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Energy Policy

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Overcoming financial barriers to small hydro development in Kenya: the role of aggregation and its policy implications.

Defended on 05/09/2018 before the following Committee

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Declaration

I, Victor Thomas Otieno, hereby declare that this thesis represents my own work, realized to the best of my knowledge. I also declare that all information, material and results from other works presented here, have been fully cited and referenced in accordance with the academic rules and ethics.

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ABSTRACT

Small Hydro Power (SHP) generation is an important way to reduce the greenhouse gases and provide electricity to rural areas. To further the dissemination of SHP in order to address climate change and access to energy in developing countries, finance is needed. The Sustainable Energy for All (SEforALL) recommends an annual investment of USD 50 billion to universal access to energy by 2030. Private investment is posed to play a major role in meeting this target. However, underlying market barriers and a perception of high risk constrain the development and financing of SHP projects. Reducing these high financing risks and costs in these investments represents an important opportunity for policy-makers. This thesis seeks to scale up financing of SHP projects in Kenya by identifying the major investment barriers and risks for SHP projects and exploring the potential of aggregation and estimating its de-risking effects by applying LCOE model. Through literature review and interviews, the thesis found that lack of capacity, high transaction costs and small volumes are the key barriers to SHP development in Kenya. Financing structures which aggregate smaller structures under one master facility can certainly take advantage of economies of scale to improve returns and therefore is able to increase the appetite of private investors in these projects. Implications for policymakers in promoting and facilitating the capacity of private sector investors and developers to aggregate SHPs investments is discussed.

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All honour and glory to God the Creator of heaven and earth!

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LIST OF ABBREVIATIONS

ARE	Alliance for Rural Electrification
BOT	Build-Operate-Transfer
CESI	Centro Elettrotecnico Sperimentale Italiano
COP21	21st Conference of Parties
DFIs	Development Finance Institution
DNEPP	Ministry of Energy, Draft National Energy and Petroleum Policy.
DRE	Distributed Renewable Energy
EIA	International Energy Agency
ERC	Energy Regulatory Commission of Kenya
EROI	Net Energy Return on Energy Invested
ESHA	European Small Hydropower Association
ESMAP	Energy Sector Management Assistance Program
EU	European Union
FiT	Feed-in-Tariff
FMO	The Netherlands Development Finance Company
GAFSP	Global Agriculture and Food Security Program
GEF	Global Environment Facility
GIS	Geographical Information Systems

GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GoK	Government of Kenya
GTZ	German Technical Cooperation Agency
GWh	Gigawatt hour
INDC	Intended Nationally Determined Contribution
IPP0	Independent Power Producers
IRENA	International Renewable Energy Agency
KenGen	Kenya Electricity Generation Company
KETRACO	Kenya Electricity Transmission Company Limited
KP	Kenya Power
KTDA	Kenya Tea Development Agency
LCOE	Levelised Cost of Energy, Electricity
LCPDP	Least Cost Power Development Plan
MoEP,	Ministry of Energy and Petroleum
MPT	Modern Portfolio Theory
MtCO2eq	Million tonnes of carbon IV oxide equivalent.
MW GWh	Megawatt
MWh	Megawatt hour
NCCAP	Kenya National Climate Change Action Plan

OECD	Organisation for Economic Co-operation and Development
PADGO	Portfolio Approach to Distributed Generation Opportunities
PPA	Power Purchase Agreement
PV	Photovoltaic
RE	Renewable energy
REN21	Renewable Energy Policy Network for the 21st Century
RES-E	Renewable Energy Sources Generated Electricity
RETs	Renewable energy technologies
SEforALL	Sustainable Energy for All
SHP	Small Hydropower
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Program
UNEP	United Nations Environmental Program
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
USAID	United States International Development
WBCSD	World Business Council for Sustainable Development

WSHPDR	World Small Hydropower Development Report

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PART I

1.1 INTRODUCTION

Approximately 1.2 billion people (about 16% of the global population) live without electricity. The vast majority are in sub-Saharan Africa and in the Oceania region, and most of them live in rural regions. In Africa, nearly 60% of people have no access to reliable electricity (REN21, 2017). In the Sub-Saharan Africa, less than 10% of the rural population has electricity supply, and many social and commercial institutions have limited or no access to electricity (Umar and Hussain, 2015). In Kenya, just 55 percent of the population (mostly urban-centred) have access to the electricity grid (Owino, Kuneman and Kamphof, 2016).

To achieve the objective of universal access to energy by 2030, the Sustainable Energy for All (SEforALL) platform recommends an annual investment of USD 50 billion. Compared to the current investment of 13 billion USD in 2013 (REN21, 2017), investments need to be scaled up significantly. According to United Nations Conference on Trade and Development, private investment is posed to play a major role in meeting this target (UNCTAD, 2014). However, attracting private investments is a challenge and has not received sufficient attention in the literature on rural electrification. Off-grid electrification projects are often unattractive for private investors due to unfavourable risk-return profiles and small investment volumes (Schmidt, 2015). Both issues can potentially be addressed by aggregating projects into larger, diversified portfolios. The potential of aggregation to redirect financial flows into small-scale renewable energy is beginning to be recognised internationally (Malhotra, Schmidt, Haelg and Waissbein, 2017). For example, the Climate Aggregation Platform (CAP) initiative was announced at the UNFCCC COP21 climate talks in Paris in 2016 (UNDP; GEF; CBI, 2015). Standardised project documentation and aggregation are important mechanisms in structured finance transactions (IRENA, 2016).

Most studies on analysing investment risks for renewable decentralised energy systems but focus on measures to reduce risks and increase stable revenue streams for mini-grid developers (Schmidt et al., 2013; Aggarwal et al., 2014; Schnitzer et al., 2014; Comello et al., 2015; Williams et al., 2015). The studies also focus on single projects, and do not consider the role of investment risks for portfolios of such projects (Malhotra, Schmidt, Haelg and Waissbein, 2017).

This thesis seeks to scale up financing of SHP projects in Kenya by identifying the major investment barriers and risks for SHP projects and exploring the potential of aggregation and estimating its de-risking effects by applying LCOE model. Reducing financing barriers represent an important opportunity for policy-makers but has not received sufficient attention in the literature of SHP in Kenya.

1.1.1 Background of Kenya energy sector

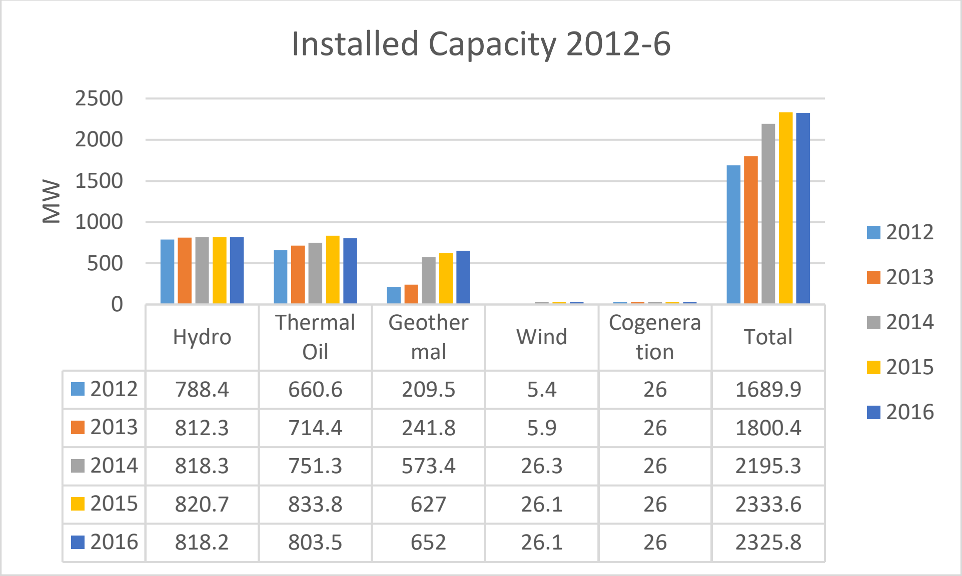
The Government of Kenya (GoK) set forth, in its Vision 2030, a programme to transform Kenya into a "newly industrializing, middle-income" country. The Kenya Vision 2030 identified energy as one of the infrastructure enablers of its socio-economic pillar. Sustainable, competitive, affordable and reliable energy for all citizens is a key factor in realization of the Vision (DNEPP, 2016).

The population is projected to reach 65.7 million by 2030. This increased population and growth projected in Vision 2030 translates into increased energy demand. Much of this increased energy demand will be in the form of electricity, one of the drivers of economic growth.

The main resources of energy in Kenya are renewable energy and fossil fuels. The country is highly dependent on biomass energy, which provides 68% of the total energy supply. Fossil fuels and electricity provide 22% and 9% respectively while other sources provide 1% of the overall energy requirements (SE4ALL, 2016).

It is estimated that Kenya's installed and effective electricity capacity as of 2016 stood at 2 325 MW and 2253MW respectively as shown in figure 1 below. The generation mix includes hydropower (818 MW), geothermal (652 MW), cogeneration (26 MW), wind (26 MW) and fossil fuel based electricity (803 MW). Domestic demand for electricity increased from 7,826.4 GWh in 2015 to 8,053.2 GWh in 2016 (KNBS, 2017). The current installed capacity is also below the government's plan to improve capacity to over 5000 MW by 2017 (MoEP, 2016).

Figure 1: Installed Capacity of electricity in Kenya, 2012-2016



	Hydro	Thermal Oil	Geothermal	Wind	Cogeneration	Total
2012	788.4	660.6	209.5	5.4	26	1689.9
2013	812.3	714.4	241.8	5.9	26	1800.4
2014	818.3	751.3	573.4	26.3	26	2195.3
2015	820.7	833.8	627	26.1	26	2333.6
2016	818.2	803.5	652	26.1	26	2325.8

Source: Adapted from KNBS, 2017

From the above information, generation from geothermal and thermal has improved while generation from hydropower, wind and cogeneration appear constant. This might be an issue of national priorities especially of the need to ensure security of supply. It may also be due to threats of climate change on large hydropower which make the government to shift focus to geothermal which is more reliable and capable of providing baseload power at competitive price. According to report by Lahmeyer International, for base load, geothermal power plants are ranked best in terms of generation costs (Lahmeyer International GmbH, 2016).

Table 1: Effective electricity capacity, 2012-2016

	EFFECTIVE CAPACITY, MW					
Year	Hydro	Thermal OIL	Geothermal	Wind	Cogeneration	Total
2012	769.9	610.6	199.6	5.3	26	1611.4
2013	766.6	693.2	236.5	5.3	21.5	1723.1
2014	797.5	712.6	558	5.3	21.5	2094.9
2015	799.5	797.1	619	26.1	21.5	2263.2
2016	797.5	764.9	644	26	21.5	2253.9

Source: KNBS, 2017

Table 2: Electricity Demand and Supply, 2012-6

DEMAND AND SUPPLY 2012-2016					
	2012	2013	2014	2015	2016
Total Domestic Demand	6414.4	6928.1	7415.4	7826.4	8053.2
Exports	32.7	43.7	30.8	46.7	39.1
Transmission losses	1404.2	1476.1	1692.5	1641.5	1965.4
TOTAL DEMAND=TOTAL SUPPLY	7851.3	8447.9	9138.7	9514.6	10057.7
Less Imports	39.1	49	158.4	58.8	86.3
Local Supply	7812.2	8398.9	8980.3	9455.8	9971.4

Source: KNBS, 2017

1.1.1 Renewable Energy Potential

Kenya is endowed with abundant renewable energy resources, namely: hydro, wind, solar, biomass, and geothermal (DNEPP, 2016; CESI, 2018). Kenyan geothermal potential is estimated between 8-12 GW and can be efficiently exploited as base load generation. For solar, Kenya has high insolation rates, and the potential for photovoltaic generation (PV) is estimated around 23 TWh/year. With reference to an average capacity factor greater than 30%, the country wind potential output is about 4.4 TWh/year. The northwest of the country (Marsabit and Turkana counties) and the edges of the Rift Valley are the two windiest areas with average wind speeds of over 9m/s at 50 metres (CESI, 2018)..

Concerning hydro resources, the potential for medium to large-scale hydroelectric power development is estimated to be 3000 MW, of which 1,310 MW is feasible for projects with a capacity of at least 30 MW (DNEPP 2016, CESI, 2018). Furthermore, the potential for small, mini and micro hydroelectric systems (with capacities of less than 10 MW) is estimated as high as 3,000 MW nationwide. The above renewable energy resources can be efficiently exploited to cope with the robust demand growth exceeding 7% per year (CESI, 2018).

1.1.2 Access to electricity in Kenya

Access to modern energy services is a necessary precondition for achieving development goals that extend far beyond the energy sector, such as poverty eradication, access to clean water, improved public health and education, women's empowerment and increase food production.

Despite the outstanding potential of renewable energy resources in Kenya, the national electrification rate in Kenya is rather poor. According to Centro Elettrotecnico Sperimentale Italiano (CESI), whereas the urban electrification rate attains 60%, in rural areas the electrification rate is less than 10% and this circumstance is typically compensated by a strong use of solid biomass for cooking and heating (CESI, 2018). According to Owino, Kuneman and Kamphof (2016), only 55 percent of the population had access to the grid electricity by 2016. At the same period, World Bank puts the figure at 56% by 2016 (World Bank 2018). Research done by Infrotrak (2017) states that only 57.2% of Kenyans are connected to the grid and attribute the low access to inadequate infrastructure in the rural areas. Concerning affordability, at least 57% of Kenyan Households feel that the current Kenya Power tariffs are either somewhat affordable or completely unaffordable. A total of 53% of Kenyans feel that the power they get from Kenya power is reliable.

From the above statistics, the electrification rate is low and gap level between rural and urban areas is wide. This means there is still a lot to be done to achieve universal access.

The government has set the ambitious target of universal access by 2020, which is an important step towards more economic inclusion and could very well be aligned with green growth objectives. One of the major obstacles to realise this goal is the country’s weak and inefficient energy transmission and distribution infrastructure, resulting not only in irregular supply but also high energy prices (Owino, Kuneman and Kamphof, 2016). Furthermore, extension of the electric power system from urban to rural areas is inefficient due to broad stretches of land and dispersed villages.

Kenya is developing a system of mini-grids to provide electricity to communities far from the national grid. Mini-grids are localized electricity networks that typically use renewable energy sources to provide electricity to rural communities and businesses. By combining grid and off-grid strategies, power can be brought to Kenyan people faster and more cheaply.

The low penetration of grid power and the development of mini-grids offer immense potential for small-hydro power projects development with the added advantage of providing reliable power supply to areas not currently supplied and to the areas at the extremities of the already stretched national grid. This is because Small-hydro systems have been demonstrated to be capable of meeting local electricity demand for regions remote to the grid (GIZ/GTZ, 2009).

1.1.3 The Energy Sector Generation Plan

Kenya's power industry generation and transmission system planning is undertaken on the basis of a 20 year rolling Least Cost Power Development Plan (LCPDP) updated every 2 year. According to the Updated LCPDP 2013-2033, the load forecast based on the Model for Analysis of Energy Demand (MAED) based excel worksheets indicates that the peak demand lies in the range of 1,370 MW in 2012 and between 11,318 and 31,237 MW in 2033. The reference case ranges from 1370MW in 2012 to 3034MW in 2018 to 14446MW in 2030 and 21,075MW in 2033 while the energy demand increases from 8010GWh in 2012 to 17,719GWh in 2018 to 81,352GWh in 2030 and 118,680GWh in 2033.

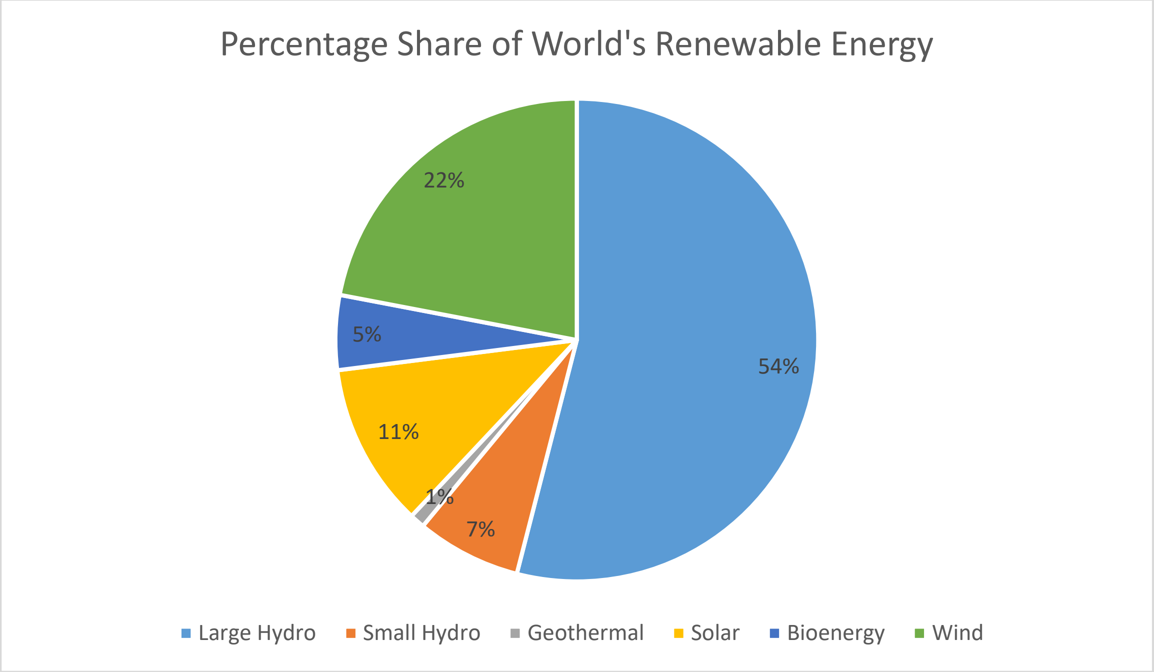
Candidate generation resources considered in the system expansion plan include geothermal, hydro, wind, coal, oil-fired and nuclear power plants, with geothermal capacity planned to increase from 209 MW (2012) to 7,264 MW (2033). Other sources by 2033 are 12% from nuclear plants, 26% from coal plants and 9% from imports. Nuclear and coal are not developed yet in Kenya but there are plans. Wind and hydro plants will provide 10% and 4% respectively while medium speed diesel (MSD) and gas turbines (GTs) – Liquefied Natural Gas (LNG) plants will provide 2% and 19% of the total capacity respectively (SE4ALL, 2016).

The Rural Electrification Master Plan that was completed in June 2009, states that the Government seeks to have 100% connectivity across the country achieved through grid extension and off -grid systems. Thus to meet the increased demand by 2030, there is a need to invest in generation, transmission and distribution. To achieve that several generation sources (RE and non-RE) are being considered: geothermal (5,110 MW); hydro (1,039 MW), wind (2,036 MW); thermal (3,615 MW); coal (2,420 MW); imports (2,000 MW); and other sources. Distributed renewable energy sources including SHP have been considered, especially for off-grid electrification (Spicer, 2014).

1.1.2 Overview of SHP status

Globally, the installed SHP capacity is estimated at 78 GW in 2016 out of the total estimated potential of 217 GW. SHP represents approximately 1.9 per cent of the world's total power capacity, 7 per cent of the total renewable energy capacity and 6.5 per cent (< 10 MW) of the total hydropower capacity (including pumped storage).

Figure 2: Percentage share of World's renewable energy, 2016.



