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Research article

Analyzing the factors that affect the renewable energy PPP market: A comparative analysis between developing and developed countries

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Abstract: Over the past few years, an increase in energy demand has been observed along with the required additional energy supply. These are some of the major challenges that governments are facing at a global level. The dependence on fossil fuels for energy generation is one of the main reasons behind global warming and the increased levels of pollution. Additionally, the limited reserve of fossil fuels means that it is not a sustainable source of energy that can be relied upon indefinitely. As a result, various governments around the world have sought renewable energy to provide a clean and sustainable source of energy. However, the main problem facing renewable energy projects is the upfront cost needed for them. Thus, governments have sought partnerships with the private sector to take advantage of their expertise and their financing. As a result, renewable energy projects have become commonly delivered as public-private partnerships (PPPs). This study reports on the renewable energy PPP market globally through a detailed literature review and questionnaire. The responses of 86 experts were collected and classified based on whether their experience was in developed or developing countries. The results showed that the main barriers affecting renewable energy PPPs globally are political and regulatory barriers. While the experts highlighted that the public sector cannot appropriately identify, value, or transfer risks, the private sector was highlighted as an efficient party in dealing with risks. In addition, the analysis contrasted renewable energy PPP market in developed and developed countries.

Keywords: renewable energy; public-private partnership; barriers; key success factors; comparative analysis; developing countries; developed countries

1. Introduction

According to published reports, the global oil and coal reserves can meet future demand for another 150 years [1]. Statistics have reported that the dependence and consumption rate of fossil fuels cannot be relied upon as the primary energy production source and hence needs to be reduced. Furthermore, the use of fossil fuels has been associated with environmental problems due to their contribution to the greenhouse gas emissions that cause global warming as well as climate change [2]. Therefore, academia and industry have focused on ways of obtaining clean, reliable, and sustainable sources of energy. In 2000, PV systems worldwide generated 1.5 GW, which has increased to 71.1 GW in 2011 and to 106 GW in 2013 [3]. Figure 1 shows the total energy generated from the different renewable energy sources per year. It clearly shows a significant increase in the generated energy over the past two decades. The energy generated from hydroelectric power has increased almost linearly while the others have grown exponentially.

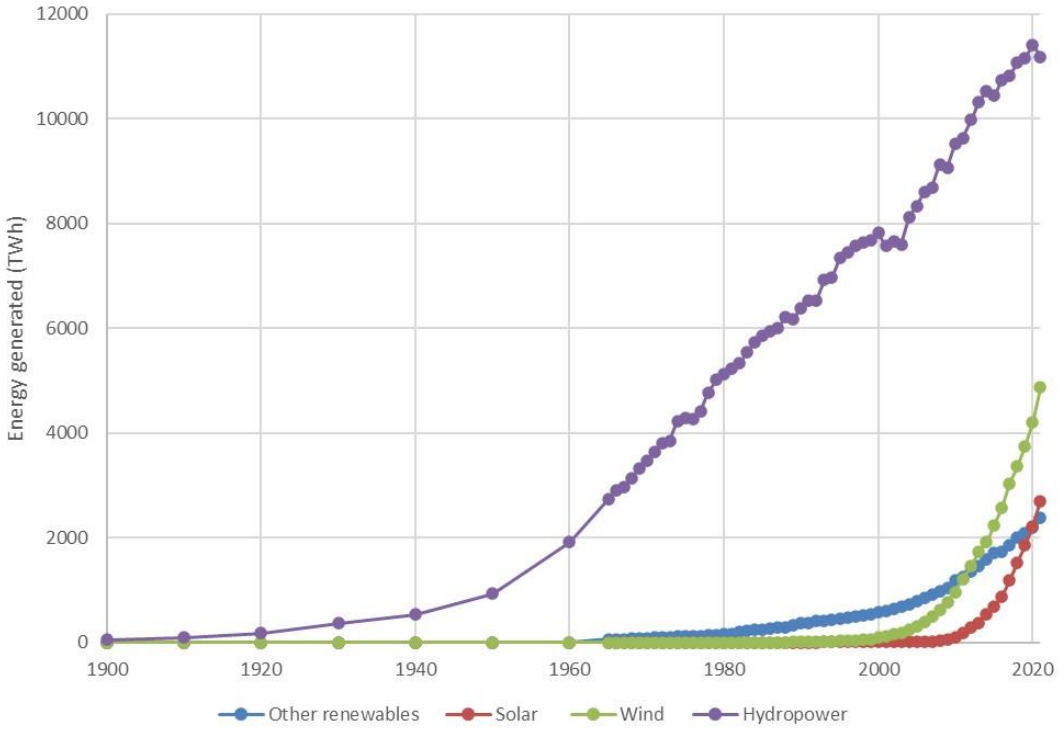

Figure 1. Total renewable energy generation by source over time.

Renewable energy projects continue to struggle with significant financial challenges with respect to securing the necessary upfront capital for project implementation. Governments worldwide have recognized this issue and have increasingly turned to the private sector to play a pivotal role in these projects, leveraging their financial resources and expertise. One prevalent method for facilitating this

partnership between the public and private sectors in the context of renewable energy projects is the adoption of a Public-Private Partnership (PPP) as the delivery method. In essence, a concessionaire, often comprising one or more private entities, assumes a central role in providing the crucial financial support required for renewable energy projects. It also takes on multifaceted responsibilities encompassing project design, construction, maintenance, and operation, thus actively participating in various phases of project development [4]. The rationale behind involving a private sector entity is to tap into their financial capabilities and technical know-how while also shifting a portion of the associated risks to them. This dynamic has far-reaching implications, ultimately contributing to reduced project costs borne by the public sector [5]. The concept of PPPs has emerged as a cornerstone for collaboration between governments and private entities in the renewable energy sector. These partnerships foster synergy between public-sector objectives and private-sector capabilities, resulting in a mutual benefit for both sides and, by extension, the broader public. The advantages of PPPs in renewable energy projects are multifold and merit closer examination. These advantages include:

- Access to private sector's resources: The most notable advantage of PPPs is the injection of private-sector capital into renewable energy initiatives. This is done to combat the budgetary constraints faced by the public sector that limit its ability to adequately fund large-scale renewable energy projects. PPPs bridge this gap by allowing private entities to invest substantial financial resources, thereby accelerating project initiation and implementation.
- Leveraging technical expertise: Private companies typically possess cutting-edge technological expertise in renewable energy projects. This valuable knowledge can be instrumental in optimizing project design, construction, and operation, leading to improved efficiency and cost-effectiveness.
- Risk sharing: The participation of private entities introduces a risk-sharing dynamic into renewable energy projects. These entities are often willing to assume certain project risks, such as construction delays or cost overruns, in exchange for a share of project returns. This risk allocation can alleviate the burden on the public sector and enhance project feasibility.
- Innovation and efficiency: Competition within the private sector drives innovation and efficiency. In PPPs, private entities are motivated to find innovative solutions and cost-effective approaches to meet project goals, which can result in superior project outcomes.
- Timely implementation: Renewable energy projects are time-sensitive, especially in the context of climate change and energy transition goals. PPPs can expedite project execution by streamlining decision-making processes and fostering a sense of urgency among private partners.
- Long-term sustainability: Renewable energy projects often have long operational lifespans. the presence of private-sector partners ensures ongoing maintenance, operation, and, when necessary, upgrades to sustain the project's performance over the long term.
- Public benefit: Ultimately, PPPs are designed to benefit the general public. By leveraging private investment and expertise, these partnerships contribute to the expansion of renewable energy capacity, thereby reducing greenhouse gas emissions, enhancing energy security, and fostering a cleaner and more sustainable future.

Accordingly, PPPs have emerged as a pivotal strategy for addressing the financial challenges associated with renewable energy projects. The benefits of PPPs extend beyond the immediate stakeholders, ultimately promoting the advancement of renewable energy, environmental sustainability, and the well-being of society at large. Therefore, the role of PPPs in shaping a more sustainable energy landscape has become increasingly prominent.

