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Addressing Challenges in Delivering Sustainable Rural Water Provision Using Solar Water Pumping in Malawi: A Stakeholder Analysis

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Abstract: Despite the presence of relatively high insolation, solar photovoltaic water pumping (SWP) is rarely used for water provision in Malawi. Current methods of water abstraction are labour-intensive and have low discharge rates. A stakeholder analysis was carried out to evaluate the role, responsibilities, and challenges faced by individuals, communities, and organisations involved in developing SWP systems. Analysis of data collected via semi-structured interviews with stakeholders from government departments, public and private organisations, entrepreneurs, non-governmental organisations, and microfinance organisations shows that the national government should provide an enabling environment for other actors to deliver SWP projects. Further, this study reveals diverse interlinked challenges in delivering sustainable water and energy services related to policies, monitoring, coordination, financing, human resources, information and awareness, stakeholder malfeasance, political interference, and flawed community management. The impacts of these challenges result in inadequate water service provision resulting from access inequality, non-functionality, substandard installations, reliance on donations, substandard renewable energy products, and slow technology uptake. The results of this study imply that, given appropriate finance and management frameworks, effective coordination, enforcement of product and installation standards, and awareness and sensitisation of communities to SWP, significantly improved access to drinking and irrigation water for the rural population of Malawi and other countries in sub-Saharan Africa can be achieved.

Keywords: rural Malawi; sustainable water challenges; solar photovoltaic water pumping; stakeholder analysis

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1. Introduction

As of 2022, around 10% of the world's population, 703 million people, lacked basic drinking water services, and of these, around 58% live in sub-Saharan Africa (SSA) [1]. Even for those countries with improved drinking water access, the quality, usability, functionality, and safety of most of these sources, particularly in rural areas, were unreliable [2,3]. Malawi was one of the few developing countries to attain its Millennium Development Goals' water target [4]. However, this was not a high target, and only 18% of the population of Malawi had safely managed drinking water in 2022, and the country is not on track to achieve universal access to safely managed drinking water by 2030 [1].

Furthermore, although over 20% of Malawi's area is occupied by fresh water, the nation still relies predominantly on rain-fed agriculture. Malawi experiences insufficient harvests that culminate in famine and poverty accentuation [5]. Sustainable water services for irrigation can positively impact food security and increase household incomes,

particularly in the face of climate variability [6]. However, traditional irrigation methods such as watering cans and treadle pumps are applicable only to small areas due to their labour-intensiveness and low discharge rates. Indeed, many treadle pumps have been abandoned as they are difficult to operate [7,8]. Motorised pumps were introduced by the government and distributed freely to smallholder farmers. However, most of these became non-functional due to farmers' inability to meet fuel and maintenance costs [7,9].

With limited grid electricity connections in most rural areas [10,11], and the disadvantages associated with fuel systems, renewable energy technologies (RETs) can provide a viable option for solar water pumps (SWP). Globally, SWP has been successfully exploited, including in SSA situations [12–15]. Malawi benefits from relatively high solar insolation, ~1800 Wh/m^2/yr [16,17]. SWP has been infrequently used for the provision of drinking and irrigation water in Malawi. It is within this context that this study seeks to address challenges related to water access using SWP. This will be achieved through a specific focus on the analysis of key stakeholders, including those within the government, finance, supply chain, and community end-user arenas. A typical SWP system is illustrated in Figure 1.

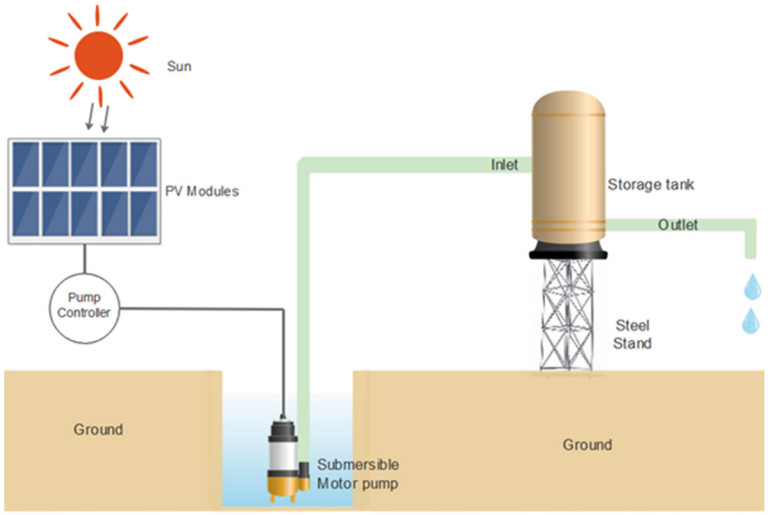

Figure 1. A typical SWP system for drinking water.

In a recent study, it was highlighted that water access was generally inadequate, with disparities in the distribution of water and non-functional manual pumps [18]. Income was a key predictor of willingness to pay for drinking water, occupation (farming), age, and household size for irrigation water. Other previous work has focused on issues related to water abstraction using manual methods such as hand pumps and on water policy issues [19–22]. Previous research on RETs in Malawi did not specifically focus on SWP for water provision [10,23]. Those studies identified the research gaps for this study: to develop a strategic view of the social and institutional landscape regarding SWP for rural areas. The purpose was to improve opportunities for sustainable water access for drinking and irrigation. Furthermore, given the prominence of renewable energy in recent years, this work aimed to expand and deepen the scholarly knowledge of this contemporary socio-technical approach and its specific application in rural Malawi, where over 80% of the population lives.

The stakeholder analysis (SA) approach used in this study was carried out with the following objectives:

1. Identify current and potential future stakeholders relevant to sustainable water provision using SWP in Malawi.
2. Specify and evaluate their roles and responsibilities, along with the challenges faced by each stakeholder group; and
3. Recommend measures to enhance SWP uptake and the successful ongoing delivery of sustainable water services.

The sections in this paper are organised as follows: Section 2 summarises SA theory relevant to this study. Section 3 provides the research method used, including information on the research design and sampling procedures. In Section 4, the results are presented with a focus on stakeholder identification, their roles and responsibilities, a discussion and evaluation of this work's emerging themes, and finally their power and interest in delivering effective, sustainable water services. Section 5 summarises this study and further recommends measures to enhance SWP uptake.

2. Stakeholder Analysis Theory

In this study, stakeholders are defined as 'actors' (whether individuals, groups, or institutions) that have interests or concerns in the situation within a socio-technical system, in this case, sustainable water provision in rural Malawi. Typically, such actors can be affected or impacted by activities, targets, or policies related to the system [24–26]. In this context, SA is a method that is used to aid policy and institutional reform processes or organisational development efforts by incorporating and accounting for the needs of those who have an interest or stake in the decisions and activities of a business. SA involves identifying the key actors and assessing their knowledge, interests, positions, alliances, and importance related to the policy [24]. Literature has argued that SA is key to identifying problems that are solved when many entities are involved, affected, or have some partial responsibility to act [25].