Source: WSHPDR 2016

According to World Small hydropower report 2016, total SHP installed capacity for Africa is estimated at 580 MW against total potential of 12,197 MW, representing approximately 5 percent of total potential installed. Eastern Africa has both the highest installed capacity and potential for SHP in the continent, followed by the Western and Middle Africa regions. Northern Africa has the highest electrification rate, but due to climatic conditions, it has low potential for hydropower. Southern Africa has the lowest installed capacity, the vast majority of which is located in South Africa. The Eastern Africa region has the highest overall potential for SHP in the Africa being the home to the Great Lakes region as well as the White Nile basin and the Congo River basin, among others (WSHPDR 2016).

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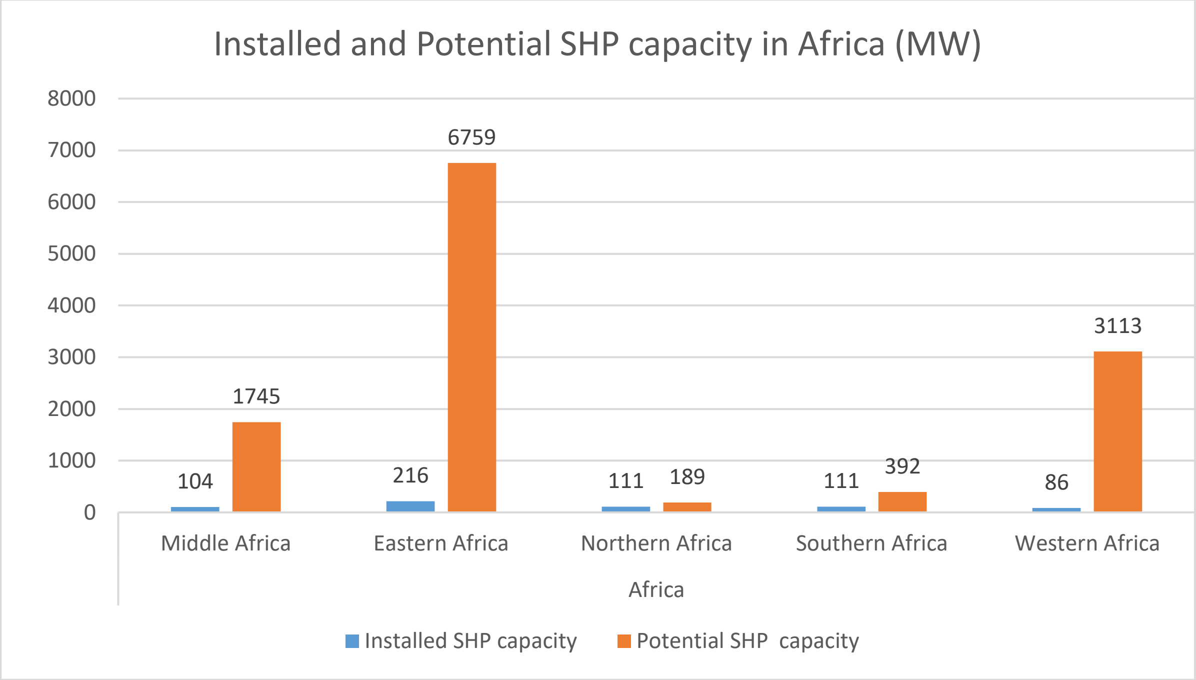
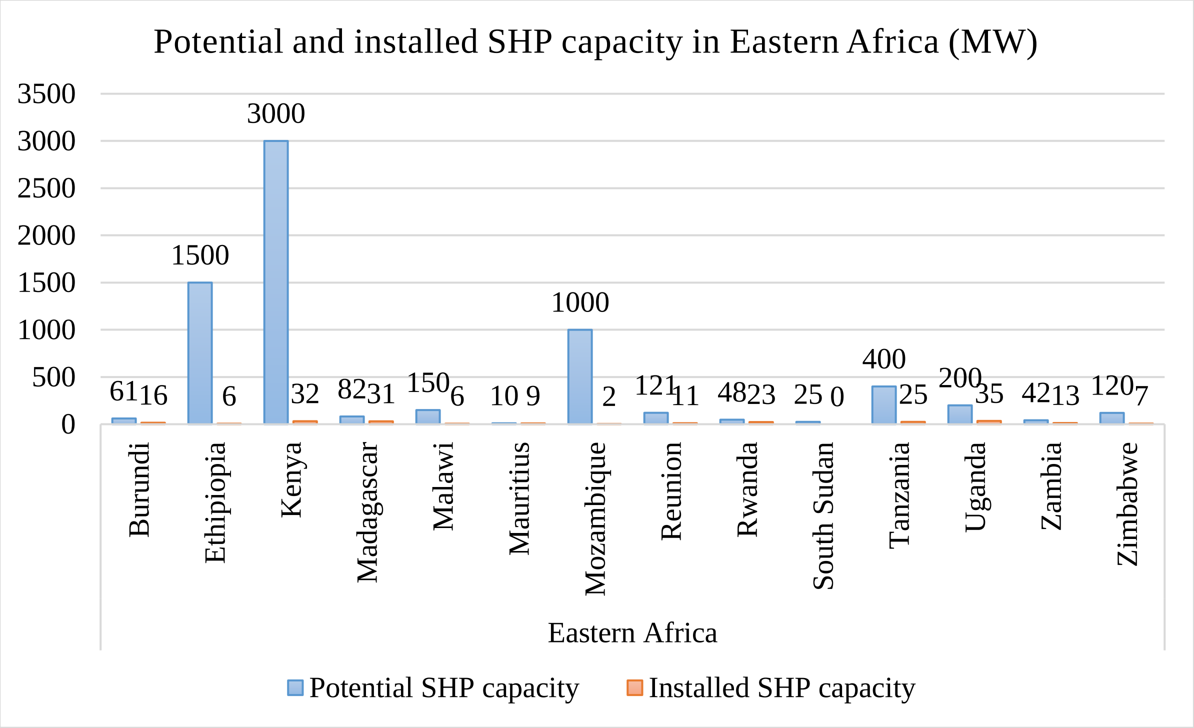
Figure 3: Installed and potential SHP capacities in Africa, 2016.



Source: WSHPDR, 2016

Of the total SHP potential of 6,759 MW in Eastern Africa, the combined SHP installed capacity in the region is only 216 MW, representing only 3 per cent of SHP potential developed (WSHPDR, 2016) as shown in figure 4.

Figure 4: Potential and installed capacities in Eastern Africa



Source: WSHPDR, 2016

1.1.2.1 Small Hydro in Kenya

Kenya's drainage system consists of five major basins: Lake Victoria; Rift Valley; Athi/Sabaki River; Tana River; and Ewaso Ng'iro North River. These basins contain the bulk of the country's hydro resources for power generation. The hydro-power potential in Kenya is estimated to be as high as 6,000 MW out of which 3,000 MW constitutes SHP (Mbaka et al. 2016; NEPP, 2016).

The SHP has been used in Kenya since 1925 by construction of Ndula hydro power plant of capacity 2MW along Thika River. SHPs has been historically used for grinding food grains, electricity generation and commercial uses in tea and other small industries. The hydro plants are owned by the Kenya Electricity Generation Company (KenGen) and private entities such as tea companies, mission hospitals and communities, as shown in the table below.

Table 3: SHP projects in Kenya

SHP	Ownership	River	Year	Capacity
Ndula	KenGen	Thika	1925	2.0
MESCO	KenGen	Maragua	1933	0.38

Selby falls	KenGen	n.a	1952	0.4
Sagana falls	KenGen	Tana	1955	1.5
Gogo falls	Mining company	Migori	1958	2.0
Tana 1 & 2	KenGen	Tana	1932	4.0
Tana 3	KenGen	Tana	1952	2.4
Tana 4	KenGen	Tana	1954	4.0
Tana 5	KenGen	Tana	1955	4.0
Wanjii 1 & 2	KenGen	Maragua	1952	5.4
Wanjii 3 & 4	KenGen	Maragua	1952	2.0
Sosiani	KenGen	Sosiani	1955	0.4
James Finlay 1	Tea company	Kericho	1934	0.3
James Finlay 2	Tea company	Kericho	1934	0.4
James Finlay 3	Tea company	Kericho	1980	0.1
James Finlay 4	Tea company	Kericho	1984	0.3
James Finlay 5	Tea company	Kericho	1999	1.1
Brooke Bond 1	Tea company	n.a	n.a	0.09
Brooke Bond 2	Tea company	n.a	n.a	0.1
Brooke Bond 3	Tea company	n.a	n.a	0.18
Brooke Bond 4	Tea company	n.a	n.a	0.24
Savani	Eastern produce	n.a	1927	0.09
Diguna	Missionary	n.a	1997	0.4

Ten wek	Missionary	n.a	n.a	0.32
Mujwa	Missionary	n.a	n.a	0.01
Tungu-Kabiru	Community	Tungu	2000	0.01
Thima	Community	Mukengeria	2001	0.01
Kathamba	Community	Kathamba	2001	0.001
Imenti	KTDA	Imenti	2009	0.9

Source: (Mbaka et al., 2016).

Between 1925 and 1958, more than 14 SHPs were built. After 1958, there was more focus on large hydro-power projects but interest to install SHP has been revived since 1990s, due to lack of adequate electricity power supply by the grid-based system, and the increased cost of electricity. For example, several private tea companies have installed SHP to reduce the cost of electricity bills (Mbaka et al., 2016). This can also be attributed to the desire of Kenya to improve rural electrification.

The German Agency for Technical Cooperation, in collaboration with the Kenya Industrial Research and Development Institute, has been involved in the determination of SHP potential, identifying 14 sites for installation in Western Kenya. The Green Power non-governmental organization has also been involved in the exploration and installation of SHP in Kenya and installed the first of three planned 80 kW turbines in Kiangurwe village to supply 800 households (Mbaka et al. 2016).

According to Kenya Renewable Energy Association website, a survey of 72 tea factories in Kenya indicates that 80% are located 3–15 km from a potential hydropower site although the resource assessment to obtain both theoretical and economical potential has not been carried out. The Kenya Tea Development Agency (KTDA) plans to construct hydro power plants in the tea growing areas. KTDA manages more than 60 tea factories for 500,000 small holder tea farmers and plans to set up a total of 16 hydro power plants on rivers close to tea factories with potential of producing 28.33MW. The Ministry of Energy is conducting a feasibility study on a further 14 sites around the country. The 1MW Imenti mini-hydro project was the first of its kind among the KTDA managed factories and a power purchase agreement has been signed. The agreement authorizes Imenti to supply surplus power to the national grid (KEREA website, n.d).

According to MoEP (2016), by the end of 2013, more than 260 small hydropower sites had been identified but the largest number of sites are found in the Tana River drainage basin, mainly in the counties of Kirinyaga, Muranga, Meru and Tharaka Nithi. These are areas that have high population density and high energy demand. As at 2014, only a few schemes had been developed as stand-alone systems or to feed to the national grid (MoEP, 2016).

According to report by Lahmeyer International (2016), there is a large pipeline of small hydropower projects promoted under the FiT scheme. Feasibility studies of twenty-one projects comprising a total capacity of 89 MW are already approved. Power Purchase Agreement (PPA) negotiations of thirteen of these projects with a total capacity of 41 MW are completed successfully. Seven projects with a total capacity of 24 MW are under construction and one project is already completed. Furthermore, feasibility studies of additional eleven small hydropower projects comprising a total capacity of 76 MW are on-going (Lahmeyer International GmbH, 2016).

1.1.2.2 Financing Small Hydro Projects in Kenya

In general, financing for SHP still faces various challenges in Kenya. Models utilized by developers in Kenya involve a combination of several approaches including community finance, public funding, equity investment, grants and loans from local financing institutions. For instance, in 2015, the Kenya Tea Development Agency (KTDA) signed a Kshs 5.5 billion loan agreement with IFC, a member of the World Bank Group, in partnership with the Global Agriculture and Food Security Program (GAFSP), The French Development Institution (Proparco), and The Netherlands Development Finance Company (FMO) to fund the construction of seven small hydropower projects (SHPs) across tea growing regions (KTDA, 2015).

Some projects have also benefited from initial project development support. For instance, Kleen energy which is developing a 6.8 MW small hydropower project along Rupingazi River in Embu County of Kenya carried out detailed feasibility study was supported by the French Development Agency (AFD) through the Kenya Association of Manufacturers' Regional Technical Assistance Program (KAM RTAP). Kleen Energy was in fact the first project developer to be awarded USD 100,000 in Technical Assistance. Project capital financing has been derived from debt (70%) and equity (30%). Debt financing has been provided by AFD through a local AFD partner bank. This loan will be repaid over a period of 10 years, following a 2-year grace period for construction (KEREA, 2016).

1.1.2.3 SHP specific policy and regulatory frameworks

This section briefly highlights general energy polies in Kenya which covers small hydro, feed in tariffs policies, power purchase agreement and institutional arrangements.

General Policies

In the last ten years the policy direction of the energy and petroleum sector has been governed by the Sessional Paper No. 4 of 2004 effected by the energy Act of 2006. However, a number of changes have taken place that have presented new challenges and opportunities for the Kenya energy sector. These include growing concerns over climate change, Kenya's new constitution adopted in 2010 and the long-term development blueprint, Vision 2030, adopted in 2008. This has necessitated the review of the Energy Policy to align with the constitution and the vision, with the government issuing a Draft National Energy and Petroleum Policy (DNEPP) dated June 2015 (DNEPP, 2015). The policy framework proposed under the Draft National Energy and Petroleum Policy is reflected in the Energy Bill, 2017, which has been published and will soon be before Parliament for debate.

The DNEPP provides for the regulation of the entire energy sector including electric energy, petroleum and renewable energy, which includes SHP. With respect to the regulation of electricity, the policy contains a detailed raft of measures which include:

i. The development of a competitive market structure for the generation, supply and distribution of electricity;
ii. The establishment a rural electrification and renewable energy corporation to be the lead agency for development of renewable energy resources other than geothermal and large hydropower.
iii. The promotion of entry of private entities into the sector

Feed-in-Tariffs

A Feed-in-Tariff (FiT) is an instrument to promote the generation of electricity from renewable energy sources. It enables a utility to produce Renewable Energy Sources Generated Electricity (RES-E) and sell the output to a distributor at a pre-determined tariff for a given period of time (DNEPP, 2015). The objectives of the Kenyan FiT Policy are to:

a) Facilitate resource mobilization by providing investment security and market stability for investors in electricity generation from Renewable Energy Sources.
b) Reduce transaction and administrative costs and delays by eliminating the conventional bidding process and lengthy negotiations of PPA.
c) Encourage private sector investors to operate their plants prudently and efficiently so as to maximize returns.

To attract private sector capital in renewable energy projects, the Ministry of Energy first established FiT policy for wind, small-hydro and biomass resources generated electricity in 2008 and revised it in 2012. The feed-in tariff allows power producers to sell and obligates the distributor to buy on a priority basis all renewable energy sources generated electricity at a pre-determined fixed tariff for a given period of 20 years. (MoEP, 2012). The FiT values for small renewable energy projects (up to 10 MW) are set out as shown below.

Table 4: Feed-in-tariffs for renewable energy projects in Kenya (revised, 2012)

Plant Type	Installed Capacity (MW)	Standard FIT (US$/KW)	Scalable Portion of the tariff	Minimum Capacity (MW)	Maximum Capacity (MW)
Wind	0.5-10	0.11	12%	0.5	10
Hydropower	0.5	0.105	8%	0.5	10
	10	0.0825			10
Biomass	0.5-10	0.1	15%	0.5	10
Biogas	0.2-10	0.1	15%	0.2	10
Solar (grid)	0.5-10	0.12	8%	0.5	10
solar (off-grid)	0.5-10	0.2	8%	0.5	1

Source: MoEP, 2012

While the FiT policy has been in place for the last 6 years, little achievement in regard to private sector involvement has been registered, raising the question of whether the instruments deployed are effective enough to attract private sector investment (Kant, Masiga and Veenstra, 2014). Also according to MoEP, submissions from potential investors point to generation tariffs higher than the FiTs due to increases in the cost of generation equipment and financing (DNEPP, 2015). To attract private sector investment therefore, a realistic review of the tariffs has to be undertaken, while also widening the scope to cover other renewable energy sources.

The Power Purchase Agreements (PPAs)

A PPA is an instrument that defines relationships of the power producer and purchaser from delivery of plant, operation stage and transfer of assets at end of the PPA period (e.g. under - Build-Operate-Transfer (BOT) Projects. The PPAs are issued to facilitate mobilization of project financing by private investors. In Kenya PPAs for grid connected renewable generators of up to 10 MW of installed capacity have been standardised (MoEP, 2016). Through a PPA power producers are guaranteed of revenue from investment (and hence also give confidence to lenders on repayment of debt) but bear the risks of supplying the power, while the utility will be assured of a supply of a certain amount of power. The

Utility however has to ensure timely payment for the delivered power. In the case of Kenya, PPAs are signed with Kenya Power and are approved and regulated by the ERC to their execution, as per the provisions of the Energy Act. The ERC ensures, among other things, the reasonableness of the rates and tariffs prescribed under the PPA and the satisfaction of the minimum criteria as set out in the Energy Act. Other aspects that ERC considers to approve the PPA include proof of land acquisition, access or usage rights, grid connection plan, a full technical and economic feasibility study, and approved EIA, after which investor/project company can apply for a generation licence to be issued in accordance with the Energy Act and the Energy (Electricity Licensing) Regulations 2012 ((SE4ALL, 2016).

Other plans by the government to promote SHP are as summarised I the table below.

Table 5: Further policies and strategies for SHPs

	Small Hydros	Short Term 2015-2019	Medium Term 2015-2024	Long Term 2015-2030
1	Finance conservation of hydro power water catchment areas.	✓	✓	✓
2	Provide incentives for public private partnerships in small hydros.	✓	✓	✓
3	Invest in hydrological data collection, management and dissemination	✓	✓	✓
4	Promote development of capacity and knowledge on usage of appropriate technologies	✓	✓	✓

Source: DNEPP, 2015

Institutional Arrangements

The following are the key actors in the energy sector. The aim is solely to provide an initial understanding of some of the organisations/institutions relevant to SHP development.

Table 6: Key energy institutions in Kenya

Institution	Description
Ministry of Energy and Petroleum (MoEP)	Responsible for formulation and articulation of energy and petroleum policies through which it provides an enabling environment for all

	stakeholders. It sets the strategic direction and planning for the growth of the sector and provides a long term vision for all sector players.
Energy Regulatory Commission (ERC)	Established as an energy sector regulator under the Energy Act, 2006, with responsibility for economic and technical regulation of electric power, renewable energy, and downstream petroleum sub-sectors. Its functions also include tariff setting, review, licensing and approval of power purchase and network service contracts.
Energy Tribunal	This quasi-judicial body established Energy Act, 2006. It came into operation in July 2007 to primarily hear appeals against the decisions of ERC. It also has jurisdiction to hear and determine all matters referred to it relating to the energy sector.
Kenya Power (KP)	KP is a State Corporation with GoK shareholding of 50.1% and private shareholding of 49.9% as at June 2014. It purchases electrical energy in bulk from KenGen and other power producers and carries out transmission, distribution, supply and retail of electric power
Kenya Electricity Generating Company Limited (KenGen)	KenGen is a State Corporation with GoK shareholding of 70% and private shareholding of 30% as at June 2014. It is mandated to generate electric power, currently producing the bulk of electricity consumed in the country.
Rural Electrification Authority (REA)	REA was established under section 66 of the Energy Act of 2006 as a body corporate with the principal mandate of extending electricity

	supply to rural areas, managing the rural electrification fund, mobilizing resources for rural electrification and promoting the development and use of renewable energy.
Kenya Electricity Transmission Company Limited (KETRACO)	GoK wholly owned company established to be responsible for the development, maintenance and operation of the national transmission grid network. It is also responsible for facilitating regional power trade through its transmission network.
Independent Power Producers (IPPs)	IPPs are private companies which generate power and sell electricity in bulk to KPLC. As at November 2014 there were nine IPPs in operation and accounted for about 24% of the country's installed capacity.