As highlighted above, renewable energy projects are complex projects that entail the collaboration of multiple stakeholders, rendering them susceptible to an extensive array of factors [6]. Previous studies have examined various barriers that pose challenges to the successful execution of these projects. These barriers encompass technological, technical, market-related, governmental, financial, environmental, and social dimensions [7–15]. However, a notable limitation of these prior studies lies in their tendency to predominantly focus on specific countries or particular project typologies, which inherently restricts the generalizability of their findings. Consequently, there exists a visible gap in the literature pertaining to a comprehensive understanding of the main obstacles facing renewable energy projects at a global scale.

It is crucial to recognize that renewable energy projects share certain universal characteristics that set them apart from other infrastructure projects. They frequently involve the participation of foreign concessionaires, possess a limited pool of accessible expertise, and operate under the notion of entering and profiting from the renewable energy market [9]. As a consequence of these distinct attributes, several countries have found themselves compelled to seek external expertise and consultancy in the planning and execution of these projects [16–23]. This endeavor, while potentially advantageous, also introduces a layer of intricacy and complexity. These intricacies arise from the inherent disparities across countries concerning communication protocols, regulatory environments, and socio-cultural contexts. One noteworthy observation highlighted by Freedman and Katz (2007) [24] is the marked contrast in complexity between the delivery of universal projects and their domestic counterparts. Universal projects, such as large-scale renewable energy initiatives, face unique challenges due to the stark disparities among countries in terms of legal frameworks, political landscapes, cultural nuances, social dynamics, and infrastructural prerequisites. Consequently, a substantial research gap persists in the academic discourse, with a dearth of comprehensive investigations dedicated to understanding the primary barriers and determinants of success for renewable energy projects. To bridge this gap and provide a more holistic understanding of the complex nature of renewable energy projects, it is necessary to conduct a comprehensive study to encompass a broad cross-section of projects spanning diverse geographical locations, project types, and stakeholder compositions. Thus, this study focuses on analyzing the renewable energy PPP market on a global scale and comparing the performance of these projects in both developed and developing countries to provide a clear understanding of this market. While previous studies have focused on a per-country/project basis, this paper focuses on comparing between developing and developed countries. An analysis of the performance of the public versus private sectors is also conducted. Finally, this paper investigates the key success indicators that can be used to evaluate the success of these projects.

This paper is structured as follows: Section one provides a review of the literature revealing the gaps behind the research motivation. Section two shows the methodology followed in this study for both the literature review process and the questionnaire survey conducted. Section three presents the analysis and results of the study revealing the main barriers, key success factors, and key performance indicators utilized for renewable energy for both developing and developed countries, while analyzing the performance of the different sectors involved in these projects (public and private) across these regions. Section four offers a discussion of the results and compares the barriers and success factors in developing and developed countries. Finally, section five provides the conclusion that summarizes the main results and outcomes of this study.

2. Methodology

This study focuses on understanding and analyzing the renewable energy PPP projects in developing versus developed countries. This includes a comparative analysis between the two markets in terms of barriers, Key Success Factors (KSFs), and Key Performance Indicators (KPIs). Thus, three main steps were followed in this study. Literature review was first conducted to collect and report on previous studies to identify the KSFs, KPIs, and main barriers. Second, a questionnaire survey was created from the results of the literature review process and distributed to experts who have worked on renewable energy PPP projects. A pre-survey or pilot survey was conducted by sending the survey to eight experts with over ten years of experience in PPP projects and over 5 years of experience in renewable energy PPPs in specific. Finally, the responses of the experts were analyzed in order to provide insights about renewable energy PPP market in both developing and developed countries. Further details about the methodologies used in this study are provided in the upcoming subsections.

2.1. Literature review

The first step of this study was to collect data through the literature review process to determine the main barriers, KSFs, and KPIs for PPP projects. The literature review process consists of five main tasks:

1. Planning task: This task identified the main keywords and search engines that will be used to identify the papers. In this study, six main search engines were identified to conduct the literature review and find similar studies. These search engines are "Scopus", "Web of Science", "ScienceDirect", "Springer", "IEEE Xplore", and "ASCE Library". In addition, the following keywords were adopted to find similar papers: "renewable energy" and "public-private partnership" in combination with one or more of the following words: "Barriers", "KSFs", and "critical success factors".
2. Search task: This task focused on using the identifying keywords to search for papers through the identified search engines.
3. Inclusion/exclusion criteria: This task focused on defining the inclusion and exclusion criteria that will be used to filter the data. In this study, the inclusion criteria were set to select articles published from 2010 onwards on related to renewable energy PPPs. Papers in a language other than English were excluded from the study.
4. Screening task: This task focused on reviewing the following items in each paper: Title, abstract, keywords, and conclusion. This ensured that all papers are within the desired scope that serves this current study.
5. Reporting task: Mainly focused on identifying the main outcomes of the literature review process. In this study, the reporting task led to the identification of the main barriers, KSFs, and KPIs that are to be used to build the survey to be sent to the experts. Figure 2 summarizes the five main tasks followed in the literature review process adopted in this study. In addition, Tables 1–3 show the outcome of the literature review process. These tables show the different barriers, KSFs, and KPIs that were studied in previous PPP and renewable energy PPP projects.

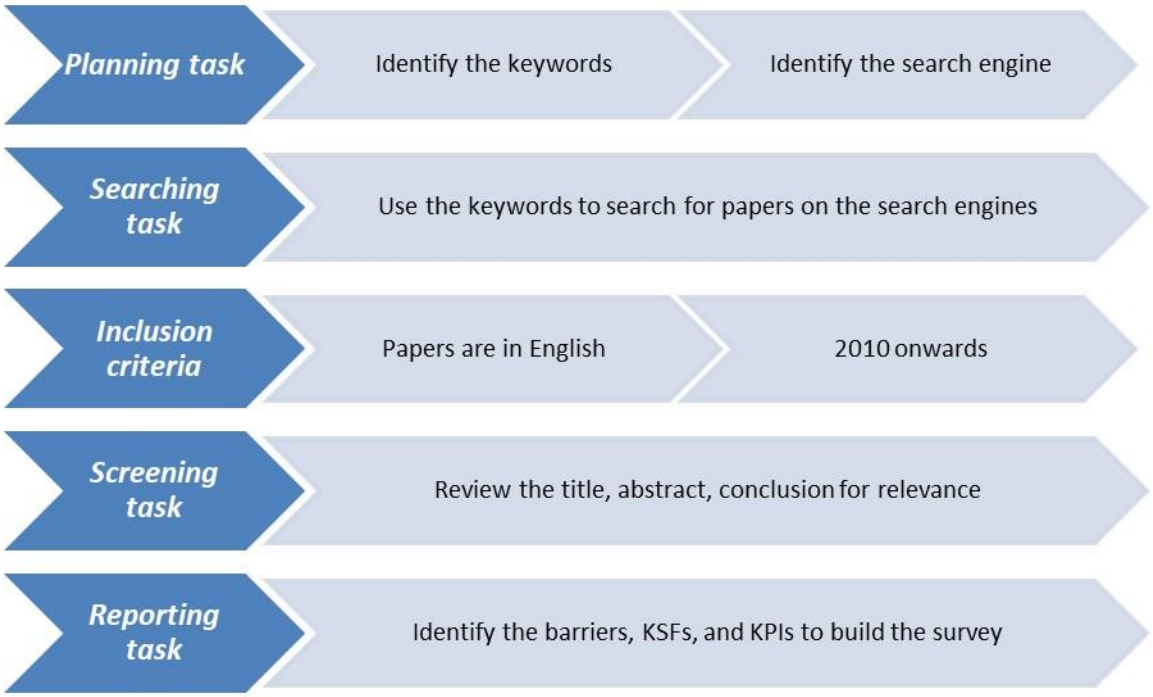

Figure 2. Literature review process followed in this study.

