[(\mu_i^{+}-\mu_i^{-})^2+(\nu_i^{+}-\nu_i^{-})^2+(\pi_i^{+}-\pi_i^{-})^2]}} \quad (10)$$

$$R_j = \max_i\left[w_i \frac{\sqrt{\frac{1}{2}\left[\left(\mu_i^{+}-\mu_{ij}\right)^2+\left(\nu_i^{+}-\nu_{ij}\right)^2+\left(\pi_i^{+}-\pi_{ij}\right)^2\right]}}{\sqrt{\frac{1}{2}[(\mu_i^{+}-\mu_i^{-})^2+(\nu_i^{+}-\nu_i^{-})^2+(\pi_i^{+}-\pi_i^{-})^2]}}\right] \quad (11)$$

Then, the rank coefficient Q_j that will prioritize the alternative a_j is computing as follow (Krishankumar et al., 2020, Tian et al., 2021):

$$Q_j = \gamma \frac{(S_j - S^+)}{(S^- - S^+)} + (1-\gamma)\frac{(R_j - R^+)}{(R^- - R^+)} \tag{12}$$

where $S^+ = \min_j S_j$, $S^- = \max_j S_j$, $R^+ = \min_j R_j$, $R^- = \max_j R_j$, γ is introduced as a weight for the decision making strategy of maximum group utility, whereas $(1-\gamma)$ is the weight of the individual regret. The value of γ lies in the range of $[0,1]$. Assigning the value of γ depends on the desired level to be achieved of the consensus within the group decision-making process as follows:

- If $\gamma > 0.5$, it denotes that the evaluation process will place higher importance on the group utility (S_j), i.e., satisfying the evaluation judgment of the majority of DEs. The evaluation process could be "voting by majority rule".
- If $\gamma < 0.5$, it indicates that the evaluation process will give higher weighting to individual regret (R_j). The evaluation process could be "with veto".
- In order to maximize the group utility (S_j) and minimize individual regret (R_j) a balanced value i.e., $\gamma = 0.5$ is given. It ensure consensus in the group evaluation process.

STEP 8: Ranking the alternatives and proposing a compromise solution.

The values of S_j, R_j, and Q_j are organized in the decreasing order and a compromise solution is proposed as the best ranked alternative $a^*$by the minimal Q index, subject to simultaneously satisfying the following conditions (Tian et al., 2021):

- **Condition 1**: $Q(a^{**}) - Q(a^*) \geq \frac{1}{m-1}$, where $a^{**}$is the alternative that is ranked second by Q, and m is the overall number of alternatives.

- **Condition 2**: Alternative a^* is also ranked first, according to S and R.

If one of the conditions is not satisfied, then a set of compromise solutions is proposed, as follows:

- Alternatives a^* and a^{**} represent the compromise solutions if only condition 2 is not satisfied.
- Alternatives $a_1, a_2, \ldots, a_j$ represent the compromise solutions if condition 1 is not satisfied, where:

$$Q(a_j) - Q(a^*) < \frac{1}{m-1} \tag{13}$$

STEP 9: Validating the generated ranking result.

4. Application of Proposed Methodology for Analyzing Renewable Energy Investments in Saudi Arabia

In this section, renewable Energy Investments in Saudi Arabia is investigated and analyzed by employing the three phases of the proposed research methodology.

4.1 First Phase: Data for Simulation and Its Results

In this phase, Leontief's method has been applied to estimate the impact of investment in renewable energy through three main scenarios (Investment of 112, 75, and 25 billion Saudi Riyals). In this regard, Leontief IO model's Eqs. (1)-(4) have been utilized and by considering 17 sectors in an IO table (see Appendix A), which are agriculture and forestry (ACT1); fishing (ACT2); crude petroleum and natural gas extraction (ACT3); other mining (ACT4); petroleum refining (ACT5); other manufacturing (ACT6); electricity, gas, and water (ACT7); construction (ACT8); wholesale and retail trade (ACT9); restaurants and hotels (ACT 10); transport, storage, and communication (ACT11); finance, insurance, and real estate (ACT12); business services and ownership of dwellings (imputed rent) (ACT13); public administration and defense and compulsory social security (ACT14); education (ACT15); health and social work (ACT16); and other community, social, and personal service activities (ACT17). The other is the final demand sector (government, household, stock change, and trade) (see Appendix B). Appendix C concludes the total value added with its distribution into the compensation of employees, other taxes less subsidies, and the operating surplus.

The three-estimated scenarios have different economic outcomes based on the amount of investment in the renewable energy sector inside the Kingdom of Saudi Arabia. The purpose of having these scenarios is to compare the cost of investment in renewable energy and its outcomes. The contribution of investing in renewable energy during the period between 2020 to 2030 (to the GDP, Labor Market, Carbon Emission, and Renewable energy) with three scenarios are depicted in Table 2 based on the Supply and used table for 2018 (see Appendix A).

Table 2: The Estimated Contributions of Three Scenarios

		Estimation Indicators				
		Investment amount	Additional growth in GDP	New Jobs (Direct, indirect, Induce)*	Carbon Emission	Renewable energy
Possible Investment scenarios between 2020 to 2030	Based scenario	SR 112 billion ($ 30 billion)	3.4 %	614,743	40 million tons	60 GW
	Alternative scenario 1	SR 75 billion ($ 20 billion)	2.3%	411,659	27 million tons	40 GW
	Alternative scenario 2	SR 25 billion ($ 6.6 billion)	0.8 %	137,219	7 million tons	10 GW

Source: Vision 2030 & researchers' calculation
* The number of new jobs would count for Tier I, Tier II & Tier III jobs

The amount of outcomes from the three scenarios are different based on the level of investments in the domestic renewable energy sector. According to Table 2, the additional growth into the local Saudi economic growth from new investment in renewable energy during the period between 2020 to 2030 is estimated to be around 3.4 percent for the based scenario. In addition, the additional growth into the GDP would be 2.3 and 0.8 percent for the alternative one and two scenarios. The Saudi Vision 2030 efforts toward diversification have been conducted in our calculation. It means the contribution of investment in renewable energy would be higher in the second half of these ten years as many Saudi efforts toward diversification would be established. Overall, the average contribution to the GDP for the second and third scenarios is around 2.3 and 0.8 percent, respectively. It concluded that additional investment in renewable energy would positively affect the expansion in the local economic sectors. This flow of investments in renewable energy would directly increase demand on the first layers, namely, the economic activities directly related to renewable energy. More demand on the first layer of the economic activities would flow to the second and third layers and so on. To increase the multiplier of new renewable energy investment, it should have a healthy development local sector of production.

This research calculates the estimated number of new jobs that would be generated by investing in renewable energy. The main assumptions were used in calculating the number of jobs that would be generated directly in the main activities related to renewable energy. A number of jobs would open in other economic production sectors, and these jobs are counted as well. These newly employed laborers would create a new demand on the local services such as restaurants, hospitals, schools, and so on. Therefore, the total number of new permanent jobs expected to be generated by investment in renewable energy should be more than 600 thousand jobs for the based scenario, and around 400 thousand jobs and more than 130 thousand jobs for the alternative 2 and 3 respectively.

In addition, the amount of electricity that would be resulting from investment in renewable energy was estimated for the based and alternative scenarios, and it would be used for domestic electricity consumption. There will be more than 60 GW generated from the based scenario. The alternative scenarios are expected to generate 40 GW and 10 GW. Using renewable energy as a supplement source of energy would help in reducing the domestic consumption of oil. Using less fossil fuel domestically would increase the energy available for export and reduce carbon emission by 40 million tons for based scenarios. The amount of carbon emissions expected to decline for alternative scenarios is 27 and 7 million tons for alternative scenarios.

