Sustainable rural energy access in rural communities of South Asia:

An analysis of the literature on the challenges and failures

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ABSTRACT

Despite the importance of access to reliable energy sources for development, large numbers of rural communities in South Asia (Pakistan, India, Sri Lanka, Bangladesh, and Nepal) have no access to electricity grids or reliable, clean cooking energies. Renewable energy can provide electricity and clean cooking energies to these rural communities because of its decentralized nature, but widespread use of Decentralized Renewable Energy Systems (DRES) face barriers, which need to be understood for the success of these systems.

The aim of this thesis is two-fold:

1. To systematically review through qualitative content analysis, the barriers to DRES in South Asia outlined in peer-reviewed and grey literature;
2. To assess the practical value to practitioners of the available literature by performing a comparative analysis of both types of literatures

The content analysis has highlighted a wide-range of barriers (categorised into Institutional, Regulatory, Monetary, Social and Technological barriers) which despite categorisation are interdependent of one another, an interdependence which is rarely highlighted in the literature. Comparative analysis of the peer-reviewed and 'grey' literature showed substantial differences in the reported barriers to DRE systems, which is attributed to the grey literature involving stakeholders involved in the development of these systems.

This thesis concludes that the peer-reviewed literature on barriers to DRES does not take a holistic interdisciplinary approach to investigating barriers to DRES in rural South Asia, nor does it provide practical answers to practitioners working on the development of DRES projects.

A new concept called ‘sustainable rural energy access’ is suggested to represent the need for rural energy access which is sustainable both in its use of renewable and clean energy sources, and in its longevity through time. It is recommended that an interdisciplinary research agenda involving all stakeholders is pursued so the knowledge generated can contribute to achieving sustainable rural energy access.

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1. INTROUCTION

The positive role of access to modern energy services[1] in the socio-economic development of human society is undeniable, and research shows that access to energy sources such as oil, gas and electricity plays an important role in the economic growth of developing countries (Soytas & Sari 2006; Yuan et al. 2008; Fondja Wandji 2013). There is also evidence that there is a direct and positive correlation between electricity (one form of energy) consumption per capita and GDP per capita (Kanagawa & Nakata 2008).

The earliest examples of energy utilisation for improving quality of life was the burning of wood and later coal to accomplish simple tasks such as keeping warm and cooking food. The industrial revolution began in the mid-eighteenth century, and provided humans with steam-powered trains and ships, and then internal combustion engines transformed global transport and logistics. Electrification and related technologies continued the revolution in the nineteenth and twentieth centuries.

