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Enabling factors for the development of mini-grid solutions in Mozambique: A PESTLE-based analysis

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ABSTRACT

Electricity is crucial for each country's economic and social development. More than half of the population in Sub-Saharan African (SSA) lack access to energy, which has dire consequences for the local population's living conditions, as well as affecting the local economy and increasing poverty. Renewable energy-based mini-grid (REBM) systems are the promising solution to mitigate the issue of energy access in rural areas, however, the expansion of renewable energy (RE) systems and the rate of energy access are both advancing at a slow pace. This study used PESTLE analysis (Political, Economic, Social, Technological, Legal, and Environmental) in the context of Mozambique, a SSA country, to identify the most important categories and factors to support decision-making processes by breaking down existing barriers and hurdles in the energy sector enabling them to plan and implement measures, subdivided in primary, secondary and tertiary for the development of REBM in remote settlements. Even though PESTLE analysis is rather often worldwide applied to the energy sector, its application to the Sub-Saharan context is rare, while its application to the Mozambique energy sector is absent in scientific literature. Besides, within our study, energy experts from different professional backgrounds and nationalities have been interviewed using an online questionnaire: 62 energy experts (48 Africans, and 14 Non-African) from 14 different countries assessed the categories and factors. The experts questioned identified the political category as the most crucial for policy-makers to prioritize, with the top three global weighting factors being, Clear Government policies (plan, regulation, priority, strategy) 5.79%, National financial scheme for RES investments 4.93%, and cost of investment 4.86%. The findings can support policy-makers breakdown barriers in the energy sector, planning and implementing measures for the REBM development, and contribute to achieving the SDG7 target.

1. Introduction

There is no country that can develop without universal access to reliable, affordable, and sustainable energy. Electricity access is the cornerstone to mitigating the economy and poverty migration [1], especially in Sub-Saharan Africa (SSA) where the number of people living deprived of electricity access estimated by IEA was 580 million in 2019, compared to 610 million in 2013 [2]. Unfortunately, this positive trend has been reversed in 2020 due to the COVID-19 pandemic, making basic energy services inaccessible to nearly 100 million people who already had electricity connections [2,3], thus undermining the efforts to achieve SDG 7 - universal electricity access by 2030 [4] (see Figs. 6–10).

Mozambique is one of the countries with the lowest rate of electrification in SSA region hovering at only 38% corresponding to about 11.8 million people, while the total population is around 31 million people [5,6]. More than 54% of the population lives below the poverty line and around 70% of people live and work in rural areas in extreme poverty, deprived of income, education, and healthcare [7]. Such a condition is reflected in the composition of the energy mix in Mozambique with biomass providing around 70% of the primary present energy supply [8]. In the African context, biomass is linked to the many types of conventional fuels (dung, charcoal, firewood, agricultural residues),

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Acronyms

REBM	Renewable energy-based mini-grids
RE	Renewable Energy
PESTLE	Political, Economic, Social, Technological, Legal and Environmental
SDG7	Sustainable Development Goal 7
SSA	Sub-Saharan Africa
O&M	Operation & Maintenance
SLR	Systematic Literature Review
R&D	Research and Development
FDI	Foreign Direct Investment
GoM	Government of Mozambique
GDP	Gross Domestic Product
GHG	Greenhouse Gas

which unsustainable use causes environmental and health problems [9]. Mozambique has a great potential for power generation, now dominated by hydropower, which generates 81% of all electricity [8]. The country has 2.7 GW of built capacity, with 95% coming from the Cahora Bassa hydropower project, 4% from solar, and 1% from bioenergy [10,11]. Still, the majority of rural communities are located far from the national grid, they reside in remote settlements which are scattered and characterized by a low density of population and low rate of electricity consumption [12,13], which often makes the electrification through national grid economically unviable [14,15]. In general, there are three possible solutions to approach rural electrification, namely: national-grid extension, standalone systems, and mini-grids (hybrid mini-grids or 3rd generation mini-grid, as in Ref. [16]. Standalone systems are particularly suitable for very dispersed populations or single households [17], representing a cost-effective option for low tiers of service, while 3rd generation mini-grids are often pointed as the superior-quality solutions to boost local development [16,18]. 3rd generation mini-grids are a very recent technology, characterized by specific parts for the generation, consumption, metering, and distribution of electricity. Moreover, they adopt remote-controlled energy management systems and prepay smart meters (to reduce operating costs), are designed to inject, and receive energy from the national grid (to reduce investment risk), has a comprehensive set of the latest software and hardware technology, and facilitate efficient use of electricity (it reduces the costs of kWh units, boosts profitability and fosters local economic growth) [16]. The context of Mozambique, characterized by dispersed and widely suppressed demand as well as a huge renewable power potential [19,20], could drastically benefit from electrification through renewable energy-based mini-grids (REBM). Such a solution can face the unpredictable nature of renewable resources, being composed of solar panels, batteries, and backup diesel generators while allowing for high and productive tiers of service [21]. They are reliable, ecologically sustainable, and more cost-effective [22], thanks to declining technological costs, new business models, and hundreds of already identified prospective locations [16,23].

Mini-grids are not a new phenomenon, since the public services have owned and operated off-grid diesel generators for remote villages for around 25 years [24]. Still, energy development is increasing in Africa at a slow pace, because of a set of barriers that are undermining the development of the mini-grids in rural areas, such as: Energy policy and regulatory barriers, economic and financial barriers, technological and human resources barriers, social and geographical barriers, [25], being the lack of clear and effective energy policy and regulatory frameworks the main barriers a [13,26]. From the literature analysis of 44 scientific papers and grey literature sources, it can be concluded that the factors responsible for the development of the mini-grids in rural areas in developing nations are rather well explored.

The scientific literature has also widely addressed the analysis of feasibility studies, resource assessment, and mini-grid sizing of the systems for rural electrification in SSA [27,28]. Still, context-specific studies of the factors, enabling the deployment of REBM in SSA and especially in the countries, characterized by low electricity access rates, while involving different categories of stakeholders are insufficiently explored. The current study, focusing on Mozambique's experiences and adopting a PESTLE (Political, Economic, Social, Technical, Legal, and Environmental) analysis methodology to identify and classify the enabling factors, is aimed at giving its contribution to filling this gap supported by interview-based feedbacks/viewpoints of energy experts from various/different backgrounds and nations, but with an experience of working in Sub-Saharan and Mozambique energy sector in particular. Overall, 62 energy experts from 14 different countries (48 Africans and 14 non-Africans) have been surveyed and evaluated the categories and factors using an online questionnaire.

The relevance of this study is also characterized by its practical output and applicability, providing policy makers with instruments and recommendations for evidence-informed policymaking based on the results of this study. Since all difficulties cannot be tackled simultaneously owing to technical, logistical, social, or economical restrictions, the study will assist governments and other stakeholders in determining which problem to address first, especially in SSA states such as Mozambique. Despite being limited to Mozambique, the conclusions of this article have broader implications because most developing countries in the region (SSA) confront similar energy challenges. In doing so this paper will address the following questions:

Q1. Among the categories that make up the PESTLE analysis (Political, Economic, Social, Technological, Legal, and Environmental), which categories should be prioritized by policymakers for the effective development of REBM in rural areas of Mozambique?

Q2. What are the most important factors that can facilitate and strengthen the deployment of REBM in Mozambique?

Q3. What are the differences in stakeholders' vision of the priorities and measures to adopt in order to boost the development of REBM in Mozambique?

The reminder of this paper is organized as follows: in section 2 the up-to-date situation in Mozambique is analyzed as far as the electrification, access to energy, and regulatory framework are concerned. In Section 3 the methodology adopted is explained, while in Section 4 the results and discussion are analyzed. Section 5 will be dedicated to the policy recommendations, based on the research output, followed by a conclusion and recommendation.

2. Current renewable energy policy and regulatory framework

Mozambique is living in an energy paradox: the country has a considerable number of dams with a total electricity generation capacity of more than 2075 MW [11,29]. Nevertheless, more than 80% of the power generated is sold to neighboring countries, and less than 500 MW is consumed internally [29,30]. Despite the huge power generation potential in the country, the lack of energy in rural areas is still acute.

Establishing an effective energy policy and regulatory framework would help to reduce barriers as well as stimulate and incentivize REBM development and attract more investment in the sector. Even though Mozambique has been using diesel mini-grids for more than two decades, the development of the sector, let alone REBM, is still slow due to ineffective energy regulations that do not foresee or consider the private sector as one of the main players having a pivotal role in the development of renewable energy in rural communities [26,31].

From the institutional point of view, the Ministry of Mineral Resources and Energy (MIREME) regulates and supervises the energy industry in Mozambique. However, there are, other significant institutions within the government structure whose missions and objectives have an impact on the industry and the implementation of critical development policies directly or indirectly. One such Institution is the Energy Fund (FUNAE), a governmental entity created under the electricity law of 1997 (law number 21/97) to tackle the problems of rural electrification, with a **mission** to promote sustainable and rational access to energy that contributes to the country's economic and social development, while its **vision** is to become the reference institution in the distribution and promotion of alternative sources of energy and rural electrification [32].

The country has several legislations, laws, policies, and strategies in the energy sector [30,33,34], such as [31,35]:

- Law on **Electricity Act Nº 21/97 of October 1, 1997** amended by Law 15/2011 of 10 August, adopted to create The National Council for Electricity (CNELEC) as regulators and Energy Fund (FUNAE) as the main entity to promote rural electrification through renewable energies.
- **National Energy Policy (decree 5/98, of March 3, 1998)** adopted for the development of energy in Mozambique. It outlines the government's intent to develop household energy access, competitive business, environmental technology, and energy efficiency in the electricity sector.
- **National Energy Sector Strategy, established by decree 24/2000 (October 3, 2000) and revised in 2009** to reflect actions and priority to implement this policy. The objectives of the strategy include electricity and fuel access to rural and peri-urbane areas, encouraging sustainable production of biofuels, and engaging in international cooperation.
- The **Policy on the Development of New and Renewable Energy (Revolution 62/2009, 14 October)** was enacted to promote clean energy access through sustainable, efficient, and culturally sensitive sources of new and renewable energies.
- **The Strategy for New and Renewable Energy Development (EDENR) 2011–2025, adopted in 2011** to develop national renewable resources for power generation to meet the demand, diversifying the energy mix and preserving the environment.
- The **National Policy and Strategy for Biofuels approved in 2009**, as the basis of the National Program for the Development of Biofuels (PNDB), aims to promote and use agro-energy resources, to encourage socio-economic development, and to address the unpredictability, instability, and volatility of fossil fuel prices in the international market [30,33].
- Finally, the latest **Regulation on Access to Energy in Off-Grid Zones** was established by **decree 93/2021 (December 10, 2021)**, to strengthen the current legal framework for the energy sector, regulating supply activities for access to energy in remote settlement areas, to boost the productive use of energy for universal access, aiming to mobilize additional funding from donors and crowd in private investment.

