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A Fuzzy PROMETHEE Method for Evaluating Strategies towards a Cross-Country Renewable Energy Cooperation: The Cases of Egypt and Morocco

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Abstract: Recognising the urgency of addressing climate change and the imperative to mitigate its effects, the European Union (EU) has embarked on a transformative journey to reshape its energy landscape, with a pronounced emphasis on harnessing renewable energy sources (RESs) and augmenting their contribution to electricity generation. To propel Europe towards sustainable development through its energy transition, EU member states are encouraged to foster collaborative efforts on a European scale, inviting neighbouring countries to participate in joint ventures aimed at leveraging RESs for electricity generation. Consequently, it becomes imperative to evaluate the potential depth of cooperation among these nations, assessing how such partnerships can align with Europe's overarching objectives while fostering mutually beneficial conditions. This paper seeks to undertake a thorough analysis and evaluation of the potential impacts of such cooperation, both in advancing RES objectives and in promoting broader cooperation goals concerning the countries involved. The appropriate methodological framework has been developed, utilising and implementing the fuzzy PROMETHEE multicriteria decision analysis method, to address the problem's multidimensional character, intending to implement an appropriate action plan and promote production from RESs. The methodology has been applied to assess alternative strategies in two case study countries, Morocco and Egypt, while important outcomes have emerged towards the successful implementation of cooperation mechanisms promoting RES.

Keywords: sustainable development; clean energy transition; regional cooperation; renewable energy sources; electricity production; policymaking; multicriteria decision analysis

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1. Introduction

It has become evident that it is of vital importance to see more progress in the level of ambition and the effectiveness of implementation to be able to achieve the goals related to energy and climate set out in the Paris Climate Agreement and enhanced by the Energy Efficiency Directive [1]. This long-term commitment to reach our zero-carbon transition could be greatly facilitated by cross-border cooperation based on renewable energy sources [2].

The EU pursues to decarbonise its energy system by 2050. There are several drivers that could boost the energy transition, and renewables are becoming increasingly competitive. Transitioning to a low-carbon economy might demand substantial investments [3]. Cost savings and other benefits like supply diversity can be achieved with electricity generated from renewable energy source (RES-E) imports from neighbouring regions like North

Africa [4]. The EU frequently discusses North Africa's potential for a swift transition to renewable energy, recognising it as a key area for supplying clean energy to the European region. North Africa boasts vast renewable energy resources, enough to meet its own energy needs and export to the EU in the future [5].

For instance, Morocco's electricity demand has surged alongside its economic growth, with an average annual increase of 6.5%. In response, energy production in the country expanded significantly, growing by 6–7% annually between 2002 and 2012 to keep up with rising consumption. By 2015, Morocco had an installed electricity capacity of 8154 MW, with 34% coming from renewable energy sources. The country's energy mix in that year was diverse, including solar energy at 2% and wind power at 10% [6]. As part of its development strategy, Morocco is heavily investing in renewable energy and aims to reach 52% of its overall energy capacity from renewable sources by 2030. According to the United Nations Conference on Trade and Development (UNCTAD), in 2021, Morocco secured the ninth-highest level of foreign direct investment in Africa [7]. In recent years, the Moroccan government successfully conducted multiple renewable energy tenders, increasing the country's installed capacity to 1220 MW of wind and 740 MW of solar energy by 2018 [8]. With a coastline spanning 3500 km and wind speeds reaching as high as 11.5 m/s, it is estimated that Morocco's total wind power potential is about 25 GW. When it comes to solar energy, Morocco's geographical location makes its solar potential one of the most notable worldwide, since it is estimated as a potential of over 5 kWh/m^2/day [6]. Another notable example is Egypt, which has an installed capacity of about 1.6 GW of wind power (2.7% of the total energy mix) and about 1.8 GW of solar (1.9% of the total energy mix). Egypt has set ambitious targets when it comes to renewable energy production since in 2035 it aims to generate 42% of its electricity from renewable sources, including 25% from solar, 14% from wind, and 2% from hydropower. The renewable energy potential of the country is notable, and is estimated to be about 7200 MW for wind, mainly exploiting the Gulf of Suez, and about 74 billion MWh per year for solar energy. It should not be neglected that Egypt has made important efforts towards providing a favourable regulatory environment and framework to promote renewable energy investment. Important examples include the Renewable Energy Law (Decree Law 203/2014), aiming to foster a conducive economic environment to boost investment in renewable energy within the country, and Cabinet Decree No. 1947 of the year 2014 on feed-in tariff, laying the foundation for the feed-in tariff scheme for electricity generated from renewable energy projects [9].

From the perspective of the EU, these aspects present an attractive starting point for active RES cooperation and the advancement of cross-border power infrastructures among the areas. The collaboration structures in the context of meeting EU 2030 objectives offer flexibility tools to enhance the cost-effectiveness of achieving the RES targets of the member states. A crucial requirement to achieve RES collaboration between North Africa and the EU is the creation of projects that benefit both North African countries and EU member states, supporting a win–win relationship. The argument of "increased cost-effectiveness for the EU" alone is insufficient and not sustainable, particularly because an approach that exports North Africa's inexpensive energy alternatives would not benefit the area, as it would need to rely on costly options for its own energy needs [10,11]. Nonetheless, certain technologies, like, for example, concentrating solar-thermal power (CSP), have notable potential to support exports without creating competition with domestic supply [12].

Ensuring mutually valuable RES cooperation and win–win projects for the EU and the North African nations will necessitate recognising and making sure that North African countries gain advantages from the synergies as well. A key factor to address in future EU–North Africa cooperation in the energy field, especially as far as RES-E exports from North African countries to the EU are concerned, is the rising of energy demand in the North Africa region [13]. North Africa is able to become a major provider of RES-E exports to the EU, especially between 2030 and 2050. This necessitates a more thorough and deeper exploration of EU–North Africa energy relations and an analysis of the obstacles that need to be addressed so as to advance the cooperation in a way that is broadly beneficial for all the involved parties. For North African countries to position themselves as providers of RES-E exports to the neighbouring areas on a large scale, it is essential to plan and prepare the actions towards the cooperation, jointly and in a short timeframe. Creating a positive environment and favourable conditions for RES-E implementation in the region necessitates several fundamental requirements.

In this context, the goal of the paper is to conduct a complete analysis and evaluation of the potential outcomes of the described cooperation, not only in reaching EU objectives in RES, but also in other sectors (for instance, social and economic impacts) for the countries and regions involved. To be more specific, a suitable methodological framework has been developed, utilising and implementing a multicriteria decision analysis to address the problem's multidimensional character, intending to implement a suitable action plan, and encourage and support clean electricity generation from RES.

