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Review

Towards sustainable financing models for micro-hydro plants in Sub-Saharan African countries: A theoretical review

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Micro-hydro plants (MHPs) have been identified as a proven and promising opportunity to alleviate energy poverty in rural areas of Sub-Saharan Africa. However, the absence of "lowest-cost, long-term financing models" is found to be one of the major barriers to wide-spread adoption of this technology in the region. This paper presents a review of the factors underlying this absence and using the van Egmond and de Vries' sustainable finance model builds a framework that visualises critical linkages in MHP development crucial to designing sustainable financing models.

Key words: Micro-hydro plants (MHPs), Sub-Saharan African countries, sustainable financing models.

INTRODUCTION

Background

Sub-Saharan Africa (SSA) is one of the least-developed regions globally. The region has one of the highest percentages of people living in extreme poverty (Simmons, 2015). This is in spite of the abundance of natural resources in the region, the poverty alleviation programmes being undertaken and a strong economic growth witness over the past decade (IMF, 2014; Shanker, 2013; Simmons, 2015). One of the contributing factors to this slow rate of development is lack of modern and reliable energy services (IMF, 2014). The region is currently in a power crisis characterized by inadequate, unreliable, and costly electricity supply (IMF, 2014). While the rest of the world has improved in the last two decades, the region's per capita electricity production has remained low and largely stagnant (IEA, 2014; IMF, 2014;KPMG, 2014). IEA (2014) reported that:

"more than 620 million people in the region (two-thirds of the population) live without electricity, and nearly 730 million people rely on dangerous, inefficient forms of cooking…..and average electricity consumption per capita is not enough to power a single 50-watt light bulb continuously."

In harmony KPMG (2014) observed that:

"The region is characterized by ageing power infra-structure that is unable to meet current power demands

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Table 1. Regional access to electricity aggregate.

Region	Electrification rate %	Urban electrification rate %	Rural electrification rate %
Developing countries	76	91	64
North Africa	99	100	99
Sub-Saharan Africa	32	59	16
Developing Asia	83	95	74
Latin America	95	99	82
Middle East	92	98	78
Transition economies and OECD	100	100	100

Source: IEA (2014).

and therefore suppresses the power demand….Power consumption, at 124 kilowatt hours (kwh) per capita per year and falling, is only a tenth of that found elsewhere in the developing world, which is barely enough to power one 100-watt light bulb per person for three hours a day."

Excluding South Africa, the entire installed generation capacity of the region is reported to be equivalent to that of Argentina (World Bank Group, 2013). Thus the current available electricity in the region is way less than adequate to support sustainable economic and social development of sources of production and of the basic social services (Shanker, 2013). Therefore making reliable and affordable energy widely available remains critical to the development of SSA region (IEA, 2014).

The energy supply situation is far much worse in rural areas (Gaul et al., 2010; IRENA, 2012B). According to the global regional aggregates (Table 1), rural electrification rate in SSA is 16% the lowest globally, seconded by other developing countries at 64%. The rate disparity is sobering, indicating the gravity of the problem in the in the rural areas of SSA. No wonder acute poverty in the region is mostly concentrated in rural areas (Alkire and Housseini, 2014).

Major contributing factors and related solutions

Contributing to the low rural electrification rate in SSA is the fact that the traditional way of providing electricity through grid extension has proven to be technically challenging and prohibitively expensive due to geographical barriers (i.e. terrain), remoteness and sparseness of most of the rural settlements and initial low demand for electricity (Gaul et al., 2010; Kaunda et al., 2012; Klunne, 2011). The problem is made worse by the existing weak, damaged and underdeveloped electricity distribution infrastructure (KPMG, 2014), which is not even adequate to satisfy urban demands.

Considering the immediate need for energy in rural areas of SSA and the challenges relating to the traditional method, alternative, cost-effective and sustainable means for energy provision are needed (UNIDO, 2006). According to Santiago and Roxas (2012) this would involve electrifying the rural communities through installation of off-grid power facilities that take advantage of indigenous natural resources. These off-grid power solutions are recognised to be ideal as they are installed closer to the end-users thereby mitigating transmission challenges. Furthermore they can be implemented more quickly due to their shorter licensing processes and construction times (KPMG, 2014). As a result, electrification in rural areas can be sped up cheaply (IRENA, 2012A; KPMG, 2014).

Renewable energy (RE) technologies therefore present an ideal solution to rural electrification based on the challenges on the ground in the region (Gaul et al., 2010). They in fact turn some of the impeding factors to grid extension (such as terrain) into an opportunity for relatively cheap expansion of energy access to the rural areas. Thus these technologies are increasingly being recognised as promising alternatives to traditional energy sources and especially critical to remote communities (IEA, 2014; KPMG, 2014; Painuly and Fenhann, 2002). SSA region stands to benefit more as it is endowed with vast untapped RE resources that can enable it to provide electricity at an affordable cost (IRENA, 2012B). However, amongst these RE alternatives, micro-hydro plants (MHPs) are recognised as a proven and more promising option (Klunne, 2011; Kölling et al., 2011). This paper presents the review of the factors underlying one of the major barriers to region-wide adoption of MHPs despite their proven potential. The rest of the paper is structured in the following way: section two presents an overview of the merits and demerits of MHPs and a crucial challenge preventing their wide scale adoption in the region of interest. Section three presents the conceptual framework for the review while section four gives the disaggregation of the MHP system and the discussion of the factors influencing financial sustainability of the system in SSA based on the conceptual framework. Section five on the other hand, consolidates the knowledge gained in section four into a framework visualising the critical linkages in MHP development critical to designing their sustainable financing models in SSA. Finally, section six gives the concluding remarks.