Source: Adapted from (DNEPP, 2015).

1.2 PROBLEM STATEMENT

Kenya, with its fast developing industrial development and commerce, is facing a difficult task providing the energy required in the various economic sectors. The existing electricity network does not have the capacity to provide power to the entire country. The inadequate capacity hinders potential local and foreign investments affecting the economic development of the country negatively (Mbaka and Mwaniki, 2016). Emissions, are projected to increase from the current 59 MtCO2eq to 102 MtCO2eq by the year 2030 with the largest absolute growth in emission coming from the energy and transportation sectors (Kant, 2014). Kenya, through Intended Nationally Determined Contribution (INDC) has committed to reduce its GHG emissions by 30% relative to business as usual levels by 2030 (USAID 2017). To achieve this, Kenya has prioritised renewable energy systems including wind, geothermal, and hydropower based electricity generation (NCCAP, 2013). With population projected to reach over 65 million by 2030 and plans to achieve universal energy access by 2020, energy demand will only continue to increase.

To meet the increasing demand for energy and combat global climate change challenge, Kenya has given priority to renewable energy systems in the expansion of her energy sector (NCCAP, 2013). Distributed renewable energy projects including Small hydropower have been considered, especially to provide off-grid electrification for areas far from the grid, with good population density and farming potential (Spicer, 2014).

It is estimated that at least 3,000 MW of potential SHP capacity exists but only approximately 32 MW are currently installed (WSHPDR Kenya 2016; DNEPP, 2016). This represents only one per cent of the SHP potential. Thus, the number of SHP projects implemented do not reflect the enormous potential that exists in Kenya. Being a mature and reliable technology, this obviously suggests that there are other barriers other than the technology itself (Klunne1 and Michael, 2010).

Some of the reasons for this low uptake have been found to be due to policy, legal and regulatory frameworks and financing constraints for renewable energy projects which have contributed to the limited investment flows from the private sector to SHP projects in Kenya (WSHPDR Kenya 2016, Mbaka and Mwaniki, 2016). As part of the solution to this, Kenya introduced the Feed-in-Tariff (FiT) policy in 2008 (more information under section 1.1.2.3) and signing of PPAs to promote the development of renewable energy to supply villages, small businesses or farms, as well as grid supply (DNEPP, 2016). This initiatives, put in place to spur interest from local banks and other investors, has evidently not taken root given the limited number of SHP projects accessing financing from local banks and other investors (WSHPDR Kenya 2016), suggesting that financial constraints is a key barrier. Reducing financing barriers represent an important opportunity for policy-makers but has not received sufficient attention in the literature of SHP in Kenya.

This thesis seeks to identify the financial barriers and explore the potential of aggregation as one way of scaling up finance for such projects by overcoming the financial barriers.

1.3 JUSTIFICATION

Small hydropower (SHP) has greatly contributed to solving the problem of rural electrification, improving living standards and production conditions, promoting rural economic development, alleviating poverty as well as reducing emissions (WSHPDR, 2016). Small hydropower can play a pivotal role in providing energy access to large parts of Africa, either in stand-alone isolated mini-grids or as distributed generation in national grids. The potential role of small hydropower in eradicating energy poverty has been recognized by a number of national governments and donors, and is a key element of the UN Energy Access for All program (Wim Jonker Klunne, 2012). Wide-spread deployment of SHP energy measures will be critical to achieving the Sustainable Energy for All (SE4All) objectives, supporting Kenya in achieving her Sustainable Development Goals, and contributing to country's INDCs under the UNFCCC.

It is hoped that this thesis will help improve the confidence of the investors in the SHP, help the developers to learn more on financing strategies, and to create more awareness about aggregation in SHPs and decentralised renewable energy development in general in the country. Moreover, it will provide insights for policymakers in promoting and facilitating the ability of private sector investors to aggregate small-scale electrification investments.

1.4 GENERAL OBJECTIVE

Given that finance constitutes one of the most vital ingredients for promoting uptake of decentralised renewable energy (RE) technologies/solutions across the country, it is important that financing gaps are understood and addressed. The general objective of this study is to overcome financial barriers in SHP investments for achieving decentralised rural electrification.

1.4.1 Specific objectives

The following specific objectives will be used to meet the main objective:

(i) To identify and classify of the major financial barriers and risks for SHP projects.
(ii) To qualitatively explore the role of aggregation in reducing financial risks and barriers for SHP projects.
(iii) To estimate the effects of aggregation by applying LCOE model to SHP projects.

1.5 RESEARCH QUESTION

This study, focusing on scaling up finance for SHPs mini-grids in achieving decentralised rural electrification addresses the following questions:

1. What are the major financial barriers and risks for SHP projects?
2. Can project aggregation strategy be used to reduce financial in SHP projects?
3. What is the effect of aggregation on a SHP portfolio of SHPs Projects?

1.6 RESEARCH METHODOLOGY AND FRAMEWORK

1.6.1 Methodology

This thesis uses qualitative research method because it involves the use of qualitative data, such as interviews, documents and observation, in order to understand and explain the risks/barriers and role of aggregation in de-risking small hydropower investments in Kenya (Peshkin, 1993). According to Boyce and Neale, 2006, interviews can be defined as a qualitative research technique which involves conducting intensive individual interviews with a small number of respondents to explore their perspectives on a particular idea, program or situation. In this thesis both structured and semi structured interviews were used. As part of achieving the objectives of this thesis, it is important produce rounded and contextual understandings on the barriers, risks and aggregation in Kenya which qualitative research provides. Even though some form of quantification is used, statistical forms of analysis are not seen as central in qualitative research (Mason, 2002).

The study began with literature survey or desk research of national studies, reports and articles related to existing SHPs, with the view of identifying and classifying barriers and risks in SHP development across the world in general and Kenya in particular. More focus was on financial barriers of upstream component. This was followed with primary research, which included interviews, site visits and key stakeholder consultations in Kenya to garner feedback on the current status, barriers to SHP development in Kenya and possible role of aggregation in overcoming the financial barriers and its policy implications. Stakeholders interviewed included developers, investors/financiers, financial institutions, insurance institutions, finance experts, energy experts, policy experts and ministry of energy representatives. Primary and secondary data will be used especially to analyse financial flows and policy environment. The interview information data is analysed using statistical techno economic model that is LCOE, to give a glimpse of the potential of aggregation. (See section 2.2 for overview of research methodology and full list of interviewees). Thus the investigation method is more of ethnography this is because Atkinson and Hammersley (1994) suggested that ethnography involves exploring the nature of phenomena and working with unstructured data, analysing data through interpretation of the meanings attributed by research respondents. This is method employed in this thesis.

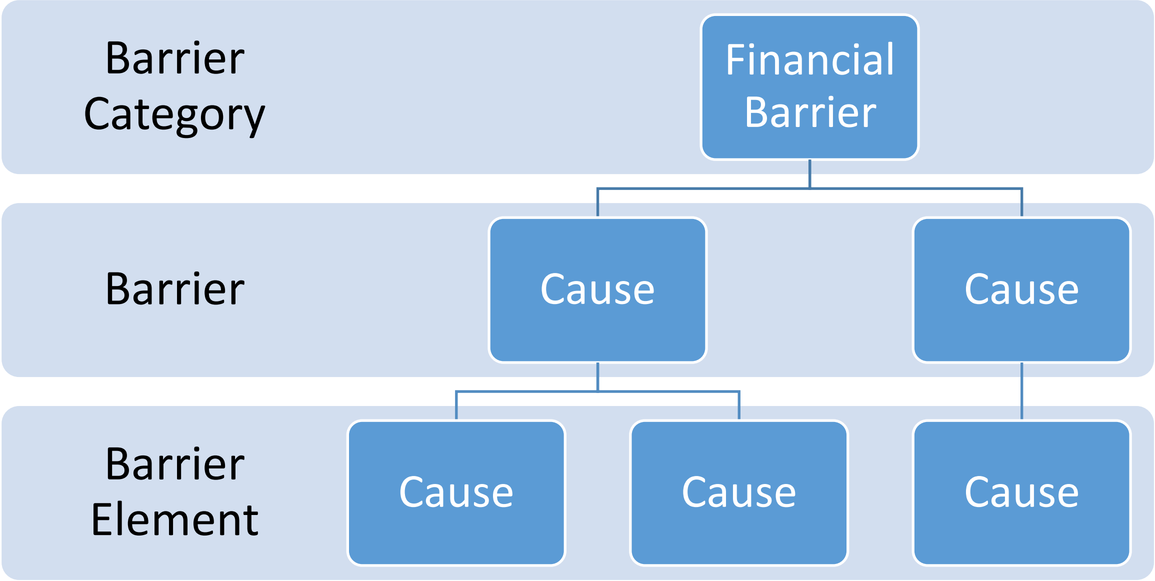
1.6.2 Framework

In this section, a framework is proposed to help identify all the important and relevant financial barriers for SHP development in Kenya. A literature review study of existing energy strategy and plans, and financial, institutional and legal mechanisms with reference to SHPs is done. The study is intended to indicate various shortcomings in the policies and mechanisms that impede implementation of SHPs. In addition to this, a review of national studies and reports related to existing SHPs, their evaluation, reasons for their success and failures and barriers to diffusion of SHP. Apart from the literature survey and study of the existing projects, the barriers were identified using the following approaches:

1. Site visits: to study the projects closely. The insights obtained from field study were valuable in barrier identification.
2. Interaction with stakeholders: It is important that stakeholders' perspective is taken into consideration. Stakeholders included developers, energy experts, policy makers (government), financiers and consumers. The interaction is through structured interviews and questionnaires.

The barriers were explored and analysed at several levels, as illustrated in the figure 5 below. The top level (first level) is a broad category of barriers and as we go to lower levels, we go into more detail and specifics. Thus at the second level, we have various barriers within a category, and at the third, various elements of these barriers. A bottom-up approach can be used to identify the presence of barriers. This means that to conclude whether a barrier or a barrier category is relevant for a SHP or not, presence of at least one of its components at a lower level is necessary. This also ensures that measures recommended to overcome the barriers are consistent with their dimensions. But this would require that respondents have the capacity and willingness to cooperate. Focus is on financial barriers. Then will do a qualitative cost benefit analysis of aggregation. For environmental projects like SHP, cost-benefit analysis is applied but the right discount rate is very difficult to calculate (Kelleher, 2012).

Figure 5: Research Framework



Source: Adapted from Painuly (2000).

PART II

2.1 LITERATURE REVIEW

This section provides a review of SHP technology (2.1.1), investment needs and barriers for SHP mini-grid based rural electrification projects (Section 2.1.2), an overview of concepts related to risk diversification, and of studies applying these concepts to investments in the power sector in general and SHP in particular (Section 2.1.3).

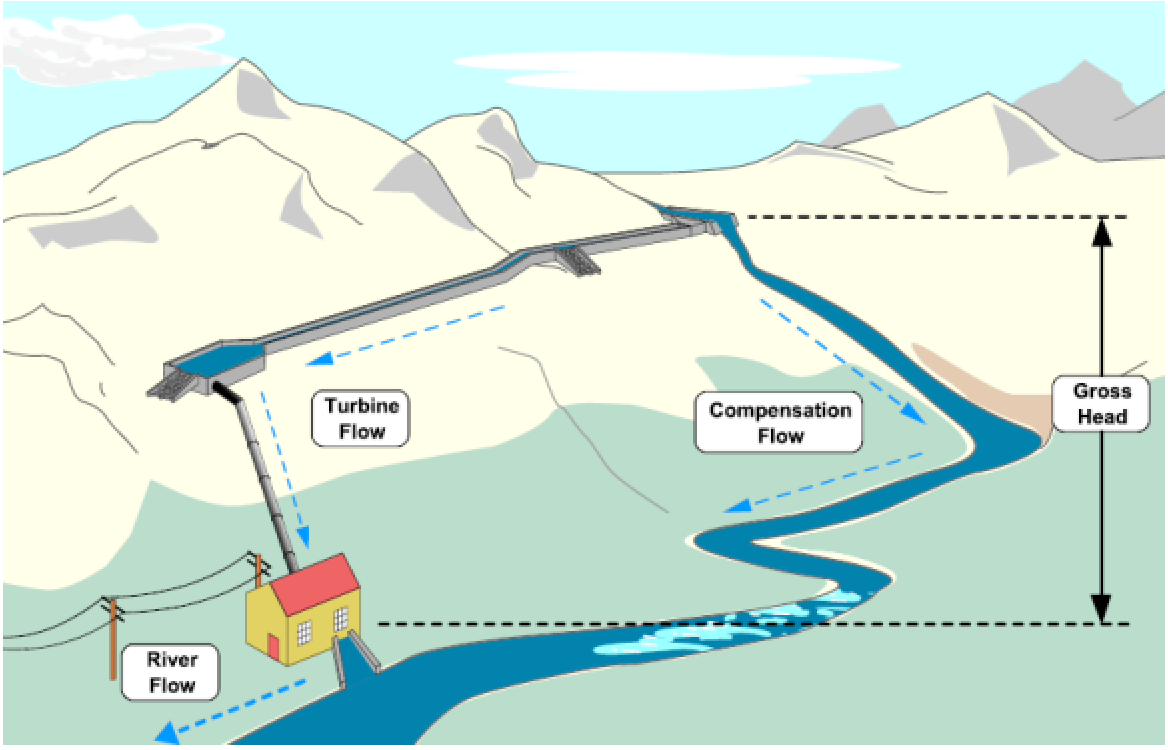
2.1.1 Small hydropower

Hydropower plant is classified "small" depending on the installed generation capacity. There is no globally agreed definition of 'small' hydro and the upper limit is usually taken as 10 MW but this can be higher in some parts of the world (WSHDR, 2013). In Kenya, SHP is defined as run-of-river power plants with installed capacities below 10 MW (MoEP, 2015). Other studies define SHP to include pico (up to 0.01 MW), micro (up to 0.1 MW) and mini (up to 1 MW) hydro-power plants (Panic et al, 2013). With these various capacities, small hydropower is more robust than a PV system and other renewable technologies (ESHA, 2004). The micro and pico SHP are typically used by communities for electricity provision in areas without grid connection, whereas the mini SHP tends to be connected to the grid system (Lahimer et al, 2013). The micro and pico can be designed and installed using local available materials and labour (Kaunda, Kimambo, and Nielsen, 2012), while mini hydro typically involves more traditional engineering approaches and will usually need access road for delivery of materials and electro-mechanical equipment (Klunne Jonker, 2009).

2.1.1.1 Basic Hydropower Operation

Hydropower systems convert the energy in flowing water to electrical energy. SHP can be installed on small rivers or streams, with varying impacts on ecosystems depending on the sites geographical, hydrological and biotic characteristics. The SHP can be of the run-of river or impoundment types. The run-of-river has no water storage and power generation is done by diverting water from the main river channel through a weir (Mbaka and Mwaniki, 2016) to pipeline, or pressurized pipeline (penstock) that delivers it to a turbine. When the turbine is rotated, the kinetic energy from the downstream flow of water is converted to electricity via a connected generator. Transmission lines then used distribute electricity to consumers.

Figure 6: Layout of a small run-of-river SHP plant



Source: Ahorlu (2016)

According to Alliance for Rural Electrification (ARE), the most important types of hydro turbines covering almost every situation are cash flow (Pelton and Bank), Francis and Kaplan turbines. The cross-flow turbine is adapted to high heads whereas the Kaplan is more used for low head rivers (ARE, 2011). In the case of the Pelton and Banki turbines, called impulse turbines, the water pressure is converted into kinetic energy (in the form of a high-speed jet) before entering the runner and generating electricity. In contrast, in the Francis and Kaplan turbines, called reaction turbines, the water pressure directly applies on the face of the runner blades to produce energy. The reaction turbines are more complex to build and install than the impulse ones, but have a higher efficiency. Concerning generators, there are three types that can be combined with the turbine: the generators with permanent magnets for small units (up to a few kW), the asynchronous for grid connected plants, and the synchronous generators (with load regulation by means of ballast loads) for bigger units (ARE, 2011).

The sites suitable for SHP installation include areas with slopes and water falls. Thus, most of the sites ideal for SHP are likely to be found in mountainous regions with permanent streams. The site determines the size and type of SHP and has an influence on the SHP installation cost (Kaunda, Kimambo, and Nielsen, 2012). Like any other hydropower plant, SHPs are site specific and their output depends on hydrological head, flow rate during the year, geological and geographical features, equipment (turbines and generators) and civil engineering works (UNIDO,"n.d"). Before investment, it is crucial to determine the amount of power that can be obtained from a site as given in the equation below:

$$P = \eta \rho g Q H$$

Where, η is the efficiency in energy conversion, ρ is water density, g is acceleration due to gravity, Q is the rate of water flow, and H is the distance from the inlet to the turbine (Paish, 2012). Information such as water flow rate and the distance between water inlet and turbine is crucial in the design of SHP. Assessment of the SHP using hydrological and topographical maps including Geographical Information Systems (GIS) help provide details such as site accessibility, size of watershed and slope, and can be used to gauge whether the project is viable (Mbaka and Mwaniki, 2016).

2.1.1.2 Advantages of SHP

Small hydropower is a mature and reliable technology that has greatly contributed to solving the problem of rural electrification, improving living standards and promoting rural economic development, alleviating poverty as well as reducing emissions (UNIDO, 2016).

Beside the advantages shared with other renewable energy sources (clean, indigenous, local job creation, security of supply), SHP are highly efficient (from 70% to 90%), have relatively low operation and maintenance costs, a lifespan up to 100 years and therefore an attractive energy pay-back ratio even for developing countries (ARE 2011).

Unlike other technologies that rely on variable sources such as local wind speed and solar radiation, a stream's flow is relatively consistent, adding to the predictability and reliability of the outputs. Micro-hydroelectric systems, in particular, have been characterised as the most predictable of all the renewable energy electrical systems (ARE, 2011).

In addition, small hydro can smooth variations in supply from other, more intermittent, generation sources, and it can provide important flexibility given that production can be shifted to periods of higher energy demand. And, given that small hydro is a domestic, distributed power source, it contributes to national security and can dispatch, with minimal start-up time, to a grid for blackout periods (Kellog and Hobbs, 2016)

SHP is equally an environmentally friendly and sustainable solution. In contrast with large hydro schemes, it usually does not require huge water reservoirs. Consequently, it has a limited or inexistent impact on hydrological regimes, sediment transport, water quality, biological diversity, and land-use change, the resettlement of people or effects on downstream water users. Importantly, it does not produce heat or greenhouse gas emissions.

European Small Hydropower Association (ESHA), due to various capacities, small hydropower is more robust compared to PV system and other renewable technology (ESHA, 2004) and can also provide a much more concentrated energy resource than other renewables. Thus, it is predictable, non-varying and has a higher capacity factor and long-life. (ESHA, n.d) and thus can provide base loads (Ahorlu, 2016). The SHP can also be integrated with other decentralised energy generation systems such as wind based systems to form hybrid systems to maximize the utilization of available resources in generating power (Kaunda, Kimambo, and Nielsen, 2012).

Finally, SHP schemes can be designed to recover energy from existing infrastructures. Such a multi-purpose scheme implies the integration of the power plant in the existing infrastructure while guaranteeing its primary function. For example, an SHP plant could be integrated in a drinking water or irrigation network, before and after a wastewater treatment plant, in a desalination plant, etc. These multi-purpose schemes do not only greatly expand the potential of SHP, but they also contribute to finding solutions for water policy issues such as the sustainable management of the resource in sectors like agriculture, wastewater treatment or drinking water supply (ARE, 2011).