The information generated from SA may be used to provide input for other analyses, to inform the development of action plans to increase support for a reform policy, or to guide a participatory, consensus-building process, strategic planning, and institutional assessments to be used by policymakers, regulators, governmental and non-governmental organisations (NGOs), businesses, and the media. In environmental policy development and natural resource management, SA has been seen as an approach that could empower marginal stakeholders to influence decision-making processes; in political science, it is used to work more effectively with stakeholders, facilitate the transparent implementation of decisions or objectives, understand the policy context, and assess the feasibility of future policy options [26]. In recent years, SA has been used in energy-related research to study the water-energy-food nexus assessment and has demonstrated the relevance of SA in nexus governance for integrated natural resource management [27,28]. In India, SA was used to study the adoption of grid-connected solar rooftop systems in the state of Jammu and Kashmir. The study findings pointed to the importance of awareness amongst the stakeholders [29]. Together with political, economic, social, technological, legal, and environmental analysis [30], SA was used to identify relevant stakeholders within the fossil energy sector to support policymakers in formulating new energy policies and help them recognise the implications of these new policies for the stakeholders involved. In Iran, SA has been used to identify the main stakeholders and organisations that have a significant impact on the development of solar energy [31]. These studies demonstrate the significance of SA in addressing numerous energy issues.

Reed et. al. [26] presented the rationale, typology, and methods for carrying out SA research and further described the following key methodological steps for SA: (i) Identify the focus issue, organisation or intervention; (ii) Identify system boundaries. (iii) Identify stakeholders and their stakes. (iv) Differentiate and categorise stakeholders. (v) Investigate relationships between stakeholders, and (vi) Recommend future activities and stakeholder engagement [26]. Several methods used for SA data gathering have been described and used, including in-depth interviews with experts, structured questionnaires, workshops, and focus group discussions. The collected information may be analysed using several techniques, including power (influence)-interest grids, stakeholder influence diagrams, and the participation planning matrix. [24–26]. The power versus interest matrix is a popular method to analytically categorise stakeholders, visually identify the individual positions of stakeholders, and compare the varying degrees of interest and power across different stakeholders [25]. The matrix helps determine which players' interests and power bases

must be taken into account to address the problem or issue at hand and can assist in identifying those most likely to be in a position to affect the actions of others, or it can be used to help advance the interests of the relatively powerless.

The power versus interest matrix consists of four grids representing four categories of stakeholders, as described by [25,26]:

i. High-power/high-interest stakeholders, referred to as 'key players': These have both power and interest, are the key players, and are supposed to be fully involved. They are the ones who have decision-making power, budgetary power, and/or resource power. Also, they can cause the most disruption for a project if they are not informed or their expectations are not managed. They are in the strongest position to affect outcomes, making them particularly relevant in the context of facilitating change. Efforts should be made to keep them satisfied with the project progress and results.
ii. High-power/low-interest stakeholders, also referred to as 'the context setters': These stakeholders must have their expectations and needs understood and managed. They have the power to cause significant disruptions to the project; however, they do not have a substantial interest. They may be recruited to a particular cause by those with a greater interest in the issue.
iii. Low-power/high-interest stakeholders referred to as 'subjects': These stakeholders need to be kept informed, and they are the ones who provide background information, user requirements, and non-functional requirements. They should be allowed to provide some input, though their input may not always be applied. However, if they are carefully managed, they can be effective promoters of the project solution by building interest and helping ensure adoption. They have a limited capacity to influence outcomes. However, they may gain power by forming alliances with other stakeholders.
iv. Low-power/low-interest stakeholders referred to as 'the crowd': They have little need to engage with or consider them in much detail. These stakeholders have only to be monitored, but they can sometimes have valuable information from a requirements perspective. Their lack of interest can make it difficult for appropriate stakeholders to engage with or identify their knowledge.

Based on this, this paper begins by identifying the important characteristics of the specific socio-technical system of interest, namely improved sustainable water-energy socio-economic outcomes for sustainable water and energy services in the rural district of Chiradzulu [18]. The results from this fieldwork represent a baseline dataset that is now used to identify, classify, and prioritise key system stakeholders (or actors) within the current system of interest, as discussed later in Section 4.1. This enables the construction of a conceptual model of the system (Figure 2). Note that for this study, stakeholders can be categorised as individuals, organisations, or both and should be identified as such within the model. Those actors defined as wielding power, interest, and agency in terms of achieving the target outcomes were given special attention during the stakeholder characterisation process.

In this context, 'power' (whether dormant or active) is defined as the ability or capacity of an actor to perform something or to act in a particular way. 'Agency' is defined as action(s) taken by actors to express their individual or collective 'power' [32]. Note that a stakeholder's 'agency' can either enable or constrain the attainment of desired socio-technical outcomes. In settings such as those characterised in the current study in Malawi, individual or collective agency may serve to reaffirm existing norms, such as institutional corruption, which can constrain the attainment of the goal of delivering successful sustainable water and energy practices. Alternatively, the stakeholder agency may serve to challenge and reconstruct the existing social order to create new norms and relationships. These new relationships, such as the creation of new policy support frameworks or community training and education programmes can lead to desired socio-technical outcomes

such as improved sustainable community water and energy services in the rural areas of Malawi.

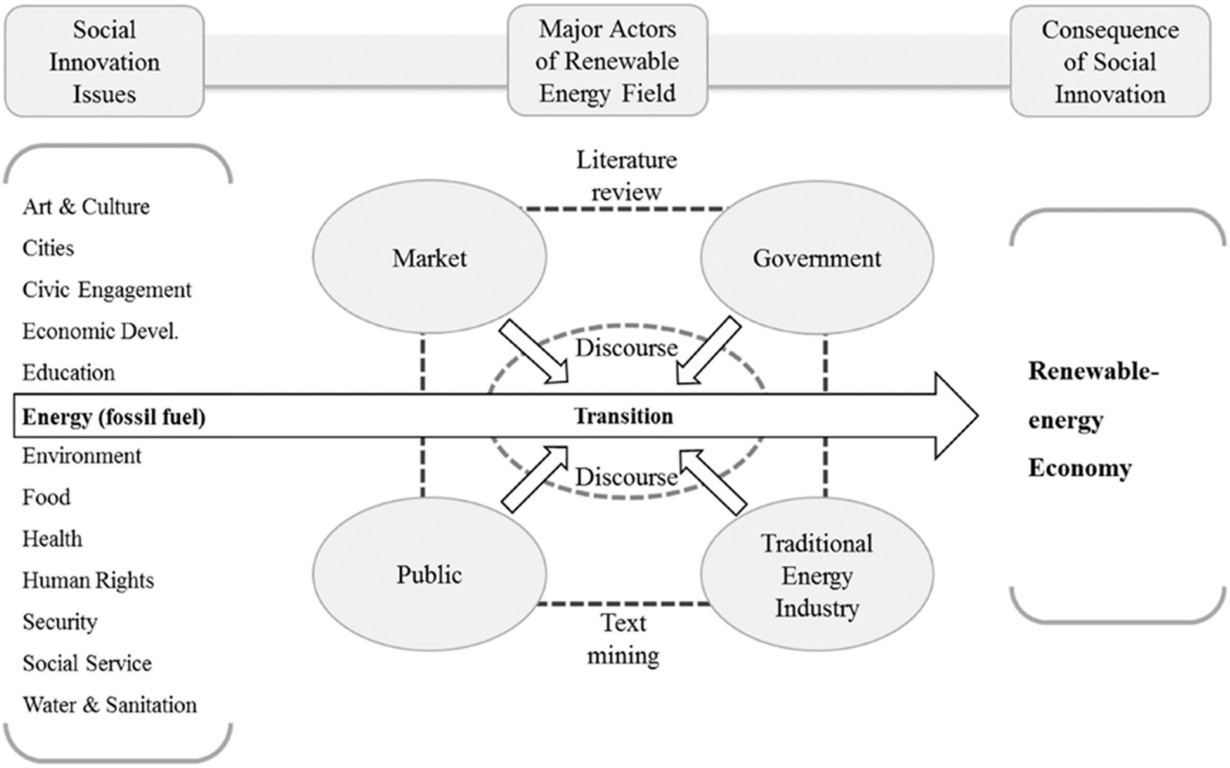

Figure 2. Conceptual model of the system.