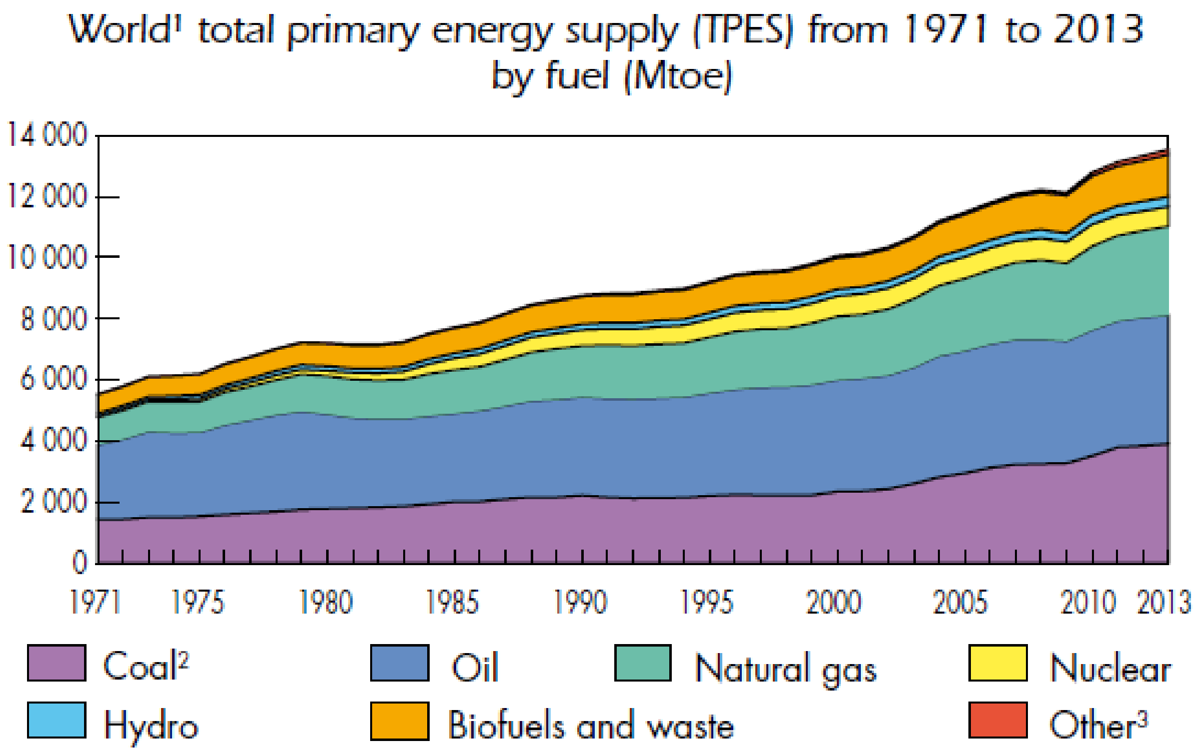
A modern life in the current world has become inextricably dependent on reliable energy access[2]. Important aspects such as education, telecommunication, transportation, healthcare, manufacturing and industries are all dependent on reliable energy access. This access to energy is derived largely from our ability to exploit fossil sources of energy (Hughes & Rudolph 2011). As can be seen from Figure 1-1, global energy consumption of

[1] Modern energy services refers to the benefits derived from using energy sources such as lighting, heating, cooking, motive power, mechanical power, transport and, telecommunications. Modern energy sources can include electricity, gas, LPG, efficient use of biomass etc. (Barnes et al. 2011)

[2] The term 'energy access' has been used to refer to energy for lighting and cooking (Bhattacharyya 2006a) but this definition has been extended to include access to electricity and modern cooking energies such as gas, efficient use of biomass etc.

fossil fuels (coal, oil & gas) has more than doubled in a span of four decades and it is estimated to double again by 2030 (IEA 2015a).

Figure 1-1 Global Energy consumption 1973-2013 (IEA 2015b)



Fossil fuels fulfilled 82% of the world's energy requirements in 2011 and their contribution in the world energy requirements is expected to be around 70% in 2035 (IEA 2013). Despite the phenomenal increase in energy consumption and dependence of essential facets of human development and prosperity on energy sources like electricity (Sharma 2007) almost 1.3 billion people worldwide, do not have access to electricity and 2.7 billion rely on unsustainable use of traditional fuels[3] (IEA 2011).

[3] Traditional fuels refers to the use of fuels such as wood, dung, agriculture residues, candles, kerosene, which often have low efficiencies (Barnes et al. 2011). They are the opposite of clean cooking energies which are based on efficient use of biomass, solar cookers etc.