Despite a considerable number of policies introduced in the past decades, when it comes to mini-grids in Mozambique, particularly those established by FUNAE, the private sector involvement remains a mirage [26,36], favoring a logic of public construction and Operation & Maintenance (O&M) contracts, and a series of other barriers owing to the ineffective energy laws and regulatory framework are slowing down the electrification pace. The research presented in this paper is aimed at contributing to filling the gap by identifying the most important dimensions and factors for the REBM development in Mozambique to support an efficient and evidence-based policy-making process.

3. Methodology

In this research, a combination of two approaches is applied, namely: ***Systematic Literature Review (SLR)*** and ***Political-Economic-Social-Technical-Legal-Environmental (PESTLE)*** analysis. The combination of both techniques helps to comprehensively identify, classify, categorize, and rank by importance the key factors that could help boost the development of REBM in Mozambique. Additionally, this research aims to support future Multiple Criteria Decision-Making (MCDM) processes, since its final goal is to provide policy recommendations to decision-makers throughout the dimensions considered [37]. The approach is implemented by applying an online-based survey/questionnaire developed and delivered to 62 respondents from 14 different countries, selected according to their experiences in the energy field, knowledge of SSA countries' energy sector, and with a particular focus on Mozambique cases. Most of these respondents are associated with academic institutions, mostly (38) Mozambican and the remaining from other Sub-Saharan African countries and non-African Countries as depicted in Fig. 1. A more detailed graph representing the number of respondents for each country is available in *Appendix A*. The energy experts were interviewed to give their opinion on REBM development in SSA, especially for Mozambique. Within the questionnaire, the respondents have been asked to provide information about the type of institution they are associated with, grouped in civil society (CS), academic (AC), international organization (IO), private sector (PS), government institutions (GI) or donors and investors (DIN).

In the following sections, the methodology will be further detailed, highlighting the specificities brought by the authors.

3.1. Systematic literature review (SLR)

Systematic Literature Review (SLR) is a technique of investigation that uses explicit, systematic approaches to collect and synthesize information from studies that address the specific subject of interest [38]. In this case, SLR has been applied to identify the factors to be then included in the PESTLE analysis. The literature reviewed for this study was systematically selected taking into consideration: i) publications applying PESTLE analysis for policy support in the energy field and/or in developing countries; ii) publications addressing factors for the development of REBM; iii) publications addressing energy barriers and challenges for the development of REBM. A total number of 44 publications has been selected, spacing from scholarly articles to grey literature and market reports. Then, for each of the six categories of PESTLE, the five most recurring factors have been collected and synthesized for a total of 30 factors, as reported in Table 1.

3.2. PESTLE analysis

PESTLE analysis is a tool for analyzing and monitoring factors that affect an organization or sector and can be used to plan or suggest decisions for a project or a policy [101]. PESTLE classifies an unspecified number of factors into six categories as political (P), economic (E), social (S), technical (T), legal (L), and environmental (E). The number of factors as well as the boundaries of each category can be shaped according to the scope of the research. The consulted articles adopting PESTLE analysis in Sub-Saharan African contexts mostly applied it as a conceptual background for discussing each category. For instance, Zalengera et al. [94], used it to analyse the factors hampering the development of renewable energy in Malawi; more recently, Zebra et al. [13], applied the PESTLE approach for macro-environment analyses specifically for hybrid renewable energy systems (HRESs) for developing countries, as similar to Thomas et al. [56] who employed it to assess the barriers influencing solar home system provision in Rwanda; finally, Agyekum et al. [55] examined Ghana's renewable energy sector environment through PESTLE analysis. Such an approach to analysis brings many advantages [52,55].

- it provides multi-perspective and cross-sectoral knowledge of the subject of interest, identifying priorities and opportunities.
- it allows to identification of essential elements, forces, and interlinkages among the dimensions of investigation, also suggesting targets and corresponding action plans.

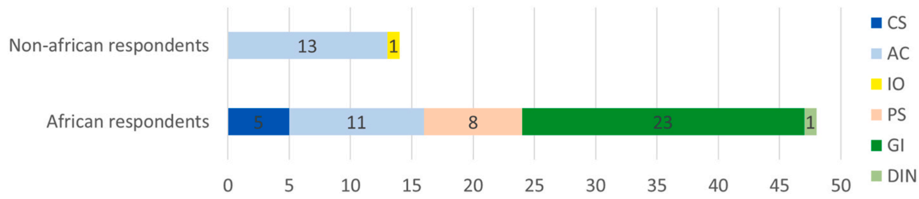

Fig. 1. Division of respondents by country and institution.

- it assists decision-makers in avoiding initiatives on irrelevant factors and adjusting their perception of the issue.
- it promotes the development of strategic and external thinking.

The comprehensive PESTLE approach here employed is based on the methodologies adopted in previous literature in the context of developed countries [40,46,99]. Particularly, it is here applied as an investigation framework using a questionnaire supplied to collect opinions from stakeholders, mainly energy experts, but belonging to different stakeholder categories, which allowed us to identify the priorities for different groups at a disaggregated level. The 62 respondents were asked first to attribute a weight (0% ÷ 100%) to each of the categories of PESTLE, identifying the most relevant ones for the deployment of REBM in Mozambique. After that, each respondent assigned a weight (1 ÷ 5) to each of the factors in Table 2., according to the following ranking: ***1*** – ***Less Important, 2*** – ***Important, 3*** – ***Fairly Important, 4*** – ***Very Important, 5*** – ***Extremely Important***. The results have then been collected and analyzed. For sake of clarity, the steps of the PESTLE analysis process adopted for the study are reported in Fig. 2.

The process develops in five sequential steps:

- STEP 1: definition of categories and selection of factors from SLR
- STEP 2: identification of stakeholders, i.e., relevant energy experts from different institutions
- STEP 3: questionnaire delivery and administration through Google form
- STEP 4: each respondent rates categories and factors, implicitly producing his hierarchy of factors as depicted in Fig. 3.
- STEP 5: the results are collected, clustered, and analyzed by the authors, and then turned into policy implications

4. Results and discussion

In the questionnaire, energy experts and stakeholders were first given to evaluate the PESTLE analysis categories (Political, Economic, Social, Technological, Legal, and Environmental) providing the percentage weights for a total sum of 100%. Then, they were asked to order by the importance of the factors within each category. The weights of the categories have been averaged among all the classes of respondents, obtaining the $cw_{k^*\ category}$ weight associated with each category. Fig. 4shows the results of the average weights of PESTLE analysis provided by different energy experts. It is interesting to note that two (Political and Economic) out of total of 6 categories are perceived by experts to cover almost half (47%) of the collective weights. According to the comments provided by different stakeholders, it is argued that the most important category is the political one for many reasons, explained in the following section. The state's monopoly on the energy sector or industry (both on and off-grid) creates considerable constraints on energy growth. As a result, significant sector changes are only achievable if there is a genuine political desire and a long-term commitment to do so. Other respondents mentioned that to accelerate the development of REBM, political will is required, which is critical in attracting investments, new technology, private sector integration, etc. Furthermore, all these arguments are supported by ***International Renewable Energy Agency***, saying the investments in off-grid electrification are hampered by a lack of adequate renewable energy policy [102], and the ineffective political commitment, according to the World Future Council, is a key hurdle to a renewable energy program in any country [103]. Therefore, the necessity of strong policy support for off-grid electricity is critical [104]. In brief, all the categories of PESTLE analysis depend on Political will to a certain extent. This category discusses deeply political stability, clear government policies (plan, regulations, priority, strategy), national research & development innovation policies, policy incentives (tariffs, taxations, and subsidies), and International/bilateral relationships (funding) (see Fig. 5).

The results of other similar studies in the renewable energy sector differ according to a geographical area and are characterized by the developed/developing country divide. So, in the context of developing countries political and economic factors are usually more important [40,43,55,105], generally confirming the outcomes of our study. In the context of developed countries and in presence of effective energy policies, other factors may gain major importance, such as environmental [99].

The following sections deal with an in-depth analysis of each factor within the six categories. The discussion is made on a local weight lw_i basis, meaning that each ***i-th*** factor is assigned with the average value computed aggregating the six classes of respondents and normalized to 100% for each category. The formula is reported in eq. (1), where w_i is the average weight of the ***i-th*** factor among all the classes j of respondents, ranging between 1 (Less Important) to 5 (Extremely Important), and computed as in eq. (2).

$$lw_{i\in k^*\ category} = \frac{w_i}{\sum\limits_{i\in k^*\ category}^{5} w_i} \tag{1}$$

$$w_i = \frac{\sum_j weights\ attributed\ to\ i - th\ factor\ by\ respondents\ of\ j - th\ class}{total\ number\ of\ respondents} \tag{2}$$

By comparing the factors on a local weight basis, it is possible to highlight the most relevant ones within each category. Vice versa, the global weight gw_i comparison allows drawing overall conclusions crossing different categories eq. (3).

$$gw_{i\in k^*\ category} = cw_{k^*\ category} * lw_{i\in k^*\ category} \tag{3}$$

Thus, 40% of the identified factors constitute 44.7% of the global weight of the factors across the categories. This allows us to skim a set of transversal factors that experts consider the most important in REBM in Mozambique. Table 2 highlights this selection: political stability, clear government policies (plan, regulation, priority, strategy), national financial scheme for RE systems investments, cost of investment, public acceptance and willingness to pay, economic capacity/ability to pay, locally available technical expertise, proper sizing, clear and transparent regulatory framework, private sector involvement and ease of doing business, sustainable exploitation of natural resources and resilience to environmental risks. Tables specific to each category of respondent have also been prepared and a comparative graph with the results is reported in Appendix B.

Table 1
Factors derived from SLR.