To enable socio-technical change in settings, as in this study, care must be taken to avoid characterising specific actors as having no agency. Such invalid subjective perceptions about the agency of individual groups such as women and girls in low-income rural communities can constrain the attainment of positive socio-technical outcomes.

3. Research Method

This study employs the case study design of inquiry, in which the researcher develops an in-depth analysis of a case, often a program, event, activity, process, or one or more individuals. Cases are bounded by time and activity, and researchers collect detailed information from a variety of data collection procedures over a sustained period. The insights gleaned from case studies can directly influence policy, procedures, and future research [33,34].

The study was carried out in Malawi, a small landlocked country in southern Africa (see Figure 3). The country's area is 118,484 km^2, of which 20% is water. Administratively, Malawi is divided into three regions: the northern region, the central region, and the southern region, which are further divided into 28 districts. The country has four cities and some town councils, which together with the 28 district headquarters and some trading centres constitute the urban areas, while the rest are classified as rural. The country's population is nearly 18 million and is growing rapidly, with 84% of the population living in rural areas [35]. The economy is heavily dependent on agriculture, making water for irrigation necessary.

The SA rationale, typology, and methods adopted in this study are highlighted in Figure 4. The study was driven by a descriptive and instrumental rationale, which is more pragmatic and largely devoted to understanding how organisations, projects, and policy-makers can identify, explain, and manage the behaviour of stakeholders to achieve desired outcomes. The instrumental rationale has been used in SA to overcome obstacles to the adoption of new technologies, adapt technologies to relevant user groups, or disseminate

the same technologies in different ways to different groups [26]. Similar methods have been adopted by [28,29] in their SA research.

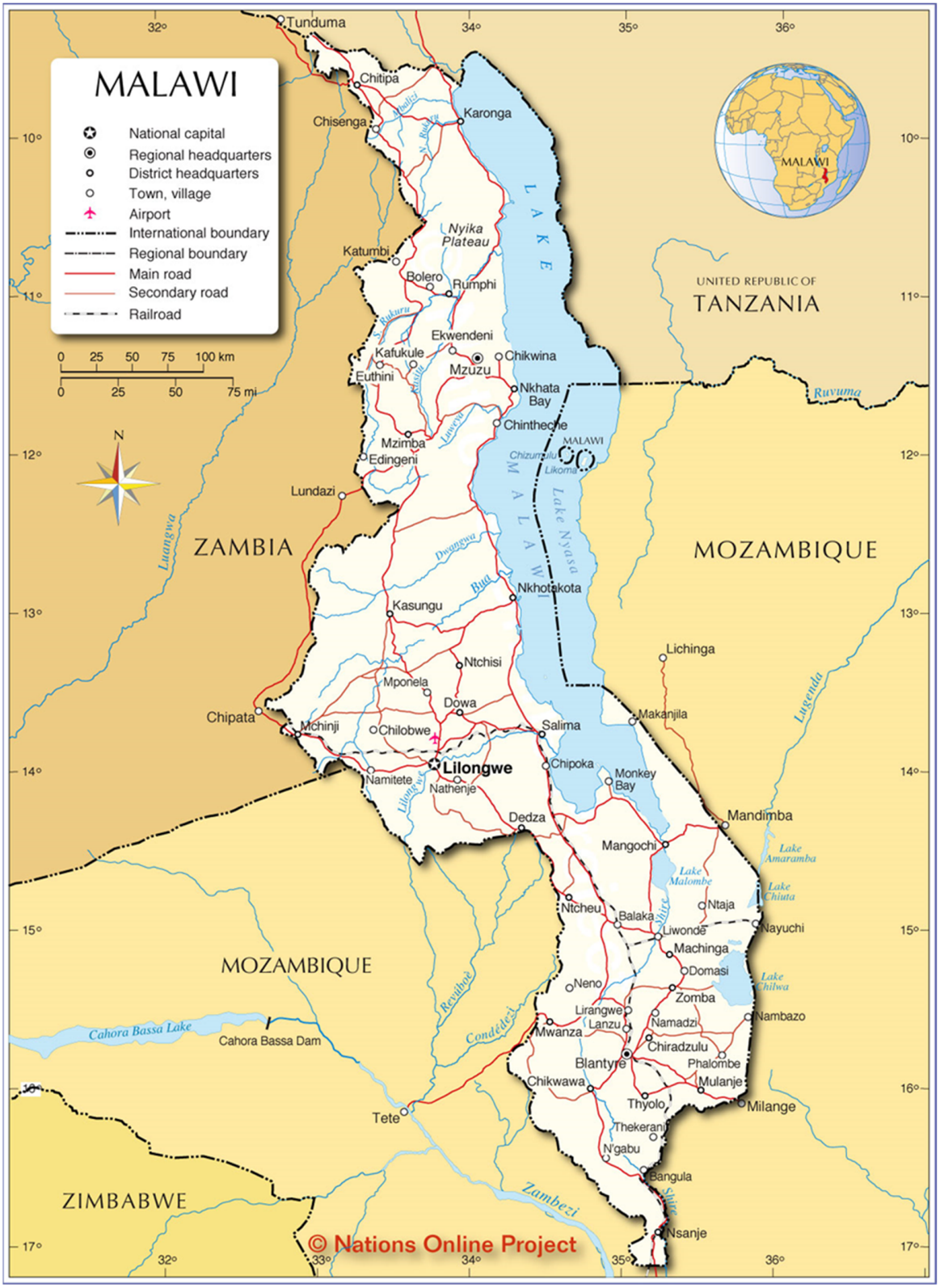

Figure 3. Map of Malawi [36].

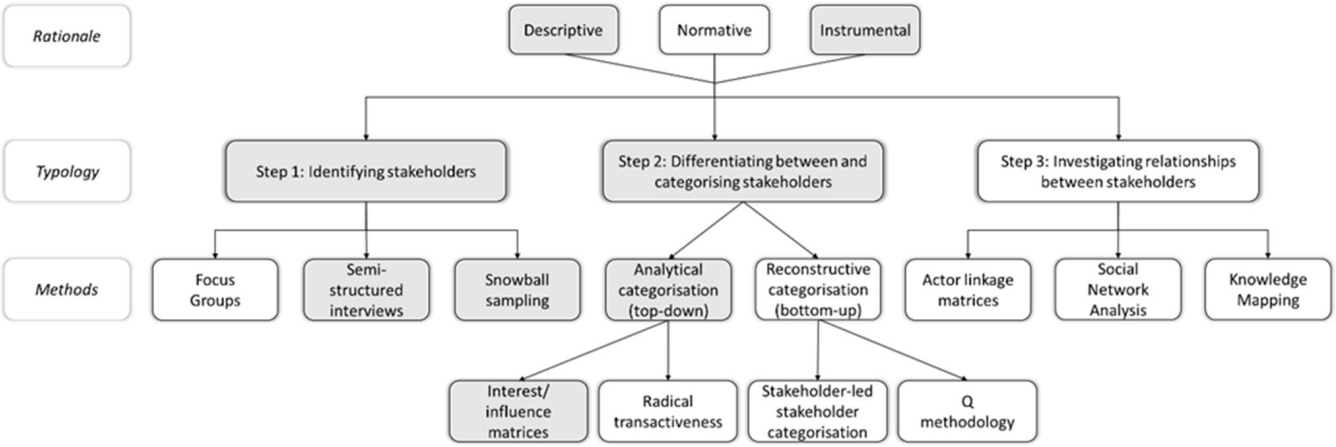

Figure 4. A schematic representation of the stakeholder analysis rationale, typology, and methods [26]. The procedures adopted in this research are highlighted.