MICRO-HYDRO PLANTS (MHPs) IN SSR

Overview

The SSA region is endowed with enormous untapped hydropower resources [eg terrains and water] (IEA, 2014; KPMG, 2014), very suitable for the adoption of MHPs. In addition, MHPs have some comparative advantages over other types of RE technologies. According to Paish (2002) the relative advantages include the fact that: MHPs are much more concentrated energy resources than either wind or solar power; their energy availability is readily predictable; the power is usually continuously available on demand; there is no need for fuel; they require limited maintenance; they are a long-lasting technology; and they have almost no environmental impact. Furthermore GVEP-International (2010) highlighted that MHP systems are very flexible in that they can either be grid-connected, stand-alone or hybrid depending on the site, grid connectivity and reliability of the water supply; they can use run-of-the-river systems hence do not require storage reservoirs/dams to harness the energy from moving water; and they are relatively reliable in operation compared to wind or solar resources though MHPs may be seasonal in nature. Besides, their running costs tend to be cheaper than other RE technologies (Min et al., 2011). On the other hand, MHPs suffer from the following disadvantages: they are site-specific; they require a close water source to make the installation and energy transmission viable; expansion is limited by the stream's amount of convertible embodied energy; they require a lot civil works; output may vary with rainfall patterns. Moreover, although they have low-level environmental impact on the water course, the amount of water in the section of the river where the water is diverted is affected, along with oxygenation levels, with potential interference with aquatic life (Langley and Curtis, 2004). Furthermore in spite of having lower running costs, their initial investment costs are relatively higher (Min et al., 2011). Nevertheless, despite the disadvantages, MHPs are applauded for fulfilling technological, environmental, economic and social sustainability criteria in remote and isolated areas (Gurung et al., 2011). Thus in addition to providing power flexibly and reliably to homes and communities in areas not served by national electricity grid, MHPs offer an opportunity to produce clean and affordable energy from a sustainable energy source (GVEP-International, 2010).

The basic challenge to MHP deployment in SSA

Despite the technological potential, extracting energy in the region remains a challenge (Gamula et al., 2013; Klunne, 2012). Implementation of a small number of micro-hydropower projects does not reflect the enormous potential for the technology, which suggests existence of additional barriers other than the technology itself (Klunne, 2012). Wohlgemuth (n.d.) noted that it is about "economics" and according to Flavin et al. (2014); it is the need for "low-cost financing". The same was also recognised by Gamula et al. (2013); Glemarec (2012) and Liu et al. (2013).

MHPs require relatively high up-front financial outlay (Glemarec, 2012; Kolk and van den Buuse, 2012; Min et al., 2011; Pierpont et al., 2011; Wohlgemuth, n.d.). Their development requires acquisition of costly capital equipments and civil works and other various pre-construction activities. Besides, they require significant market development which according to Glemarec (2012) involves considerable uncertainty and large financial outlays. As a result, current conventions for financial and economic appraisal of new hydro installation produce expensive electricity, with long recovery period (Paish, 2002). These together with the poor financial capacity of most of the end-users make the designing of suitable financing mechanisms challenging. Consequently private capital is scarce, leading to reliance on donor aid (Glemarec, 2012; Kölling et al., 2011; Liu et al., 2013). However, even with assistance from donors, the financial challenges persist (UNIDO, 2006). Moreover in some countries donors are not forthcoming either (Liu et al., 2013). Thus the availability of adequate financing has proven to be a gatekeeper for the wide-spread deployment of the technology (Pierpont et al., 2011; Wohlgemuth, n.d.).

These financing challenges coupled with a combination of various other factors, has led to the absence of "lowest-cost, long-term financing models" (Klunne, 2009; Klunne, 2011) or "dedicated financing mechanisms" (Gamula et al., 2013). This paper describes these models as "sustainable financing models" as their intended impact is to facilitate provision of energy to customers at affordable prices while ensuring long-term sustainability of the sector (Klunne, 2011).

Lack of insights regarding underlying factors

The development of alternative and innovative financing models is recognised as critical to the removal of the financing barriers (Klunne 2009; UNIDO, 2006). However there is dearth of empirical analysis that comprehensively explains the underlying factors to the failure to develop the models.

Furthermore, literature on financing of MHPs is scattered and sparingly addresses technology's uniqueness and associated context issues. It is recognised that their unique nature and related markets lead to distinct financing needs (IRENA, 2012A). Besides, MHPs are context-specific as such they require context-specific solutions (Kolk and van den Buuse, 2012) hence it is imperative to consider MHP financing contextually.

According to Painuly and Fenhann (2002), identifying and addressing the various underlying barriers is what can lead to designing of innovative policy approaches for the financing of RE technologies. Nelson and Shrimali (2014) asserted that while there is no “right way” for designing the ideal programme, thoughtful analysis of each of the decision points involved can help in designing an effective financing program. Therefore there is need for frameworks that facilitate thoughtful analysis of MHP development that can facilitate designing of sustainable financing models in SSA. This review is one such endeavour.

CONCEPTUAL FRAMEWORK

van Egmond and de Vries’ sustainable finance model

The two-part sustainable finance model developed by van Egmond and de Vries (2015), guided the review in understanding MHP system’s financial architecture. According to the model, a sustainable financial model comprises two systems – the physical system and the financial system. The physical system being where production and consumption of physical resources takes place; on the other hand the financial system is responsible for mobilising finances to facilitate the activities in the physical system (van Egmond and de Vries, 2015). The behaviour in the financial system is dictated accordingly by the interactions of the productive and consumptive parts of the physical system (van Egmond and de Vries, 2015). As such, in the search for sustainable financing models, critical considerations should be made on the behaviour of the physical system; basically the structure and condition of the system drive behaviour and in order to change behaviour, it is important to change the thinking that underpins the system structure and conditions (Zokaei et al., 2010).

One important aspect necessary for understanding the sustainable financial models is the recognition that the systems are facilitated by interactions of various stakeholders such as governments, banks, regulators etc (Mainelli and Manson, 2011); hence stakeholders are actors critical to the entire sustainable financial system. The model defines a sustainable finance model as a system which “indeed” links both the physical system to the financial system and money (van Egmond and de Vries, 2015). There are continuously feedback mechanisms and adjustment processes at work that make the system tend towards a steady-state (van Egmond and de Vries, 2015). Thus in designing sustainable financing models will require attainment of a steady-state between the physical system and the financial system. Since the behaviour of the physical system drives the behaviour of the financial system, some financing barriers may not be barriers in their own right; they are simply a reaction to the problems in the physical system. Using the sustainable financial model, the MHP system was broken into two: the physical system and the financial system. In order to thoroughly understand the constituent elements and their behaviours, systems theory and life cycle analysis were employed.

Systems theory and life cycle analysis

RE markets are described as a highly complex, “living system” with a variety of stakeholders at different stages of development, each having distinct financing needs (IRENA, 2012A). This suggests that RE markets are “open systems” and hence amiable to systems thinking. Further to that RE projects are recognised to be subject to different types of risk throughout their “life-cycle”, each of which requires active management in order to attract financing (Liebreich, 2005). The RE projects are also examples of "new economy enterprises" that demand a financial system sufficiently flexible to provide them with the different financial mechanisms as required by the particularities of their “life cycle” (Thiel, 2001). Thus within the context of van Egmond and de Vries’ sustainable financing model, the review employed systems theory and life cycle analysis in order to evaluate constituents and their behaviour in the examination of the factors underlying the absence of sustainable financing models for MHPs in SSA.