Categories	Key factors	Reference	Descriptions
Political	Political stability	[31,39–63]	The references from the political category were chosen while considering the relevant elements, each with a particular focus, such as: clear, stable, and long-term policies, international collaboration for innovation and capacity building, and incentive legislation to lure in energy players.
	Clear Government policies (plan, regulation, priority, strategy)	[13,35,41,43,46,51,52,55,56,58–87]	
	Availability of national Research & Development innovation policies	[13,40,41,46,51,52,55,56,58,60,67,69,70,72,74,79,81–83,86,88–93]	
	Policy incentives (Tariffs, taxation, subsidies)	[40–43,46,52,55,56,58–62,64,70,72,75,79,81–88,90,92–97]	
	International/bilateral relationships (International funding)	[13,42,43,46,52,55,58,64,67,69,72,75,79,81,84,87,88,90,91,93,95,98]	
Economical	General economic stability	[41,42,46,52,55,59–61,69,72,81,82,84,88,95,99],	The references in this category were chosen by considering many topics, including macroeconomic environmental concerns, RES investment strategies, high-RES investment, and effective mini-grid development business models.
	National financial scheme for RES investments	[13,41,46,56,58,64,67,69,70,73,87,92–94,96–98,100]	
	Cost of investment	[13,41,43,46,52,55,56,58,59,61,61–64,67,69,70,72,74,75,81,82,85,87,90,92–94,96,97,99,100]	
	Economic environment (interest rate, inflation, exchange rate, GDP)	[40,42,43,46,52,55,58–60,62,67,69,72–75,81,83,84,86–88,90,93,95,98,99]	
	Viable business models	[13,41,43,51,63,67,70,74,81–85,91–94,96,98]	
Social	Public acceptance and willingness to pay	[13,43,51,55,56,62–64,67,67,73,74,82,88,90,91,93,94,96]	The keywords in this category were contents like public acceptance, capability, and willingness to pay. Additionally, the content assessed in this category to discover relevant references includes the demographic change, social norms, and engagement of the energy players in RE projects.
	Social background (cultural, religious, ethnic, etc.)	[41–43,46,51,52,55,56,58,63,64,69,70,72–75,79,81,82,84–88,90–93,95,97,98,100]	
	Economic capacity/ability to pay	[40,43,51,52,58,61,62,64,67,69,70,75,79,81,83–85,93,94,98]	
	Demographic trends (Growth rate, density, migration)	[40,46,52,55,56,58–61,69,72,74,75,79,81,84,88,90,93,95,98,100]	
	Community engagement	[41–43,46,51,58,61,64,67,69,70,83,84,89–91,94,95]	
Technical	Locally available technical expertise	[13,41,46,51,52,59,64,69,70,73–75,79,81,82,87,89,91,92,94,96,97]	This category's contents include adequate mini-grid optimization, operation and maintenance culture, and local technical and energy expertise, as well as the quality of end-user appliances and the transfer of new technologies.
	Efficiency of the end-user technology	[41,52,60,62,63,69,72,81,82,90,92,96,100]	
	New technologies and technology transfer	[40,41,43,46,51,52,55,56,58–64,67,69,70,72,73,75,79,81,82,82,84,88,90–94,96,98,99]	
	Operation & Maintenance procedure and Spare parts availability	[13,55,58–60,63,64,70,74,81,83,87,88,90–92,94,96,97,100]	
	Proper sizing	[41,43,46,52,56,58,59,61,64,70,75,85,87,89,91–94,96,99]	
Legal	Clear and Transparent regulatory framework	[40–42,46,52,55,56,59–61,63,69,73–75,79,81,82,84,86,90,91,94,95,97,98,100]	The legal category's determining factors taken into account issues like a transparent and efficient bidding process, a strong regulatory framework, and ease of doing business. The management of the energy sector, governance, and private sector involvement are additional topics considered.
	Timely update of the legislation	[43,51,52,60,67,74,79,81,82,88,90,93,99]	
	Transparent bidding procedure	[41,42,46,59,63,74,75,81,83,84,91,92,98]	
	Private sector involvement and ease of doing business	[41–43,55,59,64,70,73,74,79,82,83,86,90,90,92,94–96]	
	Clear and effective governance of the energy sector & division of responsibilities	[41,43,52,55,56,59,60,63,67,69,74,75,79,81,83,84,84,86,87,90,91,94,95,97,98,100]	
Environmental	Geographical location and Weather	[41,46,55,79,81,84,90,91,93–96]	The strategic approach employed in the category was the use of specific words and topics like climate change, GHG emissions, environmental resilience and awareness, geographical location, natural disasters, and weather to identify relevant references.
	Environmental targets	[40–43,46,52,56,60–63,67,69,70,73,75,79,81,82,84,86,90,93–95,97,98,100]	
	Accountability of GHG emissions and other pollutants	[13,40,41,43,55,56,60,62,63,74,75,79,81–84,86,90,94–96,99,100]	
	Sustainable exploitation of natural resources (e.g., water basins, biomass, land)	[13,40,41,46,52,55,56,63,67,70,73,74,79,82,90,91,94–100]	
	Resilience to environmental risks	[13,41,43,46,46,52,55,	

(continued on next page)

Table 1 (*continued*)

Categories	Key factors	Reference	Descriptions
		62–64,67,69, 70,75,79,81, 84,86,88,90, 91,93–95,97, 99,100]	

4.1. Political category

4.1.1. Political stability

The second place among the factors is occupied by Political stability, classified as **very important** with a value weight of 20.5%. According to some respondents, having political instability in the country is harmful to investors who need guarantees of being able to safely operate, since most of the renewable energy projects are long-term commitments, many international investors decline investment requests from states, characterized by unpredictable occurrences and instability (corruption, terrorism) [106]. Others emphasize political stability's crucial role in the implementation of the policies to promote REBM use among the rural population in the conflict areas, particularly vulnerable and unable to settle in the areas chosen for electrification. For instance, the current armed conflict and instability issues in Cabo Delgado in Mozambique led to the suspension of all the development projects in the affected areas [107]. One respondent stated that in all contexts, political stability is fundamental for the implementation and operation of economic and especially social projects since they are the first to be suspended in case of potential risks. Besides, inward investments plummet in the event of political tension in a region, even if the government policies are clear. So, stability becomes one of the most important variables in attracting foreign direct investments, otherwise avoided by the majority of multinational corporations [108].

4.1.2. Clear government policies (plan, regulation, priority, strategy)

Clear Government policies (plan, regulation, priority, strategy) factor was classified as extremely important with a local weight value of 24.4%. Clear policies and regulatory frameworks are fundamental to creating an enabling environment for the development of solutions for energy access in SSA [109,110]. Some respondents stated that having a clear strategic plan and setting priorities for electrification assures investors and increases the confidence level for safe investment and guarantee the return by providing guidelines and a vision on national priority issues to be pursued in the short, medium, and long term. Additionally, ad-hoc institutional and regulatory frameworks, flexible policy adjustment mechanisms at different stages of mini-grid development, financing schemes, tariffs, tax regimes, and others measures to reach the strategic goals of energy access should be adopted. In fact, according to ESMAP, light regulation is typically adequate as mini-grids enter the market and expand. However, the government may need more legislation when small grids take over their local markets to guarantee high service standards at the most affordable price. Scholars agree that mini-grid projects must be part of a broader electrification strategy that tackles obvious regulatory and potential challenges at both national and local levels, and effective planning tools for designing electricity plans, strategy, and priority definition are essential for determining the best electrification approach for various sub-national areas [111]. Therefore, flexible, and constantly updated policies are required to ensure the resilience of the energy systems and mini-grid development and unleash their potential to provide electricity to as many as 500 million people by 2030 [16].

Table 2
From category weights (cw) to local (lw) and global (gw) weights.

CATEGORIES	Category WEIGHTS (cw)	KEY FACTORS	Factor WEIGHTS (w)	Local WEIGHTS (lw)	Global WEIGHTS (gw)
Political	24%	Political stability	**3.5161**	**20.49%**	**4.85%**
		Clear Government policies (plan, regulation, priority, strategy)	**4.1935**	**24.44%**	**5.79%**
		Availability of national Research & Development innovation policies	2.8226	16.45%	3.90%
		Policy incentives (Tariffs, taxation, subsidies)	3.4839	20.30%	4.81%
		International/bilateral relationships (International funding)	3.1452	18.33%	4.34%
Economical	23%	General economic stability	3.3226	19.09%	4.45%
		National financial scheme for RES investments	**3.6774**	**21.13%**	**4.93%**
		Cost of investment	**3.6290**	**20.85%**	**4.86%**
		Economic environment (interest rate, inflation, exchange rate, GDP)	3.4032	19.56%	4.56%
		Viable business models	3.3710	19.37%	4.52%
Social	16%	Public acceptance and willingness to pay	**3.6774**	**23.03%**	**3.58%**
		Social background (cultural, religious, ethnic, etc.)	2.0000	12.53%	1.95%
		Economic capacity/ability to pay	**4.0161**	**25.15%**	**3.91%**
		Demographic trends (Growth rate, density, migration)	2.6613	16.67%	2.59%
		Community engagement	3.6129	22.63%	3.52%
Technical	15%	Locally available technical expertise	**3.5645**	**21.01%**	**3.10%**
		Efficiency of the end-user technology	2.7419	**16.16%**	2.39%
		New technologies and technology transfer	3.0645	**18.06%**	2.67%
		Operation & Maintenance procedure and Spare parts availability	3.5161	**20.72%**	3.06%
		Proper sizing	**4.0806**	**24.05%**	**3.55%**
Legal	13%	Clear and Transparent regulatory framework	**4.0484**	**23.33%**	**3.20%**
		Timely update of the legislation	2.7869	**16.06%**	**2.21%**
		Transparent bidding procedure	3.2742	**18.87%**	**2.59%**
		Private sector involvement and ease of doing business	**3.6774**	**21.19%**	**2.91%**
		Clear and effective governance of the energy sector & division of responsibilities	3.5645	**20.54%**	**2.82%**
Environmental	9%	Geographical location and Weather	3.2419	19.38%	1.73%
		Environmental targets	3.0323	18.13%	1.62%
		Accountability of GHG emissions and other pollutants	2.9194	17.45%	1.56%
		Sustainable exploitation of natural resources (e.g., water basins, biomass, land)	**3.9516**	**23.63%**	**2.11%**
		Resilience to environmental risks	**3.5806**	**21.41%**	**1.91%**

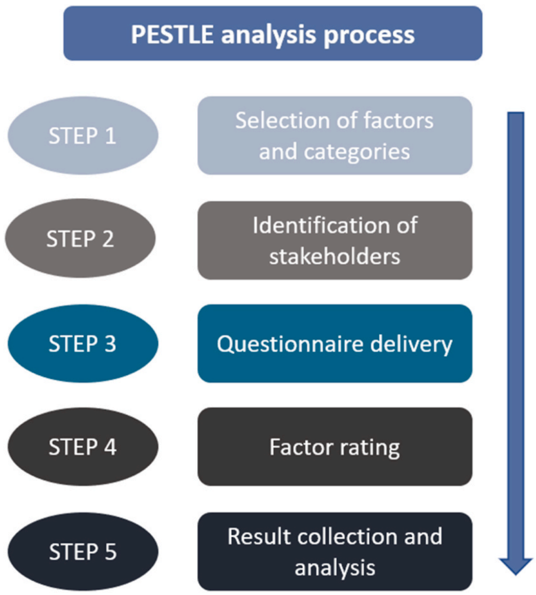

Fig. 2. Steps of PESTLE methodology adopted in the study.