4.2 Second Phase: Evaluation of the Decision Criteria

A systematic method is carried out to identify relevant decision criteria that affect the process of selecting the optimal renewable energy investment from the published literature. Opinions from experts in the renewable energy sector have been collected to help in finalizing the decision criteria. Each identified criterion is defined below:

Economic criterion ($\mathbf{c_1}$): It presents the economic benefits\costs of investment in renewable energy

(Al-Darraji & Bakir, 2020; Asplund, 2008). Studying the economic impact of investment in renewable energy should be through two primary methods, which are 'up to down' or 'down to up.' The evaluation of the amount of change in some economic variables is going to be through a number of new occupations, income, and expansion in the domestic sectors of production (Bacon and Kojima, 2011; Alvarez, Jara, Julián & Bielsa, 2010). According to the literature, investment in renewable energy is a promising strategy for enhancing economic growth, diversification, and guaranteeing a more stable and sustainable economy (Alawaji, 2001; Al-Karaghouli, Renne, & Kazmerski, 2009; Alshehry & Belloumi, 2015; AlYahya, & Irfan, 2016). Renewable energy was found to have a high value-added and labor multiplier due to its comprehensive interaction into the direct, indirect, and induced economic activities (Al Yousif, 2018; Soummane, Ghersi, & Lefèvre,2019; Dvořák, Van der Horst, & Turečková, 2017). In addition, a wide range of economic sectors would expand their current production capacities to match the new demand for new renewable energy projects. Furthermore, investment in renewable energy guarantees a high level of stable and sustainable economic growth (Dincer, 2000; Mahjabeen, Shah, Chughtai, & Simonetti, 2020; Awodumi & Adewuyi, 2020; Khan, Peng, & Li, 2019).

Environmental criterion (c_2): Environmental contributions have vital and important benefits from investments in the renewable energy sector (Dvořák et al., 2017; Anwar, et al., 2021; Karatop et al., 2021). These environmental contributions have positive impacts in terms of the landscape effects, effects on wildlife and changes in air pollution (Bergmann et al., 2006). Therefore, the renewable energy sector is considered as a clean foundation of energy that minimizes environmental degradation (Bergmann et al., 2006; Panwar et al., 2011; Anwar, et al., 2021). Indeed, the renewable energy sources play a significant role in climate change mitigation and stabilization (Luderer et al., 2013; Quaschning, 2019; Sarkodie et al., 2020). Moreover, investment in renewable energy sources is an essential tool to fight against environmental pollution and increased emissions such as Carbon dioxide (CO2) emission, Sulfur dioxide (SO2) emission and Nitrogen oxides (NOx) emission (Liu, 2014; Waheed et al., 2018; Anwar, et al., 2021; Karatop et al., 2021).

Social criterion (c_3): It reviews the social benefits from investment in renewable energy. From the literature, for instance, investment in renewable energy is a promising strategy for reducing the level of unemployment (Lehr, Nitsch, Kratzat, Lutz, & Edler, 2008; Sastresa et al., 2010; Khobai, Kolisi, Moyo, Anyikwa, & Dingela, 2020; El Moummy, Salmi, & Baddih, 2021). Unemployment has many disadvantageous effects on society, such as increased crime rate among unemployed citizens as crime represents an alternative source of money (Darity, 1999; Kaboub, Forstater, & Kelsay, 2015). Furthermore, the other social cost of unemployment includes divorce, addiction to illegal drugs, and school dropout (Darity, 1999; Kaboub et al., 2015). Indeed, Investment in renewable energy sector plays an important role for the creation of new jobs called 'green jobs', which leads to new job opportunities (Dvořák et al., 2017;

Kaya et al., 2019). In the literature, significant impacts of the investment in renewable energy sector on domestic labor markets and social stabilization have been indicated (Dvořák et al., 2017; Kaya et al., 2019; Sohag et al., 2019; Majid, 2020). On the other hand, investment in the renewable energy sector is a favorable strategy for increasing the level of prosperity and life expectation, which depend on many factors such as increasing income, low level of poverty, lower level of unemployment, high level of skills and education, and healthier weather (Rolston, 2011; Bayram, 2012; Holt, Pressman, & Spash, 2009). According to some study, increasing demand on the local goods and services from new investment in renewable energy would reduce the level of domestic unemployment (Lehr et al, 2008; Pestel, 2014; El Moummy, Salmi, & Baddih, 2021). Taking into account that the cost of renewable energy is still more expensive compared to the conventional source of energy, this new source of energy, therefore, needs to produce at a high level of efficiency. Automation of the manufacturing of renewable energy products should require highly skilled laborers, who can deal with this high level of technology framework of production. Therefore, the investment in education and innovation should be increased to produce laborers that are more skilled. Reducing the level of unemployment and increasing the level of education and income among society members would directly contribute to reducing the level of poverty and having cleaner air and a healthier environment (Hostettler, Gadgil, & Hazboun, 2015; Vasylieva, Lyulyov, Bilan, & Streimikiene, 2019).

Public preferences criterion (c_4): It is an important aspect to take into account in terms of renewable energy investment process. In general, this criterion includes benefited residents and social acceptability (Kaya and Kahraman, 2010; Liu, 2014; Al Garni, 2016; Alipour et al., 2017; Dvořák et al., 2017; Kaya et al., 2019; Sohag et al., 2019; Majid, 2020). Benefited residents index is a very important inductor that should be included in the renewable energy investment selection process (Alipour et al., 2017). Indeed, the benefited residents index measures how much residents are benefiting from the renewable energy sector (San Cristóbal, 2011; Alipour et al., 2017). Furthermore, social acceptability is an extremely important indicator since the opinion of the population may heavily influence the renewable energy investment selection process (Kaya and Kahraman, 2010; Liu, 2014; Al Garni, 2016; Kaya et al., 2019).

Risk criterion (c_5): This criterion seeks to discuss risks related to investment in renewable energy. According to the literature, there are different types of risks (Huber et al., 2005; Nuriyev et al., 2019). The primary risks for investing in renewable energy could be in energy price and financing (Guerrero-Liquet, 2016). The efficiency of renewable energy is still lower than conventional sources of energy, such as fossil fuel or coal (Ioannou & Brennan, 2017). In addition, the high initial costs, the lower efficiency of production, and unpredictable weather conditions are problems associated with less carbon sources of energy (Egli, 2020). Due to these two problems, renewable energy investors have difficulty obtaining financing for their projects. Moreover, the price risk related to the continuous fluctuation of oil prices is another problem, as a slight drop in oil prices will cause a simultaneous decrease in demand for renewable energy. Other researchers mentioned that the policy risk is usually associated with the government's commitment to support investment in renewable energy (Egli, 2020). Finally, there is a shortage of data availability and assessment tools for researchers and investors, making the future of renewable energy more uncertain (Guerrero-Liquet, 2016).

4.3 Third Phase: Evaluation Steps of IF- VIKOR Group Decision Support Framework

Based on the two pervious phases, three potential simulated investment scenarios: ‘‘Based Scenario’’ (a_1), ‘‘Alternative Scenario 1’’ (a_2), and ‘‘Alternative Scenario 2’’ (a_3), are considered to be evaluated with respect to five criteria: ‘‘Economic criterion’’ (c_1), ‘‘Environmental criterion’’ (c_2), ‘‘Social criterion’’ (c_3), ‘‘Public preferences criterion’’ (c_4), and ‘‘Risk criterion ’’ (c_5). The group decision-making procedure is conducted by a group of seven highly experienced DEs $\{d_1, d_2, d_3, d_4, d_5, d_6, d_7\}$ knowledgeable in the current renewable energy system of Saudi Arabia. The goal of the decision problem is defined as analyzing and selecting an optimal renewable energy investment scenario in Saudi Arabia. In order to generate evaluations of these decision criteria and select the optimal investment scenario, the IF-VIKOR Group Decision Support is applied as follows:

STEP 1: The hierarchical structure of the evaluation and the selection of a renewable energy investments plan in Saudi Arabia is structured and shown in Figure 2.