Table 1. Barriers of PPP projects analyzed in previous studies.

Study	[25]	[26]	[27]	[28]	[29]	[30]	[31]	[32]	[33]	[34]	[35]	[36]	[37]	[38]	[39]	[40]	[41]	[42]	[43]	[44]	[45]	[46]	[47]
Regulatory	✳		✳			✳	✳	✳	✳	✳	✳	✳			✳	✳		✳	✳		✳	✳	
Political	✳	✳	✳		✳	✳	✳		✳	✳	✳	✳	✳	✳	✳	✳	✳	✳	✳	✳	✳	✳	✳
Revenue				✳	✳		✳							✳		✳			✳	✳		✳	✳
Technical							✳			✳				✳	✳	✳			✳	✳			
Force majeure						✳	✳		✳					✳		✳							
Financial	✳			✳	✳	✳	✳	✳	✳	✳			✳	✳	✳				✳		✳	✳	✳
Construction					✳	✳			✳		✳			✳	✳	✳	✳		✳				
Operational					✳		✳							✳	✳	✳	✳		✳				
Market risks	✳			✳	✳	✳	✳	✳	✳	✳		✳	✳	✳	✳	✳	✳		✳		✳	✳	✳
Technological				✳		✳						✳			✳			✳				✳	

Table 2. KSFs for PPPs analyzed in previous studies.

Study	[25]	[48]	[29]	[49]	[50]	[51]	[52]	[53]	[54]	[55]	[34]	[35]	[56]	[57]	[58]	[46]	[59]
Technological development										✳							
Geographic location					✳			✳									
Desirable conditions								✳				✳					
Appropriate risk allocation	✳	✳	✳		✳	✳	✳			✳	✳		✳	✳	✳	✳	
Effective negotiation between parties	✳	✳		✳			✳		✳	✳	✳		✳	✳	✳	✳	
Skilled and efficient parties	✳	✳		✳			✳		✳	✳	✳		✳	✳	✳	✳	
Competitive procurement processes		✳	✳		✳	✳	✳			✳	✳			✳	✳	✳	✳
Well-prepared contract document	✳	✳					✳		✳	✳	✳						

Table 3. KPIS for PPPs analyzed in previous studies.

Study	[48]	[60]	[61]	[62]	[57]	[63]
Reduction of emissions						✳
Produced energy capacity						✳
Resources saved						✳
Traditional KPIs: cost, time, money		✳	✳	✳	✳	
Value for money achieved		✳	✳	✳	✳	
Risk-sharing allocation	✳					

2.2. Questionnaire survey

After conducting the literature review, a questionnaire survey was created to study the main factors that affect renewable energy PPP projects. The survey was designed to consist of six different sections. Section one provided an introduction to the experts about the survey and its objectives. Section two collected background information about the experts including their position, the sector they work in (public, private), number of projects (renewable energy and non, PPP projects) they were involved in, the years of experience in the renewable energy field, and the countries in which these projects were located (developing or developed). Section three focused on collecting the reasons that encourage the public sector to adopt PPPs. In this section, the respondents were asked to rank these factors according to their level of importance on a Likert scale from 1 to 5. Section four focused on understanding the main barriers for renewable energy PPPs by ranking their probability of occurrence and impact on a Likert scale from 1 to 5. The experts were also asked to allocate the risks to the appropriate sector that can efficiently handle them. Section five focused on analyzing the performance of both sectors in these projects. The experts were asked 'yes/no' questions to analyze the performance of both sectors. They were specifically asked their opinion on whether the public sector can identify, value, retain, and transfer risks appropriately. Similarly, the experts were asked their opinion on the private sector's ability to properly identify and value risks. Finally, section six focused on obtaining the main KSFs and KPIs for renewable energy PPPs and on ranking them.

Prior to sending the survey, a pilot was distributed to eight experts with over ten years of experience in PPP projects and over five years of experience in renewable energy PPPs in specific. The survey was then sent to experts from both developed and developing countries between January and April 2022. Purposive sampling was used to select experts in the field of study who meet the objective and goals of this study [64]. Furthermore, purposive sampling helps in reducing the variability in the responses of the experts due to their focused background [65]. Thus, the majority of the experts who responded to the survey had a wide experience in the field. The survey was sent to 167 experts with a total of 86 completed responses that were collected (51 from experts in developing countries and 35 from experts in developed countries) and a response rate of 51.5%. Figure 3 is a graphical representation of the framework adopted in this study.

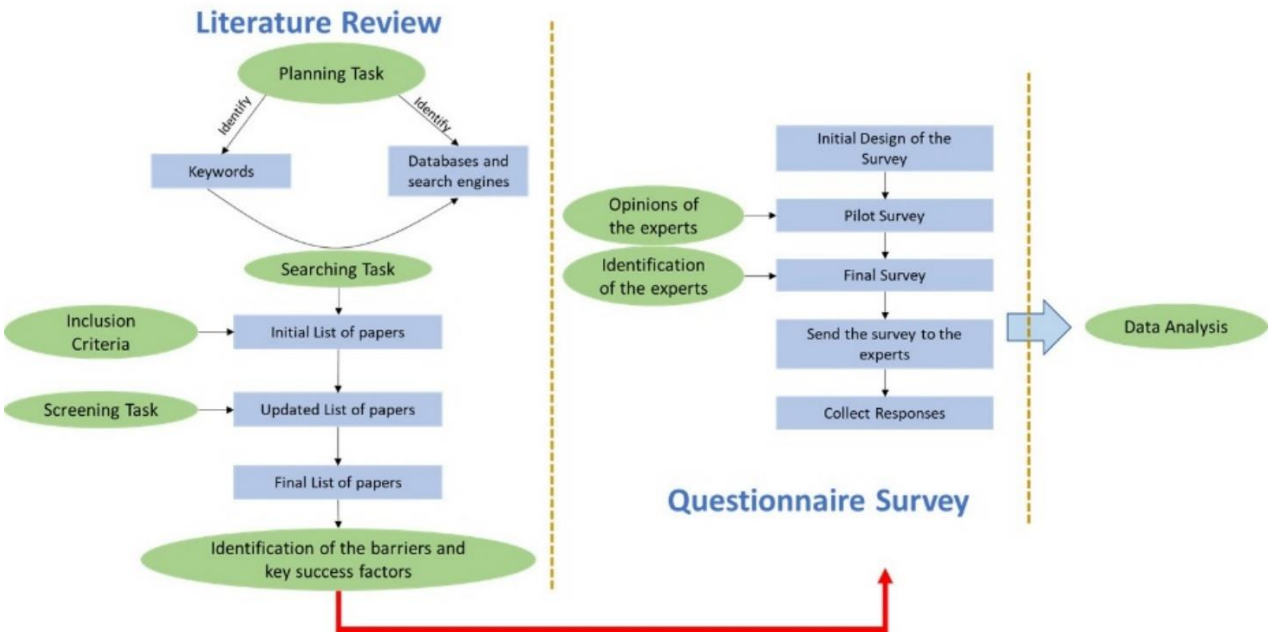

Figure 3. Framework adopted in the study.

3. Analysis and results

3.1. Profiling of the surveyed experts

86 complete responses were collected from the experts with 51 experts with experience in developing countries and 35 in developed countries. This is based on the World Bank's definition of developing and developed countries. The experts highlighted their wide experience in PPP projects and in the renewable energy sector as well as shown in Tables 4 and 5. It can be observed that experts from developed countries have a higher level of experience than their counterparts. However, the level of experience for both sets of experts (from developed and developing countries) in renewable energy PPPs is slightly less than that for all PPPs.

Table 4. Expertise of the respondents in PPP projects in terms of years of experience in both developed and developing countries.

Years of experience	Developing countries		Developed countries	
	Number of experts	Percentage	Number of experts	Percentage
0–2	2	3.9	1	2
2–5	14	27.5	8	15.7
5–10	13	25.5	8	15.7
10–20	15	29.4	8	15.7
>20	7	13.7	10	19.6

Table 5. Expertise of the respondents in renewable energy PPPs.