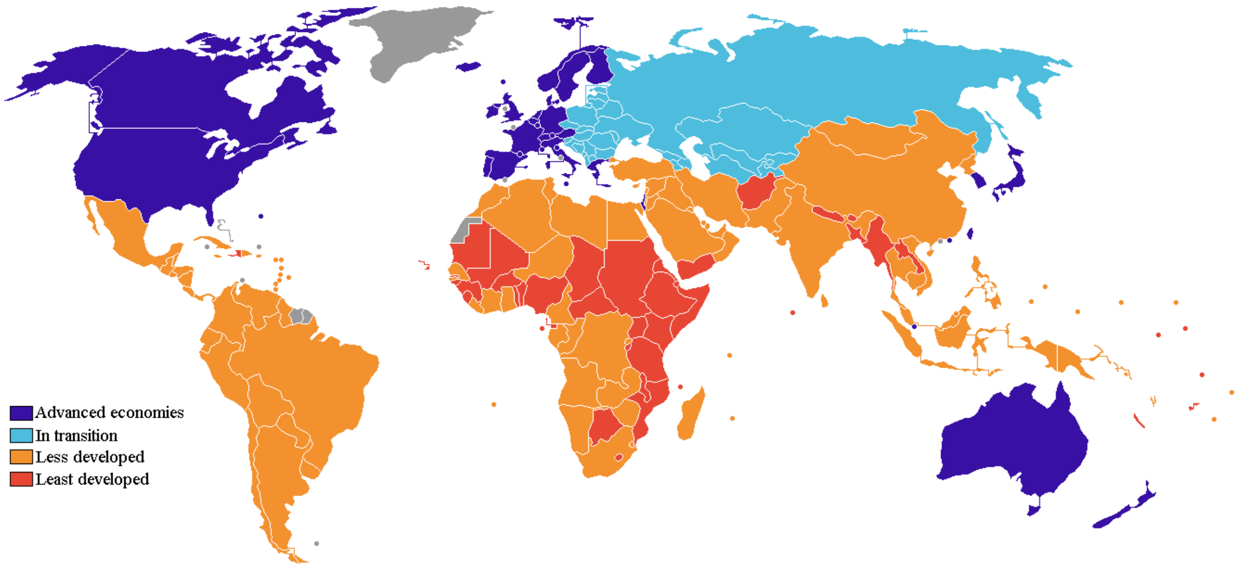


Figure 1-2 – Developed and developing countries (including in transition, less developed, least developed) (Pereira 2011)

The developing world (Figure 1-2) is worst affected by energy poverty[4] with rural areas in South Asian and Sub-Saharan African countries comprising 80% of people who do not have access to modern energy service (Saghir 2005). In 2005, India alone contained 25% of the global population without access to electricity and more than 30% of global population without access to clean cooking sources (Balachandra 2011). Rural communities not only witness an improvement in quality of life from reliable energy access but rural electrification can support refrigeration in clinics, education equipment such as computers and televisions in schools, communication, and simple entertainment systems (World Bank 2008). Access to modern forms of energy such as electricity also has potential for revenue generating activities for a rural population. Some examples of such activities are irrigation for better crop yield, food preservation, crop processing, cooling and other small-scale industries which help to raise the living standard of the local people (Kanase-Patil et al.

[4] Energy poverty is the lack of access to modern energy resources mainly electricity and refers to the bare minimum energy sources needed to survive (Barnes et al. 2011)

2010). Although energy access alone is not sufficient to bring about economic and social development, it is an essential ingredient (Bhide & Monroy 2011).

Energy poverty in rural regions of developing countries has resulted in a dependency on traditional fuels for meeting local energy requirements mostly in the form of firewood for cooking and kerosene for lighting (Sharma 2007). Traditional fuels are often used in inefficient home-made stoves, which is the cause of an estimated 4.3 million premature deaths (more than TB, malaria, HIV/AIDS combined) due to smoke inhalation (World Bank 2015). Other disadvantages of using traditional fuels are (UNCTAD 2010):

1. Traditional fuels cannot produce mechanical power and electricity
2. Traditional fuels produce energy inefficiently
3. Reduced time available for productive activities due to substantial time and effort to collect
4. Negative environmental effects (such as deforestation)

The IEA regards energy poverty[5] and the extensive and inefficient use of biomass as manifestations of poverty (World Energy Outlook 2001).