The review used life cycle analysis in identifying life cycle activity phases, mapping of stakeholder involvement, and development of context-specific indicators that help in visualisation of the system (Thabrew and Ries, 2009). On the other hand, systems thinking assisted collective analysis of system [the MHP’s life cycles, stakeholders and financing or the “physical” and the “financial” aspects], enabling consideration of cascading effects, inertia, and other systemic features related to sustainability issues and sustainability problem-solving frameworks (Claesson and Svanström, 2013 citing Wiek et al., 2011).

THEORETICAL REVIEW: THE PHYSICAL AND FINANCIAL SYSTEMS OF MHP

Typical components of the physical system

Literature suggests two critical components of the MHP physical system namely: “market development” and “MHP development and operation”, these in turn significantly determine the behaviour of the financial system in short and long-term.

Market development

Technology without a strong market is not viable. It is therefore more important to think about markets, rather than simply about the technologies themselves (Martinot

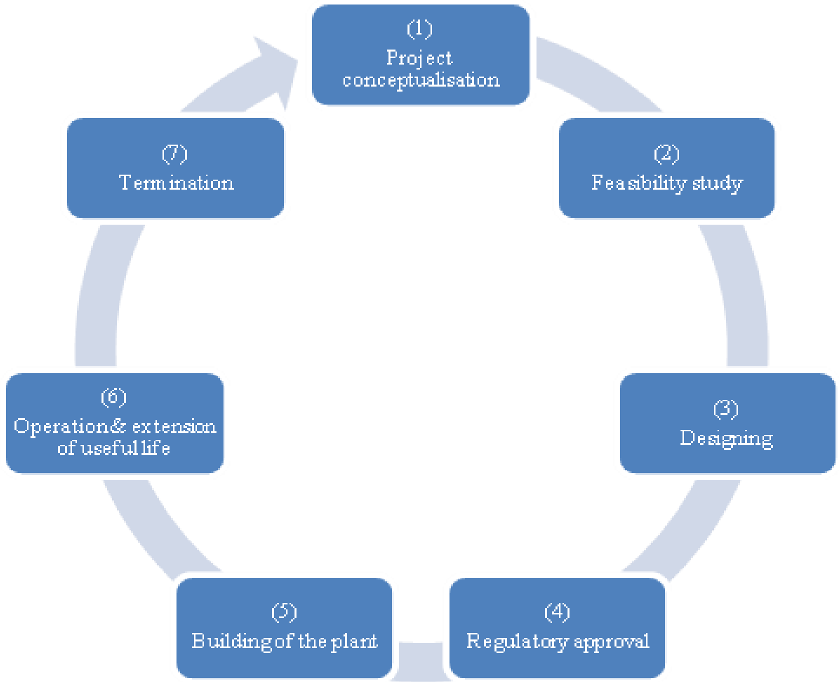

Figure 1. MHP life cycle stages. Source: Based on analysis from literature review by author.

et al., 2002). In the same vein it is important to highlight the differences between market potential and actual market. Market potential refers to the quantity of RE development that can be supported in a particular area given the available resource, and the technical, economic, and market constraints (Kreycik et al., 2010). On the other hand, the actual market incorporates market acceptance considerations such as demand, supply, commodity prices, regulations, incentives, barriers, investments, consumer response etc (Kreycik et al., 2010). It is possible simply to have market potential, when actual market is non-existent. Actual market exists when there is effective demand i.e. purchasing power and willingness to pay for the services and suitable investment environment. If actual market (and not simply market potential) already exists in a particular area, the market development activities are substantially reduced, otherwise the market creation or stimulation should be undertaken (Haselip et al., 2011).

Market development involves research and development of policy and regulations (i.e. macro-elements), and education of consumers and promotion of new income generating activities in the area (i.e. micro-elements) (Glemarec, 2012). The macro-elements are meant to create and promote a suitable investment environment, while the micro-elements are to enhance the willingness and purchasing power of the end-users to ensure affordability of energy services (Glemarec, 2012). Market development activities contribute to the long-term sustainability of technology, in that they turn the market potential into actual market. It is the existence of an actual market (and not simply market potential) that ensures financial and commercial viability of the MHP project, hence guaranteeing long-term sustainability.

MHP development and operation

MHP development and operation involves planning, building and operating the MHP. Figures 1 and 2 present the MHP life cycle. As exhibited, MHPs pass through seven distinct stages that can be categorised into three developmental phases: pre-construction (conceptualisation and feasibility); construction (project implementation); and post-construction (operations, extension-of-life and termination).

The pre-construction phase is divided into four main stages namely: project conceptualisation; feasibility study; designing; and acquisition of regulatory approval. The typical activities under this phase include identifying and planning to eliminate energy needs, site selection, assessment of resource availability, establishing a legal framework for the project and acquisition of regulatory permits (Jager and Rathmann, 2008; Management-hub; Pierpont et al., 2011).

The choice of the construction site is considered one of the most crucial steps, as it largely determines the amount of energy production and complexity of site development (Razan et al., 2012). Care should be taken

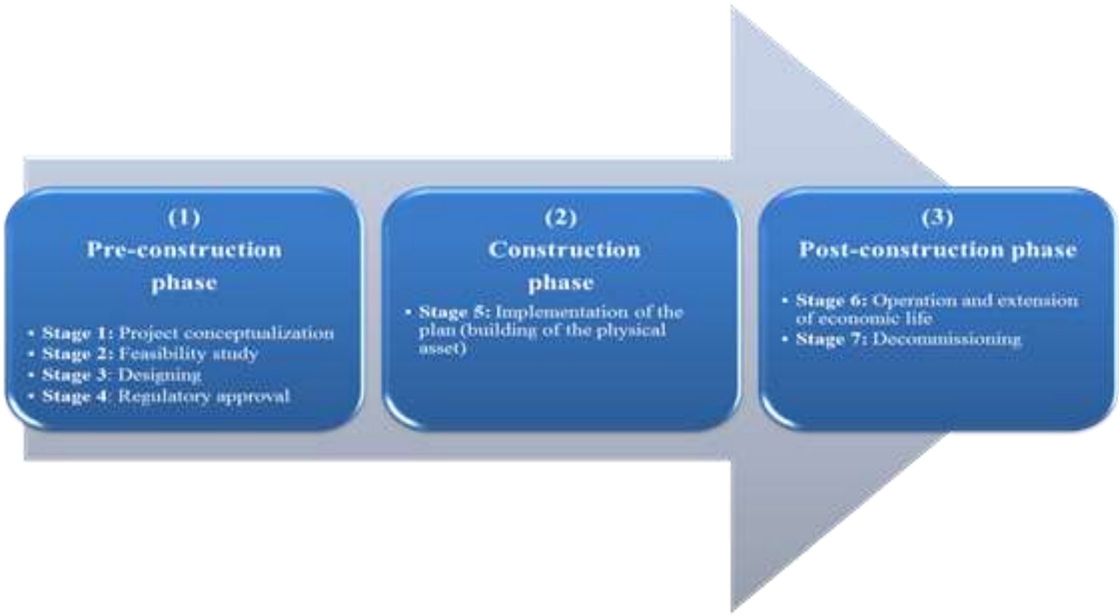

Figure 2. MHP life cycle model. Source: Based on analysis from literature review by author.