4.1.3. Availability of national research & development innovation policies

The research and development innovation policies are one of the factors that need major consideration by the policymakers. This factor scored 16.5% and was classified as **less important** compared to other factors by the experts interviewed. Therefore, they claim that research and development (R&D) policies are very important and fundamental issues for the development of RE technology in the context of Mozambique, since despite the effort of rural electrification undertaken in the last decade, there are still no tangible results. According to some studies, to achieve sustainable development in developing countries, the technical progress of energy required by the government and its transition or technological advancement of research and development (R&D) is crucial [112], and also market knowledge, network capabilities, technical expertise, and financial strengths are the primary drivers of RE development. Therefore, Research and Development (R&D) policies, according to Martins are critical in this process for understanding technology trends and promoting the development of renewable energy technologies [113].

4.1.4. Policy incentives (tariffs, taxation, subsidies)

Within this category, Policy incentives (tariffs, taxation, subsidies) were classified by stakeholders as fairly important among other factors, reaching the weight of 20.3%. The respondents state that policy incentives can facilitate a successful business plan and attract private investments in a virtuous loop, for the development of REBM. Incentives are essential as private sector companies and individuals with available funding in RE projects and research development might feel more motivated to invest. Brookings Institution's research shows that strong incentives, typically in the form of feed-in tariffs and tax credits, stimulated the large-scale growth of RE installations in the grid-scale solar and wind businesses [114]. Moreover, incentivizing economic policies is crucial to allow the implementation of tariffs that are both affordable and able to pay back the investment and the operational expenses, making mini-grid investments feasible [111,115]. In Mozambique, the government has tried to create broader incentives to stimulate investment, create jobs, and promote exports [116]. However, these tax advantages and incentives are not specifically aimed at the renewable energy industry. Therefore, the government should introduce clearer and more specific incentives to attract private investment in the sector [13].

4.1.5. International/bilateral relationships (international funding)

This factor, able to contribute to the creation of a favorable investment environment is directly linked to the next factor in the ranking International/bilateral relationships (International funding), weighted as important with 18.3%. Some experts interviewed claimed that bilateral international relations enable the mobilization of money across countries through partnerships with international funders or investors, which is fundamental for developing countries like Mozambique, with low internal investment availability. External partners funded most renewable energy projects deployed in developing nations. Therefore, in the energy industry, little can be done without the help of foreign

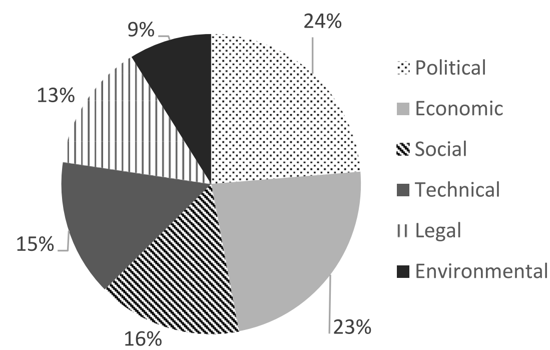

Fig. 4. Average weights of PESTLE categories, called category weights (**cw**).

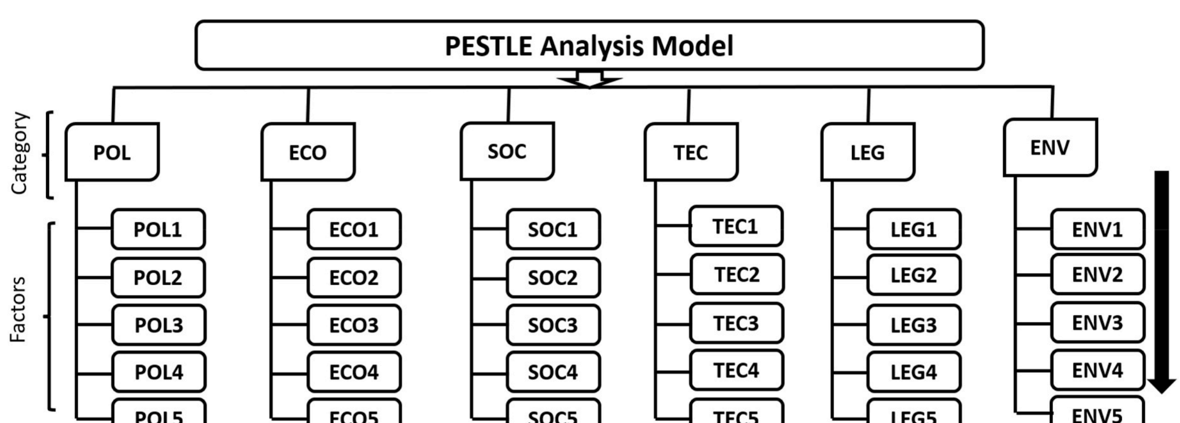

Fig. 3. The hierarchy of PESTLE factors, implicitly defined by each respondent to the questionnaire.

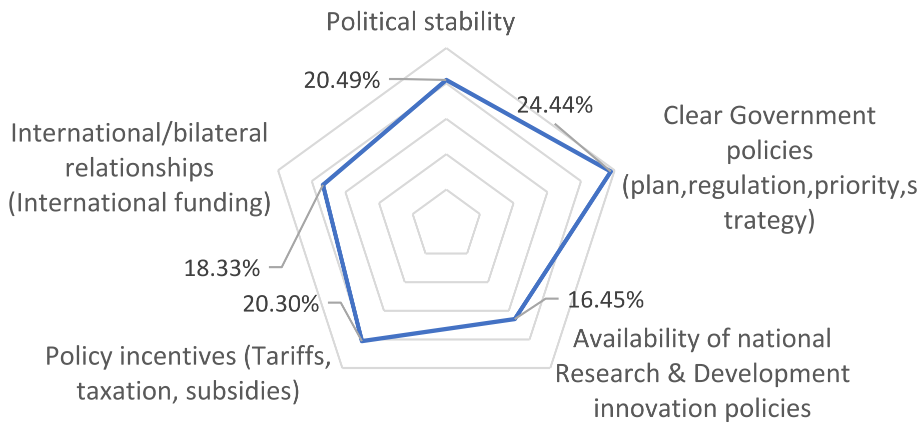

Fig. 5. Local weights for factors in Political Category.

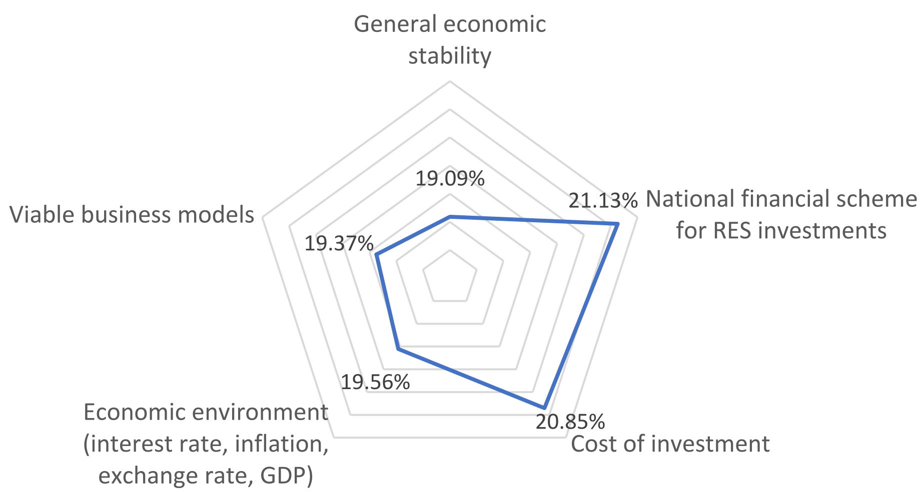

Fig. 6. Local weights for factors in Economic Category.

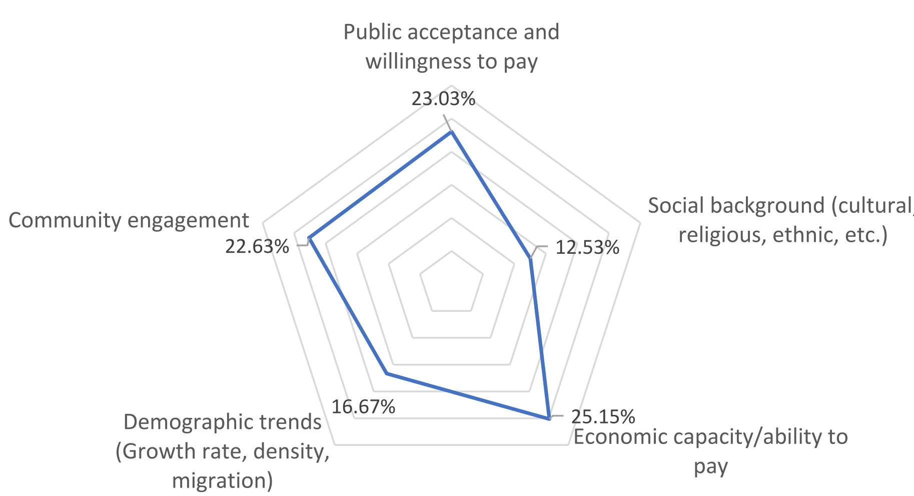

Fig. 7. Local weights for factors in Social Category.