Alternative strategies have been identified that are able to support such cooperation and have been assessed with the use of multicriteria analysis, specifically the fuzzy PROMETHEE method. PROMETHEE is an ideal method for the respective problem, as it can rank numerous alternatives considering different and often conflicting criteria while taking into account sustainability characteristics so that the optimal selections for electricity production will be made.

The remaining paper is structured as follows: Section 2 provides an overview of the methodological approach, Section 3 presents the problem formulation, the alternative strategies towards the promotion of cooperation between EU and neighbouring countries, and the evaluation criteria to assess them. It also provides details on the case study countries' profiles, i.e., Egypt and Morocco. Section 4 provides an overview of the multicriteria method that has been used to solve the particular problem, Section 5 presents the application of the proposed methodology and the results obtained, Section 6 is the discussion of the results, and, finally, Section 7 provides the conclusions that have been derived.

2. Overview of the Methodological Approach

Figure 1 depicts the methodological approach that was implemented to assess the suitability and efficacy of alternative strategies in North African countries that could support the deployment of cooperation in the field of RES towards a sustainable future for the European energy sector.

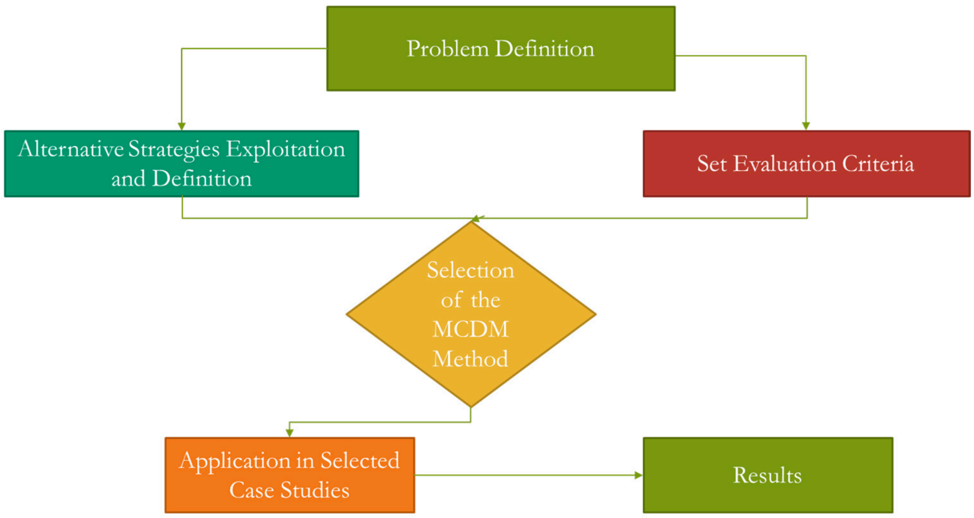

Figure 1. Overview of the proposed workflow.

As a first step, the problem was defined, which entailed the identification of alternative possible strategies that would contribute to the problem's solution. Following that, having considered the particular features of the problem and the corresponding literature, the most suitable MCDM method was chosen. The method was applied with the aim of comparing and prioritising the alternatives from the most to the least preferable based on the value system and perspectives of the decision-makers. Thus, having collected all the necessary information about the strategies and determining the method's parameters, the fuzzy PROMETHEE was implemented. Finally, the extracted rankings were examined and analysed, offering valuable insight with regard to the most appropriate strategies for accomplishing cross-country cooperation among the EU and its neighbouring countries.

3. Problem Formulation

The RES-E capacities and possibilities in North Africa are enormous. Drivers to exploit these in the framework of RES-E collaboration and the necessary activities so as to overcome non-cost barriers and enable new RES-E applications are strongly connected as depicted in Figure 2. We have tried to consider these connections when determining proposed action paths to be followed by North African regions in the near future and in the long run so as to benefit from joint RES-E projects with the EU.

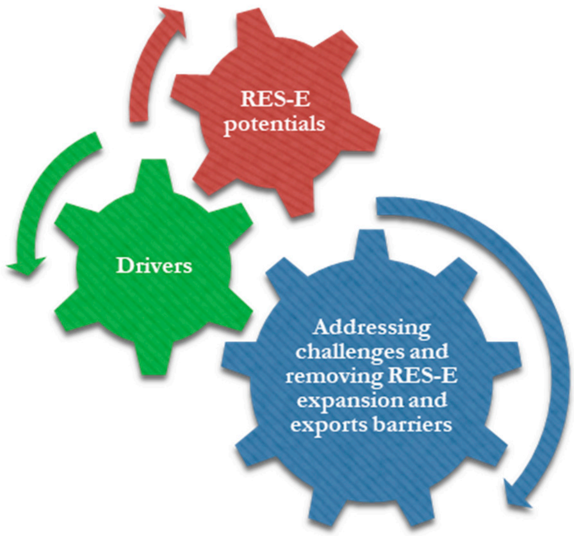

Figure 2. Interlinkage between RES-E potentials, drivers, and challenges.

3.1. Country Profiles

3.1.1. Egypt

Energy Sector Profile

Egypt is one of the major consumers in Africa, by far the largest when oil and gas are considered, consuming 69.4% from gas, 22.4% from oil and other liquids of total African consumption, 7.7% from hydro, and 0.49% from renewable sources [14]. Egypt exports both crude oil and natural gas. Nevertheless, the rising energy demand, combined with the decreasing energy generation, has resulted in a decrease in natural gas exports since 2009 because the government began to deter supplies from exporting gas to meet domestic energy needs. Therefore, Egypt has slowly become a natural gas importer since 2015. Studies have indicated that the energy mix and trend in the country is currently comparable to what is being observed in other emerging economies, where the percentage of RES in energy production is dropping, although RES penetration is increasing. This is due to the fact that energy demand is growing. The RES generation potential is fairly high in Egypt. In particular, wind and solar energy could continuously provide energy services, thus enhancing the security of the energy supply. The Egyptian energy sector is a key driver for Egypt's socioeconomic development, accounting for approximately 13% of the current GDP, and thus economic growth in the country depends on the security and stability of energy supply [15]. The comprehensive Sustainable Energy Strategy 2035, building on previous relevant plans, highlights the significance of renewable energy. Egypt aims to generate 42% of its electricity from RES by 2035, with the private sector anticipated to provide most of this capacity. Furthermore, to support the country in its transition to an energy hub, Egypt has built numerous energy interconnectors.