Data were collected using face-to-face, in-depth interviews with the identified key informants (KI), and each interview conducted lasted for 35 to 60 min. A semi-structured questionnaire was used to collect data, and the interview questions were designed in such a way as to address the objectives of this study. Semi-structured interviews are flexible, and the researcher could follow up on a question.

Respondents to participate in this study were identified from the literature and researchers' interactions during a previous study [18]. They were recruited using purposive and snowball research sampling methods. In purposive sampling, the researcher aims to sample those who are more knowledgeable and relevant to the research questions of this study, while at the same time ensuring that there is a wide variety of participants [37]. In snowball sampling, individuals from initial stakeholder categories are interviewed, identifying new stakeholder categories and contacts. For this study, these key stakeholders included government departments, donors, non-governmental organisations (NGOs), private organisations and community representatives that are involved in water, renewable energy, microfinance sectors, and water users. In total, 22 respondents from 20 organisations were interviewed. This included 6 government departments, 8 NGOs, 2 donors, and 4 entrepreneurs. In developing countries, such as Malawi, there are only a limited number of organisations and human resources, which is why the sample size was limited. It was possible to interview more than one person from two organisations due to their different roles. The ethical protocols for this study were reviewed and approved by both Loughborough University and the Malawi National Commission for Science and Technology.

The collected data were subsequently filtered and analysed. The results are presented first by describing the roles and responsibilities of the various key stakeholder-cited challenges and barriers, which were also analysed and evaluated using thematic analysis. "Thematic analysis is a method for identifying, analysing and reporting patterns (themes) within data" [38]. It minimally organises and describes the data set in 'rich' detail, and it is suited to a wide range of research interests and theoretical perspectives [39]. Challenges and barriers have been presented in SA studies [28,29,31]. The participants were requested to identify stakeholders who have or will have interest in and power in water provision in rural areas using SWP and to specify those with the most power and influence and those most relevant to SWP in rural areas of Malawi. Thereafter, the responses were presented in a power vs. interest matrix.

4. Results and Discussion

Considering the socio-technical systems in this study, it was essential to consider such social science-based concepts using an engineering or technical perspective. For example, a thermodynamic metaphor can be used to describe the relationship between 'power' and 'energy' (or agency). In this way, it is possible to move towards the creation of

a truly integrated socio-technical system modelling methodology in which social agency is comprised of directional flows of varying magnitude, typology, and polarity (or direction) within a socio-technical network. Such a conceptual network is shown in Figure 5, which includes relevant technological, market, and policy actors and their relationships.

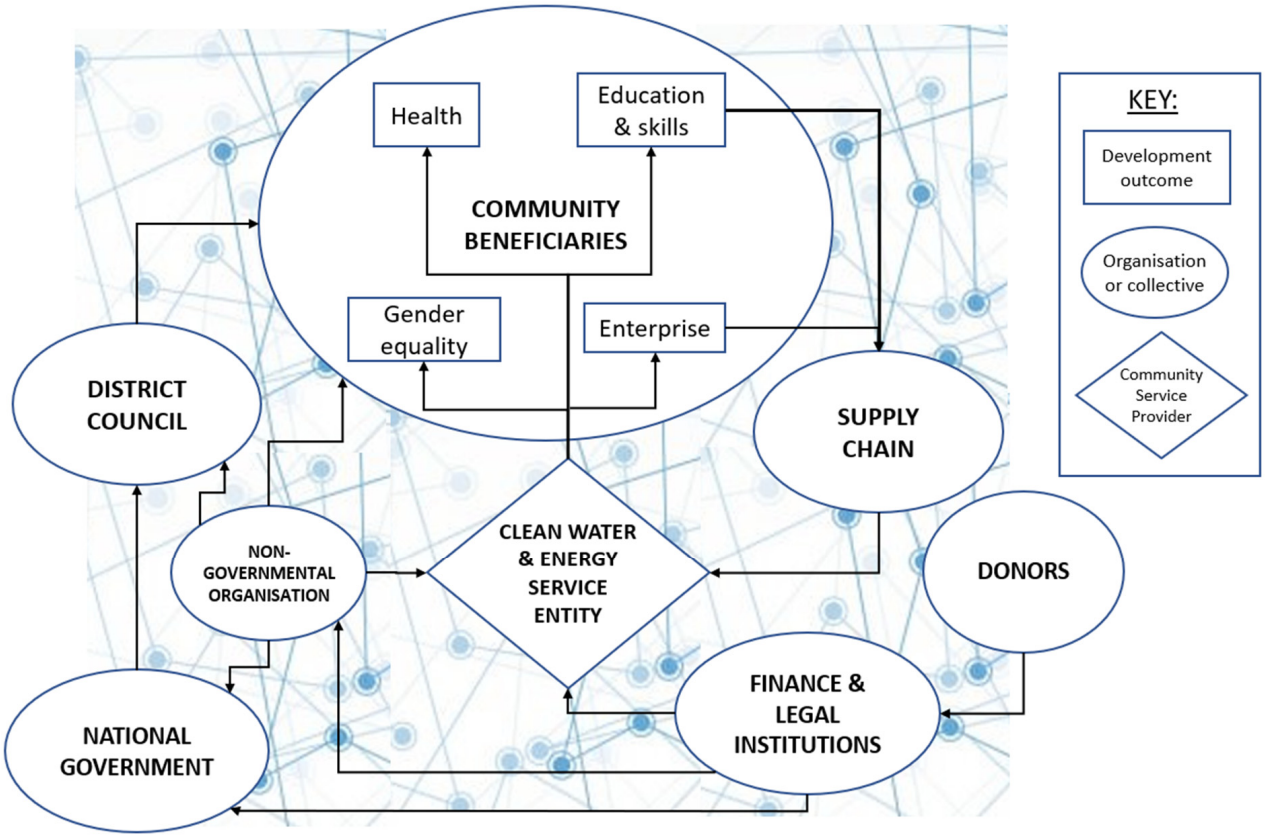

Figure 5. Socio-technical network.

In terms of subsequently producing a functional quantitative graphical network model for use in decision-making under conditions of uncertainty, characterisation of the links joining key stakeholders to preferred socio-technical outcomes (in this case, sustainable energy and water services) is required. To this end, it is useful to characterise such links as flows of a positive or negative agency that act upon such parameters as the provision of energy, water, finance, or data. Given sufficient data of appropriate quality, these links can be further characterised probabilistically. However, for this paper, qualitative identification of the links between stakeholders in the network (along with links towards the target socio-technical outcomes) was deemed sufficient as a basis for future work in this particular, or other similar, context(s). Future work could include the computational replication of the real-life water-energy network to characterise preferred socio-technical-economic transition pathways.