Years of experience	Developing countries		Developed countries	
	Number of experts	Percentage	Number of experts	Percentage
0–2	17	48.6	9	25.7
2–5	17	48.6	10	28.6
5–10	10	28.6	10	28.6
10–20	4	11.4	2	5.7
>20	3	8.6	4	11.4

3.2. Factors that encourage adoption of PPPs for renewable energy projects

Based on previous studies, five main factors were found that encourage the adoption of PPPs for renewable energy projects. These are: financial support, utilization of technology, expertise of the private sector, efficiency of the private sector, and transfer of risks. The results show that financial support and utilization of technology are the main encouraging factors. Figure 4 shows the average rank of the different factors for experts from both areas. The results show that all experts value the five factors highly. Additionally, it shows that developing countries opt for these projects to utilize the private sector's financial support and technology, while developed countries are motivated by the private sector's expertise and financial support.

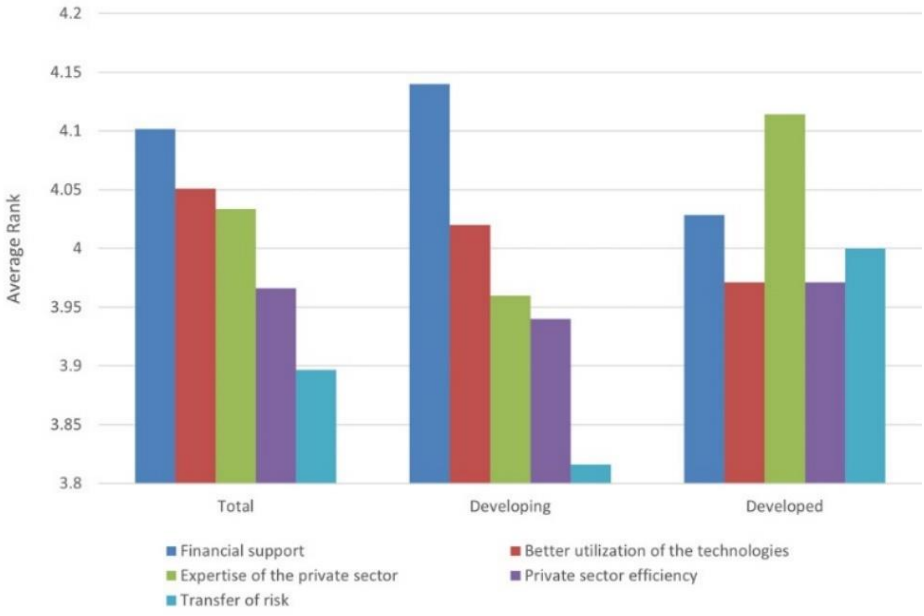

Figure 4. Average rank of the factors encouraging the public sector to opt for PPPs: Developing vs. developed countries.

3.3. Barriers for renewable energy PPP projects

This subsection is dedicated to understanding the primary obstacles encountered by renewable energy Public-Private Partnership (PPP) projects. The focal point revolves around the ten factors previously delineated in Othman and Khallaf's (2023) comprehensive literature review, which include:

- Political Barriers: Entail issues related to low political stability and insufficient governmental support.
- Regulatory Barriers: Involve challenges arising from unstable national regulations and intricate bureaucratic procedures.
- Financial Barriers: Encompass concerns such as inflation, fluctuating interest rates, and foreign exchange volatility.
- Technical Barriers: Comprise of the lack of adequate supporting infrastructure, deficiencies in quality assurance and control, inadequacies in design, and suboptimal contract documentation.
- Revenue Barriers: Related to the impact of inflation, foreign exchange risks, fluctuations in market demand, and risks of fraud or non-payment by users on revenue streams.
- Environmental Barriers: Also known as market risks. These encompass issues related to poor risk allocation, inadequate coordination, involvement of unskilled parties, and intense market competition.
- Operational Barriers: Encompass risks associated with maintenance, organizational changes or risks, and alterations in project or operational conditions.
- Technological Barriers: Involve challenges such as the availability of non-trained laborers, lack of expertise, unavailability of necessary technology, and absence of required machinery.
- Construction Barriers: Includes hindrances related to site accessibility, physical obstacles, unforeseen geotechnical conditions, and the coordination of risks during construction.
- Force Majeure: Refers to unpredictable events or circumstances that are beyond the control of the involved parties and may substantially affect the project's execution.

In this part of the survey, the experts selected the barriers they encountered in their projects. They were prompted to rank both the probability of occurrence and impact of the barriers on a Likert scale from 1 to 5. The results of these questions are summarized in Figures 5–7. Figure 5 shows the percentage of experts who faced the barriers with the most frequent barriers being regulatory and political. Additionally, the number of experts exposed to every barrier from both sets of countries was found to be similar with the exception of technical barriers where a small difference can be observed.

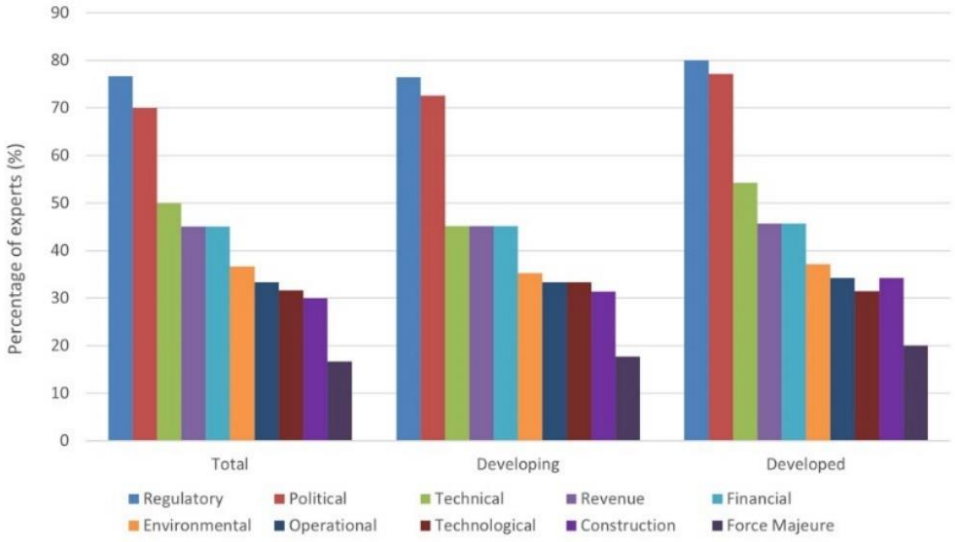

Figure 5. Percentage of experts who faced the barriers.

Figures 6 and 7 focus on showing the perceptions of the experts on the different barriers. The results show that regulatory and political barriers were the highest in all cases. It shows that the experts perceive the barriers with similar probability levels across both areas. On the other hand, experts from developed countries perceive the barriers with higher levels of impact than their counterparts. In general, these differences in the perceived impacts are minor across the different barriers except for the technological, operational, construction, and environmental barriers, where the experts from developed countries perceived them with much higher impact.