Investment Profile

Egypt has remained the largest recipient of Foreign Direct Investment (FDI) in Africa, with the United Kingdom being the largest investor. The country saw an increase of USD 2.4 billion in September 2019, compared to an increase of USD 1.3 billion in the previous quarter. Foreign investments in Egypt mainly prioritise the oil and gas industry. The influx of Arab and other foreign investors into the local market has resulted in a reduction in the cost of producing renewable energy in Egypt and is set to boost investment opportunities in the near future. Egypt's Ministry of Electricity has announced the supply of electricity produced by solar and wind sources as a part of the government's initiative to promote RES and address electricity shortages [16]. To push the private sector to generate electricity from RES, Egypt enacted the Renewable Energy Law (Decree No. 203/2014) in 2014. The law proposes various expansion plans for the private deployment of RES-related initiatives, such as competitive bidding, feed-in tariff, and autonomous energy generation via external access. Despite the COVID-19 pandemic, the economy of Egypt witnessed a 3.3 per cent growth over 2020–2021 [17]. Thanks to the successful implementation of IMF-backed structural economic reforms, Egypt is currently in a strong position to incentivise foreign investment into its renewables sector. The investment environment of Egypt, especially during the past few years, saw several legislative and institutional reforms. Despite the negative impact of Russia's invasion of Ukraine, which led foreign investors to flee from emerging markets, Egypt continues to pursue the facilitation and simplification of processes for investors, leading to positive outcomes in companies' integration regarding time, expenses, as well as the amount of procedures and activities required. Consequently, these reforms enabled Egypt to make a significant improvement in the indicator of Ease of doing business rank in 2020, moving up to the 114th place from the 120th rank in the Report of 2019 [18].

Socio-Environmental Profile

From a social point of view, Egypt stands to gain significantly from the advancement of alternative energy sources, since the advantages at the socioeconomic level are undeniable. While there is a notable enhancement of the macroeconomic environment, the social circumstances in the country continue to be challenging. Official assessments indicated that the percentage of the population surviving below the national poverty boundary in the fiscal year 2018 rose to 32.5 percent. The respective value in 2015 was 27.8 percent and the greatest poverty rates were still documented in rural Upper Egypt [19]. The Government of Egypt aided by the World Bank Group has managed to accomplish substantial progress in all three focus areas under the Egypt Country Partnership Framework (CPF) 2015–2019. Policy reforms supported by the US USD 3.15 billion Financial Development Policy Program, consisting of three operations over a three-year period (2015–2017), have reinforced Egypt's reform agenda to strengthen the economy, supporting job creation and sustainable development, particularly in the energy field. The World Bank supports the Egyptian government in mitigating the potential negative impact of the first wave of reforms on the lower and middle classes [19]. Egypt ratified the Paris Agreement on 29 June 2017, and it entered into force on 29 July 2017. The country is familiar with renewable energy technologies, particularly wind energy. Related to this, the current phase of renewable energy development provided a total of 6000 direct and indirect jobs, with solar PV providing only half of the jobs created [15].

3.1.2. Morocco

Energy Sector Profile

Morocco's energy transformation and pathway to a more sustainable energy system has been imperative to secure Morocco's energy supply, meet international targets, and contribute to addressing the climate crisis. By the end of the year 2020, renewable energy comprised 37% of the electrical capacity mix, falling short of the government's Paris Agreement target of 42%. Morocco's energy mix remained, in 2021, dominated by hydrocarbons, which accounted for 52% of the mix, mainly for transport, while coal continued to represent up to 33% of electricity production [20]. In 2022, Morocco's electricity production consisted of coal (37%), hydroelectricity (17%), fuel oil (7%), natural gas (18%), wind (13%), and solar (8%) [21]. Morocco's energy mix is characterised by heavy dependence on fossil fuel imports, leaving the country utterly reliant on external sources to satisfy domestic energy demand. Without a doubt, the deployment of renewable energy infrastructure is a unique opportunity both for Morocco's independence from fossil fuels and energy imports, while also it introduces new energy business models and investment opportunities, considering the potential of green energy exports to Europe.

Investment Profile

In a time of growing international economic instability, Morocco's economic profile manages to remain strong as the country's economy has weathered the broader economic crises of recent years [22]. The majority of the electricity market is close to complete liberalisation, which can improve the chances of RES cooperation between Morocco and European countries, simultaneously fostering and appealing foreign investments, which is an important component of the national strategy. In 2021, Morocco launched a "Green Economy War Room", a centre intending to back up more than 150 diverse investment projects that aim to sustain and enhance Morocco's shift toward a sustainable green economy. The EU is the most crucial economic partner for Morocco, representing well over half of its trade and investment. Subsequently, in February 2022, the EU granted the government of Morocco EUR 1.6 billion worth of funding under the "Global Gateway", so as to mobilise EUR 300 billion over the period 2021–2027 for sustainable projects in the field of infrastructure, digital and climate between the EU and its partners. The projects are selected based on various criteria, including their alignment with the EU strategies and priorities, as well as national development goals. Values also play a significant role in the decision-making process. These might refer to the positive social and environmental impact of the projects and the respect for human rights, among other factors. Furthermore, standards are taken into account, related but not limited to transparency, governance, sustainability, and the mobilisation of investments [23]. According to the latest Doing Business report from the World Bank, Morocco is ranked 53rd out of 190 economies, advancing seven positions from 2019 and moving up 40 spots since 2012 [24]. This progress is attributed to enhanced electricity access, including the introduction of web-based applications for new interlinkages and increasing the exploitation of prebuilt transformers). Additionally, the process of handling construction permits has been streamlined thanks to the improvement of the dedicated online platform.

Socio-Environmental Profile

Like many North African countries, Morocco is especially affected by climate change and potential sea level rise, with significant reliance on water resources, particularly in the agricultural sector. When it comes to Morocco's social sector, despite the generally decent living conditions and the steady growth rates, there are persistent issues of vital importance that are still unsolved, for instance, the elevated unemployment rates, which particularly affect the younger generation [25]. The National Sustainable Development Strategy of Morocco is founded on four key principles: international compliance; compliance—or coherence—with the principles of the National Charter for the Environment and Sustainable Development; stakeholder engagement; and an operational strategy, meaning that it maintains continuity with the already established plans and programmes [26]. The Strategy envisions to "Implement the foundations of a green and inclusive economy in Morocco by 2030". The Strategy notes a requirement for sectors to integrate socio-environmental factors more systematically into their strategic frameworks and recognises that the environmental dimension has been "the poor relation", neglected in efforts towards development. Thus, the Strategy, therefore, pursues to decouple economic development from resource strain while fostering sustainable growth in the environment sector, and the creation of green jobs.

3.2. Alternative Strategies

This section outlines high-level strategies, along with their respective short- and medium-term specific actions required to achieve smooth cross-border cooperation on renewable energy sources among Europe and countries from North Africa.