2.1.1.3 Economics and costs

According to Alliance for Rural Electrification (ARE), SHP is often presented as the cheapest technology for rural electrification over the lifetime of the system. However, an SHP plant can require substantial initial capital investments even though its operating costs are very low. It is generally considered that location and site preparation determine around 75% of project costs against only 25% for the equipment (ARE, 2011). A simplified feasibility study of the project is important in order to gather accurate estimations of hydro-technical parameters at the site of the power station and to give a rough balance of costs and expected benefits. This is because the capital required for small hydro plant depends on the effective head, flow rate, geological and geographical features, the equipment (turbines, generators etc.) and civil engineering works, and whether water flow is constant throughout the year. The investment cost also depends on local economics (Ahorlu, 2016), which includes government taxes imposed on system components, labour services, water charges, concession etcetera.

According to hydropower report by Fichtcher, costs for small HPPs are slightly higher because they lack economies of scale. Small hydro projects range from US$1,300/ kW to US$8,000/Kw in 2011, with

African Countries ranging between 2000-4000 US$/Kw (FICHTNER, n.d). The report postulates that the operation and maintenance O&M costs typically quoted as percentages of investment costs, range from 1.0 percent to about 4.0 percent. The IEA assumes 2.2 percent for large HPP and 2.2 percent to 3.0 percent for small HPP. However, those indicators do not cover major electro-mechanical equipment replacement, which are infrequent due to long design lives. Taking this into consideration, O&M costs average at US$45/kW/year for large HPP and US$52/kW/year for small HPP (FICHTNER, n.d). O&M, including repairs and insurance which represent from 1.5-5% of investment costs in the EU (ESHA, n.d) while International Renewable Energy Agency gives a global average of 4% (IRENA, 2012). However, maintenance of SHP is typically less expensive when compared with other electricity generation systems such as diesel generators and their average lifespan can be up to 50 years (Mbaka and Mwaniki, 2016). This can be attributed to minimum fuel costs, minimum investment on maintenance and replacement. Typically the cost varies from 1,000 to 20,000 US dollars per kilowatt of electricity (Kaunda, Kimambo, and Nielsen, 2012).

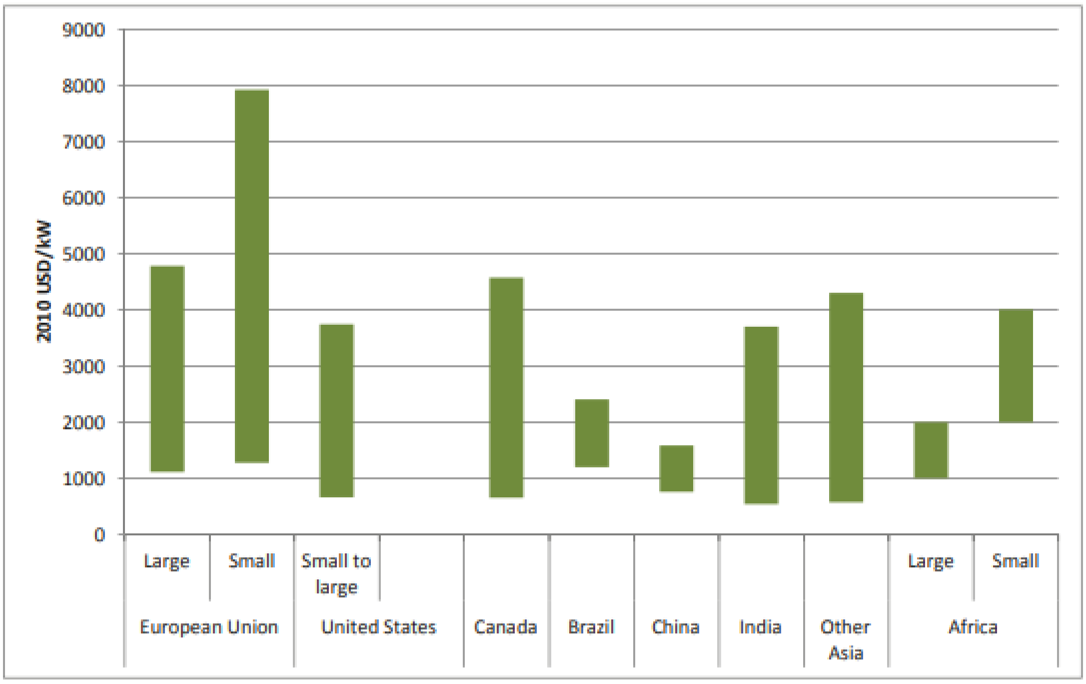
Table 7: Typical investments, O&M and cost of electricty generation.

	Installed costs(US$/Kw)	O&M Costs(%/year of installed costs)	Capacity Factor	LCOE(2010 US$/kWh)
Large hydro	1050-7650	2-2.5	25-90	0.02-0.19
Small hydro	1300-8000	1-4	20-95	0.02-0.27
Refurbishment/upgrade	500-1000	1-6		0.01-0.05

Source: FICHTNER (n.d); IRENA, 2012

Total installed hydropower cost ranges by country

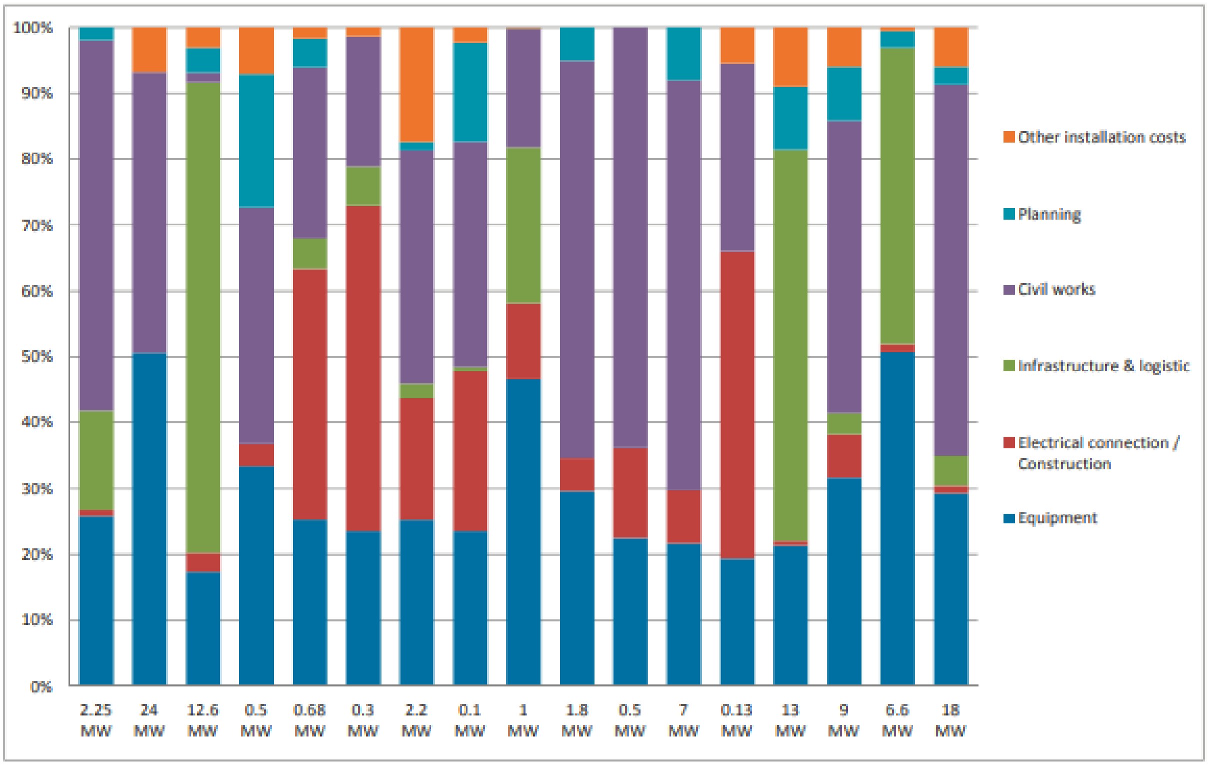
Figure 7: Total installed hydropower cost ranges by country across the world



Source: IRENA, 2012

The cost breakdown for small hydro projects in developing countries reflects the diversity of hydropower projects and their site-specific constraints and opportunities figure 8 below. The electro-mechanical equipment costs tend to be higher than for large-scale projects, contributing from 18 % to as much as 50 % of total costs. For hydropower projects where the installed capacity is less than 5 MW, the costs of electro-mechanical equipment may dominate total costs due to the high specific costs of small-scale equipment. For projects in remote or difficult to access locations, infrastructure costs can dominate total costs (IRENA 2012).

Figure 8: Cost breakdown for small hydro projects in developing countries



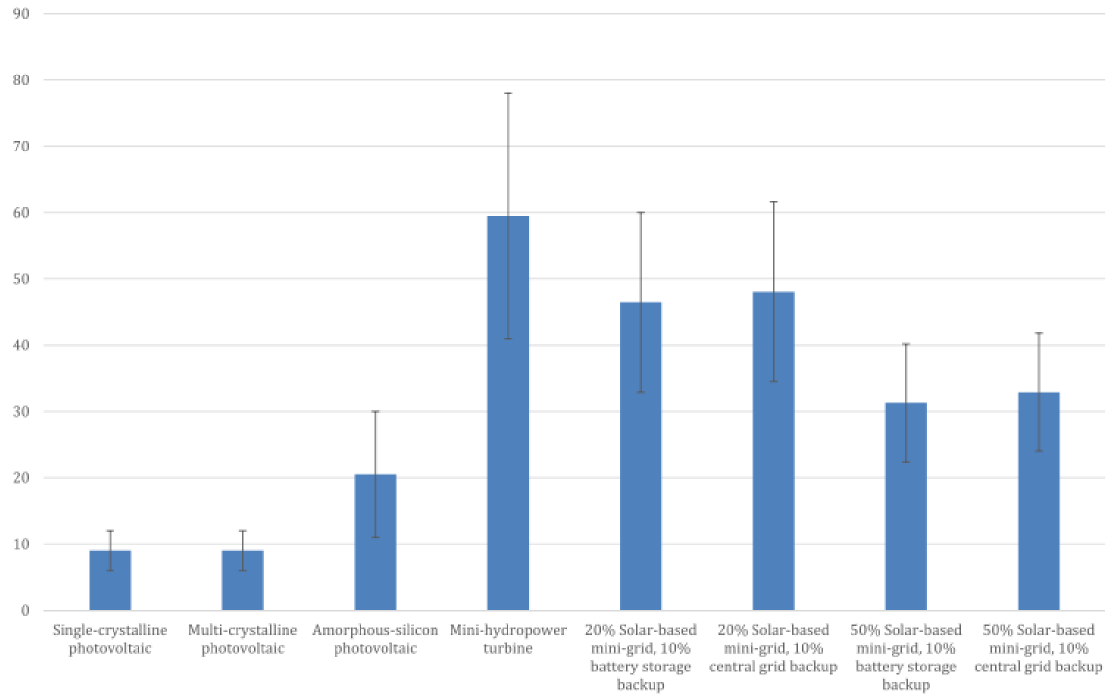
Source: IRENA, 2012

The initial investment cost, implementation and effect on the environment, can be greatly reduced by utilizing the already existing impoundments and weirs (Mbaka and Mwaniki, 2016). The systems with dual purpose - power generation and flood control, power generation and irrigation, power generation and drinking water purposes, have shorter payback period (ESHA, n.d). Although the preparation of such a plant requires technical expertise, the installation of the plant in itself is relatively straightforward and costs can be reduced by using many local materials and skills (ARE, 2011).

Due to various capacities, small hydropower is more robust than a PV system and other renewable technology (ESHA, 2004). Small hydropower also provides a much more concentrated energy resource than other renewables. Thus, it is predictable, non-varying and has a higher capacity factor and long-life. (ESHA, n.d) and can provide base loads (Ahorlu, 2016). The SHP can also be integrated with other decentralised energy generation systems such as wind based systems to form hybrid systems to maximize the utilization of available resources in generating power (Kaunda, Kimambo, and Nielsen, 2012).

A study to compare the net energy return on energy invested (EROI) of mini-hydropower and solar electricity in Thailand using life cycle found that the EROI ratio for mini-hydropower systems is higher than solar PV, as shown in figure 9; however, this does not preclude distinct advantages of solar PV to meet future electricity demand (Kittner, Gheewala and Kammen, 2016). Another study also displays that hydropower has the highest return on investment compared to many other forms of sustainable energy with Run-of-River having an even higher payback ratio than traditional storage based hydropower (Atlason et al., 2014).

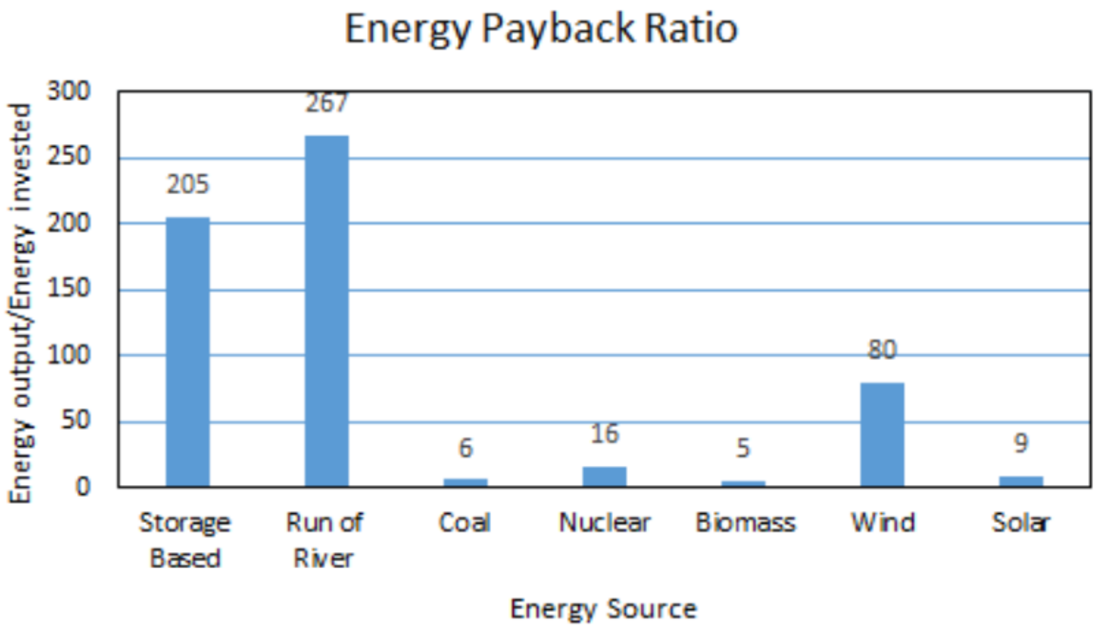
Figure 9: EROI of mini-hydros and solar PV technologies in Thailand, by technology and varied mini-grid set-ups



Source: Atlason et al., (2014).

Figure 10, below displays that hydropower has the highest return on investment compared to many other forms of sustainable energy with Run-of-River having an even higher payback ratio than traditional storage based hydropower (Atlason et al., 2014).

Figure 10: Energy payback period of different technologies



Source: Atlason et al., (2014)

2.1.2. Investment needs and barriers for mini-grid based rural electrification

2.1.2.1 Investment needs

Achieving the objective of universal access by 2030 via sustainable models of decentralized electrification will require significant capital investment. Various studies provide different estimates of investment needs and flows. Bazilian et al., in review of financing needs for achieving universal access by 2030 cite a gap of USD 12-USD 134 billion dollars per year, with most realistic estimates trending towards the high end (Brazilian et al. 2010). The Sustainable Energy for All (SEforALL) platform, other the other hand, recommends an annual investment of USD 50 billion. Compared to the actual investment of 13 billion USD in 2013 (REN21, 2017), investments need to be scaled up significantly.

Several studies show that the pace, scale and trend of investment into sustainable energy access pales in comparison to the needs of remote populations as most of the investments go to large scale investments. A report by UNEP notes that in 2013, only $93 billion was invested into renewable energy in developing economies as a whole but majority of capital flowed into large generation capacity projects (UNEP 2015). According to Sustainable Energy for All report, international finance of $11.7 billion a year, almost entirely from public sector institutions, represented just over half of the finance commitments tracked for electricity in high-impact countries in 2013-14. Of this, only $200 million was directed to support decentralized solutions, including solar home systems and mini-grids (SEforAll, 2017). According to REN21 report, public international finance for climate change and clean energy systems totalled to about USD 14.1 billion over the period 2003-2015 but only 3% of total (about USD 475 million) was allocated to DRE-specific activities (REN21, 2017). This implies a trend toward funding large-scale infrastructure projects or grid electricity making off grid systems to be deficient in in financing. According to UNEP, with the current invest flow, though it is increasing, in overall, nearly a billion people in the dark by 2030 (UNEP, 2015).

While the estimated USD 134 billion to achieve universal access by 2030 may seem an impressive number, this is less than 0.2% of the asset base of institutional investors world-wide (UNEP, 2015). It is estimated that institutional investors (pension funds, insurance companies, endowments and sovereign wealth funds) manage over USD 90 trillion in total assets in developed countries alone (OECD, 2015, IRENA 2016). This suggests that the private sector investments will play an indispensable role in meeting global targets of energy access, as it is commonly acknowledged (UNCTAD 2014; SEforAll, 2015; IRENA 2016; REN21 2017). Thus rural off grid projects need to attract these enormous resources.

2.1.2.2 Barriers and risks

Most of the challenges facing small hydropower are generic for all types of renewable energy and rural electrification projects. General barriers include the absence of clear policies on renewable energy, limited budget to create an enabling environment for mobilizing resources and encouraging private sector investment, and the absence of long-term implementation models that result in the delivery of renewable energy to customers at affordable prices while also ensuring that the industry remains sustainable. Although there is widespread desire for modern energy services in Africa, cost of electricity continues to be an issue in many rural communities, which needs to address with appropriate implementation models. (Klunne Jonker, 2012).

According to REN 2016 report, the biggest barrier to universal access to decentralised renewable energy (DRE) systems is lack of investment. The report notes that although, funding from multilateral organisations and bilateral donors continued to be the main source of financing for energy access investments, DRE investment accounts for only a fraction of their energy access investment portfolios (REN21, 2017). Financing, whether in terms of high up-front costs or lack of access to credit, remains one of the most significant challenges for renewable energy, particularly off-grid renewable energy (UNDP, 2016).

Decentralised renewable energy finance comes with higher actual and perceived risk, increasing its costs. This includes market barriers, such as countries with significant off-grid populations having low scores on ease of doing business; technology and business model risk; lack of co-ordination between small-scale suppliers and enterprises; small deal sizes; young enterprises lacking historical performance data and proven track records; capital intensive businesses and investors' belief that cash-poor household borrowers with no credit history are risky bets (Shakya, and Byrnes, 2017). These underlying market barriers and a perception of high risk constrain the development and financing of renewable energy projects, particularly off-grid renewable energy (IRENA 2016 and UNDP, 2016). Rural electrification projects in developing countries, especially off-grid projects based on renewable power, are often unattractive for private investors. These projects typically have unfavourable risk-return profiles and small investment volumes (Schmidt et al., 2013; Schmidt, 2015; Williams et al., 2015; Malhotra, Schmidt, Haelg and Waissbein, 2017).

Because of the small size of most RET projects, the transactions costs per unit of installed capacity associated with developing and financing a renewable energy facility are commonly quite high. In some cases, renewable energy project sizes fall below the minimum threshold of interest to commercial lenders (Ryan Wiser and Steven Pickle, 1997). According to World Business Council for Sustainable Development (WBCSD) there are particular challenges associated with financing portfolios of smaller projects, when compared with traditional project financing of large scale utility projects. Smaller developers or project portfolios are often financed on balance sheet, and then sold or refinanced to release capital for further investment. This makes scaling difficult. Smaller developers typically have less market power when negotiating with financiers and can be burdened by unfavourable or inflexible debt structures. Transaction costs for smaller projects are also a key barrier – requiring efficient and cost effective aggregation tools and standardisation. Sponsor risk for smaller players is a major consideration from both the financier and off-taker perspective (i.e. in the case of large corporate off-takers, who assess the creditworthiness of a renewable supplier) (WBCSD, 2017).