as that will determine the quantity of capital expenditure during construction and the future income generating capacity of the MHP. The purpose of the feasibility study on the other hand, is to assess whether to proceed with the project or not, and involves the conduct of environmental assessment, hydrology assessment, preliminary designs, and detailed cost estimates (Razan et al., 2012). According to Kaunda et al., (2012) feasibility study is undertaken in two sub-stages: the initial desk study – involving a confirmatory assessment of the availability of energy generation potential; and the comprehensive study – involving the quantification of energy potential in order to determine whether the project is worth the investment. Favourable results of the desk study lead to comprehensive feasibility studies which are undertaken by visiting the site and taking actual measurements of head and flow rate.

Upon the conclusion of the feasibility study, an appropriate design for the MHP is crafted based on the information gathered. Each project is unique (ICAST, 2011), as such, design is generally site-specific. With the design in hand, regulatory approvals can then be secured in order to proceed to the construction phase; as such the regulatory policies become particularly important (Pierpont et al., 2011). In some countries there are a number of applicable legislations and impositions, for instance, in Malawi, the Rural Electrification Act requires possession of a number of licences i.e. separate generation, transmission and distribution licences (Malawi Government, 2004). Other applicable legislations include, among others, the Electricity Act, Energy Regulation Act, Environment Management Act and Water Resources Act. Familiarity with the legal framework is therefore of great importance.

Pre-construction phase is generally developer-driven and covers activities required for realising a financial closure of the project, hence, all the elements must be carefully completed in order to come to an investment decision (Jager and Rathmann, 2008). Since the phase focuses on planning rather than building, the capital requirements are comparatively low (Pierpont et al., 2011). However the phase has significant long-term implications on capital requirements of other phases. The major challenge faced currently by developers in SSA at pre-construction phase is the fact that most prospective sites are either ungauged or has insignificant data for design analyses (Kaunda et al., 2012); as such developers tend start from scratch which further increases the cost of investment.

The second phase is the construction phase that involves actual construction of the physical asset (Jager and Rathmann, 2008; Pierpont et al., 2011). The activities include acquisition of the land, preparing and securing necessary contracts with suppliers of equipments and services (Jager and Rathmann, 2008; Pierpont et al., 2011). The construction work is carried out by various service providers such as construction contractors, equipment suppliers, assemblers, transporters, technicians, local non-skilled labour etc. Typical components of an MHP system include the civil works(settling basin, canals, forbay tank and penstock), turbines, generator, switchgear protection and transmission (ICAST, 2011). At this phase most of the capital expenditures are incurred and government incentives really matter as most of the equipment is imported. If the activities under the pre-construction

Table 2. Typical MHP development costs.

Pre-Construction	Construction	Post-Construction
1) Initial Costs include costs for i. site selection; ii. feasibility studies; iii.environmental impact assessments; iv. engineering design; v. project management; vi. permits and licencing; vii. obtaining land rights; viii. financing fees; and ix. energy purchase agreements.	**2) Construction Costs** include costs for i. civil works; ii. access roads; iii. transmission lines; and iv. others related to setting up the project. **3) Service costs** include costs for: i. Workforce and service contractors required to build the plant such as hiring engineers, managers, and labourers, also providing them other facilities like food, lodging, and so forth. **4) Costs for Equipment** include costs for: i. purchasing various equipment like protection system, control system, turbine, generators, and so forth; ii. transportation and installation of this equipment.	**5) Annual operating Costs** include for i. Operation and maintenance costs for the complete project and include administrative costs such as salaries, rentals, and fees. **6) Decommissioning costs** include cost for dismantling, site restoration etc

Source: ICAST (2011); Jager and Rathmann (2008); Razan et al. (2012) and Usman et al. (2012).

phase were superficially undertaken, the lead time for this phase is lengthened in turn affecting the project costs.

The post-construction phase is the longest phase. It can be divided into two stages: operational and/or renewal stage; and termination stage. Operational activities involve putting the MHP to use for the benefit of the intended users, involving generation and distribution of electrical power. The phase is management-oriented as much work is maintenance related. MHP technology is designed to operate as a passive system requiring less extensive maintenance (ICAST, 2011). The typical routine maintenance work involves removing debris built up in the civil works structures which comprises raking screens, mucking out settling basins or repairing leaks in canals (ICAST, 2011). The major work is basically generation of electricity, monitoring that the system is working effectively, connecting new users and collection of fees if it is fee-based (ICAST, 2011).

It is at this stage that the importance of existence of actual market is felt. The MHP needs, not merely consumers, but those with willingness and capacity to pay for the services. Operational costs incurred must be met by the income generated by the MHP itself. The income must further be adequate for further investments to maintain and/or expand the operational capacity of the MHP. Besides, after the initial operational life, the MHP may need extension of its economic useful life which is referred as “renewal”. The renewal process would involve overhauling the plant to restore the generation capacity lost through depreciation. Thus major rehabilitation of the civil works and the replacement of some major equipment may be required. Substantial financing may be needed to accomplish renewal otherwise the facility is decommissioned.

Thus the final stage of the post-construction phase and indeed of the life cycle is the termination stage; the end of the economic useful life of MHP. Activities under this stage include dismantling and disposal of the generation equipment and restoration of the site in accordance with the laws of the country. The risks of the decommissioning are generally low as in many cases the scrap value of the installations is higher than the decommissioning costs (Jager and Rathmann, 2008).

Presented above are the activities in the physical system of MHP development. The understanding of these physical stages of development helps in the appreciation of what really drives financing of MHP. The activities undertaken consume resources as such they determine the quantity of finances. Each stage in MHP life cycle has its own financial requirements. Table 2 provides an illustration of the typical costs relating to each phase in the life cycle.