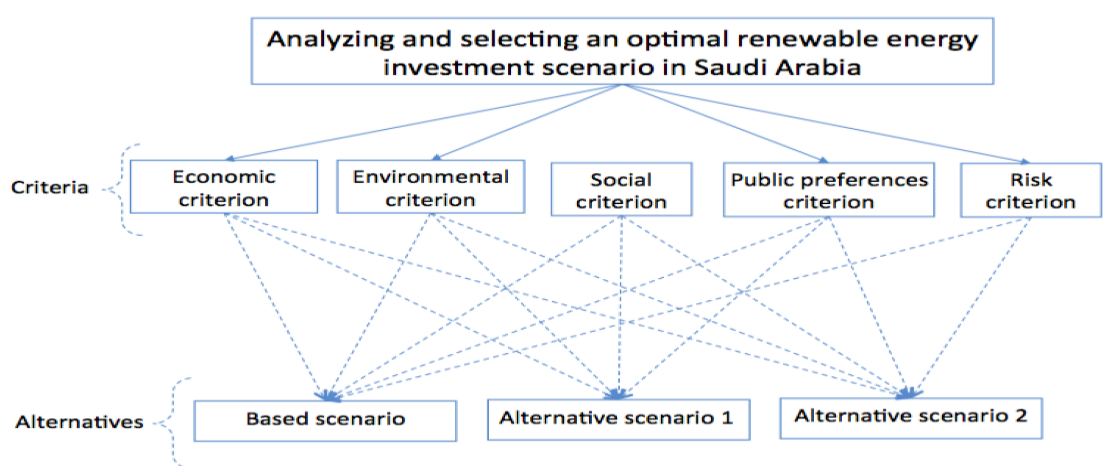

Figure 2: The Hierarchical Structure of the Renewable Energy Investment Scenarios Evaluation Model in Saudi Arabia

STEP 2: Each DE in the group was consulted to make an individual decision matrix. The opinions of all of the consulted DEs are gathered through a designed electronic questionnaire to assess the scenarios with respect to the evaluation criteria. Seven individual decision matrices were depicted in Table 3 by using

LVs and its IFN in Table1. The electronic questionnaire has been designed via Qualtrics Surveys Software.

Table 3: Evaluation Matrices by DEs Regarding Three Potential Investment Scenarios in the Form of LVs.

DEs	Alternatives scenarios	Criteria				
		c_1	c_2	c_3	c_4	c_5
d_1	a_1	VG	G	G	M	M
	a_2	G	MG	VG	M	MP
	a_3	MP	P	M	M	M
d_2	a_1	MG	MG	MG	M	MP
	a_2	M	M	M	M	MP
	a_3	P	MP	MP	M	M
d_3	a_1	MG	VP	MP	MP	M
	a_2	M	P	M	MP	M
	a_3	M	P	M	MP	M
d_4	a_1	VG	VG	G	M	M
	a_2	MG	M	M	MP	M
	a_3	MP	P	P	P	M
d_5	a_1	G	VG	G	G	P
	a_2	MG	G	MG	G	MP
	a_3	M	MG	M	G	M
d_6	a_1	VG	VG	VG	MG	M
	a_2	G	G	G	M	M
	a_3	G	G	G	M	M
d_7	a_1	G	VG	G	G	P
	a_2	MG	G	MG	G	MP
	a_3	M	MG	M	G	M

STEP 3: The importance of DEs has been measured in the form of LVs as {VI, I, VI, LI, VVI, LI, EI}. First, the DEs were asked to evaluate their knowledge of the investment in renewable energy sector. Secondly, they asked to provide some information about their position and the number of years of experience they have in this field. Later, the LVs scale presented in Table 1 was used for these purposes and adapted to our electronic questionnaire. By utilizing Table 1 and Eq. (5), the weights λ_k of DEs, $d_k;\ k = 1,2, \dots 7$, respectively, are achieved as $[0.18, 0.11, 0.18, 0.06, 0.2, 0.06, 0.21]$.

STEP 4: Considering the DEs' weights with the use of Eq. (6), all seven DEs' opinions are aggregated, and then the aggregated group decision matrix is constructed in Table 4.

Table 4: Aggregated Group Decision Matrix

Alternatives scenarios	Criteria				
	c_1	c_2	c_3	c_4	c_5
a_1	(0.793, 0.219, 0.097)	(0.77, 0.385, 0.086)	(0.744, 0.332, 0.102)	(0.606, 0.469, 0.13)	(0.312, 0.712, 0.121)
a_2	(0.668, 0.355, 0.131)	(0.659, 0.442, 0.118)	(0.639, 0.376, 0.137)	(0.606, 0.469, 0.13)	(0.37, 0.641, 0.136)
a_3	(0.414, 0.634, 0.134)	(0.495, 0.639, 0.108)	(0.455, 0.568, 0.145)	(0.604, 0.479, 0.129)	(0.485, 0.485, 0.163)

STEP 5: Based on Table 4 and employing Eq. (7) and Eq. (8), the evaluation criteria weights are calculated. Accordingly, prioritization of the evaluation criteria in terms of their impact on the simulated investments scenarios is given in Table 5. ‘‘Economic criterion’’ (c_1) is the most important criterion, followed by ‘‘Environmental criterion’’ (c_2), ‘‘Social criterion’’ (c_3), ‘‘Risk criterion ’’ (c_5) and ‘‘Public preferences criterion’’ (c_4).

Table 5: Weights of evaluation criteria.

Criteria	c_1	c_2	c_3	c_4	c_5
Weights	0.297	0.254	0.181	0.124	0.144

STEP 6: Economic, environmental, social, and public preferences are benefit criteria, and risk is a cost criterion; hence, utilizing Eq. (9) to determinate the values of IFPIS and IFNIS as seen below:

$$f_1^+ = (0.793, 0.219, 0.097), f_2^+ = (0.77, 0.385, 0.086), f_3^+ = (0.744, 0.332, 0.102),$$
$$f_4^+ = (0.606, 0.469, 0.13), f_5^+ = (0.312, 0.712, 0.121)$$

$$f_1^- = (0.414, 0.634, 0.134), f_2^- = (0.495, 0.639, 0.108), f_3^- = (0.455, 0.568, 0.145),$$
$$f_4^- = (0.604, 0.479, 0.129), f_5^- = (0.485, 0.485, 0.163)$$

STEP 7 & 8: Utilizing Eqs. (10)–(12) to compute the values S_j , R_j and Q_j for each alternative a_j ($j = 1,2,3$), respectively, and ranking the alternatives by sorting S_j , R_j and Q_j in a decreasing order as presented in Table 6. Depends on the Q_j values in Table 6; the ranking of the investments scenarios from top to bottom order are alternative scenario 1, based scenario and alternative scenario 2.

Table 6: Decision Indexes results

Indexes	a_1	a_2	a_3	Ranking order
S	3.7E-09	0.29	1	$a_1 > a_2 > a_3$
R	2.6E-09	0.099	0.297	$a_1 > a_2 > a_3$
$Q\ (\gamma = 0.5)$	0	0.311	1	$a_1 > a_2 > a_3$

According to the results from Table 6, “based scenario” is in the first ranking position because it has the minimum rank coefficient (Q) if we consider the decision-making process could be “by consensus” ($\gamma = 0.5$). The “alternative scenario 1” is ranked second. Additionally, the ranking coefficients (Q) for “based scenario” and “alternative scenario 1” are in closeness. However, condition 2 is satisfied but condition 1 is not satisfied ($Q\ (a_2) - Q\ (a_1) = 0.311 < \frac{1}{1-m} = 0.5$). From Eq. (13), the maximum value of j as $j = 2$ is determined. Thus, a_1: “based scenario” and a_2: “alternative scenario 1” are compromise plans to be selected for the future investments in renewable energy sector in Saudi Arabia by 2030. That is to say, the DEs expressed more desire to select "based scenario" or "alternative scenario 1" to be a best plan for investments, whereas the "alternative scenario 2" is significantly not preferred.