The strategies were formulated based on the outcomes of the EU-funded project "BETTER—Bringing Europe and Third countries closer together through renewable Energies" (project number: IEE/11/845/SI2.616378), supported by the Intelligent Energy Europe programme. During the EU BETTER project, and as a part of the ongoing efforts outlined in this paper, extensive input was gathered from the stakeholders involved in the renewable energy sector in Egypt and Morocco. This was achieved through structured interviews, questionnaires, and the organization of a Regional Training Workshop in Morocco. The workshop served as a platform for knowledge exchange, allowing policymakers, private sector actors, and NGOs to discuss challenges and opportunities for renewable energy cooperation between North Africa and Europe. In total, approximately 50 stakeholders were consulted, representing a range of groups:

- Government agencies (e.g., Ministries of Energy and electricity regulators);
- Private sector investors (e.g., firms engaged in wind, solar, and hydroelectric projects);
- NGOs and environmental advocacy groups;
- Academia and energy experts.

The strategies emerging provided a foundation for selecting the most appropriate and attractive energy cooperation scenarios. Using the data gathered from stakeholder input, we refined these strategies and subjected them to a multicriteria decision support analysis (MCDA) to assist in evaluating different pathways. The goal was to support policymakers and relevant actors in identifying strategies that could foster successful EU–North Africa energy cooperation while considering economic, regulatory, and socio-environmental factors.

Strategy 1*: *Accelerate RES-E expansion in North Africa

Short-term action 1: Establish a comprehensive legislative and regulatory framework at the national level. (**A_1**)

Legislative and regulatory confidence, assurance, and stability are very influential aspects of the beneficial implementation of RES-E initiatives. North African nations have progressed significantly towards making their legal and regulatory framework for deploying more robust RES/RES-E, adopting and establishing laws covering the promotion of renewable energy [11]. Regulatory issues related to project development and project financings have been addressed, including contracting procedures of public entities, land tenure rights, Energy Performance Contracts (EPCs), subsidy rights and Power Purchase Agreements (PPAs), investment protection, and dispute resolution. However, the existing regulatory framework might still not suffice to create an environment of certainty and stability when it comes to investment, particularly to attract foreign investors into the new RES-E production; thus, more efforts are necessary to guarantee the proper design and functionality of legal and regulatory frameworks [27].

The anticipated results of this short-term action are an enhanced framework for both domestic and foreign RES-E investments, and mitigated risks not only at the country level but also at the project level. It is necessary to ensure the clarity and transparency of the roles and responsibilities in the energy ecosystem, primarily when it comes to RES-E incorporation. The roles and responsibilities have to be anchored in national legislation.

Short-term action 2: Ensure efficient RES authorities. (**A_2**)

During the previous years, North African countries have taken steps towards founding authorities delegated to deploy policies and measures committed to RES-E promotion. These authorities need to have the capacity and resources to implement their mandates effectively. In certain cases, the insufficiency of resources and knowledge is impeding the capacity of the authorities to deliver the required services to expand RES-E deployment.

The anticipated result of this short-term action is well-functioning authorities mandated to deploy policies and measures to expand RES-E generation. To achieve that, obligations for RES-E production and development should be assigned specifically to dedicated authorities. Adequate capacity, resources, and expertise would be needed within these authorities to foster and enable the enhancement of investment frameworks and streamline the design and application of renewable energy projects. This should entail a curtailment of required administrative efforts for the involved actors, such as effective permitting processes.

Mid-term action 1: Enhance the intra-regional framework to promote further deployment of renewable energy sources. (**A_3**)

The countries of North Africa are not linked to a sufficient extent, and there are possible advantages to be captured from an enhanced balancing of production and demand in the region. In many cases, improved coordination among national frameworks must be pursued. Expanded RES-E exchange between North African countries combined with RES-E development targets should be aligned with the improved balancing of energy consumption and production across the area [28]. This could also alleviate the problem of reliance on external energy imports and form an essential basis for collaboration with the EU in generating renewable energy surpluses for export through equitable and transparent pricing mechanisms.

This mid-term action will lead to better connections between North African countries and create a framework for balancing load, generation, and trade in RES-E at the regional level.

Strategy 2: Develop prospects for RES-E cooperation

Short-term action 1: Detect existing advantages of RES collaboration to be realised by North African countries. (**A_4**)

Conditions that benefit the host North African countries and the EU off-take countries must be pursued. To be more specific, EU countries should be keen to grant an equitable price for the exported renewable electricity generation from North African regions. Additional outcomes, like the creation of employment opportunities or possible growth of local industries, as well as potential negative effects, for example, for the environment, and public support of export-related initiatives need to be taken into account.

This action will lead to a basis for the fair and transparent pricing of exported RES-E from North African nations to the EU nations, as it also aims to create a solid foundation for the specification of RES-E cooperation alternatives. Nonetheless, the detection of specific national costs and profits of alternative cooperation opportunities could back up this action.

Short-term action 2: Conduct pre-feasibility studies to choose suitable RES technologies. (**A_5**)

Considering the potential for RES-E export to the EU, as well as the increased preconditions that need to be met and the difficulties that need to be faced, in comparison with other "standard" RES-E investment opportunities, meticulous (pre-)feasibility studies ought to be conducted to determine the most applicable, practical, and suitable technologies. Specifically, if a large-scale grid expansion or the construction of point-to-point transmission lines are to be implemented, considerable challenges, both economic and technical, have to be dealt with [29].

The desired outcomes of this action are the identification of the most appropriate alternatives for RES-E export to the EU and the conclusion on whether to actually move forward with such an endeavour from a political standpoint. This action could be supported by assessing the commercial, financial, legal, and practical aspects and preconditions for such an endeavour in all the regions to be involved. Additionally, the positions and obligations of the involved stakeholders might have to be elucidated, particularly in cases where financing structures are affected.

Short-term action 3: Create a cross-cutting policy blend to capitalise on the socioeconomic gains. ($\mathbf{A_6}$)

The socioeconomic implications of RES-E growth are of utmost importance. The extension of economic activity and increase in employment opportunities in North Africa due to RES-E growth will be subject to the circumstances of the RES/RES-E sector in the region and the supply of the workforce, which largely depends on expertise, educational background, and capacity building.

The primary anticipated outcome of this short-term action is developing a cross-cutting policy framework, including industrial, educational, and energy considerations, tailored to the different North African countries to maximise value creation through RES-E expansion and energy exchange adapted to the specific national characteristics and needs. The action could be supported by assessing the effect that renewable electricity implementation for exports may have on value creation to support policymaking.