4.1. Stakeholder Identification, Roles, and Responsibilities

The identified stakeholders, together with their roles and responsibilities, are summarised in Table 1. The government was identified as the main stakeholder in the provision of water services, while other ministries were also involved, including health, finance and economic development, education, science and technology, natural resources, energy and mining, and local government. Other identified stakeholders included donors, NGOs, microfinance organisations and communities that are water users. At the national level, the government is represented by the ministries and respective departments, whereas at the local level, the ministries are represented by the District Councils who are the link between

the donors, NGOs, and communities, with each district having a coordinator. However, specific stakeholders are not necessarily represented at the district level due to reasons such as a shortage of human resources and a lack of policy structure. The water sector is relatively decentralised and represented at the district level, but despite recommendations, the energy sector is not [40].

Table 1. Stakeholder roles and responsibilities for the provision of water using SWP.

Stakeholder	Roles and Responsibilities
Government (National) includes Ministries, departments, and statutory bodies	Formulating and enforcing policies, planning, financing, information generation, and awareness
Local Government (District Council)	Planning for the district; identifying needs; coordinating NGO and communities; mobilisation; monitoring (water-point committee, borehole drilling, water quality); and technical support, e.g., major repairs.
Donors	Providing proposal guidelines; verifying sites; training users; financing; procuring equipment; offering skills and expertise; monitoring.
Non-Governmental Organisations	Sensitisation and mobilisation; identifying the community, contractors, and suppliers; training the water-point committee; monitoring and handover.
Community	Adoption of technology, highlighting needs and commitment, siting of water points, election of a water-point committee, offering materials and non-skilled labour; financing through monthly contributions, system security provision, operation, and maintenance.
Private sector (entrepreneurs, contractors in water, and RETs)	Feasibility study; design and construction; offering expertise, skilled labour, operation, and maintenance; making profits and earning
Financial institutions (Banks, microfinance)	Funding, loans and training.
Media	Information awareness and ensuring accountability.
Academia	Training, research, and development; offering expertise; outreach; and advocacy.
Politicians (MPs and Councillors)	Lobbying and advocacy, and providing legislature
Advocacy groups	Lobbying and advocacy, social and cultural impact

4.2. Stakeholder Insights

Regarding the adoption of SWP, the challenges and key insights from stakeholders are now presented and discussed through the lens of specific key themes that emerged from the interviews. A summary table of the issues that emerged from the interviews has been presented in Appendix A.

4.2.1. The Policy, Standards, and Regulatory Context

Both the energy and water sectors in rural Malawi are reported to lack policies favourable to the sectors' expansion. Donors and NGOs stated that they were currently guided by the available policies on standards for water provision in rural areas, as one respondent explains:

> *"We use the government standards. . . AFRIDEV pumps for deep wells which are supposed to be 20 m to 60 m and MALDA pumps for shallow wells. . .the Ministry is responsible for standards and development of the designs for the pumps and for the boreholes themselves. . ."* (KII17, Donor)

By making this statement, they implied that if there were policies and standards on SWP for water provision in rural areas, they would adhere to them. The Malawi government promoted RETs in other applications, such as lighting, but there were no specific policies, toolkits, or deliberate structures regarding SWP. The respondents positively welcomed the concept of SWP, as one of them said:

> *"It's not a bad idea, as we go. . .I think that's an improved level of service. . .I mean when you do [install] a solar supply system you don't expect the people to do this [gestures hand water pumping action] . . .you expect people opening the taps. . .and benefit women and girls who bear the burden of collecting water. . .we don't have to stay at the same level of service. . ."* (KII17, Donor).

As with the previous comment, this indicated that if there were these policies and standards, they would be adhered to. The currently available policies were stated as being either outdated or lacking enforcement, as it was observed that there were no punitive measures for offenders [20]. With favourable specific policies and political will, there can be increased uptake of technologies [41], as witnessed in India for SWP [12]. This finding highlights the importance of relevant and up-to-date policies to enable the adoption of RETs.

4.2.2. Stakeholder Information, Awareness, and Knowledge Transfer

Respondents reported low levels of information availability, sensitisation, acquisition, sharing, and access. On the sensitisation of SWP, one respondent reported:

> *"There is lack of sensitisation. . .the government has to work on sensitisation, people should know what the benefits and disadvantages are and what do they stand to gain if they go solar."* (KII15-Microfinance NGO)

Information on groundwater resources, solar resources, the number of installed boreholes, and PV systems is not readily available, as also witnessed by [21] in research on district water access points. Where available, stakeholders were reported to be reluctant to share information such as sector reports and/or progress reports. Inadequate information for citizens and investors was reported to be common in the SSA [41]. Since decision-makers are not up to date with technological innovations in renewable energy, the available opportunities are disregarded due to misperceptions of the quality and appropriateness of new technologies. Previous work in Malawi concurs and reports that awareness of solar products in Malawi is low and is coupled with a negative reputation [42]. As such, it is suggested that appropriate evidence on the benefits of solar would improve technology uptake. Similarly, Kunen et al. (2015) [43] and Mohammed (2013) [44] found that the key barriers to uptake of RETs, such as increased commercialization of SWP for irrigation, are not technological but instead centred around education. These authors argued that where people in SSA have low levels of education, sensitisation is more difficult.

Respondents also mentioned that farmers lacked information on the cost, performance, installation, and maintenance of the SWP systems. Limited information and awareness have led to problems such as dependency on donations and free services and slowed the adoption of technology, continuing to rely on rain-fed agriculture [29,42,45]. This finding suggests the need to have data and resource sharing mechanisms, such as databases, that would be available to all the relevant stakeholders.

4.2.3. Product and Installation Quality

A major finding of this study was the presence of substandard water installations and counterfeit RET products, resulting from political interference, corruption, and a lack of monitoring, which in turn resulted in the non-functionality of systems. Political interference was thought to play a significant role in the provision of water, as several stakeholders reported that politicians used their powers to interfere with the water institutions and other services in the country. Two of the respondents' organisations had their establishment aligned with a political party. This is corroborated by other authors who found that water and RET products are often used as campaign tools by politicians, which consequently discourages sustainability and ownership of systems [19,23,46]. Political interference promotes an 'aid culture' whereby communities expect donations of 'free' services and hence discourage sustainability and ownership. It also leads to compromised standards [23,47] and misuse or diversion of funds, as reported in Zambia [48]. In their

study, Dutta & Das, 2020 [29] similarly discussed significant repercussions arising from political interference. For example, on the adoption of grid-connected solar rooftop systems, the ever-changing political heads of their state made a complete mismatch between policies and the implementation of the work on the ground.

Corruption was also identified as one of the major deterrents to carrying out effective water projects in the country. Internationally, the water sector is viewed as 'high-risk' for corruption because of the financial flows involved, weak government oversight, and significant public-private interactions [48,49]. Incidences of corruption from literature in the Malawi water sector include a request for "favours" from contractors by some government staff, bribery during the tendering and award processes, and use of sub-standard materials [50].

Another cause of substandard work in the water sector was reported to be a lack of monitoring. Drillers were reported to drill shallower wells than specified, and contractors installed in areas that were more accessible or where the groundwater was accessible instead of installing where requested. Lack of supervision and monitoring was cited as a key factor in these cases.