STEP 9: Sensitivity analysis is performed to check the robustness of the generated ranking result. For that reason, ranking lists based on rank coefficient (Q_j) values by applying the sensitivity analysis is conducted through assigning different weights to the strategy of maximum group utility (γ). In this analysis, 100 cases of changing the parameter (γ) in the interval $[0,1]$ was analyzed and depicted in Figure 3. Thus, this analysis was carried out under all the consensus levels within the group decision-making process. According to the results in Fig. 3, the ranking list is always $a_1 > a_2 > a_3$, when $\gamma \epsilon$ $[0.1]$. From the sensitivity analysis, the results illustrate that condition 2 is satisfied but condition 1 is not satisfied at all 100 cases with different values of (γ). From Figure 3, it can be seen that the gap between (Q_1) and (Q_2) is small and the gap between (Q_1) and (Q_3) is extremely huge. Thus, to conclude, the compromise ranking solutions including: "based scenario" and "alternative scenario 1" are both more preferred and the most desirable options based on DEs' opinion, while the "alternative scenario 2" is not much preferred. In other words, "based scenario" and "alternative scenario 1" are always the compromise investment plans.

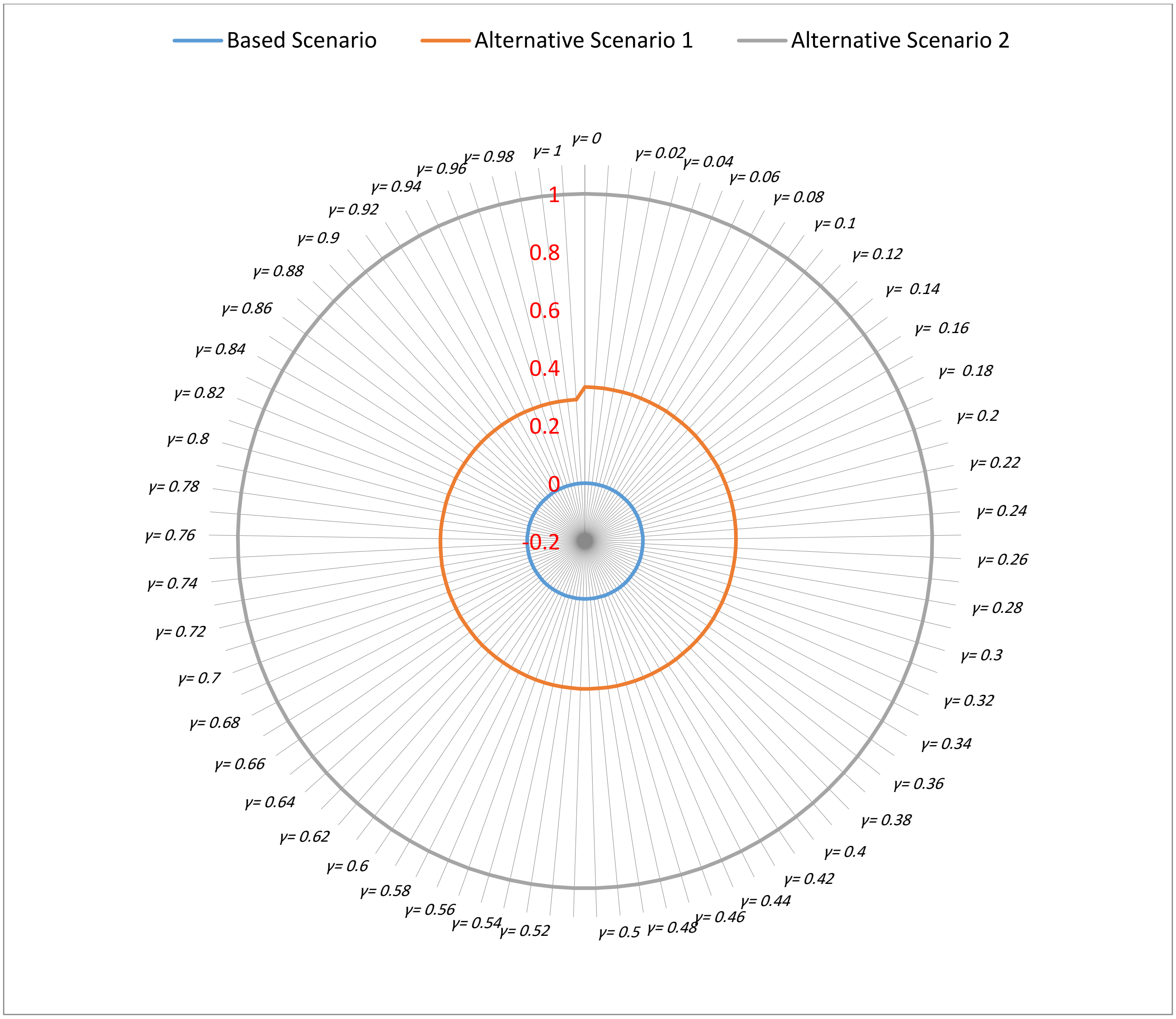

Figure 3: The Results of Sensitivity Analysis.

5. Conclusion and Policy Implications

The main objective of this research paper consists in the importance of investing in renewable energy in the Kingdom of Saudi Arabia as a complementary source of energy, which may contribute to reducing domestic energy consumption and then increasing the export capacity of oil. In addition, the Saudi government can enhance the benefit of investing in renewable energy by localizing its production and supplier chain. Thus, this additional investment would increase domestic economic activities, including construction, manufacturing, services, and utilities. In addition, it can be a good opportunity for the local small and medium enterprises (SMEs) to participate thoughtfully in this new development sector. In fact, there is a wide range of methodologies for generating renewable energy such as solar energy and wind energy, which is associated with a high level of diversification and more new jobs for local citizens (Al-

Gheethi et al., 2015).

To tackle the main objective, this paper proposes a hybrid framework that includes three phases and can assist the policy makers in Saudi Arabia to analyze the potential investment scenarios in renewable energy sector by 2030 and then select a desirable scenario. Moreover, it supports investigating the decision criteria that are needed to evaluate and prioritize in terms of their impact on the simulated investments scenarios. For this purpose, the macroeconomic analysis by using the Leontief's IO model has been applied to determine three main scenarios: "based scenario" (Investment of 112 billion Saudi Riyals), "alternative scenario 1", (Investment of 75 billion Saudi Riyals) and "alternative scenario 2", (Investment of 25 billion Saudi Riyals). Then, five conflicting decision criteria that might affect the process of selecting the best investment scenario have been defined from the literature review and experts opinion, namely: ‘‘Economic criterion’’, ‘‘Environmental criterion’’, ‘‘Social criterion’’, ‘‘Public preferences criterion’’ and ‘‘Risk criterion ’’. Afterward, the IF-VIKOR Group Decision Support has been applied by a set of seven DMs related to renewable energy and is selected to evaluate possible alternatives amongst conflicting criteria. During the evaluation process, IF was applied since DEs prefer to use linguistic terms instead of numerical ones and to tackle the uncertainty in the process of future investment of renewable energy. According to the findings of this paper and relying on DEs' expertise, ‘‘Economic criterion’’ is the most important criterion, followed by ‘‘Environmental criterion’’, ‘‘Social criterion’’, ‘‘Risk criterion ’’ and ‘‘Public preferences criterion’’. Therefore, the government and policy makers in Saudi Arabia should consider diligently the ‘‘Economic criterion’’, ‘‘Environmental criterion’’, and ‘‘Social criterion’’ during the process of selecting the appropriate scenario for renewable investment. From the results of this paper, "based scenario" and "alternative scenario 1" are always the compromise investment plans and the "alternative scenario 2" is not much preferred. Subsequently, these findings indicate that there is a strong potential to invest at least 75 billion Saudi Riyals in the renewable energy sector in Saudi Arabia, which is consistence with the Saudi vision 2030 initiatives. This investment is expected to generate more than 400 thousand new jobs and contribute to the local GDP by more than 2.3 percent during the period between 2020 and 2030. In addition, it is expected to increase the local renewable energy capacity to 40 GW a year and reduce the local carbon emission on average by 27 million tons a year by 2030.