Shakya, and Byrnes (2017), also note that, institutional investors with larger, cheaper finance are not interested in investment vehicles until they reach a minimum level of, say, USD60–100 million and collect years of data to de-risk investment decisions, since the transaction costs are otherwise deemed too high.

According to UNIDO, SHP projects generally face barriers similar to other renewable energy technologies and mini-grids (UNIDO, n.d) and thus most of the information can easily be transpose to other RES investments. However, hydro projects are more site specific and impacts of climate change may result into hydrological risks.

In a survey study of risk management for mini-grids, Manetsgruber, Wagemann, Kondev and Dziergwa (2015) explain that compared to large utility investments, higher risk profiles of mini-grid projects come with investor expectations for considerably shorter payback periods and higher returns (IRRs). However, the current return of mini-grid projects is relatively small and typically in the range of 10 to 15% IRR, much smaller than the 20% and above a typical investor would expect for a comparable on-grid project. In resolving this challenge, two main options are generally proposed: increase returns (improve the IRR) to compensate for the higher risk; and reduce the risk of the project to stabilise cash flows so that the lower risk profile of the business model corresponds to the low IRR the projects generate.

The first approach - “increasing returns” – requires mini grid operators to increase their income, by for example increasing the electricity tariffs. However, this strategy is a challenge since most rural communities have low income and may not bear increased financial burdens (Manetsgruber et al 2015). The second approach - “lowering risks” - presents a case that offers a larger number of possibilities for intervention and is the backdrop of this thesis.

Renewable based projects, due to their high up-front cost, are influenced to a much larger extent by higher financing costs as compared to fossil fuel-based generation (Schmidt, 2014). Consequently, there has been considerable attention towards identifying, classifying and understanding risks and measures to address them (IRENA 2016; Malhotra, Schmidt, Haelg and Waissbein, 2017).

Several studies have discussed investment risks and barriers for mini-grid projects, employing different classification criteria. For example, Williams, Jaramillo, Taneja and Ustun. (2015) review and classify barriers to private sector investment into three interdependent categories – financial, institutional and policy, and technical barriers. Similarly, Hazelton, Bruce and MacGill (2014) identify technical, organizational, social, sustainability, financial, and safety risks for solar PV hybrid mini-grids, which is similar with the classification by REN21 (2017) for deployment of DRE systems in developing countries. For SHP, Plummer (2011) and Cunha and Ferreira (2014) classify risks into construction/completion, technological, geological, hydrological, economic, financial, political, environmental, external events, and sociocultural risks.

Klunnel (2011) in a review of status of SHP in Southern and Eastern Africa, look specifically at small hydropower development barriers and classifies them into ‘policy and regulatory framework’, ‘financing’, ‘technical’ and ‘data on hydro resources’. IRENA (2016) notes that project risks multiple forms which include political and regulatory risk; counterparty, grid and transmission link risk; currency, liquidity and refinancing risk; as well as resource risk, which is particularly significant for geothermal and hydropower energy.

Franz, Peterschmidt, Rohrer and Kondev (2014) organise risks at the macro level into political, social, economic, and financing risks. Ahlborg and Hammar (2014) identify investment barriers in Tanzania and Mozambique and categorize them categories into ‘weak institutions and barriers’, ‘economy and finance’, ‘social dimensions’, ‘technical system and local management’, ‘technology diffusion and adaptation’, and ‘rural infrastructure’.

ESMAP (2010) report on overcoming barriers in hydropower barriers in Peru notes that hydro projects (even small hydro projects of 5 MW to 20 MW) have been the most difficult power sector projects to finance, owing to capital intensive, long construction times, unique site-specific risks and unremitting attention regarding potential environmental and social impacts. Further the report notes that financing of hydro projects requires a demonstration that the following major risks can be successfully mitigated: price risk, completion risk, hydrology risk, operational risk (inability to operate because of mechanical failures or operational problems at the plant), off-take risk (failure of the buyer to take power due to reasons of dispatch, transmission congestion, or transmission line failure).

Williams, Jaramillo, Taneja and Ustun (2013) classify investment risks by relating them with a specific stakeholder whose actions have the potential to result in negative impact on the project finances, and quantify their impact on cost of financing for renewables. They also propose policy and financial de-risking instruments, i.e. public de-risking instruments aimed at mitigating investment risks and transferring them to a public institution, respectively.

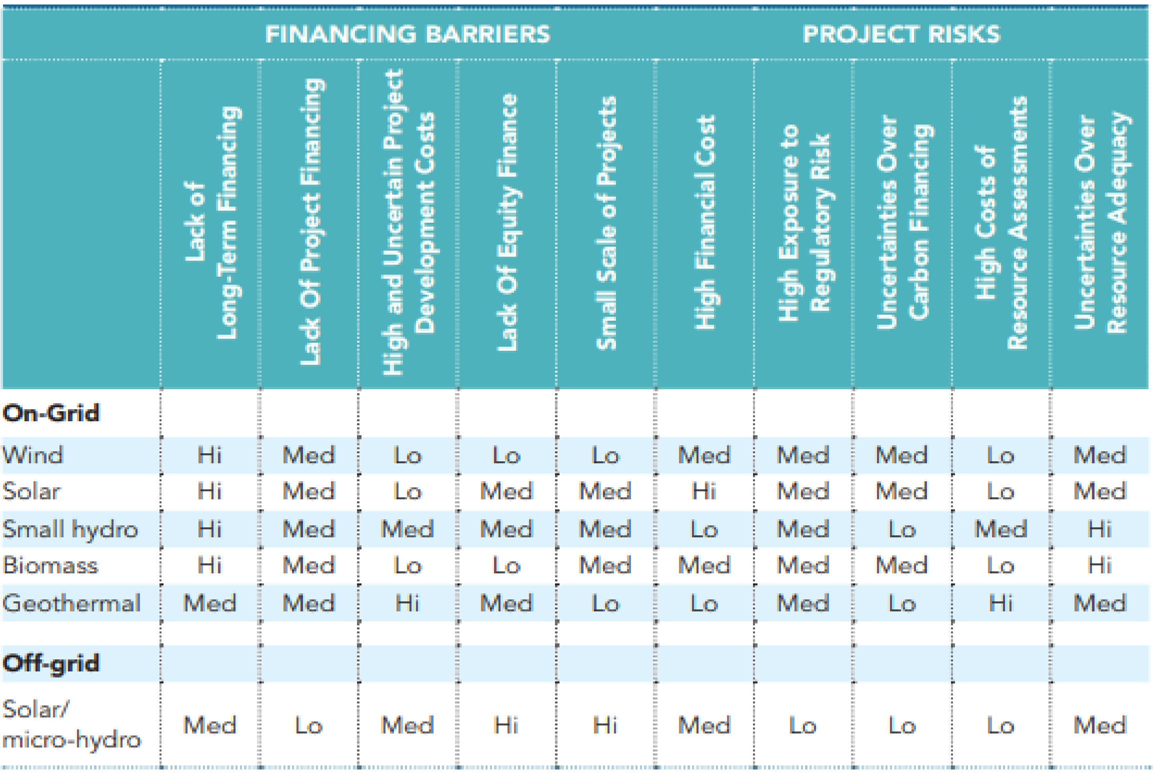
Table 8 Summary of Risks and barriers classification from different authors

Investment risks and barriers for DREs	Technology and location	Source (Authors)
Financial; institutional and policy; and technical barriers	Mini-grid projects,	Williams, Jaramillo, Taneja and Ustun. (2015)
Technical, organizational, social, sustainability, financial, and safety risks	Solar PV hybrid mini-grids-Australia	Hazelton, Bruce and MacGill (2014)
Construction/completion, technological, geological, hydrological, economic, financial, political, environmental, external events, and sociocultural risks	SHP in in Portugal	Plummer (2011) and Cunha and Ferreira (2014)
Policy and regulatory framework; financing; technical and hydro resources risks.	SHP Southern and Eastern Africa	Klunnel (2011)
Political and regulatory risk; counterparty, grid and transmission link risk; currency, liquidity and refinancing risk; as well as resource risk,	DRE in general	IRENA (2016)
Weak institutions and barriers; economy and finance; social dimensions; technical system and local management; technology diffusion and adaptation and rural infrastructure.	SHP in Tanzania and Mozambique	Ahlborg and Hammar (2014)
Price risk, financing risks, completion risk, hydrology risk, operational risk, off-take risk	SHP in Peru (5-20 MW)	ESMAP (2010)

Source: Author compilation from literature review

A study by World Bank and Climate Investment Funds summarises renewable energy technologies and degree of exposure to barriers and risks as shown in the table 11 below.

Figure 11: Technology, barriers and risks



	FINANCING BARRIERS					PROJECT RISKS				
	Lack of Long-Term Financing	Lack Of Project Financing	High and Uncertain Project Development Costs	Lack Of Equity Finance	Small Scale of Projects	High Financial Cost	High Exposure to Regulatory Risk	Uncertainties Over Carbon Financing	High Costs of Resource Assessments	Uncertainties Over Resource Adequacy
On-Grid										
Wind	Hi	Med	Lo	Lo	Lo	Med	Med	Med	Lo	Med
Solar	Hi	Med	Lo	Med	Med	Hi	Med	Med	Lo	Med
Small hydro	Hi	Med	Med	Med	Med	Lo	Med	Lo	Med	Hi
Biomass	Hi	Med	Lo	Lo	Med	Med	Med	Med	Lo	Hi
Geothermal	Med	Med	Hi	Med	Lo	Lo	Med	Lo	Hi	Med
Off-grid										
Solar/ micro-hydro	Med	Lo	Med	Hi	Hi	Med	Lo	Lo	Lo	Med

Source: World Bank and Climate Investment Funds (n.d).

> Note: Lo = Small or no impact (mitigation of risks is desirable); Med = Moderate impact (mitigation of risks is likely to be required); Hi = Significant impact (mitigation of risks is generally necessary if the project is to proceed) Lack of market funds is not included in the figure. This financing barrier could affect any technology and is driven by the size of domestic capital markets, not the specific risks of any technology

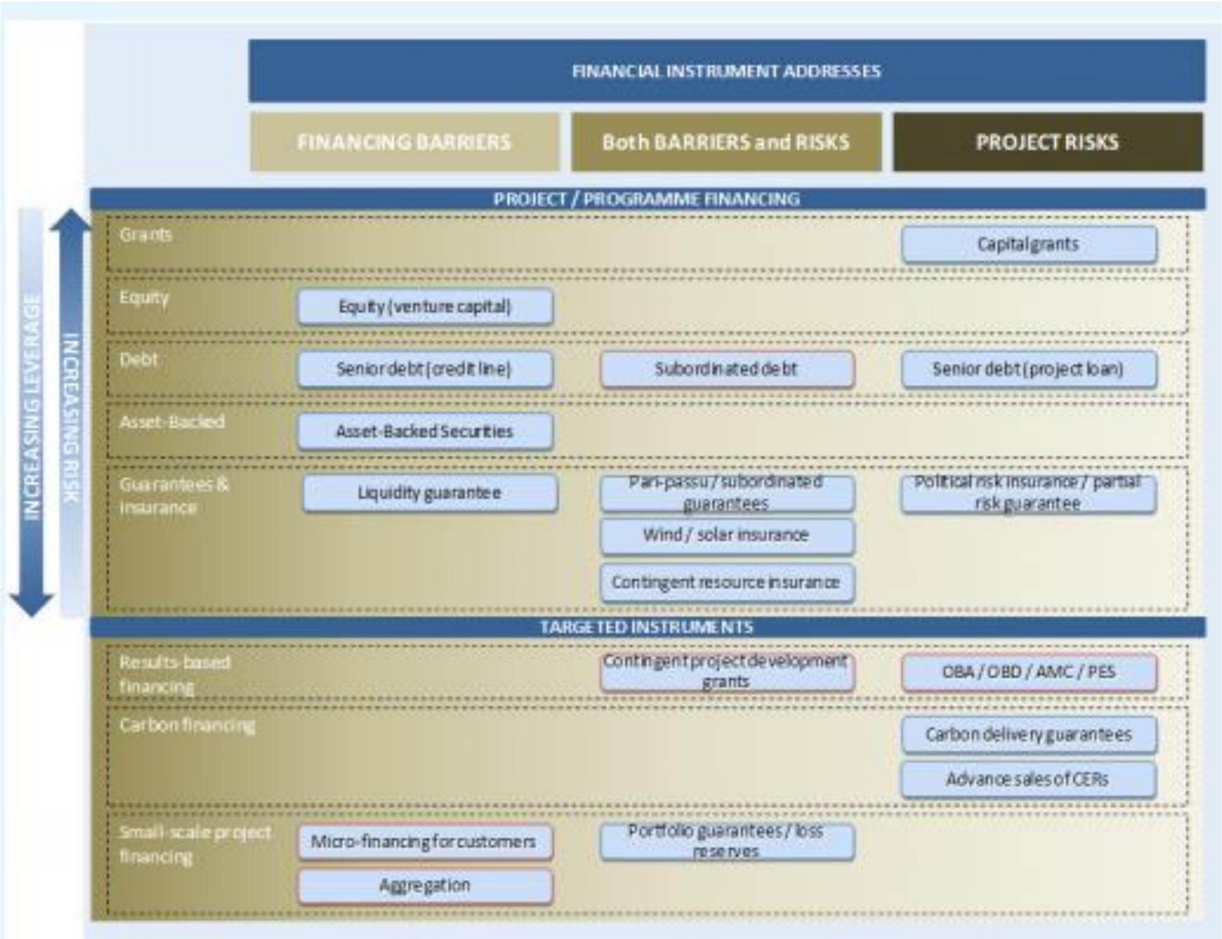
The existing literature provides a good qualitative understanding of different investment risks and barriers for mini-grid projects and generally decentralised renewable energy systems. However, these studies generally focus either on single projects, or on barriers in the investment environment, without analysing how they might affect a portfolio of projects.

Although investments have grown in recent years, they are far from sufficient to reach universal access goals. A number of factors are responsible, including mismatch between the typical project volume and the financing instrument, the lack of information about available financing sources, the relatively inexperienced private sector and financing institutions and related capacity constraints and lack of financial infrastructure to facilitate transactions (IRENA 2017).

In summary, the relationship of risk and return is an important issue for energy policy, tariff design, and project appraisal. The relationship is fundamental to private sector involvement in an energy project in general and SHP in particular, because the required rate of return will depend on the investors' perception of risk – which may itself vary across the stages of project development (Meier, 2015).

According to World Bank and Climate Investment Funds (n.d), a wide range of financing instruments can be applied in support of the scaling up of renewable energy technologies (RETs). These can be broadly grouped into those used to overcome financing barriers, those used to address the specific risks of RET investments, and those that address both simultaneously as shown in figure below:

Figure 12: Financial instruments addresses



	FINANCING BARRIERS	Both BARRIERS and RISKS	PROJECT RISKS
PROJECT / PROGRAMME FINANCING			
Grants			Capital grants
Equity	Equity (venture capital)		
Debt	Senior debt (credit line)	Subordinated debt	Senior debt (project loan)
Asset-Backed	Asset-Backed Securities		
Guarantees & insurance	Liquidity guarantee	Pari-passu / subordinated guarantees Wind / solar insurance Contingent resource insurance	Political risk insurance / partial risk guarantee
TARGETED INSTRUMENTS			
Results-based financing		Contingent project development grants	OBA / OBD / AMC / PES
Carbon financing			Carbon delivery guarantees Advance sales of CERs
Small-scale project financing	Micro-financing for customers Aggregation	Portfolio guarantees / loss reserves	

Source: World Bank and Climate Investment Funds (n.d).

2.1.3 Diversification of risk and aggregation

2.1.3.1 Modern Portfolio Theory (MPT).

The foundation of modern portfolio theory was laid by Markowitz in 1952 (Markowitz, 1952). The basis of the theory states that by diversifying a portfolio of assets, the overall risk can be lowered compared to the risk of the individual assets. In substance, Markowitz explained that it was possible to reduce risk of financial investment, if we combined financial assets with no or negative correlation with each other (Matilda 2015). Therefore it is an investment theory which attempts to maximise portfolio expected return for a given amount of portfolio risk, or equivalently minimize risk for a given level of expected return using diversification. More technically, MPT models expected return of a portfolio as the weighted average of the expected returns of the individual assets and defines portfolio risk as the variance of returns of the portfolio (depends on the variance of the returns of each of the assets, as well as on the correlations between the assets' returns) (Malhotra et al 2017).

If we considered a portfolio with Fi financial assets, where i=1, 2…n, portfolio performance would be measured by expected return E (R) and variance, V (R) OR σ2 as,

$$E(R_P) = \sum_{i=1}^{n} w_i \, E(R)_i \quad (2)$$

$$V(R) = \sum_{i=1}^{n} x_i^2 \sigma_i^2 + \sum_{i}^{n} \sum_{j \neq i}^{n} x_i x_j \sigma_i \sigma_j \rho_{ij} \, ,$$

Where V(R) is the variance of the expected returns of the portfolio, x_i is the fraction of the total portfolio investment amount invested in asset i, σ_i is the standard deviation of the returns of asset i, and ρ_{ij} is the correlation coefficient between the returns of assets i and j. When the individual assets in a portfolio do not perfectly correlate (ie ρ_{ij} less 1), the variance of the returns of the portfolio is lower than that of the individual assets.

The risk of the investment in a portfolio of different assets depends on whether the return on the individual assets tends to move together or whether some assets give good returns when others give bad returns. This is because different assets are exposed to a large extent to different kinds of risk – a combination of systematic and unsystematic risks. The unsystematic risk or specific risk or unique risks is the risk idiosyncratic risk that exists with the investment of particular project. By nature specific risk is diversifiable and linked to the uncertainty of the income of the asset. Investors reduce this kind of risk by simply allocating their resources to different types of assets simultaneously. They are guided by the principle "don't put all your eggs in one basket". However, even well diversified, a portfolio of assets is never "risk-free". The systematic risk (market risk) is the risk inherent in the market or the type of risk which is common to all kinds of assets, caused by general market influences. In this sense, the diversification effect within a portfolio is limited to the unsystematic risks (Chaves-Schwinteck (2011). In order to reduce market risk, assets from different markets, e.g. other geographies or industries, need to be included in the portfolio (Malhotra et al 2017). Small hydro can be diversified due to different hydrological patterns in different areas (Tola, 2015).

2.1.3.2 Application of MPT electricity generation

An early application of MPT to the electricity sector was presented by Bar-Lev and Katz, they analyse fossil fuel procurement in electric utility industry (Delarue, De Jonghe, Belmans and D'haeseleer, 2010). According to Ferreira and Cunha (2012), the MPT approach enables analysis the impact of the inclusion of renewable technologies in the mix of generating sources of electricity. It provides a better risk assessment of alternative generation technologies, particularly in terms of their impact in reducing the risk of the portfolio of technologies to be adopted. The MPT model allows to illustrate the trade-off between production costs and risk. Delarue et al. (2010) presents a portfolio theory model that explicitly distinguishes between installed capacity, electricity generation and actual instantaneous power delivery. They included in the investment optimization, wind power and conventional power plants and found wind power can be motivated to lower the risk on generation cost. Awerbuch and Berger (2003) employ portfolio approach to reflect upon an optimal generation mix for the EU. They use a certain expected rate of return and standard deviation, i.e., risk, on that cost and assume a total amount of installed capacity to test different scenarios. Van Zon and Fuss (2005) present the development of a vintage portfolio approach using a single objective function, total cost consisting of a weighted sum of the overall cost and the corresponding variance (risk) is minimized. To elaborate further on MPT, Huang and Wu (2008) use a risk weighted generation cost and load duration curve to define different demand blocks.