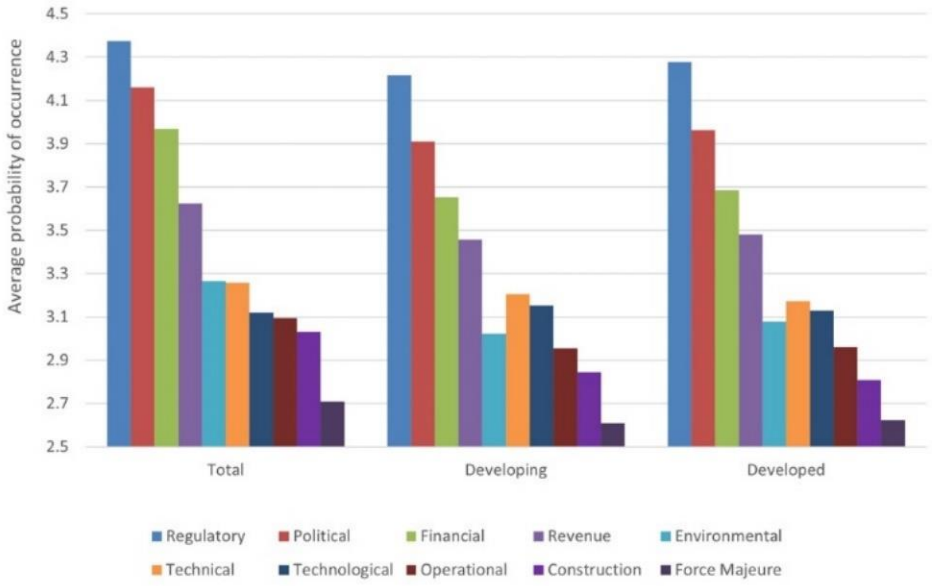

Figure 6. Probability of occurrence of the barriers.

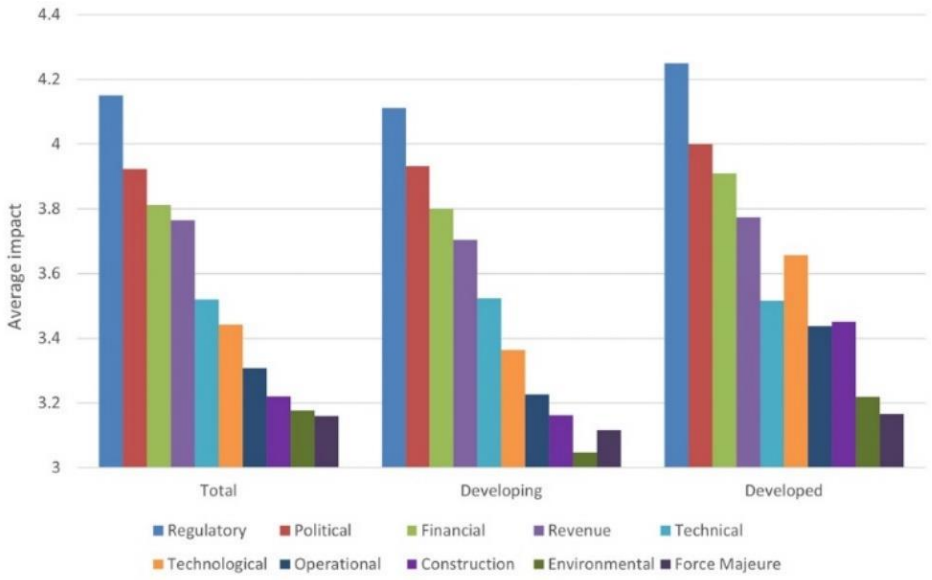

Figure 7. Impact of barriers.

While it is difficult to understand the severity of barriers using the probability and impact separately, another metric that combines both is suggested to be used to holistically reflect the severity of the barriers. Thus, a severity index was introduced. It is calculated by multiplying the probability of occurrence by the impact as shown in Eq 1. Since the probability and impact range from 1 to 5, the risk severity will have a range from 1 to 25. The higher the risk severity index for a barrier, the bigger the impact of this barrier on the performance of renewable energy PPPs. Figure 8 summarizes the risk severity index of all barriers for both sets of countries. The results show that experts from developed countries perceive the barriers with a higher level of severity. Additionally, the differences in the perceived severity of the different barriers are minor across both areas. Moreover, the barriers with the highest levels of severity are the regulatory and political ones for both areas.

$$RSI_i = P_i * I_i \tag{1}$$

where RSI_i represents the severity index of a risk/barrier (i); P_i represents the probability of occurrence of the barrier (i); and I_i represents the impact of the barrier.

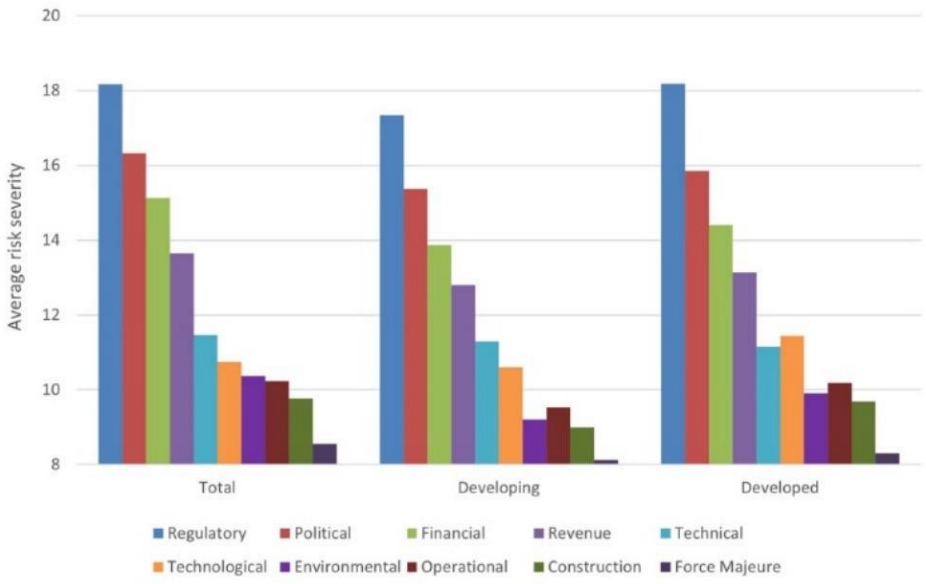

Figure 8. Risk severity index of the barriers.

Finally, the experts were prompted to select the appropriate party (public or private) to assume responsibility for every barrier to ensure appropriate risk allocation and achieve a successful cooperation between the different sectors. Figure 9 summarizes the responses of the experts for the risk allocation of the barriers across developing and developed countries. The results show that there are no major changes in the risk allocation preferences between both sets of experts. In other words, experts worldwide agreed on assigning the barriers to the same parties. There was an agreement for the responsibilities: Regulatory and political barriers should be assigned to the public sector and the technical, construction, operational, and technological barriers should be assigned to the private sector. Finally, both sectors should be responsible for force majeure, revenue, financial, and environmental barriers.