One of the 17 Sustainable Development Goals (SDG) adopted by member nations at the United Nations Development Program summit held in 2015, is affordable and access to clean energy[6] by 2030 (UNDP 2015). The SDG aims to double the share of renewables in the world's energy consumption and double the efficiency of current energy fuels. The SDG clean energy target asserts that access to affordable and clean energy not only increases

[5] Energy poverty is the lack of access to modern energy resources mainly electricity (IEA 2010)
[6] Clean energy access refers to energy access by means of renewable energy sources: solar, wind, hydro, biomass etc.

economic development, it also enables social equity and especially gives rural masses the opportunity to thrive and prosper (Kanagawa & Nakata 2008; K.C. et al. 2011). For developing South Asian countries with a large rural population, a lack of affordable, reliable and clean energy sources will hamper social and economic development (Clemens et al. 2010; Kanase-Patil et al. 2010).

Almost all countries in the world rely on a centralized power production and distribution system through a national grid (infrastructure of wires and electrical equipment) and this centralized system has been mainly perpetuated by advantages of economies of scale (Yazdanie et al. 2016). This centralized system of electricity delivery is mostly based on fossil fuel resources, causing environmental degradation due to greenhouse gas emissions (Hiremath et al. 2011). Grid extension to rural regions in developing countries is often impractical due to high costs caused by low load factors[7], low population and scattered and remote regions (Mohammed et al. 2014).

Renewable energy technologies (RETs) have been considered as a means of expanding access to electricity by means of off-grid or grid extension programmes. Similarly, the development of RETs such as improved cooking stoves[8] to increase efficiency and reduce health impacts of traditional fuel use has also been pursued. However, environmental concerns and the increasing acceptance of renewable energy sources has resulted in an increased focus on improving access to modern energy services using RETs in developing countries (UNCTAD 2010).

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[7] The ratio of energy consumption against installed capacity is known as load factor (Narula et al. 2012)

[8] Instruments that provide clean cooking energy based on renewables have been regarded as RETs in this study

Decentralized Renewable Energy Systems (DRES)[9] are not connected to the main grid and they harness energy in proximity to its intended area of consumption. They are seen as capable of providing access to affordable and clean energy in remote rural populations (Sharma 2007; World Bank 2008; Kaundinya et al. 2009; Kanase-Patil et al. 2010; Clemens et al. 2010; Narula et al. 2012; World Bank 2014; Schnitzar et al. 2014). Some other terminologies that have been used to refer to DRES in the literature are Decentralized Distributed Generation (DDG), decentralized generation technologies (DGT) (Yazdanie et al. 2016), Distributed Renewable energy (DRE) (REN21 2016) or Decentralized Energy Planning (DEP) (Hiremath et al. 2009). This thesis will use the term Decentralized Renewable Energy Systems (DRES).

Bangladesh, Cambodia, China, India, Morocco and Mali have more than 10, 000 solar PV village mini-grids (a type of DRES), and more than six million solar home systems (another type of DRES) are in operation worldwide, of which three million are installed in Bangladesh. However most of the systems are not performing adequately (IRENA 2015) and there are many challenges and problems in providing energy access to rural communities using DRES (Clemens et al. 2010). For example, one such problem attributed to the failure of solar cooker[10] adoption in India was that solar cookers are only suitable for cooking certain types of food (boiling, roasting, baking, etc.) and not for dishes that require deep frying (an integral part of Indian cuisine) and these cookers can only be a

[9] The term Decentralized Renewable Energy Systems (DRES) refers to systems that are used to deliver:

1. Electricity from Renewable energy technologies such as photovoltaics, small hydel plants, small wind turbines etc.
2. Clean energy for cooking and space heating from improved cooking stoves, solar cookers, biomass gasification plants, biogas plants etc.