Short-term action 4: Tackle investment risks with the aim of securing financial support. ($\mathbf{A_7}$)

To enable extended RES-E exports to the EU, the investments for RES-E expansion in North Africa would need to be scaled up [27,30]. The interconnections between North Africa and the EU are an important prerequisite to facilitate the collaboration, which contributes to the increase in the investment costs. Countries will have to investigate ways of mitigating risk both on the country and on the project level, emphasising the reduction in capital costs and focusing on attracting financing. The overall rationale resembles risk reduction for domestic supply projects. The difference lies in the greater size of the investments and the higher number of stakeholders involved. Although this adds complexity, the weight of the problem of risk mitigation will have to be shared by the EU collaborators. In addition, developing de-risking mechanisms together with multilateral banks would support this action and speed up the expected result. This would reduce the risk of the RES-E expansion projects (and support the interconnections for export to the EU).

Short-term action 5: Reinforce the framework for the private sector and public-private partnerships in RES-E expansion/export. ($\mathbf{A_8}$)

As explained above in short-term action 4, RES-E expansion for export to the EU at a large scale goes hand in hand with a substantial increase in investments and capital investment needs. Investment costs will rise because of the necessary interconnections between North Africa and the EU costs. For certain North African nations, their rise in financing RES-E may be dependent on the engagement of the private sector in the investment. This action will deliver a policy structure and framework to mobilise private investment to RES-E export initiatives.

Strategy 3*: *Induce social acceptance

Short-term action 1: Involve the civil society in RES-E expansion ventures. ($\mathbf{A_9}$)

Social acceptance may be increased if the public (civil society) is actively engaged in the implementation of RES-E projects, and taking into account the interest of various involved parties may enable the avoidance of traps and prevent resistance later. This could also facilitate the democratisation of the energy market since the chances of local communities to create energy cooperatives increase when they have the prospect to be direct participants.

This action could benefit civil society, providing consultation regarding RES-E project development, for instance, through energy communities or cooperatives, and has significant influence in the energy market. Supportive actions that will assist the expected outcomes could be the creation of awareness of the gains of RES-E and the involvement of civil society in the projects, both at the planning and deployment phases. Nevertheless, engaging civil society through financial involvement in RES-E projects (e.g., through cooperatives) might be challenging; therefore, different engagement methods need to be investigated as well.

Mid-term action 1: Civil society participating in RES-E cooperation plans. ($\mathbf{A_{10}}$)

Novel policies stipulating RES-E exports from North Africa to the EU should be supported politically in the relevant countries so as to be effectively implemented [31,32]. To ensure local acceptance, the projects need to be concrete, and the planning procedures should be conducted in a transparent and participatory manner for stakeholders to be actively involved. Public support for policies and projects increases the sustainability of the collaboration in the long term, as well as the likelihood of further cooperation in future projects. However, it has to be highlighted that for North Africa, achieving self-reliance in energy generation through its electricity infrastructures is essential to gain acceptance. Furthermore, project preparations need to engage participants at a local level, and the ensuing profits must be distributed to citizens in both the participating and transit countries. The EU and member states need to convey the macroeconomic gains along with cooperation objectives in terms of sustainable development and from a political point of view to warrant social acceptance in importer regions. In general, best practice examples should be taken into consideration, while connections should be made with bi/multilateral aid/ direct investment regulation. Other supportive actions would address issues of rights, load allocation, benefit distribution, control, democracy, corruption, political culture, subsidies, and various stakeholder parties involved in policy and project arrangement.

3.3. Evaluation Criteria

Different possible strategies that foster cross-country cooperation in the field of climate and energy necessitate their comparative evaluation on the basis of a well-defined and descriptive set of criteria to identify the most advantageous option. Considering the different strategy narratives, the following four criteria were established so as to capture and encompass all the critical elements of the alternatives in the assessment procedure:

- C_1: Compatibility with the regulatory and cultural framework: Assesses the adequacy of the regulatory framework to back up and guarantee the application of the respective actions and policies.
- C_2: Contribution to employment: Reflects the impact of alternative technologies on the social environment regarding employment rates, i.e., increasing labour supply.
- C_3: Market compatibility: This criterion assesses how much each strategy is consistent with the existing state or whether it is opposed to the market of each examined country following the market's rules.
- C_4: Applicability: This criterion measures whether a strategy is compliant and applicable to the examined country according to the current legislation and regulatory framework.

4. The MCDM Method

As the main purpose of the present study is to analyse and evaluate the strategies described above, a methodological evaluation framework has been developed utilising the multicriteria Fuzzy Preference Ranking Organization METHod for Enrichment of Evaluations (PROMETHEE). PROMETHEE is envisaged to handle the diverse preferences of decision-makers, and to deal with the uncertainty that occurs when solving decision problems, taking into account a set of relevant criteria, combining the principles of multicriteria decision analysis and fuzzy logic. The application of this method will result in a clear representation of the preferred choices, described in the above paragraphs, and it will efficiently map their relationship with the assessment criteria [33]. The conclusions that arise can have an important impact on energy and climate policymaking in the energy sector of Morocco and Egypt.

PROMETHEE is an ideal method for the respective problem as it can deal with the prioritisation of numerous alternatives on the basis of conflicting criteria while taking into account sustainability characteristics so that the best options for power generation can be chosen [34]. According to an extensive literature review, the MCDM methods of the PROMETHEE family have multiple applications in various areas and sectors [35], including strategic environmental and energy planning, the installation of renewable investment undertaking, and other sectors. In addition, in many of these studies, the combinations of the PROMETHEE with additional MCDM methods have been deployed to aid the decision-making processes.

In the literature, many examples of PROMETHE applications exist, also presented in Table 1. Feng et al. [36] propose a new extension of PROMETHEE by taking advantage of the application of intuitionistic fuzzy soft sets (IFSSs), while also testing the new approach in a comparative analysis of investment risks. Environmental planning is also popular for PROMETHEE applications, including GIS-based suitability analysis [37,38] or the application of Agricultural Models Using Fuzzy AHP and PROMETHEE II [39]. Also, a sustainable development-oriented comprehensive analysis of MCDM methods, also including PROMETHEE, has been realised by Li et al. [40] so as to quantitatively evaluate renewable energy alternatives.

Table 1. Literature review of PROMETHEE application in energy and environment sectors.

Studies	Application Area
K. Sotiropoulou [38], A. P. Vavatsikos [37], Y. Wu [41]	Environmental Planning and Impact Assessment
Feng [36], R. A. de Cunha [42], J. Zhu [43], S.A. Ahmadi [44]	Portfolio Optimisation, Supply Assessment, Decision Making in Investment and Risk Evaluation
C. Wulf [45,46]	Life Cycle Analysis
S. Burak [47], A. Safari [48]	Water Management
A. Makan [49], B. Kizielewicz [50], S. Nasrollahi [51]	Ranking Renewable Energy Technologies and Scenarios

Table 1 includes a variety of studies using PROMETHEE in energy-related fields and environmental management.