It is important to note that the total cost of MHP projects is site specific; it varies greatly depending on the remoteness of the site (Anup et al., 2011). Furthermore, the costs presented in Table 2 do not include market development costs.

Influence of the physical system on the financial system

Market development phase

Market development involves undertaking research and development of policy and regulations and education of consumers and promotion of new income generating activities (Glemarec, 2012). The product of the process is development of four basic instruments namely: clear policy statements and targets; consumer education and community participation; standardization of equipment; and research and development (Glemarec, 2012).

These instruments influence financial resource mobilisation (the financial system) as “resource consumers” – contributing to the quantity of the finances to be mobilised; and/or as “facilitators” of financial resource mobilisation process. Basically development of the market instruments requires the time and effort of several stakeholders and that tends to consume resources. On the other hand, when investors, lenders and other stakeholders find these instruments (eg policy, regulations etc) to be inadequate, unreliable, or too risky, they increase the cost of capital affecting the overall project cost (Jager and Rathmann, 2008) and the investment environment hence the accessibility of finances for the developers. The instruments tend to affect the investment environment by: influencing the allocation of costs and revenues, the allocation of risks, and the business practices and technology choices of investors and project developer (Pierpont et al., 2011). Hence there is a need for adequacy, coherency, consistency and conduciveness of these instruments as the absence of the same makes it difficult for the private and industrial sector to operate effectively and expand their investments (UNIDO, 2009).

Currently these market instruments are not well developed in the SSA (Klunne, 2012; Glemarec, 2012; Gamula et al., 2013), further to that the typical end-users have limited purchasing power, hence comprehensive market development is critical in the region. However, the major challenges inherent in process in SSA include the existence of considerable uncertainty, need for large financial outlays and consequent scarcity of private capital (Glemarec, 2012). There is lack of clarity of the essential market elements that need to be developed and how they are to be financed (Khennas and Barnett, 2000). Due to the uncertainty, the market risk for the financiers is greater, leading to high costs (IRENA, 2012A). Another challenge is poor recognition of market development investments by the stakeholders. Much of extant discourse seems to overlook the importance of the market development investment. Furthermore the absence of the market elements is narrowly recognised as simply the presence of non-financial barriers, and their impact on financing is hardly discussed. Basically, financeis to a great extent discussed in isolation.

MHP development and operation

Developing MHP requires substantial investment relative to other RE technologies (Department for International Development, 1999; Pierpont et al., 2011), however their running costs are relatively lower (Min et al., 2011). Due to the need for huge investment, the cost of electricity production is much higher compared to fossil fuels and other RE technologies (Glemarec, 2012; Haselip et al., 2011; Ivanova, 2012; Kolk and van den Buuse, 2012). As such, MHPs produce relatively expensive energy that requires charging of a premium in order to cover costs of production (Ivanova, 2012) and produce reasonable return on investment. The problem is made worse and more challenging by the poor financial capacity of the end-users (Kolk and van den Buuse, 2012). The typical consumers are the poor residents (i.e. poor peasants, tenants, landless and other disadvantages group) of remote rural areas, which are on the bottom of the economic pyramid (Anup et al., 2011). The majority have poor purchasing power, requiring charging of low tariffs to make the produced energy affordable (Gurung et al, 2011), this in turn impacts on the financial viability of MHPs. Basically MHPs require increased load factor of 20-25% to be financially viable. However that makes them commercially unviable, hence necessitating heavy subsidy by aid groups of between 60% and 80% (Department for International Development, 1999). The aid groups resemble, in a sense, ‘‘business’’ customer (Kolk and van den Buuse, 2012). In the absence of the aid groups, governments are supposed to step in; otherwise the MHPs’ long-term existence is affected.

Linking physical and financial systems of MHPs: A holistic view

Figure 3 presents that holistic view of the underlying financial architecture of MHPs over the life cycle derived from the review of discourse. The figure provides visual understanding of basic links of the physical aspects and activities of MHP development to financing and their contribution to long-term productive and financial sustainability. The figure expresses the physical system in financial terms.

As is exhibited in Figure 3, MHP finance can be categorised into two based on the major components of the physical system: market development finance and MHP development and operation finance. Figure **3** shows that each category of finance is critical and has a significant long-term purpose towards sustainability of the MHP. Key purposes of market development finance is ensuring affordability of the energy services to the end-users by promoting and strengthening their willingness and capacity to pay and ensuring security ofinvestment by providing safeguards in order to attract investors and other stakeholders to the sector. These in turn guarantee self-sustainability of MHPs, in that, funds from financiers can be easily mobilised for their construction and subsequently they are able to generate adequate income for covering all costs and give reasonable return on investment. On the other hand, MHP development and operation financing is aimed at creating and maintaining the productive capacity. Thus,while the former ensure long-term financial and commercial viability, the latter ensure long-term operational viability.