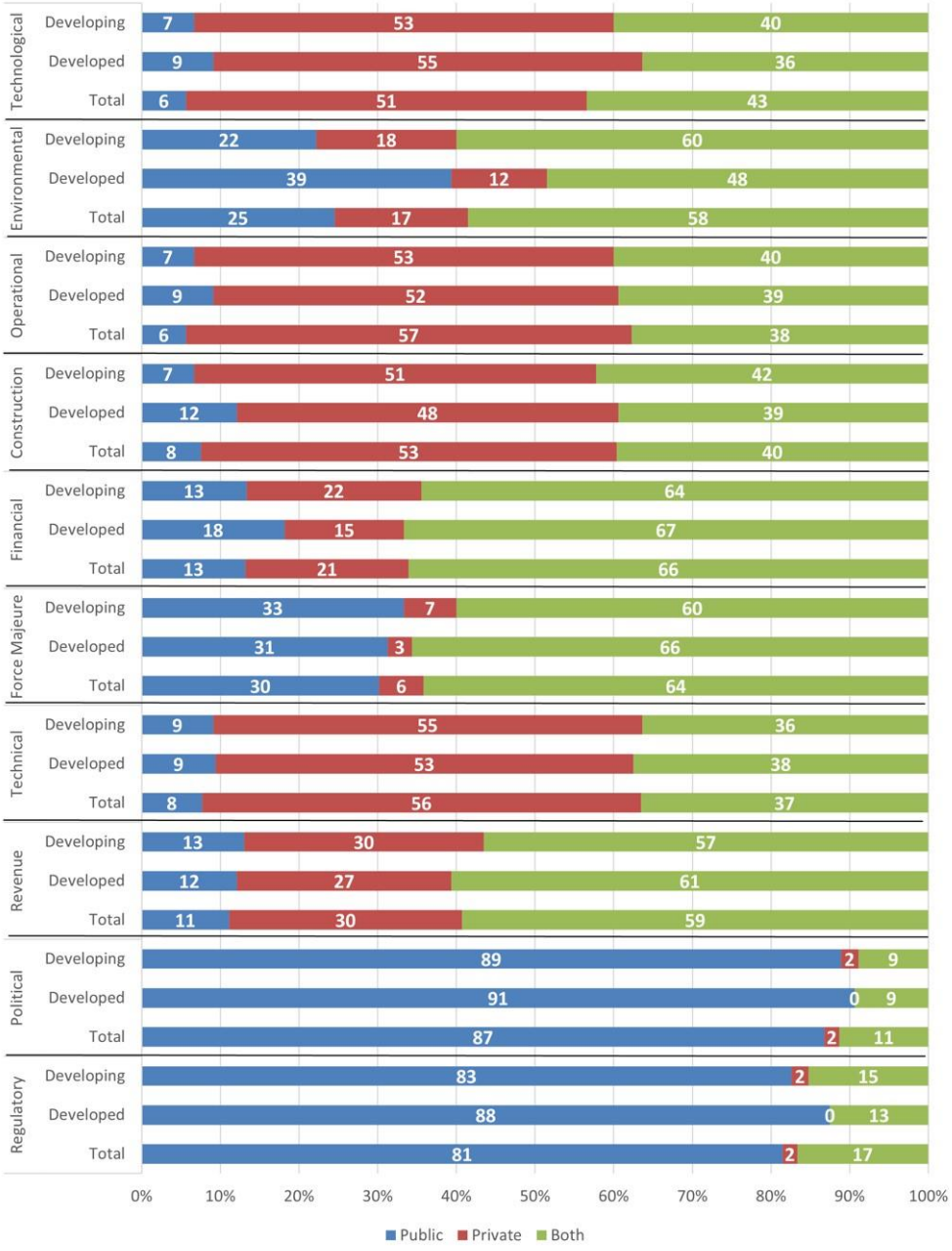

Figure 9. Summary of the risk allocation.

3.4. Analyzing the performance of the public and private sectors

It is essential to quantify the performance of the different parties involved in these unique projects. Thus, in this section of the survey, the experts were asked about the performance of the public and private sectors using 'yes or no' questions. Specifically, the experts were questioned about their opinion on the public sector's ability to identify, value, and select the risks to retain and those to transfer. Figure 10 shows a comparison between the performance of both sectors. The results show that their performance is similar across both areas. Only about 35% of the experts believe that the public sector can identify and value risks appropriately. When the experts were asked about the ability of the public

sector to retain and transfer appropriate risks, this percentage decreased to only 24% of the experts (17% from developed countries and 28% from developing countries) agreeing that the public sector can select to retain and transfer risks appropriately. On the other hand, the majority of the experts believed that the public sector can identify and value risks appropriately. In general, 61% of the experts (60% of experts from developed countries and 64% of the experts from developing countries) agree on the private sector's ability to correctly identify and value risks. As a result, this shows that the private sector is an efficient party that can deal with risks efficiently, as opposed to their counterpart. Thus, these results highlight the importance of taking advantage of the private sector's participation in renewable energy projects in the form of PPPs. They show that the implementation of these types of projects in the form of PPPs should improve their efficiency.

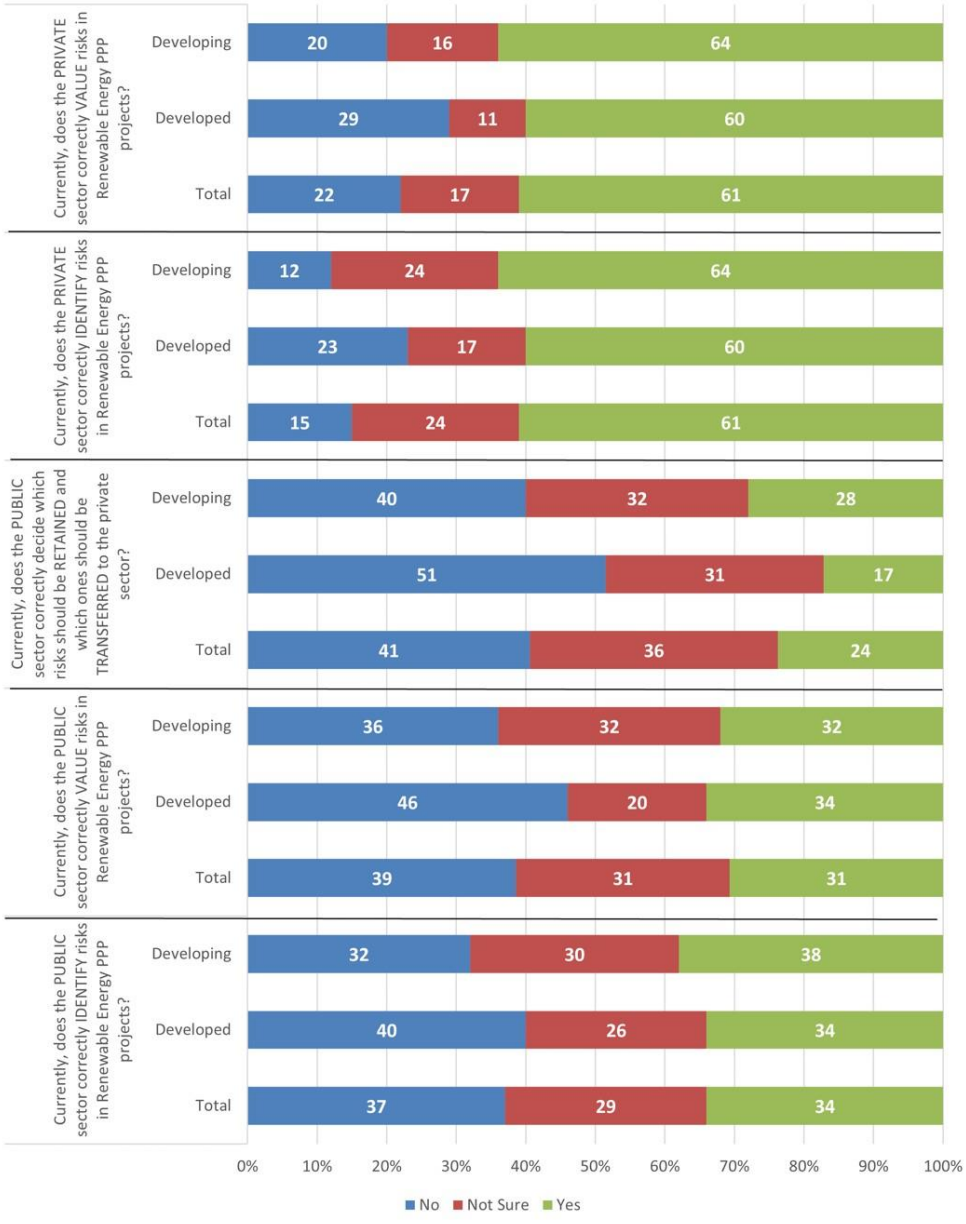

Figure 10. Comparison between the efficiency of the public and private sectors.

3.5. KSFs and KPIs of renewable energy PPPs

In this section, the experts ranked the eight main KSFs identified through the literature review process on a Likert scale from 1 to 5. These factors are: The skilled and efficient parties, technological development, desired conditions (such as weather, wind, etc.), competitive procurement, well-prepared contract documents, efficient negotiations between the different parties, appropriate risk allocation, and desirable project location. The importance of the different KSFs for both areas are summarized in Figure 11. The analysis shows that the main identified KSFs are skilled and efficient parties and well-prepared contract documents. However, the rank of these factors changes across the two sets of countries. While experts from developing countries believed that the main KSFs were technological development followed by skilled parties, experts from the other side selected skilled parties and desirable conditions. Additionally, the analysis shows that experts from developed countries gave a higher evaluation to the project location than their counterparts.