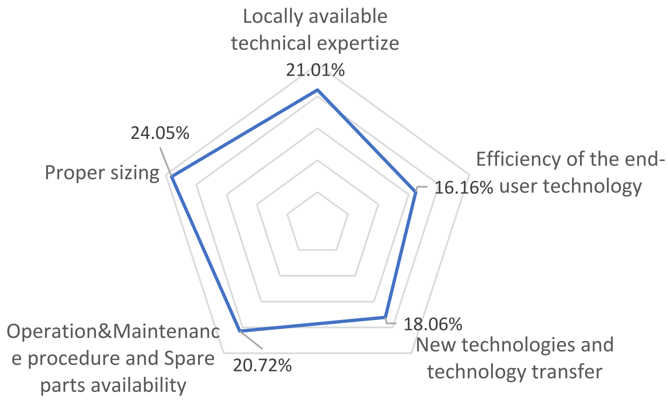

Fig. 8. Local weights for factors in Technical Category.

partners. Researchers recommend strengthening special partnerships with nations with strong expertise in strategic sectors like technologies necessary for renewable energy [117]. International partnerships or foreign direct investment (FDI) are expected to play a crucial role in supporting economic development because of their positive impacts on both environmental sustainability and economic progress. As for Mozambique, according to the World Bank, from 2018 to 2020, the FDIs have almost doubled reaching 3.19 billion dollars, demonstrating a positive trend and a growing trust on the international scene. Through increased overall investment and production efficiency, FDI is predicted to have a favorable impact on both the transfer of technology and management techniques in developing nations like Mozambique which will result in fewer carbon emissions [118]. Hence, International/bilateral relations are the cornerstone to promote (techno-economic) resources for REBM development in developing countries.

4.2. Economic category

4.2.1. General economic stability

In a nutshell, economic stability enables citizens to have access to resources that are necessary for life, such as good housing, financial resources, food, liveable income, and a job that pays a consistent salary, it also contributes to increasing the possibility to increase and stabilize the income generation. According to energy experts, general economic stability was ranked the less important factor relative to the other four factors, with a weight of 19.1%. The stakeholders argue that the economic stability of a country determines the development of its energy

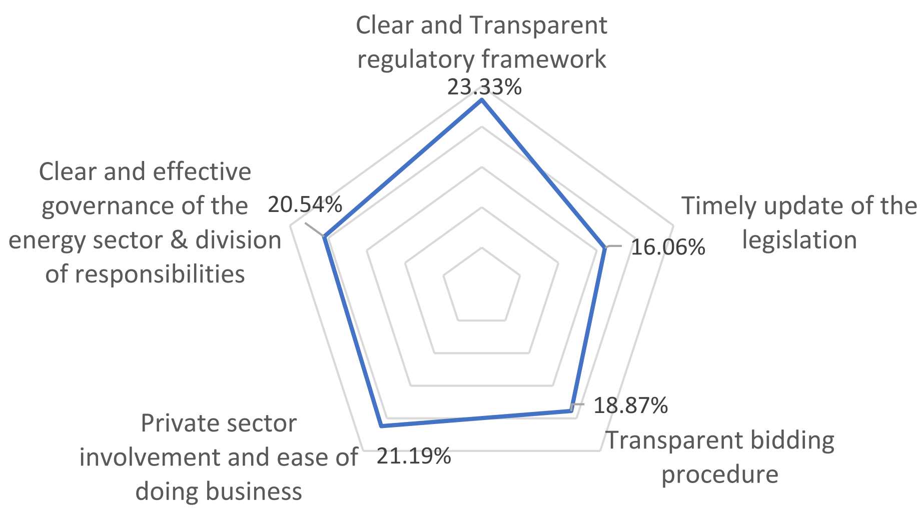

Fig. 9. Local weights for factors in Legal Category.

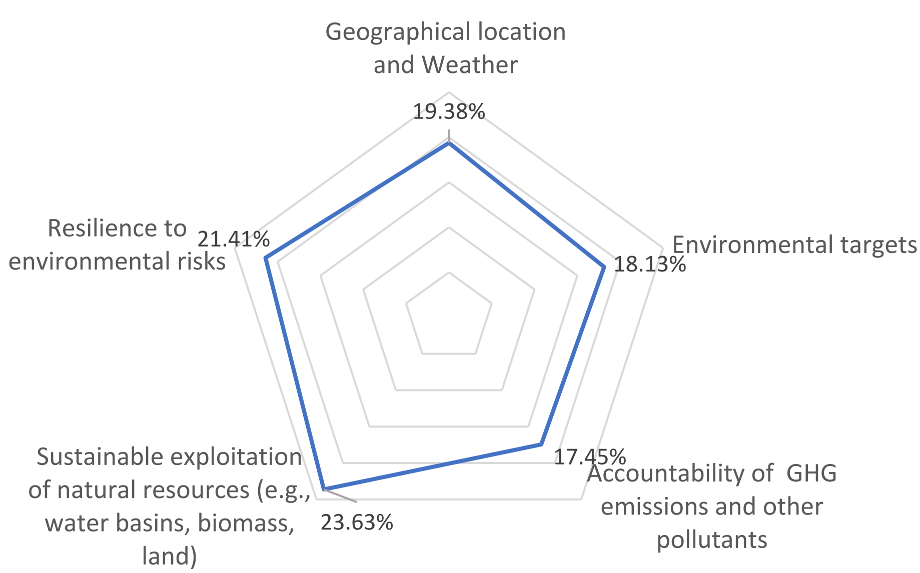

Fig. 10. Local weights for factors in Environmental Category.

sector, and the chances of return on investment and the end user's ability to pay are greater. They also stated that little can happen without economic stability and a financial framework for renewable energy, and this factor's stability impacts the flow of finance partners. While numerous studies argue that energy use and economic growth are positively correlated and the interdependence of the two is largely acknowledged. Some researchers advocate that economic variables must be considered before beginning investment to ensure financial stability and profit potential [41]. Therefore, the government and central banks are responsible for maintaining financial stability and limiting negative spill-overs by implementing large-scale fiscal stimulus programs and monetary expansion [3].

4.2.2. National financial scheme for RES investments

The national financial scheme for renewable energy system investment was the factor weighted by energy experts and stakeholders as extremely important with 21.1%. Thus, they stated that to attract financial investment from partners, the government plays a key role as the main contact to ensure cooperation with international organizations and investors. A strong national energy strategy and an effective finance plan are crucial components that can ensure the inflow of FDI. On the other hand, clear obstacles to funding include the absence of suitable energy regulations and the lack of involvement of the public and private sectors in decision-making [13]. According to the priority plan and diagnostic of the electricity sector, the Government of Mozambique (GoM), in collaboration with the African Development Bank (AfDB), is aware of the need of structural reforms with the primary goal of improving the financial and operational performance of the sector to move away from subsidies and help attract the capital needed to the sector. It intends to implement this by creating a new integrated electrification plan and updating the master plan for the electrical infrastructure. It is yet to be seen if these measures reach the set goals, but the necessity of a clear national financial plan is recognized by the national leadership (GoM) and international institutions (AfDB), investing in the country [11]. Therefore, it is crucial to reform energy laws to attract investments in the energy sector to promote the development of REBM.

4.2.3. Cost of investment

The cost of investment is one of the key factors that are undermining the development of renewable energy in SSA. This factor was ranked as the second most important factor in the economic category by energy experts as very important, with a weight value of 20.9%. As the high capital cost of investment is a major challenge in poor countries, according to the respondents an affordable investment cost in renewable energy constitutes the main leverage, able to make renewable energy feasible, encouraging private and public players in the sector, resulting in a significant increase in the deployment of mini-grid systems for rural electrification. Also, new technologies require private sector investment, and technology owners must transfer their expertise from other areas to the RE industry [119], considering the investment cost, as mini-grids are thought to be high-risk, low-return investments [120]. This fact is confirmed by several international initiatives launched, focused on investment facilitation and regulation. For instance, in Mozambique-specific initiative was approved by the Government in 2021 [121] aimed to put in place a regulatory framework dedicated to the private sector to promote the development of the REBM. Consequently, as the capital investment cost of RE is still slowly falling, it is important to create an appropriate mechanism to minimize and keep the investment viable.

4.2.4. Economic environment (interest rate, inflation, exchange rate, GDP)

This factor, being an aggregated economic indicator, including Gross Domestic Product (GDP), income levels at national and per-capita levels, profit margins, employment rates, and the government industrial, monetary, and fiscal policies, and not having a straight-forward connection to the mini-grid development was ranked as fairly important by energy experts, with the weight value of 19.6%. The respondents posit that the economic environment is decisive, therefore, motivates national and international investors to invest in the energy sector. The major constraint is the unstable economic environment and excessive fluctuation in inflation, exchange rate, interest rate, GDP, and other factors. However, creating effective economic policies will help to maintain a stable and attractive economic environment. According to Agyekum, all these indicators including currency rates have a role in investment, especially in the renewable energy industry [55]. Therefore, private sector investment in mini-grids is hampered by a lack of clear policies [120]. So, effective economic policy is the key to creating a stable economic environment to attract partner.

4.2.5. Viable business models

Feasible business models for the system's sustainability, and able to balance commercial and social objectives to accelerate the deployment of mini-grids are determinants for the success or failure of the enterprise in SSA. The weight value of this factor is 19,4% and is defined as important according to energy experts. It is critical to have transparent and comprehensive guidelines and regulations in case the distributing company connects to the main grid. Since each rural region has its needs and features and there is no one-fits-all solution, a variety of context-specific viable business models is required to ensure mini-grid acceptance and sustainability. According to Comello and Peters, in the absence of a legislative framework to manage the grid's arrival, entrepreneurs refrain from investing because of the high risk [111,122]. The major driver of the renewable business model is the energy price structure of the consumer and the mini-grid operator. Therefore, if the cost of power is too high, the user cannot afford it, and if it is too cheap, the project's financial viability is jeopardized [55,123]. For this reason, it is crucial to enact effective incentive regulations, a range of viable business models, and apply a fair cost of energy to reduce investment risks.