Fuzzy PROMETHEE

A main branch of the PROMETHEE family is fuzzy PROMETHEE, which consists of an approach of implementing the PROMETHEE method with linguistic assessments instead of crisp values. This modification introduces the theory of fuzzy sets in the original method to model the imprecise nature of the real-world decision-making problems. It has been effectively implemented in a number of decision-making problems for ordering and selecting among alternatives [52], and also in environmental and energy-related fields, as presented in Table 1.

Focusing particularly on the applications of fuzzy PROMETHEE in the energy sector, the majority of studies are dated a couple of decades ago, setting the base, but reflecting a completely different economic, environmental, and technological environment. Some publications of the most recent years incorporating fuzzy PROMETHEE in the energy sector are as follows: The application of Tabaraee et al. [53] that evaluates power plants so as to prioritise potential investments, and the evaluation of Geothermal Energy Systems by Sharaf [54] using spherical fuzzy PROMETHEE. In addition, Ghobadi and Ahmadipari [55] have performed environmental planning for wind power plant site selection using fuzzy PROMETHEE, while Samanlioglu and Funda [56] developed a fuzzy AHP-PROMETHEE II combination for the evaluation of solar power plant location alternatives in Turkey. Montajabiha [57] has also proposed an approach for Sustainable Energy Planning introducing Intuitionistic Fuzzy Logic along with PROMETHE II.

Based on the literature reviews presented above, there is a need for further research and application of fuzzy PROMETHEE MCDM with up-to-date data regarding energy and environmental updates towards a more sustainable European energy future. In this context, the effort is to expand the implementation areas of the fuzzy PROMETHEE method.

In the suggested methodological framework, the PROMETHEE method, developed by Brans (1985) [58], is integrated with fuzzy logic, introduced by Zadeh (1965) [59], with the aim of using a method that has the capacity to deal with the transformation pathways problem. Additionally, group decision making is exploited to capture the pluralism stemming from the different perspectives of the involved parties. The steps of the fuzzy PROMETHEE method are explained below.

Step 1: Determine alternatives (m), evaluation criteria (k), and group of decision-makers (n).

Step 2: The definition of the linguistic variables and their triangular fuzzy numbers. Based on them, the criteria's importance is being evaluated, and the alternatives will be rated.

In this methodological approach, a five-level linguistic variable fuzzy number was utilised following the method used by Chen and Hwang (1992) [60]. Table 2 presents the linguistic scales along with the corresponding triangular fuzzy numbers used for both the criteria weights and the evaluation of alternatives. Figure 3 illustrates the membership function μ(x) of the triangular fuzzy numbers.

Table 2. Linguistic variables and fuzzy numbers.

Ratings of Alternatives	Fuzzy Number
Very Poor (VP)	(0.00, 0.00, 0.25)
Poor (P)	(0.00, 0.25, 0.50)
Fair (F)	(0.25, 0.50, 0.75)
Good (G)	(0.50, 0.75, 1.00)
Very Good (VG)	(0.75, 1.00, 1.00)

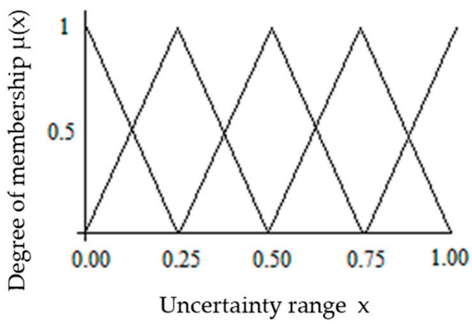

Figure 3. Membership function of triangular fuzzy numbers.

Step 3: Combine the assessments of the decision-maker. A decision is derived by integrating the fuzzy weights of criteria and the fuzzy rating of alternatives provided by n decision-makers. Moreover, the preferences and viewpoints of n decision-makers regarding to j criterion (C_j symbolises the criterion) for the importance weight $\widetilde{w}_j$ of each criterion and with respect to i alternative (A_i) for the rating of each alternative to each criterion can be determined using Equations (1) and (2).

$$\widetilde{w}_j = \frac{1}{n}\left[\sum_{e=1}^{n} \widetilde{w}_j^e\right] = \frac{1}{n}\left[\widetilde{w}_j^1(+)\widetilde{w}_j^2(+)\cdots(+)\widetilde{w}_j^n\right] \tag{1}$$

$$\widetilde{x}_{ij} = \frac{1}{n}\left[\sum_{e=1}^{n} \widetilde{x}_{ij}^e\right] = \frac{1}{n}\left[\widetilde{x}_{ij}^1(+)\widetilde{x}_{ij}^2(+)\cdots(+)\widetilde{x}_{ij}^n\right] \tag{2}$$

In the context of this paper, we also consider the case where the importance of the views of the different decision-makers is not equivalent. Particularly, the weight of decision-makers i preferences is given by the variable r_i, and table R, as demonstrated in Equation (3).

$$R = \begin{bmatrix} r_1 & r_2 & \dots & r_n \end{bmatrix} \tag{3}$$

Thus, Equations (1) and (2) are adapted as follows:

$$\widetilde{w}_j = \left[\sum_{e=1}^{n} r_e \widetilde{w}_j^e \right] = \frac{1}{n} \left[r_1 \widetilde{w}_j^1 (+) r_2 \widetilde{w}_j^2 (+) \cdots (+) r_n \widetilde{w}_j^n \right] \tag{4}$$

$$\widetilde{x}_{ij} = \left[\sum_{e=1}^{n} r_e \widetilde{x}_{ij}^e \right] = \frac{1}{n} \left[r_1 \widetilde{x}_{ij}^1 (+) r_2 \widetilde{x}_{ij}^2 (+) \cdots (+) r_n \widetilde{x}_{ij}^n \right] \tag{5}$$

Step 4: Formulation of the fuzzy decision matrix and calculation of the aggregated fuzzy weight of the criterion.

$$\widetilde{D} = \left[\widetilde{x}_{ij} \right]_{m \times k} = \begin{bmatrix} \widetilde{x}_{11} & \widetilde{x}_{12} & \dots & \widetilde{x}_{1k} \\ \widetilde{x}_{21} & \widetilde{x}_{22} & \dots & \widetilde{x}_{2k} \\ \vdots & \vdots & \dots & \vdots \\ \widetilde{x}_{m1} & \widetilde{x}_{m2} & \dots & \widetilde{x}_{mk} \end{bmatrix} \tag{6}$$

$$\widetilde{W} = \begin{bmatrix} \widetilde{w}_1 & \widetilde{w}_2 & \dots & \widetilde{w}_k \end{bmatrix} \tag{7}$$

where $\widetilde{x}_{ij}$ is the rating of the alternative A_i with respect to the criterion C_j, and $\widetilde{w}_j$ is the importance weight of jth criterion.