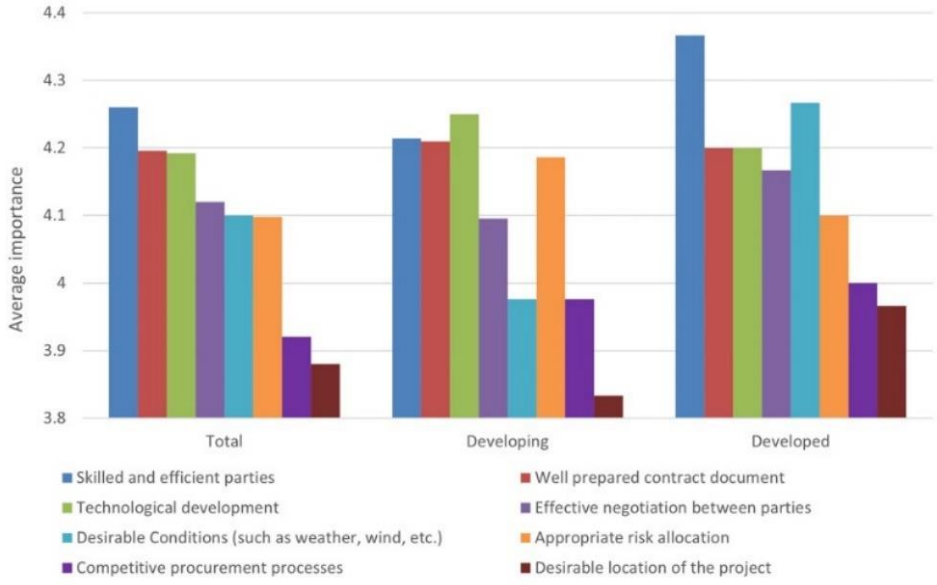

Figure 11. Level of importance of KSFs.

Furthermore, the experts ranked the KPIs on a Likert scale from 1 to 5. They were asked to rank six different KPIs: Produced capacity, reduction in emissions, resources saved, traditional KPIs (cost, time, money), VfM achieved, and risk allocation. The results of the preferred KPIs selected by the experts are summarized in Figure 12. It shows that the experts prefer the use of the produced energy capacity and reduction in emissions in evaluating the projects. However, the preferred KPIs change from developed to developing countries, while the former prefers the use of produced capacity and emissions reduction, the latter prefer the use of the produced capacity and resource saving in evaluating their projects. These results show that experts from developing countries focus on producing the largest capacity with the least resources while their counterparts focus on producing the largest capacity with the objective of minimizing the levels of emissions.

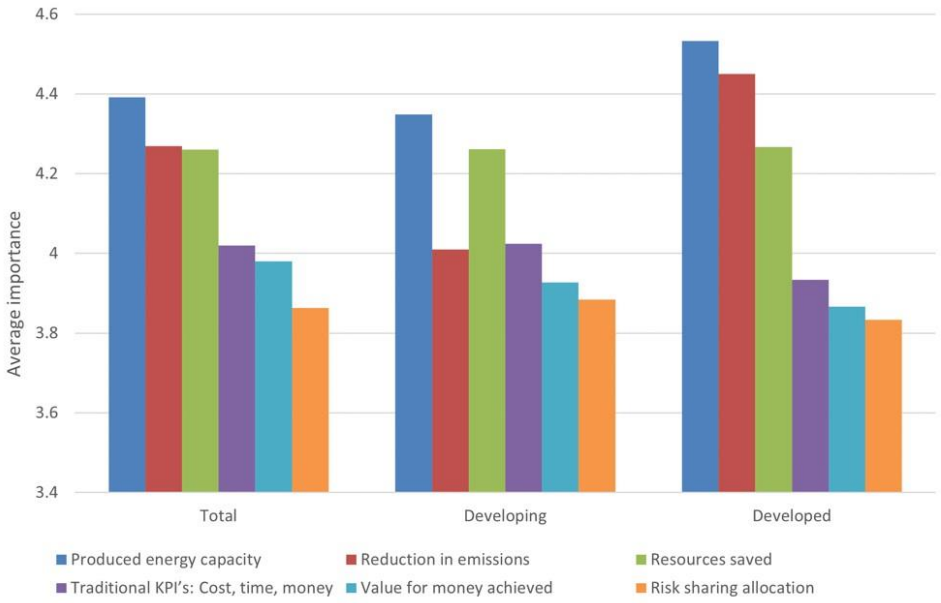

Figure 12. KPIs used to evaluate the success of renewable energy PPPs.

4. Discussion and policy implications

This study focused on providing a comparative analysis of renewable energy PPP projects in both developed and developing countries. A questionnaire survey was distributed to experts in the field to gather their opinion and insights. The results highlight the competence of the private sector in both areas. In general, the experts highlighted the private sector's experience in identifying and valuing the risks over the public sector. Thus, it is not surprising to see the public sectors seeking the involvement of the private sector to improve the effectiveness of these projects and transfer part of the risks. In terms of the barriers facing the projects, the analysis shows that both sectors face the same barriers. In general, regulatory and political barriers were the main observed ones in both areas and also had the highest severity level. Comparing these results with previous studies, a consistency can be observed. According to previous literature, political and regulatory barriers are constantly within the top three barriers for PPPs across the globe [50,55,66–81]. Thus, it can be established that renewable energy PPPs face the same barriers regardless of the project's location. Hence, governments should work on these two main barriers to reduce their impact and attract more private investments in these projects.

The analysis shows that the main KSFs were skilled and efficient parties and well-prepared contract documents. However, the rank of these factors changes across areas. While experts from developing countries believe that technological development followed by skilled parties are the main KSFs, their counterparts selected skilled parties and desirable conditions. Additionally, the results showed that experts from developed countries gave a much higher importance to the choice of project location and environmental conditions (such as weather, with, etc.) than their counterparts. Kamel et al. (2017) [82] showed that the project location and surrounding conditions can be main factor that affects the success and failure of some projects that depend on the environmental conditions such as wind. They focused on analyzing the impact of the project location on the success of two airport PPP projects in Egypt: Marsa-Alam International Airport and El-Alamain International Airport. These two projects had similar conditions, were both coastal area airports, were announced on the same date, had

similar bidding conditions, and even went through the same issues with the same governmental authorities. However, only one of these projects is achieving ascending profits (Marsa-Alam Airport) that exceed the profits estimated in the feasibility study, while the other one is achieving growing losses (El-Alamain Airport) until its top management was referred to the administrative control authority in 2014. The two projects had the same information available at time of bid including the airport location and estimated area. In the Marsa-Alam Airport case, one of the bidders visited the project location with his team to have a realistic evaluation. The bidder's feasibility study showed major issues related to the project location that could force the project to fail so they submitted an official memorandum to the authorities about the findings requesting a change in the project location. The authorities analyzed the memorandum and accepted this change. This bidder then managed to win the tender. On the other hand, in the El-Alamain Airport project, the bidder used the original plan developed by the authorities. However, the issues in the feasibility study forced the project to fail. Thus, this story shows that the location of the projects and the surrounding environmental conditions could be a deciding factor for some projects. Renewable energy projects depend mostly on the location and surrounding conditions in order to produce energy. Given that experts from developing countries gave a low importance to the location of the project and its surrounding conditions, it is crucial to highlight the special nature of renewable energy projects and the criticality of the project location.