In order to maximize the desired benefits from investing in renewable energy for the Kingdom of Saudi Arabia, the Saudi government has to invest actively in the renewable energy sector; propose financial solutions whether provided directly or as a backup by a government sponsor; and localize relevant supply chains. Localization of renewable energy demand of goods and services would exceed the economic benefits by enhancing development in the local industrial sector. This paper also has some limitations, which can offer scopes for future research. First, this paper just studied five main decision criteria and did not consider their sub-criteria. In future research work, considering more main decision criteria (such as technical criterion) and additional sub-criteria are topics worthy of investigating. Secondly, since the analysis in this paper was conducted based on just a group of seven DEs' opinions, one of the future research studies may invite large numbers of DEs to increase the accuracy of decision process results for the selection of a proper plan for investment in renewable energy in Saudi Arabia. Finally, the proposed hybrid framework methodology could be developed in an interface support system as a web application.

References

Al Garni, H., Kassem, A., Awasthi, A., Komljenovic, D., & Al-Haddad, K. (2016). A multicriteria decision making approach for evaluating renewable power generation sources in Saudi Arabia. Sustainable Energy Technologies and Assessments, 16, 137-150.

Al Yousif, A. (2020). Renewable Energy Challenges and Opportunities in the Kingdom of Saudi Arabia. International Journal of Economics and Finance, Canadian Center of Science and Education, 12(9), pages 1-1, September.

Al Yousif, M. A. (2018). Enhancing development in the Saudi renewable energy sector: A promising strategy for job creation and economic diversification (Doctoral dissertation). University of Missouri, Kansas City.

Al Yousif, M., & Al Bakr, A. (2017). Tourism development effect on saudi economic diversification. SAMA Working Paper, March 2017, http://www. sama. gov. sa/en-US/EconomicResearch/WorkingPapers/Tourism% 20Development% 20Effect% 20On% 20Saudi% 20Economic% 20Diversification. pdf.

Alawaji, S. H. (2001). Evaluation of solar energy research and its applications in Saudi Arabia: 20 years of experience. Renewable and Sustainable Energy Reviews, 5(1), 59-77.

Albqami, R. (2004). Economic impact of tourism sector on Saudi Arabian economy. Paper presented at the International Conference on Input-Output and General Equilibrium, Brussels, Belgium.

Alipour, M., Alighaleh, S., Hafezi, R. and Omranievardi, M., 2017. A new hybrid decision framework for prioritizing funding allocation to Iran's energy sector. Energy, 121, pp.388-402.

Al-Karaghouli, A., Renne, D., & Kazmerski, L. L. (2009). Solar and wind opportunities for water desalination in the Arab regions. Renewable and Sustainable Energy Reviews, 13(9), 2397-2407.

AlKhars, M., Miah, F., Qudrat-Ullah, H., & Kayal, A. (2020). A systematic review of the relationship between energy consumption and economic growth in GCC countries. Sustainability, 12(9), 3845.

Al-Saleh, Y. (2009). Renewable energy scenarios for major oil-producing nations: The case of Saudi Arabia. Futures, 41(9), 650-662.

Alshehry, A. S., & Belloumi, M. (2015). Energy consumption, carbon dioxide emissions and economic growth: The case of Saudi Arabia. Renewable and Sustainable Energy Reviews, 41, 237-247.

Alvarez, G. C., Jara, R. M., Julián, J. R. R., & Bielsa, J. I. G. (2010). Study of the effects on employment of public aid to renewable energy sources. Procesos de mercado: revista europea de economía política, 7(1), 13-70.

AlYahya, S., & Irfan, M. A. (2016). The techno-economic potential of Saudi Arabia's solar industry. Renewable and Sustainable Energy Reviews, 55, 697-702.

Amran, Y. A., Amran, Y. M., Alyousef, R., & Alabduljabbar, H. (2020). Renewable and sustainable energy production in Saudi Arabia according to Saudi Vision 2030; Current status and future prospects. Journal of Cleaner Production, 247, 119602.

Anwar, A., Siddique, M., Dogan, E., & Sharif, A. (2021). The moderating role of renewable and non-renewable energy in environment-income nexus for ASEAN countries: Evidence from Method of Moments Quantile Regression. Renewable Energy, 164, 956-967.

Asplund, R. W. (2008). Profiting from clean energy: A complete guide to trading green in solar, wind, ethanol, fuel cell, carbon credit industries, and more (Vol. 307). John Wiley & Sons.

Atanassov, Intuitionistic fuzzy sets, Fuzzy Sets Syst. 20 (1986) 87–96.

Awodumi, O. B., & Adewuyi, A. O. (2020). The role of non-renewable energy consumption in economic growth and carbon emission: Evidence from oil producing economies in Africa. Energy Strategy Reviews, 27, 100434.

Bacon, R., & Kojima, M. (2011). Issues in estimating the employment generated by energy sector activities.

Baras, A., Bamhair, W., AlKhoshi, Y., Alodan, M., & Engel-Cox, J. (2012, May). Opportunities and challenges of solar energy in Saudi Arabia. In World Renewable Energy Forum", Denver (Vol. 1, p. 4721).

Bayram, S. A. (2012). On the role of intrinsic value in terms of environmental education. Procedia-Social and Behavioral Sciences, 47, 1087-1091.

Bergmann, A., Hanley, N. and Wright, R., 2006. Valuing the attributes of renewable energy investments. Energy policy, 34(9), pp.1004-1014.

Blazquez, J., Hunt, L. C., & Manzano, B. (2017). Oil subsidies and renewable energy in Saudi Arabia: A general equilibrium approach. The Energy Journal, 38, 1-17.

Boran, Fatih Emre, Serkan Genç, Mustafa Kurt, and Diyar Akay. "A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method." Expert systems with applications 36, no. 8 (2009): 11363-11368.

Büyüközkan, G., Göçer, F., & Karabulut, Y. (2019). A new group decision making approach with IF AHP and IF VIKOR for selecting hazardous waste carriers. Measurement, 134, 66-82.

Çalı, S., & Balaman, Ş. Y. (2019). A novel outranking based multi criteria group decision making methodology integrating ELECTRE and VIKOR under intuitionistic fuzzy environment. Expert Systems with Applications, 119, 36-50.

Callen, M. T., Cherif, R., Hasanov, F., Hegazy, M. A., & Khandelwal, P. (2014). Economic diversification in the GCC: Past, present, and future. Washington, DC: International Monetary Fund.

Darity Jr, W. (1999). Who loses from unemployment. Journal of Economic Issues, 33(2), 491-496.

Davar, E. (2000). Leontief and Walras: Input-output and reality. Paper presented at the 13th International Input-Output Association Conference.

Dincer, I. (2000). Renewable energy and sustainable development: a crucial review. Renewable and sustainable energy reviews, 4(2), 157-175.