It is worth noting that market development costs will

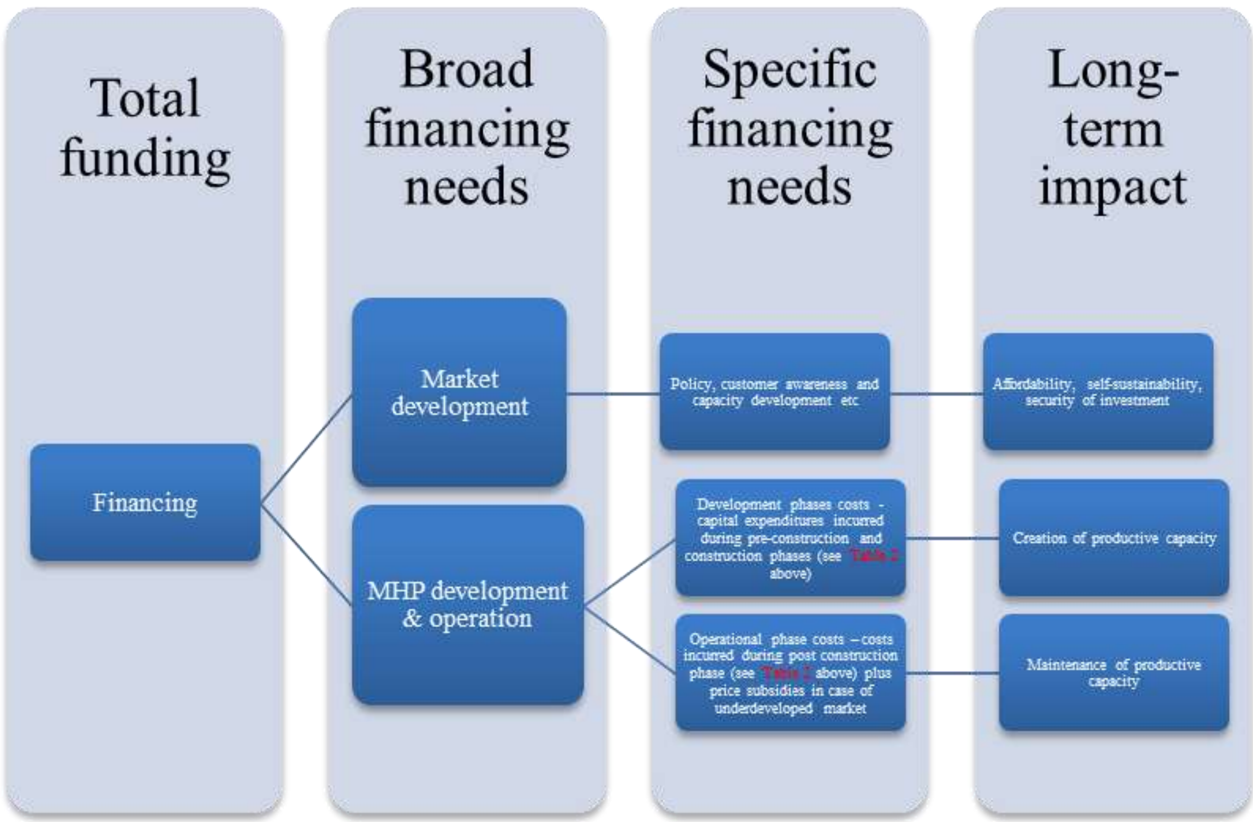

Figure 3. A holistic view of financing needs for MHPs. Source: Based on analysis from literature review by author.

generally be low in areas with already existing actual markets. In such, the main activities may only be customer awareness and education. Otherwise, failure to carry out market development in areas with non-existing actual market leads to the need for continuous assistance in form subsidies to ensure sustainability of MHPs during operational stage. A rational investor will be discouraged from entering into the sector in such a situation. SSA countries therefore need to wake up to the realities of these factors and move accordingly to ensure growth and long-term sustainability of the sector.

Stakeholders: the facilitators of the system

Nature of stakeholder engagement

The facilitators of both the physical and financial system of MHP are the various stakeholders across many sectors (IRENA, 2012A). Woerlen (2011) cited in Glemarec (2012) categorised the stakeholders into four groups: users of the technology, supply chain players (e.g. local manufacturers, assemblers, shops and maintenance technicians etc), policy makers and financiers. According to Foster-Pedley and Hertzog (2006) stakeholders include: policy makers, international agencies, philanthropists, banks, venture capitalists, ‘angel’ investors, and pressure groups. Other groups of stakeholders are: project developers, planners, managers, engineers, private sector, utility companies, rural entrepreneurs, consumers, community groups, financial sector, government entities etc (Klunne, 2012; Martinot et al., 2002; Usman et al., 2012). The study by Nfah and Ngundam (2012) in Cameroon, apart from revealing some more key stakeholder groups, also provided some empirical support in key roles to success. It identified local management committees, microfinance institutions, Non-Governmental Organisations (NGOs), Renewable Energy Enterprises (REEs) and universities as key stakeholders behind the successful RE applications in Cameroon. It further identified the different roles of the stakeholders as follows: the local management committees – supervision, operation and maintenance of installed systems as well as revenue collection; microfinance institutions – granting of loans for the acquisition of financially and economically viable off-grid RE systems to communities; NGOs – providing technical assistance for the conception of community projects, procurement of funding from cooperation partners and realization of projects; REEs – sizing, installation and post-installation maintenance of RE equipment and, universities – training the technicians and engineers used by NGOs and REEs.

Levels of stakeholders' engagement

The participation and cooperation of the relevant stakeholders in different levels is of paramount importance and is what really determines behaviour with the physical system and consequently the financial system. Due to the multiple activities needed in the process of developing an MHP, it is recognised that none of the stakeholders or stakeholder groups can alone transform sector, hence the support of each of the stakeholder groups is necessary (Glemarec, 2012).

Currently in SSA there is lack of knowledge of the key stakeholders that need to be engaged at all costs, few are active and others are not aware that they are stakeholders or find the sector unattractive. It is therefore crucial that the key stakeholders should be identified and categorised according to roles, stake or level, facilitate role awareness and secure their active participation. Due to the multiplicity of the stakeholders, the categorization is necessary in order to expedite smooth stakeholder engagement. Furthermore, it is important to recognise that some stakeholders may have diverse roles at different levels at the same time. That is, it is possible that a stakeholder affected by problem situation can have the ability to actively influence the situation, and/or possess means needed to implement solutions (Enserink et al., 2013). For instance economically empowered rural communities may have the ability to initiate, implement and operate an MHP project, whilst governments can fall in many stakeholder groups i.e. policy maker, regulator, financier, implementer, operators etc.

It is also important to recognise that the multiplicity of stakeholders in the MHP sector entails complexities in the implementation of any required measure; hence the need for agreement and cooperation amongst the stakeholder groups (Foster-Pedley and Hertzog, 2006). Besides, as a system, consideration must be taken of the influence each stakeholder may have on the others and the driver of the sector must be identified. This is particularly crucial since active engagement of the driver or influencer facilitates or triggers active engagement of other stakeholders resulting in sector growth and vibrancy. On the other hand, their passivity frustrates determined stakeholders and scares off other stakeholders – the cascading effect. According to Glemarec (2012) important lessons can be learnt from the growth of the mobile phone industry, which suggests to RE sector that:

"…with the right regulatory environment and business

models, the poor [end-users] have the capacity and the willingness to fully or partially pay for services that provide clear, immediate and substantial benefits. Similarly, the private sector has the capacity and appetite to invest in new service delivery mechanisms provided that there is commercially viable unmet demand."