Step 5: Select the type of the preference function and establish the corresponding thresholds. The use of Type V (Linear preference function with indifference area) is considered to be the most appropriate (Figure 4) [61]. As a first step, thresholds are determined as follows: the indifference threshold q for the criterion j is set to the slightest difference between two alternative ratings with respect to the criterion j, and the preference threshold p for the criterion j is set to the maximum difference between two alternative ratings concerning the criterion j.

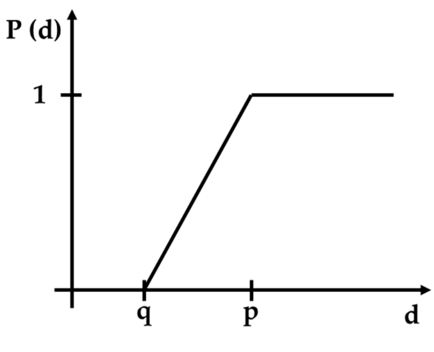

Figure 4. Type V preference function.

Step 6: Extract the fuzzy multicriteria preference index $\widetilde{\pi}$ for each pair of alternatives A_i, A_j according to Equation (8).

$$\widetilde{\pi}(A_i, A_j) = \sum_{t=1}^{k} \widetilde{w}_t \; (\mathrm{x}) \; p_t(x_{it}(-)x_{jt}) \tag{8}$$

where $p_t(x_{it}(-)x_{jt})$ is the preference degree occurring from the comparison between alternatives A_i, A_j with respect to the criterion t, which is computed as the value of the preference function $p_t()$ based on the difference—Subtraction operation (ii)—between the two alternative ratings based on the Function Application operation (v). Lastly, the total sum is determined based on the Addition operation (i).

Step 7: Compute fuzzy Leaving Flow $\tilde{\Phi}^{+}(A_i)$ as a measure of the superiority of the alternative A_i (9) and fuzzy Entering Flow $\tilde{\Phi}^{-}(A_i)$ as a measure of the inferiority of alternative A_i (10). The difference in the quantities described above generates the fuzzy Net Flow (11).

$$\tilde{\Phi}^{+}(A_i) = \frac{1}{m-1} \cdot \sum_{j=1}^{m} \tilde{\pi}(A_i, A_j) \quad (9)$$

$$\tilde{\Phi}^{-}(A_i) = \frac{1}{m-1} \cdot \sum_{j=1}^{m} \tilde{\pi}(A_j, A_i) \quad (10)$$

$$\tilde{\Phi}(A_i) = \tilde{\Phi}^{+}(A_i)(-)\tilde{\Phi}^{-}(A_i) \quad (11)$$

Step 8: The final total ranking is reached after the defuzzification of fuzzy Net Flow. There are various models that could be used in the context of the defuzzification process. However, there is no model that would be regarded as optimum regardless of the conditions. Following the reasoning of outranking methods, PROMETHEE in particular, the applied approach should be the easiest that could be exploited in the decision-making process [41]. Subsequently, the proposed assessment is based on the Centre Of Area (COA) approach [56] (Equation (12)), the most commonly utilised selection. $\tilde{\Phi}(A_i) = x_i$ is determined for conciseness.

$$x_i^{defuzz} = \frac{\int x_i \cdot \mu(x_i) dx_i}{\int \mu(x_i) dx_i} \quad (12)$$

where $\mu(x_i)$ is the membership function of the fuzzy number x_i.

The final ranking of the problem's alternatives is acquired directly from arranging all the defuzzified x_i.

5. Application and Results

In this section, the results of the application of the fuzzy PROMETHEE method will be presented. To begin with, Table 3 presents the preferences of the decision-maker in the different criteria for each of the alternative strategies.

Table 3. Performance of each alternative in the criteria of the Morocco case.

Morocco	C_1	C_2	C_3	C_4
A_1	G	G	F	G
A_2	VG	F	G	G
A_3	F	F	G	F
A_4	F	F	F	G
A_5	G	G	G	VG
A_6	G	F	G	F
A_7	F	F	F	P
A_8	G	F	F	F
A_9	G	VG	G	G
A_{10}	F	VG	F	G

In order to quantify the p and q variables, values have been chosen in a way so that they do not interfere with the calculation of the results. Therefore, the indifference threshold q of the criterion j has been set equal to the smallest difference $d(A_i, A_j)$ between any two alternatives for the criterion j that there is a strict preference over the alternative

A_j. Similarly, the preference threshold p of the criterion j has been set as the largest positive difference between any two alternatives in the criterion j (Table 4).

Table 4. Threshold values of the preference p and indifference q for each criterion for the Morocco case.

	C_1	C_2	C_3	C_4
p	0.42	0.42	0.25	0.67
q	0	0	0	0

After generating the fuzzy multicriteria preference index $\tilde{\pi}$ for each pair of alternatives A_i, A_j and calculating the fuzzy Leaving Flow $\tilde{\Phi}^+(A_i)$ and fuzzy Entering Flow $\tilde{\Phi}^-(A_i)$, based on the methodological steps defined in Section 4, finally, the fuzzy Net Flow is calculated and presented in Table 5.

Table 5. Table of net flows for the Morocco case.

Alternatives	$\Phi(A)$
A_1	0.157
A_2	1.046
A_3	−0.478
A_4	−1.177
A_5	1.546
A_6	0.189
A_7	−2.007
A_8	−0.922
A_9	1.712
A_{10}	−0.066

Based on the results, the rank could be described as $A_9 > A_5 > A_2 > A_6 > A_1 > A_{10} > A_3 > A_8 > A_4 > A_7$ which designates as the best alternative the ninth in the row, as it has the highest value of net flow.

The same steps were followed also for the case of Egypt and the results are displayed in Tables 6–8 and Figure 5.

Table 6. Performance of each alternative in the criteria for the Egypt case (1st iteration).

Egypt	C_1	C_2	C_3	C_4
A_1	G	F	G	G
A_2	VG	F	G	VG
A_3	G	F	VG	G
A_4	G	G	F	G
A_5	F	F	G	G
A_6	G	G	G	VG
A_7	G	G	G	G
A_8	G	F	G	G
A_9	VG	G	G	G
A_{10}	G	G	G	G

Table 7. Threshold values of the preference p and indifference q for each criterion for the Egypt case.

	C_1	C_2	C_3	C_4
p	0.42	0.25	0.42	0.17
q	0	0	0	0

Table 8. Table of net flows for the Egypt case.