> "*If drilling contractors are not monitored, they may drill a shallower borehole than required and report that they have drilled the required depth. Problems would show up when the borehole which was thought to be deep gives low yield or dries out altogether*" (Int17, Donor)

In the water sector, an absence of close supervision and monitoring has been attributed to limited finances for transport and accommodation for supervisors [50]. Evidence derived from interviews indicated that a lack of human resources was not the root cause of poor monitoring. There were usually no verifications of the completed installations and an absence of penalties for substandard installations [20,21,48]. Hence, the quality of products and installations can be compromised, resulting in water access inequality, dry boreholes, or non-functionality, as substantiated by [21,48,50].

The lack of quality installation monitoring was also cited by interviewees, resulting in the substandard installation of RET products. Although the Malawi Energy Regulatory Authority and Malawi Bureau of Standards are responsible for issuing and enforcing regulations and standards, some counterfeit products are still in use. It was reported that some companies resorted to buying counterfeit products (which are usually of low quality and prone to early failure) to cut costs and enhance their profits. This study's findings on the proliferation of poor-quality products and/or counterfeit products in RETs have been confirmed by [42,51], who found out that the quality of products sold in Malawi was generally low, with a high proportion of customers returning, being dissatisfied, or losing trust with products.

4.2.4. Economic Issues

Interview respondents reported issues related to economic factors, including high capital costs of equipment, lack of access to finance, high inflation, excessive loan interest rates, a lack of foreign exchange, and high levels of poverty. These findings were consistent with those of [23], who identified a major drawback of solar-powered systems in Malawi as the prohibitive capital costs of RET systems and products, a factor that is exacerbated by the absence of RET manufacturing companies. High-quality products are expensive and unaffordable to most rural people, hence the proliferation of counterfeit products. Thus, it was recommended that the government play a role in the manufacturing or assembly of basic RETs to facilitate cost reduction.

Interviewees noted that the financial environment was reported to be unfavourable to investors given high inflation, excessive interest rates, high lending rates, and exchange rate fluctuations, as similarly reported by [42]. Interviewees argued that currency fluctuations, together with high value-added tax rates, pose a high risk to the long-term sustainability of solar companies in Malawi. As all RET products and accessories are imported, this puts a constraint on the availability of foreign exchange, leading to project delays. Likewise, [44]

affirmed that high interest rates were a common challenge in SSA and asserted that investors were not often willing to accept the resulting high project risks. In Kenya and Nepal, portable SWP systems were introduced at lower costs for smallholder farmers to accelerate irrigation [43]. A possible solution for the Malawian government and development partners would be to consider offering low-cost loans or subsidies, as occurs in other programmes in the country, for example, farm input subsidies and housing construction projects for people in rural areas.

A lack of finance was further reported as one of the main challenges in the water sector in Malawi, resulting in chronic underfunding, which constrains ministries' ability to carry out their budgeted plans [52]. Indeed, Gutierrez [48] noted that the funds allocated for the water sector do not match the corresponding projects identified for funding. This lack of finance is exacerbated by donors frequently pulling out of projects due to corruption [53]. Economic issues were also reported as a challenge in the management and sustainability of water points, along with non-functionality, with boreholes remaining non-functional because the finances required to buy required spares were lacking or had been misused [21]. For SSA, the lack of transparency and accountability relating to finances has been reported [46].

In the current study, respondents recommended that the government explore funding mechanisms such as grants, loans, and subsidies. Additionally, microfinance organisations could offer revolving funds and soft loan policies, or private enterprise institutions could offer 'pay as you go' RET products to increase awareness and build trust to promote a faster uptake of technology among the population, as recommended by [42]. Research into the provision of irrigation water using SWP should be encouraged to enhance income-generating activities.

4.2.5. Skilled Human Resource Availability

Respondents reported a shortage of appropriately skilled human resources, both in the water and energy sectors. For example, the water ministry reported a 35–40% workforce vacancy rate at both the ministry and district levels, together with a high staff turnover rate. In the energy sector, it was reported that there was an inadequate supply of qualified experts and technicians ranging across the fields of planning, manufacturing, distributing, installing, maintaining, and marketing of RETs. Without qualified experts in the country, the development of technologies is slowed, especially given that in the private sector there are relatively few distribution, installation, and maintenance entrepreneurs, which causes a lack of competition in the market. Even for the few that exist, their competence and skills are limited; for example, they have limited skills to develop business plans and marketing. Given that most of the entrepreneurs in RET are based in Blantyre and Lilongwe, the two major cities of Malawi, this made the RET systems more expensive in rural areas due to travel costs, as pointed out by one of the respondents:

> "*We travel from here [Southern Region] to the North to install or maintain some water pumping systems because there are no other entrepreneurs in the North or Centre to match our capability and quality standards. More time is spent travelling and the distance adds to the cost of the system*" (KII21, Entrepreneur).

Human resources issues have been reported to constrain the development and management of water resources in Malawi [20]. It was noted that the level of local skills for the manufacture and maintenance of RETs is low, and companies have to train their staff [42]. Along with high financial expenditure, a lack of human resources in Malawi was one of the main causes of the non-functionality of RETs, and sometimes human resources have to be either imported or components have to be sent outside the country for maintenance [23]. This demonstrates the need for capacity building at all levels and professions in the energy sector supply chain. This includes the establishment of training institutions in RETs such as vocational schools at the lower levels, the training of experts at higher-level institutions, and the establishment of energy research centres to carry out research and service centres in the rural areas closer to where the services are needed.

4.2.6. Community Management, Theft, and Vandalism

It was reported that current community management models possess weaknesses, which result in the unsustainability of water extraction and supply points. For example, after commissioning boreholes, an NGO or implementing partner hands over the borehole to the community. Commonly, there is no consensus as to what extent communities are expected to repair or maintain the borehole, such that when a borehole malfunctions, it is not exactly known whose responsibility it is to repair the system. Sometimes boreholes remain non-functional because the host communities are unable to pay for the O&M costs. If it is ensured that borehole spare parts supply and pump mechanics are within the vicinity, maintenance of the boreholes is possible with less downtime. However, in such cases, sometimes the trained water-point committee (WPC) members moved away with no proper handover, as reported by a respondent:

> "*For me the major challenge is over real ownership and responsibility which is connected with ownership for the upkeep of infrastructure or operation and maintenance side. . . this is a huge challenge in Malawi and I think one of the biggest issues is that the current kind of model for rural communities is community owned so it means in some level there is a disconnect between the government or even the districts in terms of their responsibility . . .to me the lesser challenge is putting in the infrastructure, and the bigger challenge is managing it*" (Int18, Donor)

The failure of community-based management has also been documented by [21,54]. Another challenge cited is theft and vandalism of system parts, which resulted in non-functionality, as discussed in [18]. One respondent reported that to prevent solar PV module theft, they bolted and welded the solar modules to steel structures, employed security guards, or built the systems close to residences. In the Algerian Saharan regions, RET uptake was reported to be low because of a fear of theft [55]. These findings suggest that the challenges of ownership, theft, and vandalism and the funding of O&M costs should be taken into consideration when designing SWP systems.