In other words, active involvement of the policy actors and developers (i.e. through provision of clear policies, etc), can positively influence the financing stakeholders (i.e. private sector) and acceptance among the end-users. Thus Glemarec (2012) stressed for an integrated approach considering the facilitative impact of some stakeholders especially at macro-level that if well managed can spur new business models and accelerate the commercialization of RE sector. In the same vein it is also important to recognise that each group of stakeholders may have different motives such as: supporting environmental purposes, others simply assisting start-up ventures, while others may be involved to encourage energy diversification (Foster-Pedley and Hertzog, 2006). Hence when promoting stakeholder involvement, diverse motives must be must be taken into consideration. All in all, there is a need for a holistic, stakeholder inclusive, role and motive-sensitive, sector-wide approach to addressing barriers and promoting the sector in order to spark stakeholder motivation to action and eliminate of barriers, through the ripple effects of the intervention of drivers and influencers cascading the other parts of the system (Agyepong et al., 2014). This approach has consequent financing impact. Foster-Pedley and Hertzog (2006) observed that:

"By looking at the industry in a holistic manner and bringing all the motives, barriers, stakeholders and investment opportunities together in one system, a renewable energy entrepreneur can approach a bank or other commercial financier with a financial proposition that may be better targeted to their investment motives or better suited to a given risk profile."

Furthermore, Foster-Pedley and Hertzog (2006) asserted that a rigorous analysis of stakeholders, payoffs and complementarities is what can provide valuable insights to different funding formulae. Unfortunately, that is lacking in SSA region no wonder the sector is beset with a lot of uncertainties and barriers.

Stakeholders' involvement pyramid

Figure 4 presents a stakeholder involvement pyramid proposed by this paper which synthesises the various roles and functions, levels and impacts of various groups of stakeholders in the MHP sector based on the review of literature. The pyramid is based on the recognition of the facilitative roles and influences of various stakeholder groups from macro-level to micro-level. According to the pyramid governments have the basic driving role to the MHP sector through the formulation of clear policies,

Figure 3. Stakeholders' involvement pyramid**.** Source: Based on analysis from literature review by author.

regulations, provision of incentives, maintenance of updated and easily accessible database of the potential sites and opportunities and public education and awareness. No other group of stakeholders can assume these roles better than the governments. The other stakeholder groups may at best lobby and assist the governments in delivery. regulations, incentives, public awareness and education

The implementers are attracted to the sector and become effective in project planning and implementation based on the robustness of the facilitative instruments made by the government. Through these they are able to operate viably and develop better funding proposals to project financiers. The financiers will respond favourably if they perceive that the facilitative instruments provide enough security to their investments and the business models presented by the implementers are robust. On the other hand, effective management during operational stage by the operators will depend on facilitative instruments made by governments (eg in relation to pricing and price adjustments, availability of spare parts, operational standards etc), implementers' decisions during planning and building of the MHPs and the financiers' terms and conditions. The end-users are at the receiving end of the pyramid. However they have lobbying influence on the other stakeholders and if economically empowered may assume other roles such as being implementers, financiers and operators.

CONSOLIDATION

It is actions and inter-actions of the stakeholders within the physical system (that is, market development and MHP development and operations) that determines the financial system behaviour (that is, the quantity and the mobilisation of the finances). On the other hand, inactions of one or more stakeholders, leads to the system imbalance or the unsteady-state. In other words failure to "indeed" link physical system and financial system (van Egmond and de Vries, 2015) hence the lack of sustainable financing models. Steady-state of the sustainable financing system is yet to be found in SSA region due to lack of cohesion and inactions of some of the stakeholders, the actors within the system. A critical look at the key barriers of MHP deployment one will realise that they are simply "actions or lack of actions" of some of stakeholders within the physical system, which drives it to unsteady-state. The same drives the behaviour of the financial system. This is the reason the barriers are generally categorised into policy, regulation, institutional, information, behavioural, technical and financial (Glemarec, 2012; UNIDO, 2009) and can be traced back to the actions or lack of action of stakeholders.

In order to consolidate the review, Figure 5 presents a framework that provides a visual display for underlying connections between stakeholders, market development,

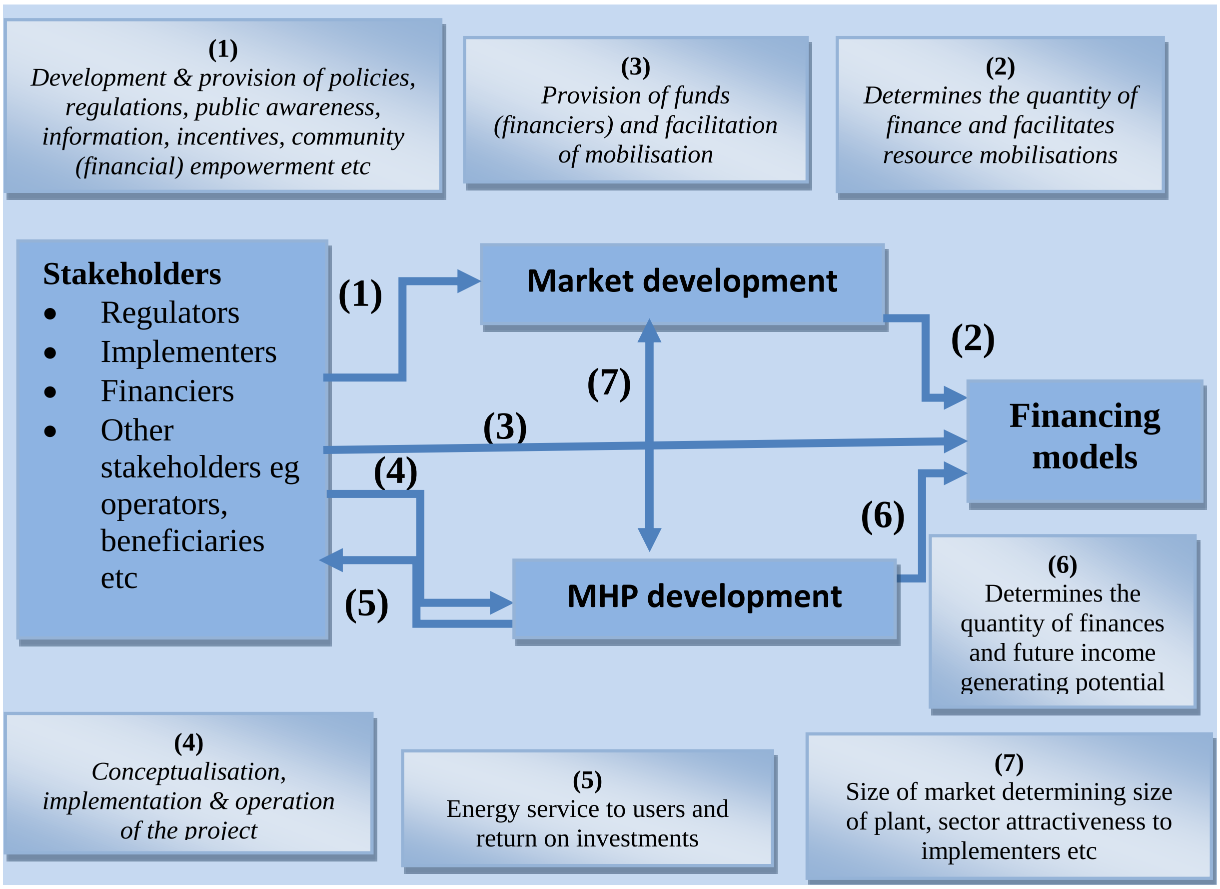

Figure 4. Physical and financial systems linkages. Source: Based on analysis from literature review by author.