Finally, for the preferred KPIs that should be used to assess the success of renewable energy PPPs, analysis shows that the experts prefer the use of produced energy capacity and emission reduction. However, the preferred KPIs changes from developing countries to developed countries. While experts from developed countries prefer the use of the produced capacity and reduction in the emissions, their counterparts prefer the use of produced capacity and resources saved in evaluating their projects. These results show that experts from developing countries focus on producing the largest capacity with the least resources while experts from developed countries focus on producing the largest capacity in order to minimize the levels of emissions. As a result, it can be concluded that experts from developed countries prefer the use of environmental indicators while those from developing countries focus on resource saving. Thus, these results shed light on a gap between the nature of renewable energy projects and the objectives of the experts from both areas. Although renewable energy projects are generally driven by environmental goals, none of the main KPIs used in developing countries are environmental, which necessitate the need to educate experts from developing countries about the nature of renewable energy projects and their objectives.

5. Conclusions

The research in this study was undertaken to provide valuable insights onto the global renewable energy PPP market, offering a microscopic analysis of various factors that influence the success of such partnerships. Through the development and analysis of a questionnaire survey, this study sought to shed light on several critical aspects of this market, including the factors influencing the public sector's choice of PPPs, the key barriers and Key Success Factors (KSFs), the performance of both public and private sectors, and the preferred Key Performance Indicators (KPIs) for evaluating the success of renewable energy PPP projects. The survey-based research conducted herein delved into the complex decision-making process that governs public sector involvement in renewable energy PPPs. The responses from 86 experts, encompassing both developed and developing countries, provided valuable insights into these factors. Understanding the motivations behind the public sector's choice

to engage in PPPs is vital, as it sets the stage for the entire partnership. Such insight can aid governments in formulating more informed policies and strategies in the realm of renewable energy. Our study revealed that the decision to opt for a PPP model in renewable energy projects is influenced by a multitude of factors and that financial support is the main observed factor. Renewable energy projects, especially those involving cutting-edge technologies, typically require substantial upfront capital investments. The public sector, constrained by budgetary limitations, may find it advantageous to collaborate with private sector entities possessing the necessary financial resources to facilitate project implementation.

One of the most striking findings of our research is the disparity between renewable energy PPPs in developing and developed countries. Both groups of experts emphasized a common challenge: The public sector's limited ability to identify, assess, manage, and transfer risks. Conversely, the private sector was perceived as being more adept at handling risk-related issues. This revelation emphasizes the crucial role that private sector involvement plays in the success of renewable energy projects. It suggests that governments should actively seek private sector partnerships to leverage their risk management expertise. The issue of risk management is intrinsically linked to financial viability, which emerged as a key issue for the public sector in our research based on the responses of the experts from both developed and developing countries. Developing countries, in particular, often face hurdles in securing adequate funding for renewable energy projects. This is exacerbated by uncertainties surrounding revenue generation and the prolonged return on investment timelines associated with renewable energy technologies. Governments, in these contexts, can benefit immensely from private sector collaboration, sharing the financial burdens while tapping into private sector innovation and efficiency. In addition, identifying and addressing barriers while leveraging KSFs are essential aspects of project planning and execution in renewable energy PPPs. This study revealed critical insights into these factors, shedding light on the obstacles that need to be overcome. The results also revealed that regulatory and political barriers are the main risks, with the highest level of severity in both developing and developed countries. These barriers can manifest as bureaucratic hurdles, unstable political climates, or inconsistent regulatory frameworks. Addressing these challenges necessitates proactive government involvement and the establishment of a stable and supportive policy environment.

Understanding the performance of both the public and private sectors in renewable energy PPPs is critical for gauging the effectiveness of such partnerships. It provides valuable insights into where each sector can improve its contribution to project success. The results highlighted a noteworthy distinction in the perceived strengths of each sector. The public sector was often seen as less equipped to manage risks effectively. This raises questions about the suitability of the public sector as the primary driver of such projects, particularly when it comes to risk-intensive projects like renewable energy. Conversely, the private sector was generally regarded as more efficient in risk management, making it an attractive partner for governments looking to minimize exposure to financial and operational uncertainties. This finding highlights the importance of a collaborative approach, where the strengths of both sectors are leveraged. Governments can focus on creating a conducive policy environment, providing incentives, and ensuring regulatory stability, while the private sector can bring its expertise in project management, risk mitigation, and innovation to the table.

An important outcome of this study was the allocation of various barriers to either the public or private sector. This allocation provides clarity in terms of responsibility and accountability, essential for effective project management and dispute resolution. Regulatory and political barriers were consistently assigned to the public sector. This allocation aligns with the notion that governments have

the primary responsibility for creating and maintaining a stable regulatory and political environment conducive to private sector investments. By acknowledging this allocation, governments can take steps to streamline regulatory processes, minimize bureaucratic red tape, and promote political stability, thus reducing barriers for private sector participation. On the other hand, technical, construction, operational, and technological barriers were predominantly associated with the private sector. This is in line with the expectation that private sector entities are responsible for the execution and operational aspects of renewable energy projects. It emphasizes the need for private sector partners to possess the necessary technical expertise and capabilities to manage these challenges effectively.

This study revealed a significant knowledge gap among experts in developing countries regarding the unique complexities of renewable energy projects. Experts from these regions did not consistently consider factors such as project location and environmental conditions (e.g., weather and wind patterns) as critical determinants of project success. These findings highlight the need for education and capacity building among stakeholders in developing countries. Efforts should be directed toward enhancing the awareness of experts in developing countries about the nature of renewable energy projects. These experts should be equipped with the knowledge and tools to assess the environmental and geographical suitability of project sites, as these factors can significantly impact energy capacity and project viability. Moreover, a comprehensive understanding of these elements is crucial for effective project planning and risk management. Furthermore, the results show that there is a diversity in the preferred KPIs between experts in developing and developed countries. Experts in developing countries favored traditional KPIs that focused on maximizing capacity with minimal resource utilization. In contrast, experts in developed countries emphasized the importance of maximizing capacity to minimize emissions, aligning with a more sustainable and environmentally conscious approach.

In conclusion, this research has provided valuable insights into the global renewable energy PPP market, offering a comprehensive understanding of factors that influence project success. The findings emphasize the importance of private sector participation in risk management and highlight the significance of addressing regulatory and political barriers in both developed and developing countries. Additionally, the study highlights the need for knowledge dissemination among experts in developing countries regarding project-specific factors and objectives. By recognizing these differences and fostering collaboration between public and private sectors, governments and industry stakeholders can work together to optimize and maximize the efficiency of renewable energy PPP projects.

6. Study limitations and recommendations for future research

While this investigation offers a macroscopic understanding of renewable energy projects on a global scale (developing and developed countries), there exists a need for additional research studies that aim to understand barrier and KSFs facing renewable energy projects in every country or in the microscopic level. This necessity arises in order to corroborate the findings derived from the current survey and to understand the variabilities in these factors across various nations. Furthermore, although this study relied upon the implementation of a questionnaire survey, it is advisable to supplement these methods with in-person interviews. Such an approach would offer the experts the latitude to articulate their experiences within distinct projects and acquire supplementary insights that traditional surveys might not facilitate. It is crucial to acknowledge that renewable energy projects are progressively evolving over time, with governments actively trying to attract private-sector investments in this sector. Consequently, the barriers and KSFs associated with these projects are anticipated to vary in the future.

Thus, it is incumbent upon the research community to conduct periodic surveys to capture the dynamics of these barriers and critical success factors as they evolve over time across the different areas.

Use of AI tools declaration

The authors declare that they have not used Artificial Intelligence (AI) tools in the creation of this manuscript.

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Author contributions

Conceptualization, K.O. and R.K.; methodology, K.O. and R.K.; software, K.O.; validation, K.O. and R.K.; formal analysis, K.O.; investigation, K.O. and R.K.; resources, K.O. and R.K.; data curation, K.O.; Writing—original draft preparation, K.O.; Writing—review and ed-iting, K.O. and R.K.; visualization, K.O.; supervision, R.K.; project administration, R.K.; funding acquisition, R.K. All authors have read and agreed to the published version of the manuscript.

Conflicts of interest

The authors declare no conflicts of interest.

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