[10] Solar cookers are devices that concentrate thermal radiation from the sun to cook food.

supplementary cooking source (Pillai & Banerjee 2009). Out of the 35 million Improved cooking stoves (ICS) installed in India, it is estimated that less than 6 million are in use which raises serious concerns about the longevity of DRES (Bhattacharya & Jana 2014). South Asia accounts for 42% of the global population without access to electricity (Palit & Chaurey 2011b) and 38% of the global population without access to renewable or clean cooking energies (REN21 2016). In this study an analysis of literature on barriers to DRES in South Asia has been carried out. This study will analyse peer reviewed and grey literature discussing barriers to DRES in five countries in South Asia namely, Bangladesh, India, Nepal, Pakistan, and Sri Lanka (Figure 1-3). These countries were chosen for the study with the intent of capturing a broad range of development in DRES and energy conditions in the South Asian region.

Figure 1-3 Map of South Asia

1.1 AIMS

The aim of this research is to develop concepts that explain the challenges to DRES and to assess the practical, real-world implications of peer-reviewed and grey literature on barriers to DRES in South Asia

1.2 OBJECTIVES

The objectives of this research are as follows:

- To systematically review and analyse the barriers to DRES in South Asia in peer-reviewed and grey literature, to discover major themes and implications;
- To perform a comparative analysis of the content and practical impact of both types of literatures to discover main characteristics and qualities of the two sources and the implications to their usefulness to DRES practitioners.

1.3 STRUCTURE OF THE THESIS

The thesis is structured as follows:

- Chapter One: A general introduction which sets the premise for the research including research aims and objectives
- Chapter Two: Provides background to the research questions and different types of DRES
- Chapter Three: Discusses the methodology and methods used to achieve the research aims
- Chapter Four: Presents analysis of the barriers to DRES
- Chapter Five: Provides a comparative analysis of the peer-reviewed and grey literature

- Chapter Six: Discuses the wider implications and limitations of the study
- Chapter Seven: Conclusion and areas for further study

2. BACKGROUND

The first part of this chapter discusses some problems associated with fossil fuel use and also discusses subsequent routes taken to address these problems. The second part of the chapter discusses the energy access problem currently being faced in rural parts of the developing world and how renewable sources of energy and specifically Decentralized Renewable Energy Systems (DRES) have the potential to decrease energy poverty in these regions. Brief descriptions of different types of DRES along with relevant supporting information are also given. The last part of the chapter discusses some previous studies and research carried out in the area of challenges to Decentralized Renewable Energy Systems in South Asia.

2.1 FOSSIL FUELS

The burning of fossil fuels causes atmospheric pollution and produces greenhouse gases. Water sources are also polluted due to polluted rain, and discharge of used oils and liquids containing heavy metals. (Akella et al. 2009). Pollution and greenhouse gases from fossil fuels have adversely affected the climate and besides the detrimental effects of fossil fuels on the environment, its finiteness is a matter of much contention and debate in the world.

There is little consensus on the remaining resources of fossil fuel (Hughes & Rudolph 2011) accompanied by substantial speculation and uncertainty (Bauer et al. 2015). The existing debate on peak oil (maximum oil production) has two views. One view is that a peak in current oil production will take place in the next few years while the other view is that due to new sources being continuously discovered in addition to newer efficient techniques to extract more oil from fields, it is difficult to gauge the exact time for peak oil (Hughes &

Rudolph 2011). Shafiee and fellow (2009) have corroborated the second view and said that it is difficult to estimate the reserve quantity of fossil fuels as it has risen with time as more reserves have been discovered. Author Shirgholami (2016) estimates that fossil fuels will be depleted by the end of the next century. Despite these speculations and debates it is undeniable that there is indeed a net reduction in actual reserves which will eventually exhaust.

Depletion of fossil fuels has forced the world to look to more non-conventional sources of fossil fuels such as tar sands currently being explored on a wide scale in places such as Canada (Hughes & Rudolph 2011) and also to other non-conventional methods such as fracking where large amounts of water and chemicals are pumped deep into the earth to fracture oil and gas bearing rocks to facilitate release of the gas and oil (Evensen et al. 2014).