4.2.7. Infrastructure and Accessibility

It was reported that Malawi has limited infrastructure, such as roads, power supply, water supply, and telecommunications services, particularly in rural areas. This hinders potential inward investment and constrains development. It is difficult for personnel to access rural areas and perform duties because of the long distance and bad roads, or no roads at all. Additionally, organisations such as banks do not set up offices in such areas because of relatively low market demand. Water drillers were reported to concentrate on villages that are easily accessible; hence, villages without road infrastructure may have fewer water points, as observed by [48]. Entrepreneurs find it unprofitable to invest in rural areas, as some respondents observed:

> "*As a sector, I would say the number one challenge is limited infrastructure. By this I mean issues of connectivity-network, power outages, poor roads, lack of essential services in the rural areas. . .*" (Int16, Microfinance NGO).

Similar challenges were also cited by [56], who indicated that electricity and transport infrastructure are the biggest challenges to the economic development of Malawi. This finding suggests the necessity for the government and related organisations to prioritise infrastructure development both in urban and rural areas.

4.2.8. Environmental Degradation

Interviewees reported that environmental degradation is widespread in Malawi due to human activities such as farming crops along the rivers and the use of artificial fertilisers. Another concern was deforestation caused by the dependency on biomass for energy, construction, and land clearing for agriculture. These cause damage to the water sources, including siltation and pollution. The generation of hydroelectricity is also affected owing to the dependence on the Shire River, which experiences siltation. Increased turbidity

was also experienced in gravity-fed systems because of deforestation and encroachment in water catchment areas. Whereas in the past the water needed little or no treatment, nowadays the water may need to be filtered and treated, with intake positions moved to higher ground. A respondent reported as follows:

> "*But also, environmental degradation. . .lots of tree cutting in water catchment areas that are contributing to the drying of rivers . . . that contributes to the decline and pollution of water resources. . . We are witnessing a decline in terms of groundwater levels in that we have seen a number of shallow wells that are drying up*" (KII8, WASH NGO).

Borehole exhaustion is one of the problems encountered at the drilling stage, which is commonly attributed to the high incidence of low water tables due to climate change impacts. Some of the environmental degradation issues reported in this study could be alleviated by raising awareness of environmental protection issues, such as encouraging afforestation.

4.2.9. Research and Development

There was a general concern from the respondents that academic and industrial researchers in the country are not active in applied research and development other than with regards to research for academic purposes. It was felt that the results of academic research were typically published in journals that were not accessible in Malawi, and the findings were not widely disseminated and applied in Malawi. They felt that researchers and academics should be at the forefront of spearheading research that addresses existing problems and should generate and share knowledge.

The respondents recognised the need for research into more sustainable water provision systems other than hand pumps, which they said had frequent breakdowns. Several respondents mentioned that they do interact with academia and felt that interaction between academia and the private sector, NGOs, industry, and government could be improved. The lack of information dissemination by researchers was also referred to by [57], who reported that a lack of research and development is a barrier to the adoption of RETs. Other authors recommend the need for research to inform the design and siting of water points [58]. This finding highlights the importance of academic and research institutions in advancing scientific development and increasing knowledge. Intensive research could offer solutions for more sustainable energy and water solutions, such as in the design of SWP systems and other RETs.

4.2.10. Coordination and Harmonisation

This study identified a lack of coordination and harmonisation across relevant policies and amongst stakeholders. Several comments were made regarding the impacts of poor coordination, such as the following:

> "*We saw lots of disparities, where most of the water points were piled up in one area of the district at the expense of the communities. . .you find that this village with 1000 people has got one or two facilities, the nexts village with 1000 people has got four to eight facilities. . .or sometimes to make it worse still, this has got eight, the next one has got zero. . .suffice to say is that lack of coordination of investment is one key element that leads to that unequitable provision of services*" (Int8, WASH NGO).

> "*For example, we are promoting irrigation and sometimes irrigation is being done in river banks, if you use a treadle pump how far away can you extract water. . .it could be 5, 10 m but the environment policy provides for a 20-m buffer zone from the river's course, that area is not supposed to be cultivatable land to avoid impacts such as siltation*" (Int8, WASH NGO).

The lack of coordination and harmonisation within and across relevant policies in the water sector was also recognised by [20,52,59] and in the Kenyan energy sector by [41]. This was consistent with other studies where poor coordination resulted in disparity in the distribution of boreholes, duplication of water projects, and difficulties in planning and

monitoring the overall performance of the sector [21,48]. Though the NGOs acknowledged some interaction and assisted one another in specific projects, there is still a general lack of coordination amongst them. In response, the Water and Environmental Sanitation Network was introduced in 2012 to be an umbrella organisation. Despite reports that it had not yet reached some parts of the country, there was hope that the organisation would eliminate some of the coordination issues.

4.3. Power-Interest Matrix

From the respondents' descriptions during the interviews, as summarised in Table 1 and explained in the stakeholder insights in Section 4.2, a matrix illustrating the power and interest relationships of the various stakeholders was created, as shown in Figure 6. The classifications are dynamic and may vary depending on the project stage.

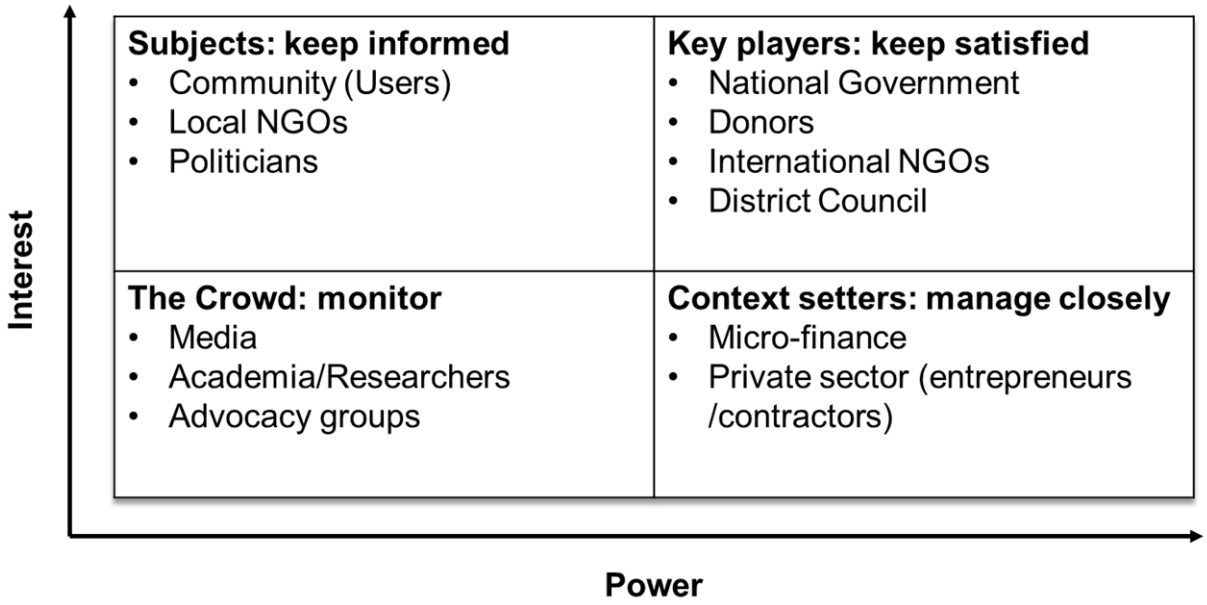

Figure 6. Power vs. interest matrix for solar SWP in Malawi.