Wüstenhagen and Menichetti (2012) give a review of several studies applying MPT to investments in power generation assets. The studies reviewed include evaluation of the diversification effect of including renewable power generation assets in conventional power mixes (Awerbuch, 1993, 2000; Bhattacharya and Kojima, 2012), identification of optimal generation portfolios in the power sector (Roques et al., 2008), and evaluation of strategies for diversifying plant-specific risks for renewable energy technologies (Laurikka and Springer, 2003). Matilta (2015), employs MPT to address issues on planning electric generation supply to achieve maximum reliability for Albania, by analysing present generation risk from hydro resources, considering diversification effect on Albania's electricity generating portfolio and how MPT proposes solutions to an optimization problem. The study uses simulation to demonstrate that adding new generating technologies can reduce risk and improve power generation. Kienzle and Anderson (n.d) introduces the application of mean-variance portfolio theory to portfolios generating multiple forms of energy such as electricity, heating or cooling power. In order to illustrate the proposed method, the model is applied to a portfolio of distributed electricity and heat generation technologies and shows how efficient risk-return combinations for multi-energy generation portfolios can be determined.

Chaves-Schwinteck (2011), presents an application of the principles of the Modern Portfolio Theory as a strategy to the reduction of the risks around the energy production of wind farms. The results demonstrated by case studies shows the potential of geographical diversification to reduce the risks related to the availability of wind as a primary resource and once a sufficient history of technical performance data is available, a reduction of the risks linked to the technical performance of the wind turbines can be achieved in a similar way. Nevertheless, the existence of “non-diversifiable” risks still presents a challenge for the financing of wind farms. In this sense, it is important to point out that the financing performance of a portfolio of wind farms is extremely dependent on the individual performance of the single projects. In the study Chaves-Schwinteck describes a quantitative approach developed to assess the reduction of the overall uncertainty around the energy production of a portfolio of wind farms once their diversification aspects are taken into account and further complements with an investigation of key project finance parameters like the Debt Service Coverage Ratio (DSCR) and the ratio debt to equity finance of the single wind farms and the portfolio.

Ferreira and Cunha (2012), explored the possibility of applying MPT approach to define efficient electricity generation portfolios with particular in renewable energy sources (RES technologies), that is, wind, hydro and solar plants along with their power demand. The study considers three different approaches for designing the efficient frontiers aiming at maximizing the RES electricity generation, minimizing deviation between the demand and the RES production and minimizing the levelised cost of the RES system. The results demonstrate how the approach can be an effective tool to support decision making.

2.1.3.3 Aggregation

The OECD defines financial aggregation as bundling together similar small projects to reach a scale where they become attractive to large investors while the Climate aggregation platform (CAP) defines it as the aggregation, or bundling together, of small loans and asset to create investment products that meet the large-scale needs of institutional investors including global pension funds and insurance funds (Shakya, and Byrnes, 2017).

Shakya, and Byrnes (2017) in their research found that aggregation in the decentralised renewables sector is not limited to bundling financial products into a platform, but includes:

(i) Aggregating demand: where communities join up in energy cooperatives to aggregate their energy demand and access finance for a mini-grid.

(ii) Aggregating enterprises or projects: developing a portfolio of enterprises or projects delivering decentralised renewable energy services with similar technologies or similar business models.

(iii) Aggregating information: such as platforms that seek to improve access to finance for decentralised renewable energy enterprises, through standardising the information that enterprises provide to investors: risk, returns and impact, or the credit-worthiness of the target population.

According to concept note by UNDP, GEF and CBI, 2015, aggregation can be can be generally understood as a process in which an aggregating entity standardises and bundles together multiple small-scale, low-carbon energy assets. The aggregating entity then obtains financing, or refinancing, from investors on the basis of the future cash flows from the low-carbon energy assets.

The definitions above make it clear that the purpose of aggregation therefore is to attract lower-cost finance, particularly working capital, into the decentralised energy market to enable faster expansion.

According World Bank and Climate Investment Funds, a major barrier to lending to small-scale projects is that of associated transaction costs. These will rule out many SHP projects from the commercial financing market, even if they are otherwise attractive. Aggregation of projects is one way to overcome this barrier. Various forms of aggregation can be used. One approach is to adopt standard project specifications and agreements so that each individual project can be rapidly appraised at low cost. For example, Sri Lanka and Vietnam have both adopted standard power purchase agreements and tariffs for small hydro projects, avoiding the need for these to be reviewed for each new project. Another is to establish a dedicated financing intermediary that, because of the large volumes of similar transactions it deals with, can realize economies of scale in their appraisal. Such an intermediary could be a public entity or could be a CFI through which loans for RET projects are channelled (World Bank and Climate Investment Funds, n.d).

Shakya and Byrnes (2017) note that aggregating finance can overcome some of the challenges faced in financing decentralised renewable energy by reducing both risk and the cost of finance, and tackling market barriers. Through portfolio, the transaction costs of investing individually in each energy enterprise or end user at the local level lies within the aggregation platform, minimising these costs for investors. Renewable energy projects tend to vary in terms of size ranging from very small, that is micro-scale (<100 kW) to large, utility-scale projects. Since transaction and due diligence costs tend to be similar for all project sizes, smaller-scale projects are at a relative disadvantage in attracting large-scale investors (UNEP, 2015). Banks are looking for larger deals partly to cover the due diligence and transaction costs involved and partly to have a meaningful impact on their portfolios (IRENA, 2016).

Therefore, aggregating smaller-scale renewable energy assets can help scale up investment volume and reduce due diligence costs per project for institutional investors. This is because, bundling together smaller loans and assets from relatively small-scale decentralised renewable energy projects and enterprises can create investment products that meet the larger-scale needs of institutional investors. Aggregation can tackle some of the markets barriers that relate to risk, such as policy, tax and regulatory issues; or driving up costs, such as servicing remote, small and isolated markets. For instance, National aggregation platforms like IDCOL in Bangladesh and AEPC in Nepal bring governments and donors together as co-investors in stimulating the decentralised energy market, providing a forum to tackle policy barriers such as product standards. In Rwanda, aggregator Ignite partners with the government to address several market barriers, including product standards and requesting the government to clarify where the grid will expand in the next years, providing certainty to the off-grid market. The aggregation design depends on the technology, business model and geography as well as the size and characteristics to be aggregated. For instance, in a sector characterised by many small individual investments, standardising the investment process can reduce transaction costs (Shakya, and Byrnes, 2017).

It can also increase the financing capability of (development finance institutions) DFIs. Assuming that the probability of default for any one project remains the same, the amount of reserves held by a DFI is much less when lending to an aggregated project than many individual projects (Hussain, 2013). Through aggregation, small or medium-scale renewable energy projects can improve their access to financing sources and investors. However, building a replicable aggregation model that can be scaled up requires strong support and commitment from governments as well as consensus on specific terms of standardisation from industry stakeholders (IRENA, 2016).

In Sri Lanka, power sector models are based on a large central generation model not amenable to distributed generation (DG). Although promising technologies – biomass, wind and small hydro – are available, access to credit is particularly difficult given the banks' high perceived risks and lack of adequate capacity to identify, assess and structure this type projects. In 2008, IFC, with support from the Global Environment Facility (GEF), launched the Portfolio Approach to Distributed Generation Opportunities (PADGO) program to develop DG from renewable energy sources in Sri Lanka. PADGO included both investments and advisory work supporting financial intermediaries, project developers, investors, equipment suppliers, and other stakeholders, to develop, finance and implement renewable energy projects. In order to increase access to private financing, IFC partnered with two of Sri Lanka's largest financial intermediaries, providing them with pari-passu portfolio risk sharing facilities to cover a portion of the potential losses from loans to eligible small scale renewable energy projects (GEF, n.d).

According to World Business Council for Sustainable Development (WBCSD) there is a fundamental need to develop cost-effective aggregation tools and processes to meaningfully scale up finance for distributed renewable projects given that the industry is considerably more fragmented than the traditional utility sector. Identifying and developing more effective and efficient ways to aggregate and finance portfolios of smaller projects is essential for further market development and further suggests that projects can be effectively aggregated for securitisation provided that systems and processes are standardised for efficient project execution - standardisation of contracts, due diligence and other processes are critical to reduce costs under this type of business model (WBCSD 2017).

Due the emergence of new aggregative financing models for distributed solar in the US, there has been an increased interest in investigating the benefits of project aggregation (Malhotra et al 2017). Lowder and Mendelsohn (2013) estimate the potential for aggregation of distributed solar PV generation in the US, and discuss the potential reduction in financing costs due to diversification of credit risk and geographic risks. Mendelsohn and Feldman (2013) calculate the levelised cost of electricity (LCOE), assuming lower financing costs for aggregative financing structures due to increased access to low cost capital, increased liquidity allowing access to a wider class of investors, and increased diversity of the underlying assets (Malhotra et al 2017). Alafita and Pearce (2014) identify and model the influence of some key parameters on the cost of financing for aggregated residential solar PV assets. Overall, this thesis observes that spatial diversification across geographies and jurisdictional boundaries is a common theme touched upon across these studies but little is focussed on developing countries with particular focus on small hydro plants. Further few of them analyse in detail the mechanisms by which it can lead to reduced risk correlations.

Davidsen et al., 2015; Gershenson et al., 2015 and Orlandi et al., 2016) study aggregation and diversification in the context rural electrification. They identify several advantages of this approach: First, portfolio diversification results in reduction in investment risk. Second, investment volumes are increased. Third, the transaction costs are reduced on a per project basis due to the centralisation or standardisation of expenses. Gershenson et al. (2015) and Orlandi et al. (2016) qualitatively assess the risks of off-grid electrification projects (in particular solar PV) as well as the transaction costs, and propose possible ways to structure pooling facilities. Davidsen et al. (2015) propose a strategy in which a pooling facility creates portfolios of mini-grid assets with telecom towers as base loads, and sells asset-backed securities to capital market investors.

From the review of the literature, studies indicate that risks that are specific to projects and geographic locations can be addressed to some extent by diversification across multiple projects in different locations (Malhotra et al 2017). Yet these studies do not provide a systematic and quantitative assessment of investment risks and how diversification individually acts on each risk and the overall project financing cost (Malhotra et al 2017). Furthermore, in order to make use of imperfect risk correlations for project pooling and diversification of risks, it is important to understand the causes and mechanisms for correlation between risks for electrification projects located at different distances from each other. Thus there is a lack of studies conducting a systematic assessment of all possible risks, their respective contributions to financing cost (Schmidt, 2014), as well as correlations between risks for projects located in different geographies. This thesis seeks to address this gap address with particular focus on SHP.

According to Power Advisory report, the key to the success of such financing structures is the upfront planning and coordination required to ensure that the projects are structured identically and occur within a very close timeframe. Aggregation, however, is still in the infancy and all the problems related to project cycle, baseline problems, need for fast tracking by the national authorities, lack of institutional and expert capacity, and high transaction cost may still barriers. However, development of local expertise in small renewable energy projects will help bring transaction costs down substantially, and it can be more expected in case of aggregation (Power Advisory, 2012).

Table 9: Summary of aggregation impact on Small Scale RE (SHP) investments

Impact of project aggregation	**Literature Review**
Reduction in investment risk.	Davidsen et al., (2015); Gershenson et al., (2015) and Orlandi et al., (2016); Shakya and Byrnes (2017).
The transaction and due diligence costs	Davidsen et al., (2015); Gershenson et al., (2015) and Orlandi et al., (2016); Shakya and Byrnes (2017), (World Bank and Climate Investment Funds, n.d).
Financing capability of DFIs	IRENA, (2016).
Investment volumes are increased	Davidsen et al., (2015); Gershenson et al., 2015 and Orlandi et al., 2016; Shakya and Byrnes (2017)
Market barriers such as policy, tax and regulatory issues	Shakya and Byrnes (2017), WBCSD, (2017).
Access to financing sources and investors	IRENA, (2016).

Source: Author compilation from literature review

As shown by the literature review, aggregation of electrification projects in developing countries can potentially decrease unique and market risks depending on the extent of spatial diversification (Malhotra et al 2017). However, not many academic studies investigate portfolio diversification in this context of distributed energy with focus on SHP mini grids.

2.2 DATA COLLECTION AND DATA ANALYSIS

The study began with literature survey or desk research to collate background information on key barriers to financing SHP in Kenya and the role of aggregation in de-risking decentralised renewable energy investments. This was followed with primary research, which included interviews, site visits and a stakeholder consultations to find more information. A good range of market participants (developers, financiers, and finance and policy experts) with experience or involvement in the development of renewable energy projects in Kenya across the world and with SHP in their portfolio were interviewed. The choice of the respondents Most of the interviews were conducted face to face, others through telephone and Skype. Semi structured interview questions were used which were focussing on the financial barriers and the role of aggregation on addressing the barriers. At least one member of the project team participated in most of the interviews. Tables 7 and 8 below show the overview of the research methodology and the list of persons interviewed respectively.

Table 10: Overview of Research Methodology

Secondary Research	Primary research	Synthesising the Report
Conducted literature review on investment barriers risks to SHP development and the role of aggregation in de-risking rural electrification investments. Compiled a stakeholder list for one-on-one interactions	Designed questionnaires for stakeholder interviews – different for developers, financiers, investment enabling institutions organisations. Telephonic; skype and one on-one interviews. Field/site visits to study the projects closely. The insights obtained from field study were valuable in barrier identification.	Weave in findings from the literature review, interviews, field visits and stakeholder consultations into the thesis report

Source: Compiled by author

Table 11: List of interviewees

Type	Name of Interviewee	Name of Organisation	Position of Interviewee
Developers	Samuel Mwangi	Virunga Power	Snr Projects Development Manager
	Egadwa Mudoga	KTDA SHPs	Manager - Corporate Affairs

	Altaz Kassam	responsAbility Investments AG	Senior Associate
	Rosemary Mugo	Rupingazi Hydropower	Director
Fund Managers/Financiers	Axel Luizy	InfraCo Africa	Business Development Manager
	Eugene Obiero	Camco Clean Energy	Snr Project Manager
	Isaac Mwathi	Hivos	Programme Development Manager
Donor Organisations/NGOs	David Mwangi	World Bank	Energy Consultant
	Victor Gathogo	SNV	Renewable Energy Advisor
Policy and Financial Experts	Clarice Wambua	Kieti Advocates LLP	Partner
	Susan Mwaniki	PowerGen Renewable Energy	Finance Manager
	Crystal Adero Okudo	GreenMax Capital Advisor	Transaction Advisory Associate
Non-Governmental organisations	Clare Shakya	IIED	Climate change group director, IIED
Governmental Organisations	Peter Kinuthia	African Union Comission	Senior Energy Advisor
	Joseph Oketch	Energy Regulatory Commission, Kenya	Director Electricity

Source: Author’s compilation

2.3 RESULTS AND INTERPRETATION OF RESULTS

This section attempts to answer the research questions:

1. What are the major financial barriers and risks for SHP projects?
2. Can project aggregation strategy be used to reduce financial in SHP projects?
3. What is the effect of aggregation on a SHP portfolio of SHPs Projects?

2.3.1 The major financial barriers and risks for SHP projects based on expert interviews

The interview results broadly revealed three categories of barriers as listed below:

a) Lack of sufficient capacity and skills and
b) Financial-related barriers.
c) Small size of projects

Lack of sufficient capacity and skills by developers and local banks

The interview partners indicated that among many private sector parties in Kenya, renewable energy generation projects in general are comparatively new. However, for small hydropower projects have seen limited private development. Only after the introduction of feed-in tariffs in 2008 has interest in small scale IPPs grown. Before this introduction the vast majority of small scale projects were designed, engineered, and financed by the public generator Kenya Electricity Generating Company (KENGEN). As a result, there is a lack of familiarity with technical and financial aspects of developing and financing small scale renewable energy projects. How lack of sufficient knowledge and skills impacts on SHP is considered by looking at developers and financiers (local banks).

Project developers: The technical capacity of the developers is found to vary significantly amongst those interviewed. Developers supported or sponsored by large established organisations like UNIDO and engineering companies did not mention lack of expertise and stated that procuring the required engineering did not pose a problem for them. For the other developers however, for whom the majority were new to the sector, securing the required technical expertise for specific tasks was clearly an issue. All projects without exception had experienced time and cost overruns, which in some cases were significant. This shows a tendency of the developers to underestimate the difficulty and complexity of developing small scale renewable energy projects. Many of the developers interviewed stated that detailed engineering designs were changed over the course of the construction as a result of onsite conditions encountered (mostly civil components). For small hydro facilities, landslides triggered by excavation works were also a common problem experienced by developers. This shows that the level of detail of feasibility studies is likely lower than it should be, and that subsequent technical due diligence procedures are not given sufficient priority at project preparation stage.

Time overruns are of most concern for developers, because of the effect this has on the project’s cash flow and liquidity. Loans from banks are disbursed based on progress in the field and a squeeze on liquidity can result when delays occur while monthly operational costs continue to accrue. Developers reported this as one of the most critical obstacles they faced. To compound this situation there is a clear lack of awareness of the importance of putting in place proper technical due diligence measures (external consultant) to assess and scrutinize designs at planning stage. The reason for neglecting the step of technical due diligence is more due to lack of awareness rather than economic considerations (the cost of a consultant to carry out this work is largely irrelevant in the context of the overall project cost). Engineering services for project preparation is almost exclusively procured locally, with few exceptions where international expertise had been mobilized to carry out technical due diligence. Equipment is exclusively imported, predominantly from China and to a lesser extent India and Japan, particularly for larger scale projects. There is no locally manufactured equipment.

Financial institutions/Funders: Both developers and financiers expressed that the initial challenges associated with financing decentralised projects in Kenya (of which SHP is part) and some of the development difficulties were attributable to the more limited experience of local developers and smaller project sizes of the initial projects. This made it more difficult to realize economies of scale and some of the inexperienced developers structured projects in ways that made securing financing more difficult.

Several interviewees also noted that, in their experience, small developers are more likely to have less development experience, to be more prone to overlook key risk factors or to make other mistakes in project structure, and in general to require more assistance from the lenders. This experience is not surprising as project developers are keenly focused on the success rate of their projects, and experienced developers will chase larger projects which offer larger returns for the same level of development effort as a smaller project. This experience reinforces the banks' reluctance to undertake relationships with such smaller developers. Further, small developers will have more difficulty accessing capital for such projects. For example, bank applications for smaller loans (say, up to $10 million) would be made to the local or regional commercial loan departments, which will not have expertise in lending to renewable developers and would not have ready access to such expertise from elsewhere in the bank. In addition, the due diligence and structuring costs can overwhelm the economics of a smaller project. Further, bank processes are not optimized for the needs of small renewable energy projects and more importantly the risk they represent. This adds significant costs to the project.

Many of the interviewees pointed out that the conditions for financing renewable projects are quite different for small projects than for large projects, especially if the developer is also small and relatively inexperienced.

Finance experts interviewed also mentioned that bank loan officers have limited experience in financing renewable projects or projects with similar characteristics. Their capacity to accurately assess renewable energy business proposals and financial viability of proposed projects is limited. The lack of human resources to deal with technical studies on the potential for energy production, characteristics of locations, the necessary construction works, and particularities of different technologies is a big barrier.

This corroborate with Wolff et al. (2016) study which mentions that bankers have a limited understanding of RE technologies and are therefore unwilling to approve financing of RE projects.