4.3. Social category

4.3.1. Public acceptance and willingness to pay

In the social category, public acceptance, and willingness to pay were ranked as very important, with a weighted value of 23.0%. The experts believe that the community must be comfortable with the technology, and services provided and perceive its usefulness to justify the amount charged. The experience in renewable energy projects shows that if the project is not accepted in the community, it is 100% likely to fail, even if you put in a lot of effort [124,125]. Energy experts believe that the integration and involvement of the community at the beginning of the project is crucial for the development and deployment of the system and leads the community to embrace the initiative during the installation and operation of the mini-grid, because the respondents mentioned that if public embraces renewable energy initiatives, they are more likely to develop, with the community acceptance playing a crucial role in ensuring minimal rejection during the implementation and operation of the mini-grid. Lack of acceptability, often linked to a low level of awareness has a negative impact on community involvement and ownership creation among the population. Many people in Mozambique, for instance, still prefer energy from the main grid. According to Ruggiero, a community ownership strategy can mitigate local objections in terms of community acceptance [126], while a study developed by Jung, advocates the involvement of important stakeholders, such as the society at large [124]. Moreover, social acceptability is not just a gap, but may vary from active support to active opposition [124,125], and has a direct impact on the willingness to pay. That's why the integration of stakeholders including local leadership at the early stage of the project, public acceptance can be taken for granted.

4.3.2. Social background (cultural, religious, ethnic, etc.)

It recorded a weight value of 12.5%, the social background was classified by the energy experts as less important compared to the other factors. When it comes to renewable energy transitions, most researchers focus on the techno-economic aspects of these systems. However, without sufficient consideration of the local culture, such an approach might be deceptive. According to Sovacool, culture necessitates innovative research systems, as well as the participation of the local people in the research and planning process [127], while the respondents highlighted that Africans live by laws of their tradition, religion, and culture. In traditional societies, strongly characterized by religious and cultural factors and influences, community representatives and traditional leaders need to be engaged in sensitizing about the electrification process and mini-grid development. In SSA, where 80% of the population cooks with solid fuels (wood, charcoal, or coal) [128], and a large part of the population has never experienced access to electricity, engagement of such strategic key stakeholders as community traditional and religious leaders may become a game changer in acceptability rate of the new technologies. As a positive example of such initiatives, one can cite the engagement of 7350 traditional leaders in Nigeria to fight against COVID-19 by sensitizing, mobilizing, and convincing the rural population [129]. Therefore, it is crucial to emulate the successfully applied approach for common well-being.

4.3.3. Economic capacity and ability to pay

The highest score in this category 25.2% was given to the economic capacity and ability to pay, making it an extremely important factor in the social context. The interviewees believe that people's capacity to pay must be consistent with a successful business plan. They also believe that a robust business model will secure the long-term mini-grid viability while increasing the chances of the consumer's payments and contributing to their ability to pay their power bills. Some studies mentioned that an African family has a strong desire to use electricity, even though rural households and small businesses often have little financial resources [111]. In Mozambique, there is a region where some consumers consider the mini-grid to be common property, and they are not always convinced or well-informed of the necessity to pay to cover expenditures. For instance, if mini-grids are powered entirely by renewable energy (wind, solar or hydro), the public may believe the service should be supplied for free. Furthermore, due to external funds, investment expenses do not have to be collected from users for using the system, even the charging of minimal financial resources for maintenance and repair is often overlooked. In rural subsistence villages where paid work is the exception rather than the rule, the ability to pay operational people may appear unnecessary [111]. It means that the capability of the community to pay is low because many of them work in the informal sector or engage in seasonal activities [130]. They have limited access to traditional funding channels due to a lack of regular income, a lack of credit history, and an inability to meet funding needs, which further reduces their ability to pay for traditional services [120]. Thence, raising community awareness about O&M payment and injecting money into the business model will improve the local economy and increase their income generation to pay electricity bills.

4.3.4. Demographic trends (growth rate, density, migration)

Demographic trends registered a weight value of 16.7%, representing the fourth position as an important factor in this category. In the interviewed energy experts' point of view, the electrification of a certain locality is determined, first and foremost, by the size of the community, demographic density, and growth prospects in the near future. For instance, Mozambique has had a steady growth trend in the last 20 years, and it amounted to 2,9% in 2020 [131], in comparison to the global average of 1,1%, 63% of which is the rural population, even though this trend is in decline due to the urbanization process. Considering the continuous population growth, it is critical to creating solutions that may assist in preventing uncontrolled resources exploitation, as well as technology that can adjust the population growth. Thus, demographic trends (increased local population and urbanization tendency) will exacerbate the need for localized energy generation. Thus, it is important to use a mixed energy generation system (on and off-grid) considering the growth of energy demand, allowing for a better balance between local production and energy consumption [62]. A study stated that changes in consumer demographic data can have an impact on a country's economy - the more numerous the working population is, the greater its energy usage [55,132]. Therefore, community electrification is determined by the energy demand of the village, taking in consideration the technical solutions that satisfy the population growth trend.

4.3.5. Community engagement

Community engagement was classified by energy experts as fairly important and recorded a weight value of 22.6%. In the consulted experts' opinion, the community must be involved in the project at all the phases of its implementation and further maintenance. It is also acknowledged by numerous studies, have that advocating local communities' engagement from the start of a project can raise the consciousness of renewable energy and ensure its long-term viability and social acceptance [13]. In the past community involvement was given a low priority, and the interactions with mini-grid consumers reveal that more work will be needed in this area to ensure that mini-grid services meet consumer expectations [83]. In addition, experts highlighted that community engagement may give a substantial contribution to the success of the energy project because it allows citizens to participate in awareness, ownership creation, and consumer education, leading to a major level of acceptance, and willingness to pay to sensitize a community of how access to energy can improve their lifestyles as well as provide opportunities for income through productive use of energy. The utilization of community engagement initiatives promotes the effective implementation of renewable energy projects in rural areas [133]. Hence, engaging the local community in all phases of the project will increase awareness, long-term viability, and social acceptance and contribute to the success of RE projects.

4.4. Technical Category

4.4.1. Locally available technical expertise

The lack of local technical expertise in the remote settlement is a reality. This factor recorded a weight value 21.0% and was classified as very important. The energy experts suggest that the presence of local expertise allows the implementation of the technology that, otherwise, the system would be abandoned in a short period. Therefore, training is necessary and advisable since it will increase the quality of energy generated and ensure the system's long-term viability [134]. They also highlighted that local technical expertise is vital to prevent a system from taking too long to perform critical maintenance. Studies suggest the need of combining training with the local community will help to create local technical expertise and to generate reliable energy for the village [134] and will reduce risks that affect beneficiaries' satisfaction [135]. Lack of technological knowledge among people participating, for instance, might result in dirty solar panels, lowered output, decreased reliability, and poor performance [136]. Hence, the local technical skills are responsible to generate reliable energy and ensuring the operation of the system during its useful lifetime.

4.4.2. Efficiency of the end-user technology

Regarding the efficiency of the end-user technology, the rural communities newly connected to smart mini-grids are leapfrogging the use of inefficient appliances. Still, this factor scored the local weight value of 16.2% and was classified as less important among other factors. The energy experts stressed the relevance of the satisfaction of the end-user. However, end-user adaptation to technology and the use of efficient appliances is crucial to ensure their satisfaction, as it influences acceptance, power bills, and willingness to pay for energy services at high tiers. Furthermore, most the renewable energy projects go hand in hand with smart and efficient technologies. According to Mert, the reduction of losses in the energy system is linked to the reduction of peak load, increasing energy efficiency and a reduction of the cost of the service to the final user [137]. Thus, the use of efficient appliances can reduce by 60% the capacity installed [16], and electricity bills, and increase the reliability of the system in the community.

4.4.3. New technologies and technology transfer

Technology transfer to developing countries is meant to foster the diffusion of renewable energy technologies, also included in the clean development mechanism of the Kyoto Protocol [138]. This factor was classified as important, with a weight value of 18.1%. Some interviews highlighted that mini-grids require the advancement and arrival of new technology. They recommend countries adopt modern technologies that are suitable for the local context, accounting for their social acceptance. Technology transfer for local production of renewable energy systems is critical to the renewable energy device take-up model, as well as price reduction that will minimize most economic hurdles [139]. However, to ensure the continuity of new technologies and technology transfer, operation and maintenance, spare part availability, and proper dimensioning must be considered [59]. Therefore, transformation and effective development will not be achieved unless the technology is properly disseminated, and financial resources are appropriately managed [106]. Whence, the new technologies, and technology transfer will ensure the development of REBM if O&M, spare parts, proper sizing, and proper use of resources are considered.

4.4.4. Operation & Maintenance procedure and spare parts availability

O&M and spare parts availability assure the long-run functionality of the system. This factor recorded a local weight value of 20.7% and was classified as fairly important. The experts mentioned that as economic conditions improve, individuals tend to consume more power, placing greater demand on infrastructure in the long run. Therefore, on the one hand, this ensures the success and financial sustainability of the project, but on the other, it burdens the facilities and leads to the need for adequate and constant technical maintenance. Studies reported some cases where mini-grids have been properly sized but have failed to run beyond a few years after commissioning, lacking consistent operation and maintenance [140,141]. Thence, these factors are the cornerstone for REBM development and ensure long-term system operation.

4.4.5. Proper sizing

This factor was ranked with the highest weight value of 24.1% and classified as extremely important by energy experts. Results from the questionnaire mention that proper sizing is essential to avoid inefficient investments (oversized systems), or energy systems insufficient to enable growth (undersized systems). When economic conditions improve, people tend to consume more power, putting additional pressure on infrastructure in the long run. That's why proper sizing is crucial for the infrastructure's performance over its lifetime. Furthermore, the performance of the system is largely determined by effective resource assessment and an appropriate optimization model. Adequate sizing, including load demand estimation [142,143] and optimal capacity installation [144,145], is reportedly critical for the long-term sustainability of the system. The process of mini-grid optimization is quite complex and challenging, that's why, the lack of knowledge about the load conditions, electricity demand, and projected load increase might pan out in poor service quality and unreliable optimization. For such reason, standards for aligning sequential mini-grid sizing procedures have been proposed both by researchers [146,147] and public institutions [148,149].

4.5. Legal Category

4.5.1. Clear and transparent regulatory framework

This factor was classified as ***extremely important*** among others and recorded the highest weight value 23.3%. According to our respondents, a clear and transparent regulatory framework is the top priority, as it facilitates successful mini-grids, allows for investments (both national and foreign), mitigates conflicts, facilitates the involvement of relevant actors, and is also important for market development. As per Comello and Peters, if no regulatory framework exists to govern the grid's arrival, entrepreneurs will avoid investing due to the risk [111,122]. The main regulatory hurdles in the context of mini-grids are laws, rules, and legal frameworks that either favor or hinder the implementation of energy technology solutions in different sizes of these mini-grids [122]. It also allows for the creation of a viable developer's business model, providing specific technical, quality, and process standards to the actors engaged, such as renewable energy agencies. Therefore, it is crucial to enact an effective, and clear regulatory framework to attract investments, and new actors, and to ensure a viable business model for the sustainability of REBM.