These impending problems of fossil fuel depletion along with fluctuating market prices of crude oil are two of the reasons which have led to concerns about energy security[11] among world leaders. One way of alleviating concerns of energy security and climate change is to utilize the current cache of energy more efficiently, to prolong its use until a viable alternative option to answer the energy challenge is developed. Increasing the efficiency of current energy use will reduce dependence on fossil fuels and slow down the increase in greenhouse gases (Prindle & Eldridge 2007; Stram 2016). Prindle (2007) suggests that efficiency and renewable energy are two pillars for sustainability of energy. Efficiency is able to achieve short term benefits whereas renewables offer more long term benefits.

[11] Energy security is defined as having access to adequate, affordable and reliable supplies of energy (International Energy Agency 2010). Energy security has also been referred to availability of diverse energy fuels and reliability of the energy supply system (Pepermans et al. 2005).

Synergies between efficiency and renewable can successfully make the energy sector more sustainable. The International Energy Agency regards efficiency as key in achieving a sustainable energy future (IEA 2013).

Environmental repercussions such as global warming and energy security concerns have created a worldwide impetus to accelerate replacement of current energy sources (Shafiee & Topal 2009). At this juncture in time when damage to environment and people's health has started manifesting, renewable sources of energy offer a potentially benign route to meet the world's energy requirements.

2.2 RENEWABLE ENERGY

At one time nuclear power was thought to be the only alternative to fossil fuels but this changed during the 1990s, especially after the oil crisis when the world's nations started experimenting with renewable energy, and renewable energy started emerging as a viable energy source (Jacobsson & Johnson 2000; Soytas & Sari 2006; Bhattacharyya 2006b; Nepal 2012). The emphasis on renewable energy grew even more in the post-Kyoto era which focused on reducing greenhouse gas emissions and tackling global warming, and led to an increase in investment in renewable energy sources (Negro et al. 2012).

Renewable energy has five major sources: solar, wind, hydro, biomass, geothermal, tidal and wave energy (Luthra et al. 2015). Energy obtained from these sources is often called clean energy as they have no direct pollutant by-products. Although there is debate about the sustainability of sources like biomass and geothermal, this is beyond the scope of this research and has not been discussed here.

Renewable energy Technologies (RETs) are energy-providing technologies that utilize energy sources in ways that do not deplete the Earth's natural resources and are as environmentally benign as possible. These sources are sustainable in that they can be managed to ensure they can be used indefinitely without degrading the environment (Renewable Energy Association, 2009).

Theoretically, it is possible to meet the world's energy needs many times over through renewable sources of energy such as micro hydro power, solar power, biomass and geothermal but there is considerable debate among researchers on its practicality due to financial, political and regulatory issues (Painuly 2001; Akella et al. 2009). RETs are often termed more expensive than fossil fuels and cost analysis of fossil fuel-based electricity suggest that it is cheaper than electricity generated from renewable sources. This cost analysis only compares the fuel and conversion expenses for fossil fuels, and externalities of fossil fuel use are often ignored in calculating the actual cost of using fossil fuels. Externalities to be considered when calculating the cost of fossil fuels are the costs of removing the pollutants and reversing any environmental damage, and additional healthcare costs due to diseases caused by the use of non-clean fuels (IRENA 2012). Cost analysis of fossil fuels and renewable sources of energy which includes these externalities can tip the scales in favour of renewables. It is estimated that the external effect cost due to air pollution and climate change are in the range of USD 2.2 trillion – 5.9 trillion per year compared to the global energy supply cost of USD 5 trillion per year (IRENA 2012).