Financial-related Barriers

A barrier commonly challenge posed by the interviewees especially the developers is lack of equity finance. This lack of equity capital means that project sponsors are often unable to cover the costs of development activities without external assistance. The lack of equity capital also increases the dependence on project financing, as sponsors are unable to provide collateral for loans or to put up large amounts of equity. As a result, loans have to be secured against future cash flows, given the absence of alternatives. Also mentioned is long-term financing is often difficult to obtain. Some of the investors provide unsecured loans that these are provided only in short term, in most cases for a term of less than 5 years. Long-term financing is heavily dependent on investors looking for long-term assets to match the profile of their liabilities— such as pension funds. No example is found in Kenya of such fund investing in SHPs.

Developers interviewed cited mobilizing finance as the main hurdle they faced in developing their projects. They mention there is mismatch between the financial instruments offered by financial institutions and the financing needs of small renewable energy project developers; in particular with respect to the availability of adequate debt financing, equity capital, and risk mitigation instruments. There is a mismatch also in expectation of investors (for example, social impact investors/venture debt/venture capital investors) and developers' financing needs with investors looking at higher returns than what developers are capable of delivering. For instance, developers seek risk capital from investors while most investors seek more installations and sales prior to investment or within a short period after the provision of capital.

Small project size

Small project sizes were frequently cited by investors, financiers and developers as a barrier to investment for such projects. In discussions with debt and equity capital providers, there was a common comment that it is difficult to provide non-recourse asset level financing for projects less than $50 million in size. The major financial institutions, banks and insurance companies, consistently said that they are generally not interested in projects where the total financing is below $50 million, though some said they might consider projects as small as $30 million. The reason for this size threshold is that these institutions have finite resources to perform the required analysis and due diligence for projects and it costs them almost as much to do this for small projects as for large ones. Given the corporate expectation that they will lend a certain amount, they cannot afford to spend these limited resources on small projects. Investing in utility-scale projects, therefore, offer better returns from loans and lower transaction costs when compared with funding large numbers of small decentralised projects. As a result, they often struggle to attract funding from larger financiers. These small systems also face the problem of lack of local demand in rural areas, leading to underutilized assets and worsening financial returns and attractiveness to financiers.

Developers and investors interviewed estimate the due diligence and structuring costs for a typical renewable power project financing can easily reach $1 to $2 million in total transaction costs, and a significant portion of the transaction costs is fixed regardless of the size of the project. Examples of these fixed costs include:

- the legal costs of the investor and the debt provider;
- independent engineer's report
- resource assessment;
- environmental review;
- interconnection review; and
- Financing and advisory fees.

Projects that do not have the required due diligence will be unable to obtain project financing, and would require additional credit support from a third party source (equity provider, other assets or the government) to finance the project.

Investors interviewed also cited shortage of proven business models and good quality business plans as a barrier. Funders are looking for proven business models and well-developed business plans, a clear understanding of risks and returns, and an indication that risks are being managed. This confirms that market pioneers on energy access, many providers still need to prove their business model and to demonstrate scalability and replicability, which takes time (Rai, Best and Soanes, 2016).

Other barriers

Interviews revealed that in the current financing environment in Kenya, lenders and investors are reluctant to finance SHP projects which don't have a long-term power purchase agreement (PPA) which provides revenue certainty for project output. Without a PPA, the project proponent faces the risks of uncertain future revenues. Smaller projects have difficulty attracting capital and will suffer from lower returns unless the PPA price offers a sufficiently high premium over the PPA price for larger utility-scale projects. PPAs in Kenya typically have a term of 20 years. The interviews revealed also that financiers are interested in the quality of the power purchase agreement (PPA), the creditworthiness of the off-taker, the compliance to environmental and social regulations, the experience and technical capability of the developer and the development team, and the financial stability of the developer. They want to know that risks are identified, appropriate measures to mitigate them are put in place, and assigned to appropriate parties (i.e., the party that is best able to manage these risks). Most developers find it difficult to comply with these requirements and to access the risk mitigation instruments.

Further, it was also revealed the electricity market conditions are such that few utilities sign power purchase agreements for terms up to or beyond 20 years, which is well short of the 50-year-plus operational life of hydropower assets. The resulting lack of guaranteed revenue over the long life of a hydropower project hinders the availability of conventional (i.e., commercial bank) financing sources. This is explained by the fact that conventional energy sector investors will not provide lower cost debt financing beyond the life of guaranteed revenue streams.

Amongst interviewed investors, all reported that investments in their small-scale renewables portfolio were experiencing time and cost overruns, some of these significant. SHPs developers and IPPs in general face financing risks associated with changes in financial market conditions during the period from finalization and acceptance of a contract pricing proposal until the project is financed. These financial and economic risks include foreign exchange rate variability where significant changes in foreign exchange rates (e.g., depreciation of the Kenyan Shilling) can increase the effective cost of equipment contracts that are priced in a foreign currency (US$ or Euros).

Further, interviews revealed that financing costs are a major component of the cost of renewable energy and a bad financing package can make many good projects, unviable. Because renewable energy projects have high investment needs, they are more sensitive to financing costs than conventional generation.

Developers and finance experts indicated that local banking sectors may not consider SHPs to be an attractive market segment, and thus do not provide loan products tailored to the needs of these projects. Traditional loan products (e.g. those tailored to the needs of other infrastructure projects), have very different financial characteristics and are not effective vehicles for financing of small renewable energy projects (SREP). SREP plants are not perceived as infrastructure investments and are unable to avail the benefit of low-cost loans charged for usual infrastructure projects.

Finance experts also mentioned high equity or collateral requirements as a key barrier to SHP financed using a corporate finance approach. They indicate that this approach often require 40-50% equity and at times even more.

Interviewed lenders cited the unpredictable nature of renewable energy projects that rely on natural resources as being the main factor increasing the perceived risk from their perspective. For example, for small hydropower, fluctuating stream flows make accurate future revenue calculation and subsequent financial analysis more speculative and therefore more risky in the eyes of the banks. Without high-quality assessments water resources, the risks of SHP projects are greatly magnified, and private financing will be correspondingly harder to obtain. Resource assessments for hydro in particular need to be available on a site-specific basis.

Other significant market access risks for renewable Independent Power Producers (IPP) projects in Kenya are the potential for transmission constraints that cause the project to be constrained down or off. A critical determinant of the magnitude of this risk is the transmission service for which the IPP contracts and how this risk is addressed in the PPA. For example, the 300MW wind project in Kenya has not come online since its completion in 2017 and this leads to a lot of revenue loss. Another market access risk that IPPs have to manage is the uncertainty associated with interconnection costs that they will have to bear.

There is general consensus from the SHPs was that local/county governments were constructive and supportive of their initiatives and whilst the administrative process was sometimes overly cumbersome and time consuming, overall they did not perceive this as being a major obstacle.

The developers mentioned that one of the most complex technical aspect of project preparation is that of land acquisition particularly where it involves individuals rather than formal institutions (such as government). Where land is state owned, local government are entitled to issue long-term lease concessions to developers. These are usually for 20-25 years and extendable at the end of the lease term. Where plans encroach into areas of protected forest, approval from the respective ministry is required prior to concessions being awarded. One IPP had even successfully negotiated permission to construct a project within a National Park area highlighting the fact that given the right approach is adopted, obtaining the necessary permits etc. can be achieved even in difficult environments. The developers interviewed note that although often lengthy, land acquisition procedures and costs via government authorities are at least relatively predictable. The more complex and unpredictable land acquisition arrangements are usually where privately owned land is involved. Private landowners often attempt to maximise their return by demanding unrealistic and irrational sums for land if they know it has a strategic value for the developer. This is confirmed by (Hayton and Nugraha 2013) who observes that this happens even where land is non-productive and of relatively low value.

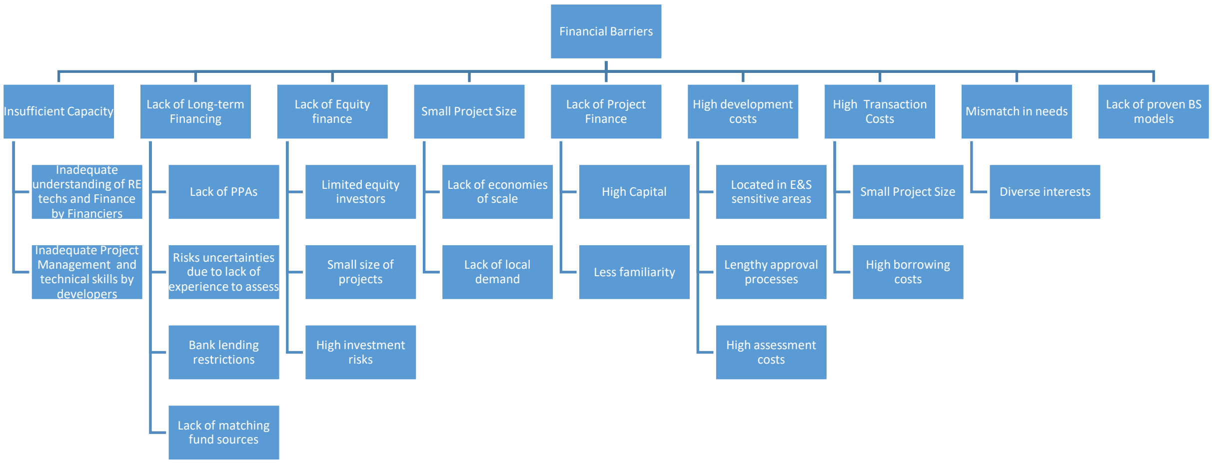
Asked about the financing conditions of the SHPs, there respondents said that this is dependent on the individual project, the financing institution, and the general conditions in the bank market. For this reason, any discussion of financing terms is rather general. In general, 60 % to 90 % of the total cost can be provided as debt. The level of debt that is acceptable to the lender depends on how the loan is secured. The respondents also postulated that for limited-recourse arrangements several additional elements were mentioned:

- Financiers require an up-front fee for covering the arrangement expenses of financing.
- A number of conditions must be met before the loan can be drawn. Normally this requires that all contracts be to the bank’s satisfaction, that all permits are in place, the existence of a favourable review from an independent technical consultant, all insurances in place etc.
- The financiers also require all fees to external legal and technical advisers to be paid by the developer.

To summarize the results of the interviews, it is clear that lack of equity and long term financing, the small size of individual projects make SHP unattractive to investors who also perceive them to be more risky investments. High transaction costs and low sales realizations also deter project developers. The financial barriers of different type are predominant including the lack of knowledge of the developers and local banks. The respondents clearly stated that the most desirable projects from the financier's viewpoint are not small projects.

Figure 13 below summarises the financial barriers based on the research framework.

Figure 13: Results of financial barriers based on research framework



The respondents also gave their insights on aggregation as one way to address these challenges as presented below.

2.3.2 Role of aggregation in addressing Major investment barriers and risks for SHP projects in Kenya, challenges and policy implications

In many cases, SHP will have to compete for funding in the private finance market, where the project is judged on the basis of its economic viability. In order to promote small hydro it is important to look for ways of reducing the costs of development. The respondents were asked on how aggregation can contribute one of such ways.

As mentioned above, debt and equity capital providers, tend not to lend to smaller projects as it would not meet their minimum size threshold ($30 to $50 million). For these lenders to lend to a project, the interviewees agree that the projects would need to be aggregated to meet the minimum size threshold.

The interviewees observed that bundling/aggregating of SHPs projects for scaling finance purposes can help pool the risks, reduces the default risk and transaction costs besides taking advantage of simplified procedures, involvement of several entrepreneurs and favourable environment. However, they point that attention may need to be paid to address issues relating to building of the bundles - homogeneity, redundancy risk, time scaling, size and ownership. Legal and taxation issues may also be relevant. It is commonly noted that aggregation has potential to make a difference to SHP projects provided that issues of capacity building, and development of information and databases are well addressed. Some interviewees warned that aggregation may add another dimension to the risk. The aggregator has a very limited control over various projects in the bundle; for example in community projects involving various mini hydro plants or biogas plants. Bundle may contain many projects, which in turn may have different parties involved in implementation and the financing, and the bundler may have little control over the success of the projects.

The interviews generally argue that the costs of identifying and negotiating trades, securing transmission, and scheduling them on the system do not decrease proportionately with the size of the trade. Therefore, for smaller sellers, these transactions costs are a relatively high which a barrier to trade for small developers has already discussed above. These barriers could be mitigated by the creation of an aggregator which would negotiate trades, secure transmission and schedule the electricity for a number of smaller developers. The aggregator could thereby spread the transaction costs over a larger volume of trade, making the trade feasible.

Also highlighted in the interview is that if the size of the projects in a bundle is large, failure of even a few constituents may severely impact the quantum. On the other hand if it is small, despite the diversification of risk that comes with a portfolio of projects, the redundancy risks for small-scale projects may be high. From the point of view of applicant, it is argued that it may also make sense not to develop too large bundles because implementation of large project bundle consisting of many individual projects in possibly different locations would require enormous efforts as regards coordination of implementation of individual projects within the bundle. Aggregators will need to devise an appropriate model for their operation and will need to prove that actually aggregation lead to increased return on investment.

Benefits of aggregation which appeared in the interview is that it can help cover project management and development skills deficiencies. This is because aggregation is able to attract to bring multidisciplinary development team at different experience levels. Each project involves a number of parties: developer, engineer, contractor, and various equipment suppliers, power purchaser and lender. For each project a series of contractual arrangements is needed to distribute responsibility, risk and revenue among all the parties involved. The cost and effort involved prohibits limited-recourse project financing of the smallest projects and adds considerably to the cost of larger projects. Thus, permanent co-operation among important parties in the development will have several cost-saving effects. The parties will get to know each other better, which makes the arrangements run more smoothly.

Another factor highlighted is that aggregation will provide more lobby power i.e. collective planning and procurement of equipment, contract negotiations reduces costs and saves time and money. This is postulated by Mr Obiero of Camco Clean Energy (renewable energy funding institution) who explains that aggregation can help reduce transition costs to about half and even less because leverage benefits, for instance, benefits of bulk discounts on EPC, engineering studies, pre-feasibility, feasibility studies etc, to the approximate tune of 10%.

Some respondents asserted that aggregation projects can benefit from the sale of Certified Emissions Reductions (CERs) through the Clean Development Mechanism (CDM) since it is widely recognized source of revenue and can help reduce their costs relative to conventional technologies (in effect acting as a form of subsidy). They however warn that unless some way be found to mobilize this potential revenue source up front, it is unlikely to help at the time of project development and implementation. There are significant uncertainties over the timing and amounts of revenues from the sale of CERs especially in the current carbon market. Thus aggregation with the view of benefiting from CDM may not be very effective.

Regarding the models or approach to aggregation, Mr Obiero suggests that tender design system by the government especially in a river regime that can supports cascade of small hydropower projects. In such a case legal frameworks should be put in place to ensure same tariffs, the developers work together and to help in acquiring land.

According to Mr Samuel Mwangi of Virunga Power, small hydropower developer in Eastern Africa, cited that one way to achieve aggregation benefits is to a portfolio of projects would enhance the degree of firmness of the energy offered and reduce the effective cost of transmission and the risks of imbalance penalties. This is what they are considering in their Tanzania portfolio. He asserts that having a portfolio of projects held receiving discounts for consultants.

Barriers or challenges that come with aggregation

Despite the potential benefits of aggregation, there are some challenges which were highlighted by the interviewees asked to give their opinion on challenges that can come with aggregation. Some of the challenges highlight are:

1. Bundling or aggregating of small-scale projects where there is either a large number of project stakeholders involved, for example developers, lenders manufacturers, dealers and distributors will be far more complex contractually as each will depend on their own project financing and will require a separate sharing agreements, which may include the sharing of possibly transaction costs, monitoring responsibilities and risks.
2. Lack of experience in aggregation may lead to high costs to structure and monitor aggregation transactions, especially for first-of-a-kind transactions in the country
3. There will be resistance to change and maintaining the status quo. There are so many different parts, nature of the projects so different, the terrain so different, and resource so different
4. Furthermore, the project developers will still run some project specific risks.

Key points in successful financing

The respondents were also asked about the advice they could to give to SHP stakeholders to help scale up finance in these projects. The following points were mentioned:

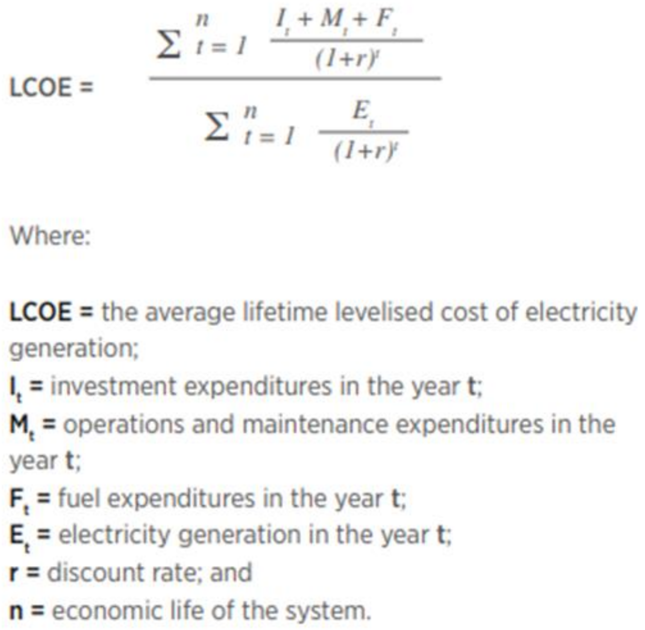
1. They advised that the stakeholders especially the developers and local banks need to understand project finance and to develop proper project management and development skills.
2. The developers should seek professional advice at an early stage in order to determine how to arrange the financing.
3. Lenders wish to see evidence of the water flow available for power production. Therefore reliable assessment of the water flow should start as early as possible, at a location close to the likely intake site.
4. Carry out careful structuring of the contractual arrangements and analyse the project risks and develop a plan for apportioning these risks.
5. Pay early attention to planning and consents and prepare a list checklist of all the permits necessary for the development must be drawn up, and a plan developed as to how these permits and consents will be obtained.
6. Develop comprehensive financial model of the project economy is important information to be provided to the lenders focussing project cash flow, conservative assumptions and a sensitivity analysis that demonstrates the viability of the project for a range of scenarios.

2.3.3 Impact of aggregation on transaction costs: An example using LCOE.

This example describes the derivation of the LCOE for fiction SHP projects: (5MW, 3W, 1MW, 9MW (the first three combined but not bundled or aggregated) and 9 MW (the first three bundled together or aggregated). The projects are not real and are for purposes of illustrations, using the following variables shown in table 10 (assumptions are based on literature review, expert interviews and personal judgement) as inputs in order to show the impact of aggregation on LCOE. See appendix B for the models and estimates.

The Levelized cost of electricity (LCOE) is the price of electricity required for a project where revenues would equal costs, including making a return on the capital invested equal to the discount rate. The LCOE is defined as the NPV of all costs divided by the NPV of electricity generation. In essence, the LCOE is the constant price per unit of energy that allows the investment to just break even over the period of analysis. An electricity price above this would yield a greater return on capital, while a price below it would yielder a lower return on capital, or even a loss. Broadly speaking, the lower the LCOE, the more profitable the project will be (FICHTNER (n.d).

The formula used for calculating the LCOE of renewable energy technologies is (IRENA, 2012):



$$\text{LCOE} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Where:

LCOE = the average lifetime levelised cost of electricity generation;
I_t = investment expenditures in the year **t**;
M_t = operations and maintenance expenditures in the year **t**;
F_t = fuel expenditures in the year **t**;
E_t = electricity generation in the year **t**;
r = discount rate; and
n = economic life of the system.