4.5.2. Timely update of the legislation

The weight value of this factor is 16.1% and was classified as less important. The respondents are convinced that the energy sector should be more involved in the process of updating energy legislation, having as a reference the legislation of the countries, that have made significant progress in off-grid rural electrification. The energy laws and legislation must be more detailed and clearer and constantly adjusted to accompany the dynamics of the energy market, to guarantee technological and economic development and specific needs. ESMAP defends the option of introducing laws that make more sense in each area and accommodate the dynamic evolution of the community, ecosystem, and development over time [150]. Thus, the technology, economy, and development of a country are dynamic processes, so it is essential to maintain legislation up to date to keep up with the trend.

4.5.3. Transparent bidding procedure

It recorded a weight value of 18.9% and was classified as an important factor. Bids in form of fixed-amount award grants or cost-reimbursable grants represent an important leverage for renewable energy project development in general and mini-grids in particular. Energy experts believe that having a transparent bidding process is crucial for giving investors a clear picture of the regulations and creating confidence, as well as attracting private investments. Furthermore, excellent procedure and transparency must be created in the auction bidding process. The World Bank advocates the same position as the respondents, highlighting procurement based on adequate bidding documents and an open procedure [16]. Ergo, a transparent bidding process raises reliability and guarantees the quality standard required for the service.

4.5.4. Private sector involvement and ease of doing business

This factor was ranked with the second-best weight value of 21.2% and was classified as very important by the respondents. Experts agree that the regulatory framework and the engagement of the private sector are necessary preconditions for REBM development. The latest Mozambique regulatory policy mentioned above, is intended to support the energy supply of the private sector and challenge the Mozambican energy sector, to adapt to new technological trends, and new financial models, improve relevant facts of the rural market, show competence and coordination in dealing with an increasing number of associated stakeholders [151]. The experts highlighted that the private sector is an accelerator of the national energy sector, driving development in all economic sectors through capital investments, capable of complementing and adjusting government action. However, the private sector's involvement relies on a favorable business environment, and ease of doing business. Zebra, with its technological expertise, defends the same idea as the experts regarding the role of private companies in the energy sector. Therefore, its contribution is dependent on government cooperation, which is supplied in the form of subsidies, exemptions, and lower taxes [13]. However, policy goals aimed at the private sector must be balanced against the social and developmental demands of the poor community [83].

4.5.5. Clear and effective governance of the energy sector & division of responsibilities

This factor recorded a weight value of 20.5% and was classified by the respondents as fairly important. The primary state organizations, ARENE, MIREME, and FUNAE, have historically been in charge of the country's energy industry, which has suffered from problems with poor coordination between state actors and other market participants [151], aggravated by the hidden debt scandal in 2016 with the involvement of senior government officials that undermined international trust, credibility, and foreign investments in the country for the years to come. Some literature mentioned that through their influence on the level of uncertainty for business, the quality of governance and political instability have a direct impact on the volume and character of investment in a country [110]. Thence, clear, and effective governance can attract international partners, help the country to meet the SDG7 goal, and provide good living conditions for rural communities.

4.6. Environmental Category

4.6.1. Geographical location and weather

It recorded a weight value 19.4% and was classified as fairly important. As per energy experts, renewable energy resource availability is determined by geographical location and climate. Africa has vast resource potential for the majority of RES: wind, solar, hydro, and geothermal energy and RE is becoming more affordable, thanks to dropping costs [152]. Mozambique has so far largely explored and put into action only its hydropower potential, which accounts for 81% of installed capacity. Still, the profile of renewable resource distribution is not uniform and site-specific, there are places of greater and lesser occurrence, which is a key determining factor in attracting or repelling investment in development in RE in a certain area. However, having adequate road access makes it easier to get to after a breakdown, because the road conditions and RE are extremely dependent on the local climate. Andrijanic stated that technological development and investment are crucial elements in increasing quality and efficiency, which will result in lower emissions, improved systems, and climate resilience [62]. The literature mentioned that the environmental consequences of RE systems are highly dependent on capacity and location, both of which impact the generation capacity of the systems [153]. Therefore, effective resource assessment is crucial to determine the availability of the local resources (site and weather conditions) to properly define the type of technology to be employed.

4.6.2. Environmental targets

According to the experts, the weight value of the factor was 18.1% and was classified as important. Results from the questionnaire demonstrate that mini-grids were designed for areas with limited access to the national grid because they are in general, non-polluting, sustainable during operation, and pose few threats to the environment. Moreover, RE is a suitable solution to mitigate the problem of energy access to meet the SDG7 goal. However, one of the key motivations for the transition to sustainable energy sources is to meet climatic and environmental goals. Therefore, hybrid systems provide superior efficiency, and planning flexibility, are reliable and generate stable electricity [154], and is cost-effective compared to main-grid energy [87].

4.6.3. Accountability of GHG emissions and other pollutants

The experts classified accountability of greenhouse gas (GHG) emissions as less important among other factors and recorded a weight value of 17.5%. Even though in the case of Mozambique the most stringent priority remains access to energy, using RES decreases GHG emissions, contributing to the creation of a more sustainable society and enhancing resilience to environmental threats, while the introduction and spread of clean cooking can improve health conditions of the rural population, women, and children. Researchers believe that with rising energy demand and growing environmental concerns, RES is developing rapidly also due to their low pollution and GHG emissions [59]. Hence, REBM is highly recommended to be deployed in rural areas because it will help to meet the energy transition and community health.

4.6.4. Sustainable exploitation of natural resources (e.g., water basins, biomass, land)

Sustainable exploitation of natural resources scored a weight value of 23.6% and was ranked as extremely important. As per energy experts, REBM projects must be legally regulated in the context of long-term resource exploitation and reasonable utilization. Basins, and biomass, like all other natural resources, must be utilized just enough for the current generation while remaining sustainable so that future generations can benefit from them. Researchers believe that rational exploitation of renewable energy sources can determine the RE contribution to the national energy mix and promote the deployment and wise use of renewables. Therefore, can also assist decision-making in renewable energy planning by providing information on regional potentials and constraints to various stakeholders, thus envisaging an energy development vision that can promote energy development towards sustainability and prevents losses due to energy transport over long distances [155]. Overall, the effectively established energy policy and laws are the cornerstones to guaranteeing and fostering sustainable exploitation of natural resources.

4.6.5. Resilience to environmental risks

According to the questionnaire's results, this factor was classified as very important and registered a weight value of 21.4%. The energy experts believe that resilience to environmental risks ensures the long-term viability of deployed energy resources and infrastructure, and adaptation to regional natural phenomena. Mini-grids require a solid and flexible regulatory framework to guarantee their long-term viability while also considering their exposure to environmental challenges. The mini-grid projects must be designed taking into account the effects of climate change and natural disasters that the region has suffered and ensuring the resilience of the systems in the future as part of a strategic prevention framework. Renewable energy technology and a stable infrastructure contribute to the creation of a resilient and long-term energy system [156]. Therefore, the deployment of hybrid systems is advisable because tend to be more cost-effective and resilient to technological uncertainty, as well as offer more operational efficiency and a more stable power source [157]. Ergo, resilient power systems combine a variety of technological solutions with integrated planning procedures to enable systems to supply dependable, safe, and secure energy in the face of short-term disasters and occurrences, as well as long-term climate change. In addition, also help to reduce GHG emissions, which will help to offset future climate impacts [158].

5. Conclusion and recommendations

5.1. Conclusion

This study investigates and classifies the most important factors for the development of REBM in Mozambique, merging two different approaches: a systematic literature review (SLR) and a PESTLE analysis. This holistic approach was necessary due to the multifacetedness of the problem characterized by a high rate of the population living without energy access (62%), and the lack of development of REBM in Mozambique, despite the huge potential of RE resources available. The study was developed with the contribution of 62 energy experts from 14 different countries (48 Africans and 14 non-Africans). Experts classified the most important category that should be taken into consideration or prioritized by policymakers. According to the experts' answers, the classification of the categories was as follows: the Political category had the highest percentage weight of 24%, followed by the Economic category at 23%, and Social, Technological, and Legal categories at 16%, 15%, and 13% respectively, and the Environmental category had the lowest weight of 9%.

The experts also ranked the factors that can facilitate and strengthen the development of REBM according to their importance and urgency. The two main factors (extremely important and very important) in each category were as follows: Political - Clear Government policies (plan, regulation, priority, strategy) 24.4%, and Political instability (20.5%). Economic - National financial scheme for RES investments (21.1%), and Cost of investment (20.9%). Social - Economic capacity and ability to pay (25.2%), and public acceptance and willingness to pay (23.0%). Technical – Proper sizing (24.1%), and locally available technological expertise (21.0%). Legal - Clear and Transparent regulatory framework (23.3%), and Private sector involvement and ease of doing business (21.2%). Environmental - Sustainable exploitation of natural resources (e.g., water basins, biomass, land) with 23.6%, and Resilient to environmental risks (21.4%). Among all the categories the experts prioritized the political as the most important category followed by economic. This demonstrates that the political category in the sector must be prioritized by the government (policy makers). Therefore, updating policies, legislation, and strategies in the energy sector will promote the effective development of REBM and the growth of the sector. Comparing the global weight of factors across all the categories allowed us to identify the key factors in the process: Clear Government policies (plan, regulation, priority, strategy) at 5.79%, National financial scheme for RES investments 4.93%, and cost of investment 4.86%. A comprehensive mapping for global weight factor comparison is reported in Annex A, also highlighting the different attributions by class of expert. It is interesting to note that different stakeholder groups prioritized different categories and factors. For example, representatives of academia emphasized the leading role of political category and clear government policies in particular, civil society attributed major weight to the economic category (economic capacity and willingness to pay factor), private sector attributed major weight to the economic category (national financial scheme for investment) while government institutions prioritized political category (political stability and clear government policies).

5.2. Limitations and future research options

The present study proposed a new methodology based on SLR and PESTLE analysis. Even though most of the respondents are originally from Mozambique, there is an inherent risk to disregard different social and cultural aspects of REBM. Social aspects, within the domain of social theory and cultural practices, can be further investigated and integrated into the methodology, since energy system change is a complex, non-linear socio-technical transition. Energy and society are networked cohesively, being co-associational and co-productive, and the methodology adopted for the study does not reflect these dynamics. The cohesive strength of any production-consumption system lies in its contextual grounding, requiring a deeper social and cultural investigation. The social theory was out of the scope of this study, yet PESTLE analysis was able to provide a wide picture with a broad range of aspects, but without a deep focus on the causal and feedback relationships between categories and factors. Methodological improvements could be achieved by adopting semi-structured interviews and/or more specific social research methods such as the Delphi method.