MHP development and operations (that is, physical system) and financing models (that is, financial system). The arrows indicate the direction of relationship and the numbers point to the narrative giving examples of the activities that are supposed to be provided by the stakeholders andif not provided turn into barriers to MHP deployment.

The framework provides a simplified display that visualizing the underlying relationships and inter-connections and their ultimate influence on financing of MHP which is critical to the designing of the lowest cost long-term financing models. Though there is no "right way" to design a program for lowering the total cost, it is however recognised that thoughtful analysis of each ofthe decision points can help in designing an effective financing program (Nelson and Shrimali, 2014). This framework contributes to the thoughtful analysis in four main ways. Firstly, by revealing and visualizing the impacts of activities in the physical system on financing. As is exhibited, market development and MHP development and operation activities defines the quantity of finances and facilitates the process of mobilizing the finances. For example, construction work of MHP consumes resources thus determining the quantity of finance, and in long-term it is a source of income through energy sales. Similarly policy formulation consumes resources and facilitates the creation of suitable invest-ment environment that attracts financiers, entrepreneurs and other supply chain players to the sector.

Secondly the framework provides insight of the role of the stakeholders both in creating and eliminating the barriers to MHP deployment. This is the case because most of the barriers are basically a result of the actions, inadequate actions or lack of actions by the stakeholders. If all stakeholders were actively involved most of the policy, regulatory, information, technical barriers would have been eliminated. Since financial system behaviour is dictated by the physical system, elimination of these physical systems barriers will also eliminate or mitigate the financial barriers.

Thirdly, the framework indicates efficiency-oriented avenues through which the actual costs of MHP development may be lowered. The two main ways being through: (1) streamlining of the physical system activities;

and (2) ensuring active engagement of all relevant stakeholders. As already stated, it is the activities that define the quantity of finances, hence in order to lower the costs; it is the activities that should be the target and not the costs. As such in search of lowest-cost models, cost effective means must be found for undertaking the activities. On the other hand, if the all relevant stakeholders can be active: there will be "costs and risks sharing" among a wide number of stakeholders, which may not be significantly felt by each one of them as most of the activities are already part of their normal activities. Besides, activeness will remove uncertainties that characterise the sector, which leads to overall risk reduction, hence lowering the cost of capital. Currently, the burdens of developing MHPs in the SSA region are borne by a few stakeholders mainly the developers, donors, NGOs and government. However, in many cases the developers bear much of the burden, for instance, lobbying for formulation of policies and regulations, conducting public awareness and education, empowering local communities, pushing for incentives, convincing donors and other financers etc, over and above facilitating the actual work of MHP development from conceptualisation to operation. If, for instance, various agencies of the governments were proactive and cooperatively work with other stakeholders in formulation of clear policies, provision of incentives, conducting comprehensive feasibility studies on all potential sites and public education and awareness, and undertook other activities such as construction of access roads, the burden would be significantly reduced on the developers and the uncertainties that abound could be cleared. This would have a significant impact on financing.

The fourth contribution of the framework is the confirmation of the importance of various key stakeholder groups hence the need to promote active stakeholder engagement and cooperation amongst themselves. No one or a few stakeholders can alone transform the market (Glemarec, 2012); moreover carry the financing burden for the development. It is therefore crucial to striving for growth of a network of stakeholders in order to overcome the barriers and design sustainable financing programme (IRENA, 2012A). Review of extant literature from SSA region suggests passive stakeholder engagement and inactivity of the majority. Besides, the few active ones lack coordination and information sharing (Gamula et al., 2013). This results in constant repetitions of setbacks already encountered by others, difficulties in financing projects, weak industrial back-up for the various components which have to be imported, high information costs and long lead times that hampers the emergence of entrepreneurs (Brunnschweiler, 2006; Gamula et al., 2013). Thus exchange among stakeholders must be encouraged as it would help circulation of feedback on market activity and anticipation of factors that may impact them (IRENA, 2012A). Furthermore regular engagement among local technology innovators, academics, entrepreneurs, investors and public administrators is also considered crucial in the formation of strategic relationships and builds a critical mass of RE development capability (IRENA, 2012A citing GIZ, 2011).

CONCLUSION

Although underemphasised, efforts to understand the holistic nature of MHP development and the underlying symbiosis between stakeholder engagement and financing is crucial to the development of sustainable financing models. The paper has attempted to analyse the challenges underlying the absence of sustainable financing models in SSA region based on the van Egmond and de Vries' sustainable finance model using systems theory and the life cycle model. The paper highlights the significant role of the physical system of MHPs in dictating the behaviour of the financial system. Basically, it is not the financial system necessarily that posed the financial barriers, but a combination of physical system challenges facilitated by the stakeholders' actions or lack of action. The framework developed helps visualise the same by revealing comprehensively the MHP development process and bringing together the market issues, the building process of the actual asset, the stakeholders and their underlying influences on financing in a single framework. The paper reveals that without the effort to bring together all key stakeholders into action, the problem of sustainable financing in the region will persist. The major factor underlying poor MHP deployment in SSA region is actions or lack of action of stakeholders within the physical system. In the same vein the paper indicates that though some barriers are "non-financial" in nature, they have some underlying influence on financing. Thus sustainable financing mechanism must be companied by and coordinated with non-financial measures (IRENA, 2012A). Therefore the promoters of the MHP sector in the SSA countries should strive to grow a network to include all key stakeholders, ensure role awareness and action and inter-actions.

The main limitation of this paper is its theoretical nature that needs to be complemented with empirical research (Jabbour et al., 2010). Since MHPs are context specific, this paper recommends country specific case studies to further develop and test the theoretical framework developed. Also recommended are comparative studies between SSA countries and other developing countries where MHPs have been a success story such the Nepal and India, on order to learn from their experiences.

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Conflict of Interests

The authors have not declared any conflict of interests.

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