Based on IRENA (2012) cost analysis for small hydro power plants (provided in section 2.1.1.3), investment costs for Small hydro projects in Africa ranges between 2000 and 4000 US$/KW. Taking average, 3000 US$/kW is used. According to FICHTNER (n.d), hydropower plants can have an operating lifespan of up to 50 years or more, which is quite long compared to thermal power plants. Typically economic and financial analyses assume a lifespan of 30–40 years. Taking average, 35 years is used. Capacity factors of run-of-river hydropower plants should range from 40 to 70 percent, and 20 to 40 percent for storage HPPs, depending on installed capacity. Taking average for Run-off River, 55 percent is used. From interview results, aggregation can reduce project development and engineering, procurement and construction costs by approximately 10%, while O%M costs by approximately 5%.

Table 12: Parameters of LCOE calculation

Parameter	5 MW	3 MW	1 MW	9 MW (Not aggregated)	Aggregated (9MW)
Annual power generation (kWh/year)	24090 000	14 454 000	4818 000	43 362 000	43 362 000
****Investment costs (US$)**	15000 000	10 000 000	3500 000	28 500 000	24300000
O&M costs (US$)	375 000	250 000	87 500	712 000	641 250
Lifespan	35	35	35	35	35

Discount rate (%)	10	10	10	10	10
Capacity factor (%)	55	55	55	55	55
LCOE (US$/kWh)	0.0726	0.0807	0.0847	0.0766	0.0660

Source: Compilation

*Note that this illustration doesn't cover all the costs but rather for comparability purposes and the estimates are based on the interview results with developers who attest that aggregation can reduce the transaction costs by almost half.

** It is commonly understood that the smaller the capacity the higher the investment cost per kW.

From the above results, aggregated projects produce the lowest LCOE and thus would greater return on capital than when the projects handled separately.

Limitations of the study

The thesis relied on interviews for data collection. Most interviewees were reluctant to provide detailed costing information on the basis of confidentiality. Thus the cost estimations developed in this thesis clearly has its shortcomings, but may be developed further to a more accurate one to analyse the impact of aggregation on returns. On the other hand, there were difficulties associated with longer time requirements and arranging an appropriate time with perspective respondents to conduct interviews.

PART III

3. CONCLUSIONS AND POLICY RECOMMENDATIONS

3.1 Conclusions and future research

3.1.1 Conclusions

This study identifies financial barriers to small hydropower projects as associated with Lack of sufficient capacity and skills by Stakeholders, Small projects size and Financial-related barriers eg lack of equity investors, high transaction costs etc. It concludes that financing structures which aggregate smaller projects under one master facility can certainly take advantage of economies of scale and help address risks and barriers especially in early project development and therefore is able to increase the appetite of private investors in these projects.

It is, however, a first attempt to qualitatively estimate the potential role of aggregation in de-risking SHP investments in Kenya, and thus will not be free from challenges.

3.1.2 Future Research

- While this study has focused on same technology, future studies can investigate impact different technologies, business models, and project developers.
- Further, future research could guide policymakers about the specific policy instruments and designs required to enable aggregation work well in Kenyan context.
- This thesis does not address the possible issues with the current FiT programme in supporting the SHP development and this an area that needs to be explored.

3.2 Policy and general recommendations

1. **Formation of an aggregator**. As independent power producers continue to look to develop SHPs in Kenya, they could profit from the presence of a renewable energy aggregator. In the existing industry set-up in Kenya, a number of organisations may take up role of aggregator. Of these project developers e.g. Virunga Power (with a portfolio of SHPs); financial institutions and government agencies like Electricity Regulatory Commission (ERC) or Rural Electrification Authority (REA) have the potential to operate as aggregators.
2. **Development of policy and regulatory environment that favour aggregation** and further development of SHP e.g.
    - (a) Promotion common SHP industry due diligence metrics e.g. template contracts, performance metrics, transaction structures. This will promote the standardisation essential to aggregation.
    - (b) Simplifying legislation procedures to ensure laws and regulations are understandable for all the parties involved in a project so that inexperienced developers can easily understand it. This would not obstruct project development.

3. **Capacity building** to institutional lenders (local banks), developers and investors to understand renewable energy project financing, support for the strengthening of financial intermediaries and bundling organizations.

Finally, wide-spread deployment of SHP energy measures will be critical to achieving the Sustainable Energy for All (SE4All) objectives, supporting Kenya in achieving her Sustainable Development Goals, and contributing to country’s INDCs under the UNFCCC. It is hoped that this thesis will help improve the confidence of the investors in the SHP and help the developers to learn more on financing strategies, and to create more awareness about aggregation in SHPs and decentralised renewable energy development in general in the country. Moreover, it will provide insights for policymakers in promoting and facilitating the ability of private sector investors to aggregate small-scale electrification investments.

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APPENDICES

Appendix A: Interview Questions

INTERVIEW QUESTIONS FOR DEVELOPERS AND PROMOTERS

Greetings!

My name is Victor Thomas Otieno. I am MSc Energy Policy student at Pan African University Institute of Water and Energy Sciences (PAUWES), Tlemcen, Algeria. The purpose of this interview is to aid me in my master thesis research on the topic: Overcoming Financial Barriers to Small Hydro Development in Kenya: The role of aggregation in De-risking SHP development and its policy implications.

Your responses are voluntary and will be confidential. Responses will not be identified by individual. All responses will be compiled together and analysed as a group.

If you have any questions, concerns or your rights as a research subject you may contact Malik Bendimerad Master Thesis Consultant Pan African University Institute of Water and Energy Sciences (PAUWES), Tlemcen, Algeria at rm.merad@gmail.com to discuss them.

Company name:-____
Name of respondent: ______________________________________
Title of respondent: ____
Type of Company: ____
Nature/Portfolio of the company: ____

Abstract/Concept

Small Hydro Power (SHP) generation is an important way to reduce the greenhouse gases and pollutant emissions, and produce electricity to rural areas. To further the dissemination of decentralized renewable energy in order to address climate change and access to energy in developing countries, finance is needed. The Sustainable Energy for All (SEforALL) platform recommends an annual investment of USD 50 billion to universal access to energy by 2030. Private investment is posed to play a major role in meeting this target. However, Small hydropower plants (SHPs), like other decentralized renewable energy, are not attractive to investors due to underlying market barriers and a perception of high risk that constrain the development and financing of these projects. This thesis seeks to scale up financing of SHP projects for achieving decentralised rural electrification by considering the potential of aggregation in de-risking investments within a portfolio of SHP projects.

Finance and risks/barriers/challenges

1. Hydropower is one of the energy projects adversely affected by climate change especially drought. Why SHP?

2. Which geographies are you focusing on?

3. As far as SHP is concerned, do you have data on the possibilities of draught in the area the areas of your operation?
4. Which rural activities benefit directly from your electrification projects?
5. Who are the key stakeholders and what are their interest in this project?
6. As stated in the abstract above, SHPs like other decentralized renewable energy, are not attractive to investors due to underlying barriers and a perception of high risk that constrain the development and financing of these projects. Which risks/barriers affect your ability to attract finance?
7. How have you managed the above the mentioned risks in your projects?
8. In your view how can they be overcome?
9. As part of the barriers, have any of the SHP projects faced opposition from the local communities? Why?
10. Which institutions provide (d) funds for your project? Are they local or international?
11. What is their approach to financing this type of projects and expectation of ROI (return on Investment)?
12. What are (were) the main constraints experienced in sourcing for the finance this project (s)?
13. Which financial instruments do you prefer? Why?
14. Are the commercial banks in Kenya willing to finance SHP projects? What are their terms? Which IRR is considered attractive?
15. What are the bank loans secured used for?

16. What do your investors look for in order to finance your projects?

17. What is the lending terms picture? Please fill in the below.

Name	Reported Values
Interest rate	
Loan term	
Grace period	
Maximum loan to equity ratio 70	
Cash sweep	

Aggregation

1. How does the scale or size of your projects a worry to you?
2. Aggregation or bundling together of small hydropower projects to reach a scale where they become attractive to large investors is a strategy that that can help reduce risks and improve access to financing of SHP projects and DRE in general. Do you agree with this statement or you have a different perspective?
3. Investors are concerned about the high risk profiles of decentralised renewable energy projects? What leads to higher actual and perceived risk for decentralised renewable energy finance?
4. Can aggregation help reduce these risks or help overcoming these challenges leading to these risks?
5. From the challenges facing renewable energy financing can aggregating finance overcome these challenges? How?

6. Which stakeholders should be involved in aggregation? What are their roles and how do they benefit?
7. How does aggregation work and how can the concept be applied effectively in decentralised renewable energy, especially SHP?
8. How do you think aggregation be designed to achieve max benefit?
9. What are the policy implications come with aggregation? What policies make aggregation possible?
10. What might some of the challenges in implementing aggregation in Kenya?
11. In your view, can aggregation work in the Kenya's decentralised renewable energy enevironment? What can be your role in realizing this?
Summary
From your experience, what advise can you give to SHPs stakeholders to help scale up finance flow to these projects?

INTERVIEW QUESTIONS FOR INVESTORS/FINANCIERS
Greetings!
My name is Victor Thomas Otieno. I am MSc Energy Policy student at Pan African University Institute of Water and Energy Sciences (PAUWES), Tlemcen, Algeria. The purpose of this interview is to aid me in my master thesis research on the topic: Overcoming Financial Barriers to Small Hydro Development in Kenya: The role of aggregation in De-risking SHP development and policy implications. Your responses are voluntary and will be confidential. Responses will not be identified by individual. All responses will be compiled together and analysed as a group.

If you have any questions, concerns or your rights as a research subject you may contact Malik Bendimerad Master Thesis Consultant Pan African University Institute of Water and Energy Sciences (PAUWES), Tlemcen, Algeria at rm.merad@gmail.com to discuss them.

Company name:-____

Name of respondent: ______________________________________

Title of respondent: ____

Type of Company: ____

Nature/Portfolio of the company: ____

Abstract/Concept

Small Hydro Power (SHP) generation is an important way to reduce the greenhouse gases and pollutant emissions, and produce electricity to rural areas. However, Small hydropower plants (SHPs), like other decentralized renewable energy, are not attractive to investors due to underlying market barriers, a perception of high risk and small size that constrain the development and financing of these projects. To further the dissemination of decentralized renewable energy in order to address climate change and access to energy in developing countries, finance is needed. This thesis seeks to scale up financing of SHP mini-grids projects for achieving decentralised rural electrification by considering the potential of aggregation in de-risking investments in SHP projects.

Finance and risks/barriers/challenges

1. Which kind financing facility do you run? How is it different from others? What are your funding sources?

Early stage debt, unsecured. Not very common. Raer to get debt very early when the concept is

2. Have you ever been working on SHP besides other renewables?
3. What is your approach to financing this type of projects and expectation of ROI (return on Investment)?
4. Which financial instruments do your developers prefer you could use? Why?
5. What do you look for from your developers in order to finance their projects?
6. Which risks affect the ability of investors/financial institutions to finance SHP?
7. Which tools do they use to mitigate them? What could developers and investors do to overcome this risks?

8. How does the scale or size of DRE projects a worry to you?
9. Can aggregation help reduce these risks or help overcoming these challenges leading to these risks?
10. From the challenges facing renewable energy financing can aggregating finance overcome these challenges? How?
11. How does aggregation work and how can the concept be applied effectively in decentralised renewable energy, especially SHP?
12. What are the policy implications come with aggregation? What policies make aggregation possible?
13. What might some of the challenges in implementing aggregation in Kenya?
Summary
From your experience, what advise can you give to SHPs stakeholders to help scale up finance flow to these projects?

INTERVIEW QUESTION FOR FINANCE AND POLICY EXPERTS

Greetings!

My name is Victor Thomas Otieno. I am MSc Energy Policy student at Pan African University Institute of Water and Energy Sciences (PAUWES), Tlemcen, Algeria. The purpose of this interview is to aid me in my master thesis research on the topic: Overcoming Financial Barriers to Small Hydro Development in Kenya: The role of aggregation in De-risking SHP development and policy implications.

Your responses are voluntary and will be confidential. Responses will not be identified by individual. All responses will be compiled together and analysed as a group.

If you have any questions or concerns or your rights as a research subject you may contact Malik Bendimerad, Master Thesis Consultant Pan African University Institute of Water and Energy Sciences (PAUWES), Tlemcen, Algeria at rm.merad@gmail.com to discuss them.

Company name:-____

Name of respondent: ______________________________________

Title of respondent: ____

Type of Company: ____

Nature/Portfolio of the company: ____

Abstract/Concept

Small Hydro Power (SHP) generation is an important way to reduce the greenhouse gases and pollutant emissions, and produce electricity to rural areas. To further the dissemination of decentralized renewable energy in order to address climate change and access to energy in developing countries, finance is needed. The Sustainable Energy for All (SEforALL) platform recommends an annual investment of USD 50 billion to universal access to energy by 2030. Private investment is posed to play a major role in meeting this target. However, Small hydropower plants (SHPs), like other decentralized renewable energy, are not attractive to investors due to underlying market barriers and a perception of high risk that constrain the development and financing of these projects. This thesis seeks to scale up financing of SHP projects for achieving decentralised rural

electrification by considering the potential of aggregation within a portfolio of SHP projects and suggest policy recommendations. The thesis will survey two existing SHPs and one planned SHP and the other key players/stakeholders. Data will be collected using primary and secondary methods and analysed with statistical and probability tools.
Risks, barriers and challenges
1. There is potential of over 3000MW for SHP in Kenya but only about 32MW is installed up to date. What are your comments on this?
2. What is the government plan on the development of SHP?
3. As stated in the abstract above, SHPs like other decentralized renewable energy, are not attractive to investors due to underlying barriers and a perception of high risk that constrain the development and financing of these projects. Which risks affect the ability of investors/financial institutions to finance SHP?
4. Which tools do they use to mitigate them? What could developers and investors do to overcome this risks/barriers/challenges?
5. How large is the rural market for renewable energy options and how affordable is DRE technologies, especially SHP to customers especially in rural set up?
6. There is feed-in tariffs to support renewables in Kenya. How worried are you that the law might change?

7. Which financial mechanisms or instruments can be well applied in small renewable energy projects, more so in the Kenyan context?
Aggregation
Scale is another challenge in developing renewable energy in the developing world. You may not be able to do a 200-megawatt wind farm.
1. Aggregation or bundling together of small hydropower projects to reach a scale where they become attractive to large investors is a strategy that that can help reduce risks and improve access to financing of SHP projects and DRE in general. Do you agree with this statement or you have a different perspective?
Why aggregation?
1. Investors are concerned about the high risk profiles of decentralised renewable energy projects? What leads to higher actual and perceived risk for decentralised renewable energy finance?
2. Can aggregation help reduce these risks or help overcoming these challenges leading to these risks?
3. Some companies/communities don't have the electricity needs/demand to justify building a whole renewable DRE. Some prefer a portfolio approach to renewable energy, investing in multiple projects in different locations. In both cases, how could aggregation help bring more businesses into the field?
4. What are some of the challenges facing renewable energy financing? Can aggregating finance overcome these challenges? How?

5. Which stakeholders should be involved in aggregation? What are their roles and how do they benefit?
Application
1. How does aggregation work and how can the concept be applied effectively in decentralised renewable energy, especially SHP?
2. How can aggregation be designed to achieve max benefit? Are there specialised tools, skills for implementation?
Policy
6. What adjustment may stakeholders make in order to benefit from aggregation?
7. What are the policy implications come with aggregation? What policies make aggregation possible?
8. What might some of the challenges in implementing aggregation in Kenya?
9. Any suggestion on how to overcome the challenges?
10. In your view, can aggregation work in the Kenya's decentralised renewable energy environment? What can be your role in realizing this?
Summary
From your experience, what advise can you give to SHPs stakeholders to help scale up finance flow to these projects?

Appendix B: LCOE MODELS

These models show the model inputs and output. It is in excel format for 5MW, 3MW, 1 MW, 9 MW (non-aggregated) and 9 MW (Aggregated) projects for purposes of illustrations. The one shown here is for 3MW

LCOE Model		*Levelized Cost of Energy (LCOE) Model*
Hydroelectric Model Direct Inputs		Input Description and/or Justification
I: Investment Upfront Cost ($)	15,000,000.00	*Based on IRENA (2012) cost analysis for small hydro power plants investment costs for Small hydro projects in Africa range between 2000 and 4000 US$/KW. Taking average, 3000 US$/kW is used.*
M: Maintenance & Operations Cost ($/year)	375,000.00	*The O&M costs, typically quoted as percentages of investment costs, range from 2.2 percent to 3.0 percent for small HPP. Taking average, 2.5 percent is used.*
E: Electricity Production (kWh/year)	24,090,000.00	*Actual Electricity Generated based on NC, CF and Hrs/Year*
r: Discount Rate (%)	0.10	*Discount Rate approximated by developers in the interview*
n: Lifetime (years)	35.00	*Typically economic and financial analyses assume a lifespan of 30–40 years (IRENA, 2012). Taking average, 35 years is used.*
Hydroelectric Model Indirect Inputs		
Nameplate Capacity (MW)	5.00	*Assumed SHP project*
Capacity Factor (%)	0.55	*(IRENSA, 2012)Capacity factors of run-of-river hydropower plants should range from 40 to 70 percent, and 20 to 40 percent for storage HPPs, depending on installed capacity. Taking average for Run-off River, 55 percent is used.*

Model Equation		
$LCOE = \frac{\text{Sum of Costs over Lifetime}}{\text{Sum of Electrical Energy Produced over Lifetime}} = \frac{\sum_{t=1}^{n} \left(\frac{I_t + M_t}{(1+r)^t} \right)}{\sum_{t=1}^{n} \left(\frac{E_t}{(1+r)^t} \right)}$		
LCOE Hydroelectric Model Outputs		
Sum of Costs over Lifetime ($/Lifetime)		
35 Year	18,616,559.61	
Sum of Electrical Energy Produced over Lifetime (kWh/Lifetime)		
35 Year	256,417,789.65	
Levelized Cost of Energy ($/kWh)		
35 Year	0.0726	

LCOE Model	*Levelized Cost of Energy (LCOE) Model*

Hydroelectric Model Direct Inputs		Input Description and/or Justification
I: Investment Upfront Cost ($)	10,000,000.00	*Based on IRENA (2012) cost analysis for small hydro power plants*

		investment costs for Small hydro projects in Africa range between 2000 and 4000 US$/KW. Taking average, 3000 US$/kW is used.
M: Maintenance & Operations Cost ($/year)	250,000.00	*The O&M costs, typically quoted as percentages of investment costs, range from 2.2 percent to 3.0 percent for small HPP. Taking average, 2.5 percent is used.*
E: Electricity Production (kWh/year)	14,454,000.00	*Actual Electricity Generated based on NC, CF and Hrs/Year*
r: Discount Rate (%)	0.10	*Discount Rate approximated by developers in the interview*
n: Lifetime (years)	35.00	*Typically economic and financial analyses assume a lifespan of 30–40 years (IRENA, 2012). Taking average, 35 years is used.*

Hydroelectric Model Indirect Inputs		
Nameplate Capacity (MW)	3.00	*Assumed SHP project*
Capacity Factor (%)	0.55	*(IRENSA, 2012)Capacity factors of run-of-river hydropower plants should range from 40 to 70 percent,*

		and 20 to 40 percent for storage HPPs, depending on installed capacity. Taking average for Run-off River, 55 percent is used.

Model Equation

$$\text{LCOE} = \frac{\text{Sum of Costs over Lifetime}}{\text{Sum of Electrical Energy Produced over Lifetime}} = \frac{\sum_{t=1}^{n}\left(\frac{I_t + M_t}{(1+r)^t}\right)}{\sum_{t=1}^{n}\left(\frac{E_t}{(1+r)^t}\right)}$$

LCOE Hydroelectric Model Outputs

Sum of Costs over Lifetime ($/Lifetime)	
35 years	12,411,039.74

Sum of Electrical Energy Produced over Lifetime (kWh/Lifetime)	
35 year	153,850,673.79

Levelized Cost of Energy ($/kWh)	
35 year	0.0807