Durganjali, C. S., Bethanabhotla, S., Kasina, S., & Radhika, S. (2020, March). Recent developments and future advancements in solar panels technology. In Journal of Physics: Conference Series (Vol. 1495, No. 1, p. 012018). IOP Publishing.

Dvořák, P., Martinát, S., Van der Horst, D., Frantál, B., & Turečková, K. (2017). Renewable energy investment and job creation; a cross-sectoral assessment for the Czech Republic with reference to EU benchmarks. Renewable and Sustainable Energy Reviews, 69, 360-368.

Egli, F. (2020). Renewable energy investment risk: An investigation of changes over time and the underlying drivers. Energy Policy, 140, 111428.

El Moummy, C., Salmi, Y., & Baddih, H. (2021). The role of renewable energy sector in reducing unemployment: The Moroccan case. In E3S Web of Conferences (Vol. 234, p. 00101). EDP Sciences.

El-Nakla, S., Yahya, C. B., Peterson, H., Ouda, O. K., & Ouda, M. (2017, May). Renewable energy in Saudi Arabia: current status initiatives and challenges. In IEEE GCC conference.

Ferroukhi, R., Khalid, A., Renner, M., & López-Peña, Á. (2016). Renewable energy and jobs: Annual review 2016. International Renewable Energy Agency (IRENA).

Gao, J., Guo, F., Ma, Z., & Huang, X. (2021). Multi-criteria decision-making framework for large-scale rooftop photovoltaic project site selection based on intuitionistic fuzzy sets. Applied Soft Computing, 102, 107098.

Guerrero-Liquet, G. C., Sánchez-Lozano, J. M., García-Cascales, M. S., Lamata, M. T., & Verdegay, J. L. (2016). Decision-making for risk management in sustainable renewable energy facilities: A case study in the Dominican Republic. *Sustainability*, *8*(5), 455.

Halkos, G. E., & Tzeremes, N. G. (2013). Renewable energy consumption and economic efficiency: Evidence from European countries. Journal of Renewable and Sustainable Energy, 5(4).

Hashemizadeh, A., Ju, Y., Bamakan, S.M.H. and Le, H.P. (2021). Renewable energy investment risk assessment in belt and road initiative countries under uncertainty conditions. Energy, 214, p.118923.

Holt, R. P., Pressman, S., & Spash, C. L. (Eds.). (2009). Post Keynesian and ecological economics: Confronting environmental issues. Cheltenham, UK: Edward Elgar Publishing.

Huber, C., Faber, T., Haas, R., Resch, G., Green, J., Ölz, S., ... & Lins, C. (2005). Green-X. Deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market. Final report of the project Green-X-a research project within the fifth framework programme of the European Commission, supported by DG Research.

Ioannou, A., Angus, A., & Brennan, F. (2017). Risk-based methods for sustainable energy system planning: A review. Renewable and Sustainable Energy Reviews, 74, 602-615.

Ivanovski, K., Hailemariam, A., & Smyth, R. (2021). The effect of renewable and non-renewable energy consumption on economic growth: Non-parametric evidence. Journal of Cleaner Production, 286, 124956.

Kaboub, F., Forstater, M., & Kelsay, M. (2015). The cost of unemployment and the job guarantee alternative in Saudi Arabia. (Policy Report No. 101). Binzagr Institute for Sustainable Prosperity.

Kammen, D. M., Kapadia, K., & Fripp, M. (2004). Putting renewables to work: How many jobs can the clean energy industry generate. Berkeley, CA: University of California, Berkeley.

Kammen, D. M., Kapadia, K., & Fripp, M. (2004). Putting renewables to work: How many jobs can the clean energy industry generate. Berkeley, CA: University of California, Berkeley.

Karatop, B., Taşkan, B., Adar, E., & Kubat, C. (2021). Decision analysis related to the renewable energy investments in Turkey based on a Fuzzy AHP-EDAS-Fuzzy FMEA approach. Computers & Industrial Engineering, 151, 106958.

Kaya, İ., Çolak, M. and Terzi, F., 2019. A comprehensive review of fuzzy multi criteria decision making methodologies for energy policy making. Energy Strategy Reviews, 24, pp.207-228.

Kaya, T. and Kahraman, C., 2010. Multicriteria renewable energy planning using an integrated fuzzy VIKOR & AHP methodology: The case of Istanbul. Energy, 35(6), pp.2517-2527.

Khan, S., Peng, Z., & Li, Y. (2019). Energy consumption, environmental degradation, economic growth and financial development in globe: Dynamic simultaneous equations panel analysis. Energy Reports, 5, 1089-1102.

Khobai, H., Kolisi, N., Moyo, C., Anyikwa, I., & Dingela, S. (2020). Renewable energy consumption and unemployment in South Africa. International Journal of Energy Economics and Policy, 10(2), 170.

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.

Kingdom of Saudi Arabia, Saudi Vision 2030, 2016. National Transformation Program 2020. Saudi Vis. 2030.

Krane, J. (2019). Energy governance in Saudi Arabia: An assessment of the Kingdom's resources, policies, and climate approach.

Krishankumar, R., Premaladha, J., Ravichandran, K. S., Sekar, K. R., Manikandan, R., & Gao, X. Z. (2020). A novel extension to VIKOR method under intuitionistic fuzzy context for solving personnel selection problem. Soft Computing, 24(2), 1063-1081.

Kronenberg, T. (2012). Regional input-output models and the treatment of imports in the European system of accounts (ESA). Jahrbuch Für Regionalwissenschaft, 32(2), 175-191.

Lehr, U., Nitsch, J., Kratzat, M., Lutz, C., & Edler, D. (2008). Renewable energy and employment in Germany. Energy Policy, 36(1), 108-117.

Leontief, W. (1928/1991). The economy as a circular flow. Structural Change and Economic Dynamics, 2(1), 181-212.

Leontief, W. (1936). Quantitative input and output relations in the economic system of the United States. The Review of Economics and Statistics, 18(3), 105-125.

Leontief, W. (1987). The ins and outs of input-output-analysis. Mechanical Engineering, 109(1), 28-35.

Líšková, L. (2015). The strengths and limitations of input-output analysis in evaluating fiscal policy (Master's thesis). Charles University, Prague.

Liu, G. (2014). Development of a general sustainability indicator for renewable energy systems: A review. Renewable and sustainable energy reviews, 31, 611-621. Luderer, G., Krey, V., Calvin, K., Merrick, J., Mima, S., Pietzcker, R., Van Vliet, J. and Wada, K., 2014. The role of renewable energy in climate stabilization: results from the EMF27 scenarios. Climatic change, 123(3), pp.427-441

Mahjabeen, N., Shah, S. Z., Chughtai, S., & Simonetti, B. (2020). Renewable energy, institutional stability, environment and economic growth nexus of D-8 countries.

Majid, M.A., 2020. Renewable energy for sustainable development in India: current status, future prospects, challenges, employment, and investment opportunities. Energy, Sustainability and Society, 10(1), pp.1-36.

Martínez, J. C. C. (1998). Quantification of the socio-economic effects of renewable energy technologies in southern Mediterranean countries: An Input-output evaluation. Work Performed in Partial

Fulfillment of the Joule Contract No JOR-CT95-0066: Task 5-INTERSUDMED Project. Institute for Prospective Technological Studies.

Miller, R. E. (1998). Regional and interregional input-output analysis. In W. Isard et al. (Eds.), Methods of interregional and regional analysis (pp. 41-134). Farnham, UK: Ashgate Publishing Limited.

Miller, R. E., & Blair, P. D. (2009). Input-output analysis: Foundations and extensions. Cambridge, UK: Cambridge University Press.

Mosly, I., & Makki, A. A. (2018). Current status and willingness to adopt renewable energy technologies in Saudi Arabia. Sustainability, 10(11), 4269.