Alternatives	$\Phi(A)$
A_1	−0.778
A_2	0.778
A_3	−0.333
A_4	−0.333
A_5	−1.444
A_6	1.444
A_7	0.333
A_8	−0.778
A_9	0.778
A_{10}	0.333

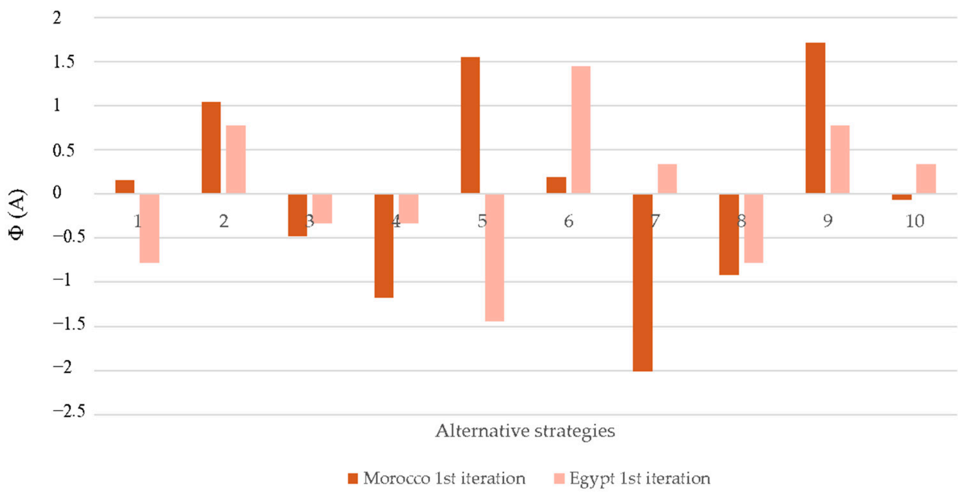

Figure 5. Net flows of alternatives for the Egypt and Moroccan case.

Based on the results, the rank could be described as $A_6 > A_2 = A_9 > A_7 = A_{10} > A_3 = A_4 > A_1 = A_8 > A_5$ which designates as the best alternative the sixth in the row, as it has the highest value of net flow.

6. Discussion of the Results

6.1. Morocco

In Morocco, the development of renewable energy sources contributes to the improvement in energy security, as well as to the fulfilment of Morocco's commitments to clean energy and climate change. Morocco is making significant progress towards improving and installing reasonably priced, reliable, sustainable, and advanced energy. Climate policy and the development of RES contribute to the development of the economy, attract foreign investments, create employment, and strengthen Morocco's industrial sector. With the ambitious clean energy transition on a global focus, Morocco attracts green financing internationally and becomes a collaborator in the Mediterranean region and Africa. It is the only country that has a direct connection with the European electricity grid, while the current social conditions are prosperous and will assist the development and promotion of RES in the region.

Based on the results, the most suitable action is Short-term action 1 from Strategy 3, namely: "Involve the civil society in RES-E expansion ventures". This means that cooperation with society and citizens is perceived as an essential factor in achieving a possible cooperation mechanism. Society can participate in RES development projects through cooperatives, while the energy market has the potential to open up even more.

According to the methodological application, the second-best strategy is Short-term Action 2 of Strategy 2: "Conduct pre-feasibility studies to choose suitable RES technologies".

Suppose Morocco's government is ready for potential cooperation with the EU and the export of RES to it. In that case, the RES technologies that are preferable to develop must be determined. In the medium and long term, the exports of RES are likely to consist of a variety of RES types. The country's leading RES technologies should focus on solar and wind energy. Although in 2018 Morocco's hydroelectrics had the largest installed capacity [62], the potential of the hydroelectric sector is not great as Morocco is considered a semi-arid country.

The results analysed above were not far from expectations. In general, there is high social support for RES in the country, although there is limited know-how. Therefore, considering that the appropriate training and planning will take place, the country can further develop its energy sector by incorporating civil society's participation in its plans.

6.2. Egypt

Regarding Egypt, the conditions concerning the promotion of RES and the possible cooperation with the EU are prosperous. The country seeks to ensure energy security, stability, and sustainability through successfully adopting renewable energy technologies. Major renewable energy projects are under development, reflecting the government's willingness to turn this vision into reality. The country has received several recent offers, substantial international interest, and promising proposals, which could further help increase renewable energy production in the following years. The know-how around RES is of a high level, while various relevant programmes have been implemented.

The proposed analysis highlighted Short-term action 3: create a cross-cutting policy blend to capitalise on the socioeconomic gains, from Strategy 2, as the preferred action. This indicates that with the development of industrial, educational, and energy policies, the potential profit that will emerge from the cooperation could be maximised.

In comparison to Morocco, Egypt is a country that has a well-developed and established RES industry. Indeed, familiarisation with new RES technologies has been a strategy of the country for many years. Therefore, having the appropriate knowledge about RES, Egypt can focus on the RES-E market and develop its commercial impact.

7. Conclusions

This paper introduces a multicriteria approach utilising fuzzy PROMETHEE to promote cross-border cooperation in the context of renewable energy, with a focus on fostering long-term commitment towards Europe's clean energy transition. The approach aims to assess alternative strategies for achieving a carbon-free, sustainable energy future within the EU. By recognizing the complex, multifaceted nature of Europe's energy future options, this method shifts away from the outdated single-objective framework that seeks to find an optimal transition path by focusing on only one goal, such as the contribution of RES to the overall power generation or the cost of transition.

The suggested approach, along with the developed methodological framework, could be an important point of reference and a valuable instrument for the decision-makers and actors involved in the energy sector. Firstly, by selecting a comprehensive collection of criteria, the framework realistically models the problem, highlighting the fundamental and often contradictory factors that influence the success of potential strategies to be followed in terms of their contribution to the transition towards a more sustainable energy system. Secondly, by defining thresholds, assigning weights to criteria weights, and rating the alternatives, a precise portrayal of the decision-makers' opinions is realised, therefore integrating them into the procedure of the assessment of the alternatives.

Furthermore, the use of linguistic variables plays a significant role. It simplifies the decision-making process, making it more understandable for stakeholders, while also addressing the inherent uncertainty of the problem, as fuzzy numbers are used to account for imprecision in the input data.

The proposed decision-making framework effectively addresses the uncertainty, ambiguity, intricacy, and complexity of the decisions that arise from the conflicting criteria involved. To further enhance the proposed framework, the possible employment of additional criteria should be examined to result in a more detailed investigation of the proposed pathways. The proposed framework could also be applied to multiple decision-makers by adapting the problem so that the fuzzy PROMETHEE method for group decision making can be implemented. This will enhance the precision and introduce impartiality in the approach by entailing diverse and possibly conflicting viewpoints. Finally, this framework could be replicated in other potential host countries. Possible candidates include the Western Balkans and Turkey. Applying and replicating this methodology could help EU policymakers identify and map key factors and potential risks that may arise in cross-border cooperation on renewable energy in neighbouring regions.

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