Given the thorough study conducted to recommend to the policy-makers, possible suggestions can also be given to future research on the topic. Despite the relevant number of REBM installed in SSA, particularly in Mozambique, most of them are not working as expected since the systems are either oversized or undersized, and some systems have been deployed without backup. As already claimed, the disregarding of socio-technical aspects of solutions such as REBM brings to the ineffective. Therefore, the absence of a standard model for installing mini-grids, an ineffective plan for resource assessment, and a lack of knowledge to optimize mini-grids considering demand growth over time are the root causes of these issues. It's crucial to develop research that considers all these difficulties at once to eliminate these challenges since those who are in the field working in this position, like FUNAE, needs it. The current study has indeed prescribed some factors to account for from very different dimensions, showing that a comprehensive approach to rural electrification planning is necessary.

5.3. Policy implications

Due to the high rate of people living without energy access in a remote settlement, and the low pace of REBM growth, it was necessary to identify the best strategy for analyzing and classifying PESTLE categories and factors to promote the development of REBM for rural electrification. Therefore, all the categories and factors in this study are important for the development of REBM. Based on the results and opinions acquired by the contribution of energy experts, we recommend the following to government/policy-makers:

5.3.1. Primary measures (P, E)

- Prioritize the political category by establishing effective energy policies and regulatory framework, as the policies are the cornerstone to attract investment for the development of REBM and can enable progress on all SDGs and energy democracy, empowerment of the local community and local authorities can mitigate vested interests and political interference. In particular, political instability and corruption should be addressed, while the regulatory framework should include short-; medium-; and long-term electrification objectives and strategies.
- Creation of a national financial scheme for RES investments, and reduction of capital investment cost, as funding institutions play a critical role in promoting mini-grid integration in developing countries. The government should gain greater weight and more credibility with potential financing partners and act as a guarantor for international investors. A clear roadmap and legislation should be proposed for the cases of eventual connection to the main grid to derisk investments, creating business opportunities and long-term sustainability of the REBM.

5.3.2. Secondary measures (T, S, L)

- Promote effective, successful, and robust business model with a detailed explanation of the procedures required during project planning, study, and implementation of renewable-based mini-grid projects in Mozambique. It will secure the long-term mini-grid viability, while also providing consumers with the capacity and ability to pay their power bills, helping to develop the local community and improve their living conditions.
- Community involvement and community ownership model in RE projects by promoting productive uses can mitigate local objections in terms of community acceptance. The engagement of local and community leaders will contribute to the development of REBM in rural communities, adding to its credibility within the village and attracting people from neighboring villages to invest or develop a business around the mini-grid.
- Prioritizing education and local technical qualification (capacity building) will contribute to better and more effective resource assessment, demand estimation, and proper sizing of the systems. The lack of knowledge about the load conditions, electricity demand, and projected load increase might pan out in blackouts and poor service quality, unreliable supply, which will lead to a high level of disappointment and unacceptance of the technology.

- Engagement of the private sector in RE projects by derisking the investment and guaranteeing the ROI and providing a clear and transparent regulatory framework will facilitate the development and success of REBM systems, attracting great investments, mitigating conflicts, facilitating the involvement of relevant actors, for the fulfillment of the SDG7 goal.

5.3.3. Tertiary measures (E)

- A holistic approach to the management of all available resources and not only energy ones should be applied by environmental policies creation for sustainable exploitation of natural resources (e.g., water basins, biomass, land). Within this common framework deployment of resilient RE systems should be promoted to mitigate environmental risks, accelerate decarbonization and ensure the future generation is not harmed by current electrification initiatives, and avoid resource depletion.

Credit author statement

Castro Antonio Soares: Conceptualization, Methodology, Investigation, Software, Data curation, Validation, Writing original draft and editing. **Diana Shendrikova**: Conceptualization, Investigation, Software, Visualization, Writing original draft and editing. **Giacomo Crevani**: Methodology, Investigation, Data curation, Visualization, Writing original draft and editing, **Berino Silinto**: Conceptualization, Methodology. **Emanuela Colombo**: Supervision, Conceptualization, Methodology, Writing review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A

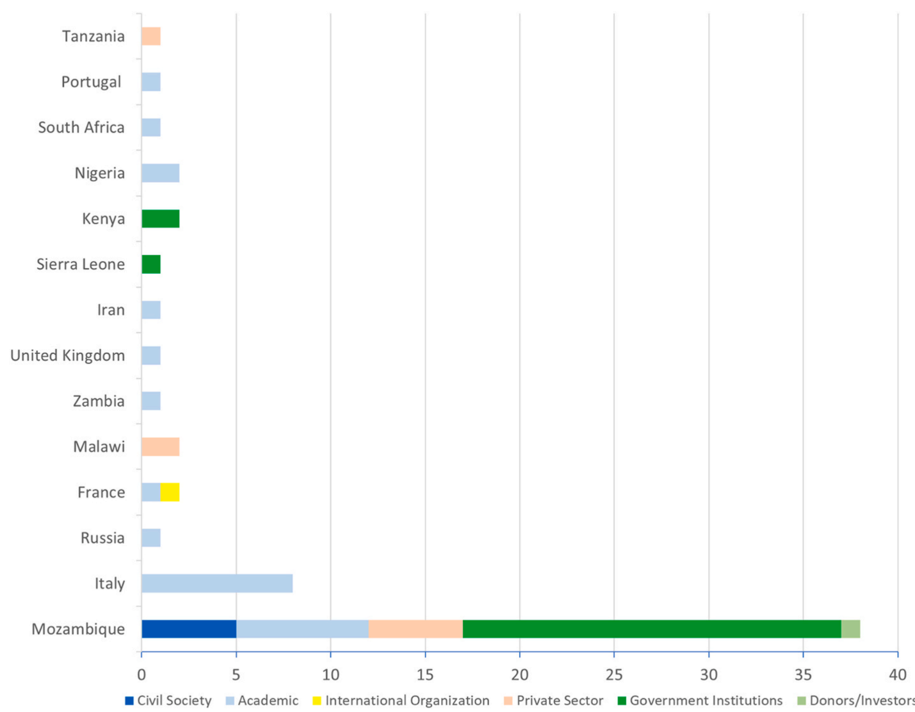

Fig. 11. Number of respondents by institutions from each country.

Appendix B

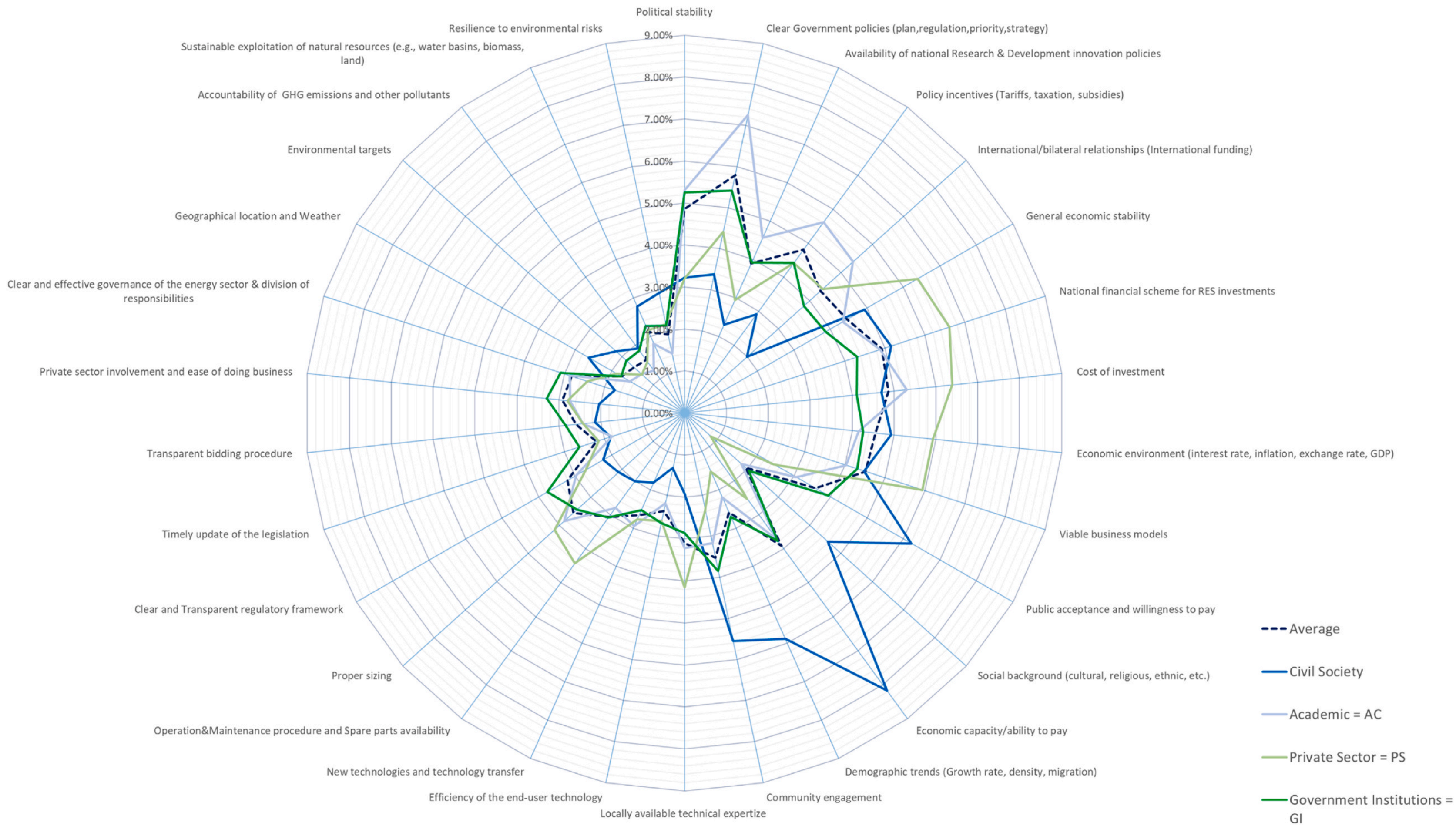

Fig. 12. Comparative analysis of global weights for all the factors.

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