Negewo, B. D. (Ed.). (2012). Renewable energy desalination: an emerging solution to close the water gap in the Middle East and North Africa. World Bank Publications.

Nuriyev, M. N., Mammadov, J., & Mammadov, J. (2019). Renewable energy sources development risk analysis and evaluation: the case of azerbaijan. European Journal of Economics and Business Studies, 5(3), 11-20.

Opricovic, S. (1998). Multicriteria optimization of civil engineering systems. Faculty of Civil Engineering, Belgrade, 2(1), 5-21.

Opricovic, S., & Tzeng, G. H. (2007). Extended VIKOR method in comparison with outranking methods. European journal of operational research, 178(2), 514-529.

Opricovic, S., & Tzeng, G. H. (2004). Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. European journal of operational research, 156(2), 445-455.

Panwar, N.L., Kaushik, S.C. and Kothari, S., 2011. Role of renewable energy sources in environmental protection: A review. Renewable and sustainable energy reviews, 15(3), pp.1513-1524.

Park, J. H., Cho, H. J., & Kwun, Y. C. (2013). Extension of the VIKOR method to dynamic intuitionistic fuzzy multiple attribute decision making. Computers & Mathematics with Applications, 65(4), 731-744.

Pestel, N. (2014). Employment effects of green energy policies: Does a switch in energy policy toward more renewable sources create or destroy jobs in an industrial country. IZA World of Labor, 76.

Quaschning, V. V. (2019). Renewable energy and climate change. John Wiley & Sons.

Rambo, K. A., Warsinger, D. M., Shanbhogue, S. J., V, J. H. L., & Ghoniem, A. F. (2017). Water-Energy Nexus in Saudi Arabia. Energy Procedia, 105, 3837–3843. doi: 10.1016/j.egypro.2017.03.782.

Ramli, M. A., & Twaha, S. (2015). Analysis of renewable energy feed-in tariffs in selected regions of the globe: Lessons for Saudi Arabia. Renewable and sustainable energy reviews, 45, 649-661

Rentschler, J., &Bazilian, M. (2017). Policy Monitor—principles for designing effective fossil fuel subsidy reforms. Review of Environmental Economics and Policy, 11(1), 138-155.

Rolston, H. (2011). The future of environmental ethics. Royal Institute of Philosophy Supplements, 69, 1-28.

Rose, A., & Miernyk, W. (1989). Input-output analysis: The first fifty years. Economic Systems Research, 1(2), 229-272.

Safa, H. (2017). The impact of energy on global economy. International Journal of Energy Economics and Policy, 7(2), 287-295.

San Cristóbal, J. R. (2011). Multi-criteria decision-making in the selection of a renewable energy project in Spain: The Vikor method. Renewable energy, 36(2), 498-502.

Sarkodie, S. A., Adams, S., & Leirvik, T. (2020). Foreign direct investment and renewable energy in climate change mitigation: does governance matter?. Journal of Cleaner Production, 263, 121262.

Sastresa, E. L., Usón, A. A., Bribián, I. Z., & Scarpellini, S. (2010). Local impact of renewables on employment: Assessment methodology and case study. Renewable and Sustainable Energy Reviews, 14(2), 679-690.

Sdralevich, M. C. A., Sab, M. R., Zouhar, M. Y., &Albertin, G. (2014). Subsidy reform in the Middle East and North Africa: Recent progress and challenges ahead. International Monetary Fund.

Sen, S., & Ganguly, S. (2017). Opportunities, barriers and issues with renewable energy development: A discussion. Renewable and Sustainable Energy Reviews, 69, 1170-1181.

Sohag, K., Taşkın, F.D. and Malik, M.N., 2019. Green economic growth, cleaner energy and militarization: Evidence from Turkey. Resources Policy, 63, p.101407.

Soummane, S., Ghersi, F., & Lefèvre, J. (2019). Macroeconomic pathways of the Saudi economy: the challenge of global mitigation action versus the opportunity of national energy reforms. Energy Policy, 130, 263-282.

Sung, B., & Park, S. D. (2018). Who drives the transition to a renewable-energy economy? Multi-actor perspective on social innovation. Sustainability, 10(2), 448.

Taher, N., & Hajjar, B. (2014). Energy and environment in Saudi Arabia: Concerns and opportunities. New York, NY: Springer.

Tian, C., Peng, J.J., Zhang, S., Wang, J.Q. and Goh, M., 2021. A sustainability evaluation framework for WET-PPP projects based on a picture fuzzy similarity-based VIKOR method. Journal of Cleaner Production, 289, p.125130.

Tlili, I. (2015). Renewable energy in Saudi Arabia: Current status and future potentials. Environment, Development and Sustainability, 17(4), 859-886.

Vasylieva, T., Lyulyov, O., Bilan, Y., & Streimikiene, D. (2019). Sustainable economic development and greenhouse gas emissions: The dynamic impact of renewable energy consumption, GDP, and corruption. Energies, 12(17), 3289.

Waheed, R., Chang, D., Sarwar, S. and Chen, W., 2018. Forest, agriculture, renewable energy, and CO2 emission. Journal of Cleaner Production, 172, pp.4231-4238.

Wuester, H., Lee, J. J., Lumijarvi, A., Flannery, S., Veilleux, N., & Joubert, A. (2016). Unlocking renewable energy investment: the role of risk mitigation and structured finance. Int Renew Energy Agency IRENA.

Wüstenhagen, R., & Menichetti, E. (2012). Strategic choices for renewable energy investment: Conceptual framework and opportunities for further research. Energy Policy, 40, 1-10.

Xu, Z. (2014). Intuitionistic preference modeling and interactive decision making. Springer Berlin Heidelberg.

Zadeh, L. A. (1965). Fuzzy sets. Information and Control, 8(3), 338–353.

Appendix A

Table A

Saudi Arabia Input and Output for 2018 (SAR Millions)