Figure 6 illustrates that the key players are: The National Government, Donors, International NGOs, and District Councils. The analysis in the previous sections shows that respondents picked the national Government as the most important of the key players. One of the limitations of this study was the relatively small sample size, although this did include all stakeholders who could be identified in Malawi. It was noticeable that half the stakeholders were international NGOs and donors who have their own targets that are often time-limited or have particular agendas. Future research could consider how this reliance on external actors influences SWP policy and projects. This study is timely as, as of November 2023, policies on the productive use of energy, including SWP, are being worked on and will be incorporated in the upcoming National Energy Policy Review.

5. Conclusions and Recommendations

Through semi-structured interviews with respondents from public and private organisations, this study identified and examined the nature and characteristics of stakeholders involved in water and energy provision issues in the rural areas of Malawi in the context of adopting SWP, objective 1. This study has highlighted stakeholder roles and the current challenges that are being encountered, which could constrain the uptake of SWP in water provision in rural areas. Several challenges were identified in the energy and water sectors, which included high costs of RETs, a lack of finances, suboptimal coordination between policies and stakeholders, a shortage of relevant skills and human resources, political interference, corruption, failed community management models of water provision, and

limited information and awareness. The effects of these challenges include inadequate water access, non-functionality, substandard installations or counterfeit RETs products on the market, an 'aid culture', a lack of sustainability of systems, slow technology uptake, planning and budgeting problems, and poor resource management.

This study recognised that the government was a key stakeholder and policymaker with the responsibility to provide an enabling environment for the SWP market (objective 2). This required formulating or revising harmonised policies to enable the uptake of SWP for drinking and irrigation water with minimal damage to the environment. At the same time, it was concluded that the government should ensure that relevant policies, laws, standards, and regulations are enforced by the existing regulatory bodies. This study further identified a lack of coordination amongst stakeholders and across relevant policies, which contributed to non-functionality, environmental degradation, a lack of equity, planning and budget challenges, and sector evaluation constraints. Another finding was a lack of information and awareness at several levels. On one hand, at the national level, the government lacks an easily accessible database on resource availability and distribution, both for energy and water. In addition, the stakeholders do not share the information that is available in their institutions. This causes a disparity in water access and presents planning and budgeting challenges. On the other hand, communities lack awareness and sensitisation about the capabilities of SWP, which leads to constrained uptake and dependency on rain-fed agriculture. Decision-makers need to be up-to-date about technological innovations in renewable energy and should have clear guidance on how to develop and incorporate new technologies. Such information could be passed on to stakeholders, including those within end-user communities. Extensive consultation, engagement, and training are needed to change the communities' perspectives with regards to new technologies and applications. This is important for the diffusion of innovation. Additionally, political interference has been found to be one of the major challenges in the water and energy sectors, which causes a lack of access equity, promotes an 'aid culture' contributes to substandard installations, and hence discourages sustainability and ownership. It is quite incredible that people actively contribute to the discord for their own benefit. Further, the research found that a lack of monitoring causes reduced equity and non-functionality due to sub-standard installations and the presence of counterfeit products on the market. Additionally, a general lack of oversight and supervision is the result of investment shortfalls and limited human resources in relevant government departments. Similarly, in the private sector, there were few entrepreneurs and little competition in the market. The limited infrastructure, high inflation and interest rates, poor currency exchange rates, costs, and high risk of investment are detractors for investors. Limited finance is further exacerbated as donors become reluctant to engage due to systemic corruption. Corruption was also reported to affect the quality of installations, which derails development.

This study concludes that policy, financial, and management frameworks must be improved for the sustainable provision of drinking and irrigation water to the rural areas of Malawi. This study shows that provision for water in such developing countries goes beyond sound technical design and is necessary to include socioeconomic and managerial aspects. Hence, for enhanced uptake of SWP, institutional, policy, financial, and management frameworks have to be improved. It is hoped that the new National Energy Policy Review will help to progress the deployment of SWP and be an enabler to mitigate the complex web of barriers that currently exist. To this end, this study makes the following recommendations to enhance SWP uptake, objective 3:

- Development of relevant harmonised water and energy policies;
- Provision of funding mechanisms for drinking and irrigation water for communities;
- Support for academia and researchers to carry out research addressing the water and energy challenges;
- Awareness and sensitisation on the possibilities of SWP;
- Establishment of training centres in RETs at all levels;
- Encouraging investors in RET design and manufacture.

- Coordination of all relevant stakeholders;
- Enforcement of standards and monitoring of water and energy installation quality; and
- Creation of a database of relevant information on water and energy which is readily accessible to all stakeholders.

There are some elements that were beyond the scope of this study that need to be addressed by future analysis. Malawi is one of the poorest countries in the world, and poverty is a major obstacle to development. In order to address poverty and access to water/energy, access would require a significant increase in the standard of living. Universal energy access only occurs when countries reach middle income status [60]. It is highly unlikely that this will occur in the foreseeable future.

The participants identified corruption as another significant challenge. To solve this issue, anti-corruption legislation and enforcement are required. Corruption is not unique to Malawi or developing countries, but by tackling it, low investor and donor confidence could be turned around to help improve the water and energy access situation in the country.

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Appendix A

Table A1. Summary of issues arising from stakeholder interviews.

No	Issues Arising	Effects	Recommendation
1	Lack of policies or old policies	• Lack of/slow uptake of technologies • Poor resource management • Absence of punitive measures	• Develop/revise appropriate policies
2	Limited Research and Development	Unresolved challenges	Research on technologies applicable to Malawi
3	Lack of Information and awareness	• No database on resources availability and distribution • Lack of equity • Planning challenges • Dependency on rain-fed agriculture • Enhances 'aid culture' • Citizens unable to exercise their rights	• Develop energy and water database • Share available information with stakeholders • Carry out awareness and sensitization • Develop a GIS application • Consultation and engagement with communities
4	Lack of Coordination	• Non-functionality • Environmental issues • Lack of equity • Planning and budget complications • Evaluation constraints	• Harmonise policies • Integrated planning • Involve private sector
5	Political Interference	• Lack of equity • Encourages lack of sustainability/ownership • Substandard installations	
6	High capital cost	• Few entrepreneurs • Lack of access • Unaffordability	• Establish RETs manufacturing companies • Tax and VAT waiver on RETs and accessories • Explore funding mechanisms such as apex fund, revolving fund and microfinance organisations

Table A1. *Cont.*

No	Issues Arising	Effects	Recommendation
7	High Inflation and interest rate	• High Capital Cost • Few entrepreneurs • Risky environment for investors	As for high capital cost
8	Lack of Finances	• Lack of monitoring • Unaffordability • Lack of sustainability	• Government loans and subsidies • Work with VSL groups
9	Corruption	• Deters development • Substandard installations	• Close supervision and monitoring
10	Lack of Human Resources	• Lack of Monitoring • Derails development • High financial expenditure • Non-functionality	• Vocational schools • Business training for entrepreneurs and communities • Renewable energy service centre
11	Lack of Monitoring	• Lack of equity • Non-functionality • Presence of counterfeit products	• Government to enforce regulations and standards
12	Failed management model	• Non-functionality • Unable to manage and set aside funds for O & M	• Explore alternative ownership model • Professionalise system • Life cycle costing • Government to provide O & M funds
13	Limited Infrastructure	• Lack of equity • Investors are reluctant to come in the country	
14	Environmental Degradation	• Pollution of water resources • Decline of water table	• Encourage afforestation • Proper design and siting of water points

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