Sectors	Act(1)	Act(2)	Act(3)	Act(4)	ACT(5)	ACT(6)	ACT(7)	ACT(8)	ACT(9)	ACT(10)	ACT(11)	ACT(12)	ACT(13)	ACT(14)	ACT(15)	ACT(16)	ACT(17)	Inter-Industry Subtotal
Agriculture, Forests	3,755.25	-	691.43	-	1,246.36	39,425.49	-	2,596.21	-	2,921.61	-	-	1,490.91	721.93	726.82	-	452.26	**87,465.00**
Fishing	-	-	-	-	-	3,237.03	-	-	-	225.61	-	-	-	-	-	-	-	**3,339.00**
Crude Petroleum and Natural Gas Extraction	-	-	2,095.61	480.10	63,922.27	82,528.05	9,055.04	11,405.61	-	404.62	8,330.64	-	-	-	528.71	1,059.87	170.27	**154,959.00**
Other Mining	-	-	-	-	-	15,751.07	1,129.28	8,104.79	-	-	-	-	-	-	-	-	-	**28,489.00**
Petroleum Refining	2,361.74	586.90	1,006.26	480.65	2,785.84	18,167.33	5,599.97	3,693.32	2,796.94	912.41	20,362.00	851.59	1,753.92	7,611.00	1,877.86	1,503.17	591.28	**131,546.00**
Other Manufacturing	12,211.75	2,638.68	5,952.07	2,614.55	2,362.00	90,090.14	12,679.11	148,322.32	28,223.54	5,585.43	33,103.17	2,575.64	13,669.69	32,369.30	14,459.07	18,364.55	5,174.76	**372,701.00**
Electricity, Gas, and Water	828.42	137.31	469.82	169.28	1,614.96	20,219.44	981.03	4,529.95	9,542.45	1,304.14	7,818.97	1,135.11	2,775.73	6,866.49	2,858.19	2,678.26	667.26	**66,755.00**
Construction	1,313.06	209.72	851.36	331.42	4,207.68	39,605.33	3,445.75	7,024.19	12,918.17	2,272.67	18,520.16	1,789.41	6,481.39	18,338.08	5,388.50	6,012.56	1,599.95	**135,442.00**
Wholesale and Retail Trade	566.14	95.17	294.03	132.22	1,567.56	8,187.05	831.65	4,585.52	2,730.33	438.75	2,760.08	367.99	845.11	2,160.05	963.90	916.36	292.42	**27,710.00**
Restaurants and Hotels	714.94	-	291.63	-	1,599.10	9,276.11	885.05	5,976.43	4,226.94	483.40	4,069.77	560.72	1,256.69	3,804.76	1,237.41	2,222.09	436.96	**28,065.00**
Transport, Storage, and Communication	1,935.50	513.94	1,624.68	1,332.46	7,247.87	21,077.92	2,788.71	16,587.61	40,920.92	1,004.66	20,673.55	1,408.67	2,848.20	6,625.10	6,296.51	3,560.31	1,206.11	**125,762.00**
Finance, Insurance, and Real Estate	1,258.59	217.73	867.46	356.08	3,811.60	21,876.95	3,462.90	13,273.08	12,883.74	1,934.36	12,213.57	11,473.77	19,334.50	6,846.16	4,235.90	2,885.34	1,507.06	**75,963.00**
Renting and Business Services, Ownership of Dwellings (Imputed Rent)	538.84	182.04	227.82	102.90	1,824.53	13,938.88	1,337.16	6,103.68	17,281.63	616.38	4,875.16	899.41	2,747.30	8,708.05	3,533.36	3,905.43	1,507.50	**78,926.00**
Public Administration and Defense, Compulsory Social Security	506.79	83.10	348.60	114.85	1,759.60	6,956.16	839.90	3,731.42	2,322.47	360.63	2,448.05	358.38	775.14	1,969.42	868.85	878.51	314.71	**15,399.00**
Education	509.63	94.88	261.42	106.98	1,440.01	5,163.02	730.14	-	1,260.57	361.97	2,468.22	324.93	735.33	1,885.65	782.24	804.62	260.48	**9,447.00**
Health and Social Work	713.26	139.91	376.12	171.59	2,372.86	6,439.70	1,184.48	6,545.11	3,422.78	583.70	3,662.16	531.31	1,273.65	3,198.44	1,218.61	1,222.62	432.77	**9,435.00**
Other Community, Social, and Personal Service Activities	195.19	45.08	107.24	44.94	611.73	3,294.00	239.91	1,402.85	1,245.35	132.91	901.54	127.60	457.86	1,398.58	315.48	286.79	131.36	**16,074.00**
Total Input	**26,121.00**	**4,769.00**	**25,495.00**	**5,926.00**	**116,992.00**	**363,796.00**	**40,810.00**	**253,448.00**	**134,782.00**	**18,845.00**	**134,552.00**	**20,137.00**	**45,748.00**	**85,000.00**	**38,248.00**	**39,310.00**	**13,498.00**	**1,367,477.00**

Note. Obtained from the General Authority for Statistics, in addition to authors' calculation

Appendix B

Table B

Final Use (SAR Millions)

Init;	Sectors	Final consumption expenditure by households (FUSE1)	Final consumption expenditure by government (FUSE2)	Total Final consumption expenditure (FUSE3)	Gross fixed capital formation (FUSE4)	Changes in inventories (FUSE5)	Gross fixed capital formation + Change in inventories	Exports of oil	Exports of non-oil goods	Exports of services	EXPORTS (TOTAL)	FINAL USES
ACT(1)	Agriculture, Forests	72,121.26	2,154.22	74,275.48	-	23,851.65	23,851.65	-	5,814.38	-	5,814.38	103,941.52
ACT(2)	Fishing	9,674.40	-	9,674.40	-	93.67	93.67	-	48.90	-	48.90	9,816.97
ACT(3)	Crude Petroleum and Natural Gas Extraction		235.38	235.38	-	1,082.82	1,082.82	704,504.70		-	704,504.70	705,822.90
ACT(4)	Other Mining		123.71	123.71	-	292.71	292.71		3,083.26	-	3,083.26	3,499.68
ACT(5)	Petroleum Refining	46,862.61	-	46,862.61	-	1,703.42	1,703.42	163,937.70		-	163,937.70	212,503.74
ACT(6)	Other Manufacturing	418,801.04	1,474.81	420,275.85	354,193.55	64,075.11	418,268.66	-	226,563.06	-	226,563.06	1,065,107.56
ACT(7)	Electricity, Gas, and Water	62,005.42	11,590.06	73,595.48	-	246.11	246.11	-		4.27	4.27	73,845.86
ACT(8)	Construction	9,527.09	-	9,527.09	264,599.86		264,599.86	-		703.74	703.74	274,830.69
ACT(9)	Wholesale and Retail Trade	19,182.29	-	19,182.29	-			-		88.72	88.72	19,271.01
ACT(10)	Restaurants and Hotels	64,300.51	-	64,300.51	-			-		932.39	932.39	65,232.90
ACT(11)	Transport, Storage, and Communication	66,188.13	10,182.46	76,370.59	-			-		19,117.70	19,117.70	95,488.29
ACT(12)	Finance, Insurance, and Real Estate	15,429.91	1,535.86	16,965.77	-			-		3,551.54	3,551.54	20,517.31
ACT(13)	Renting and Business Services, Ownership of Dwellings (Imputed Rent)	220,300.11	2,511.25	222,811.36	-			-		647.44	647.44	223,458.79
ACT(14)	Public Administration and Defense, Compulsory social security	12,923.13	345,454.76	358,377.89	-			-		-	-	358,377.89
ACT(15)	Education	31,444.24	220,186.21	251,630.45	-			-		-	-	251,630.45
ACT(16)	Health and Social Work	15,670.34	94,824.30	110,494.64	-		-	-		-	-	110,494.64
ACT(17)	Other Community, Social, and Personal Service Activities	20,023.16	35,827.60	55,850.77	-		-	-		225.20	225.20	56,075.96

Note. Obtained from the General Authority for Statistics. In addition to author's calculation.

Appendix C

Table C

Value Added (SAR Millions)

Val	Type	ACT(1)	ACT(2)	ACT(3)	ACT(4)	ACT(5)	ACT(6)	ACT(7)	ACT(8)	ACT(9)	ACT(10)	ACT(11)	ACT(12)	ACT(13)	ACT(14)	ACT(15)	ACT(16)	ACT(17)
Val(1)	Compensation of Employment	8,996.69	385.44	32,967.52	1,311.27	9,347.00	51,911.49	13,897.43	38,379.55	49,065.16	14,850.06	35,170.45	19,116.60	23,352.75	214,317.11	182,673.35	63,072.90	17,430.99
Val(2)	Other Taxes Less Subsidies on Production	15.31	0.77	7,352.63	880.62	2,358.18	3,659.91	753.37	2,798.45	2,057.04	288.52	2,063.15	3,919.82	177.82	-	(108.49)	(250.50)	272.91
Val(3)	Operating Surplus	50,832.57	2,704.17	829,551.35	9,678.70	87,126.82	186,543.81	44,869.57	103,377.65	182,924.65	19,613.23	142,121.11	77,554.41	196,189.63	33,790.13	13,918.20	25,417.48	25,422.90
Total Value Added	Value Added Total	59,844.58	3,090.38	869,871.50	11,870.59	98,832.00	242,115.21	59,520.37	144,555.65	234,046.84	34,751.81	179,354.71	100,590.83	219,720.20	248,107.25	196,483.06	88,239.88	43,126.80

Note. Obtained from the General Authority for Statistics, in addition to authors' calculation