Due to recent commitments in the Sustainable Development Goals (formerly known as the Millennium Development Goals), REN 21 and COP21, the share of renewable sources in the world energy mix is increasing slowly. The year 2014 saw a ground breaking change in emissions where CO_2 emissions remained stable despite increased energy consumption (REN21 2016). This positive trend has been attributed to the increased use of renewables globally with additional emphasis on increasing efficiency. Many technologies have made staggering increase in installed capacity. For example 2014 saw installation of 40 GW out of a total of 177 GW of global installed capacity of Solar energy, wind capacity saw an addition of 51 GW out of a total of 370 GW installed capacity (REN21 2016). Countries like Austria, Canada, Denmark, Finland, New Zealand, Portugal, Sweden and Switzerland already produce more than 20% of their power from renewables, with some countries such as Denmark planning to go up to 60% by 2025 and Germany planning to go up to 100% by 2030 (REN21 2016). Developing countries are increasing their share of renewables at rates higher than most of the developed countries (IRENA 2014). As with Sustainable Development Goals, more than a hundred countries (eighty-five of which are developing countries) have made commitments to meet three objectives to help meet future energy demands: 1) Enabling universal access to modern energy services 2) Doubling the share of renewables in energy mix 3) Doubling efficiency in energy usage.

Despite this favourable trend, there remains a staggering dependence on fossil fuels, along with a huge untapped renewable energy potential. Currently renewables supply approximately only 20% of the world's energy demands which includes many of the world's largest dams built in the seventies (REN21 2016). Hydroelectric power from reservoir dams have fallen out of favour in the world due to several negative ecological effects which include flooding or clearing of large areas, increasing humidity in the vicinity, providing a habit for diseases like malaria, displacement of people and also affecting the quality and levels of groundwater (Taher et al. 2016).

Developed countries are under pressure to switch to renewables due to reasons such as climate change and energy security among some but for many developing countries adopting renewables often offers a quick, affordable method to deliver energy to remote and rural locations in developing countries which still do not have energy access. The exploitation of RETs has great potential to fight energy poverty in developing countries.

2.3 ENERGY POVERTY

Developing countries often have faster growing economies and populations compared with developed countries, and significant focus and investment is needed if developing countries are to move to a more sustainable source of energy such as RETs (Kennedy & Basu 2013). In developed economies, utilization of renewable energy sources is prioritized for strengthening security of energy supply and mitigating climate change impacts for reduction of greenhouse gases (Moselle 2011). While in developing economies decentralized renewable energy sources are perceived as a favourable option for intensifying rural electrification and improve electricity access in those areas where electricity infrastructure remains centralized (Pereira et al. 2010). Policies that support RETs are often more difficult in developing countries due to their relatively limited economic, technical, and institutional capabilities (Chaudhary et al. 2014)

Enabling energy access is one of the driving forces behind the use of renewables in developing countries and it can be seen that the use of renewables is on the rise in the developing world. Investments in renewable energy installations in developing countries almost equalled investment in developed countries in 2014 (REN21 2016) but despite this move towards renewables to provide energy access, more than a billion people in developing countries still do not have access to modern energy services (International

Energy Agency 2010). As seen in Figure 2-1 and 2-2, rural regions of the world are the worst affected with almost 80% of the rural population in Sub-Saharan Africa and South Asia having no access to electricity and clean cooking energy (Clemens et al. 2010; REN21 2016). Energy consumed per capita is often used as a measure of the economic status of a country and as can be seen from Table 3-1, it is quite low for developing countries. In some cases a small proportion of rural population in Africa and Asia have access to electricity but this supply is plagued by sporadic outages and unreliable power supplies (Rofiqul Islam et al. 2008; Katuwal & Bohara 2009).

Table 2-1 Energy consumption per capita (Younas 2016)

Country	Per capita energy consumption (kWh)
USA	13,361
France	7756
Germany	7217
China	2942
Turkey	2474
India	644
Sri Lanka	636
Pakistan	457
Nepal	454
Bangladesh	278
Afghanistan	119

Figure 2-1 – World electricity access and lack of access by region (REN21 2016)

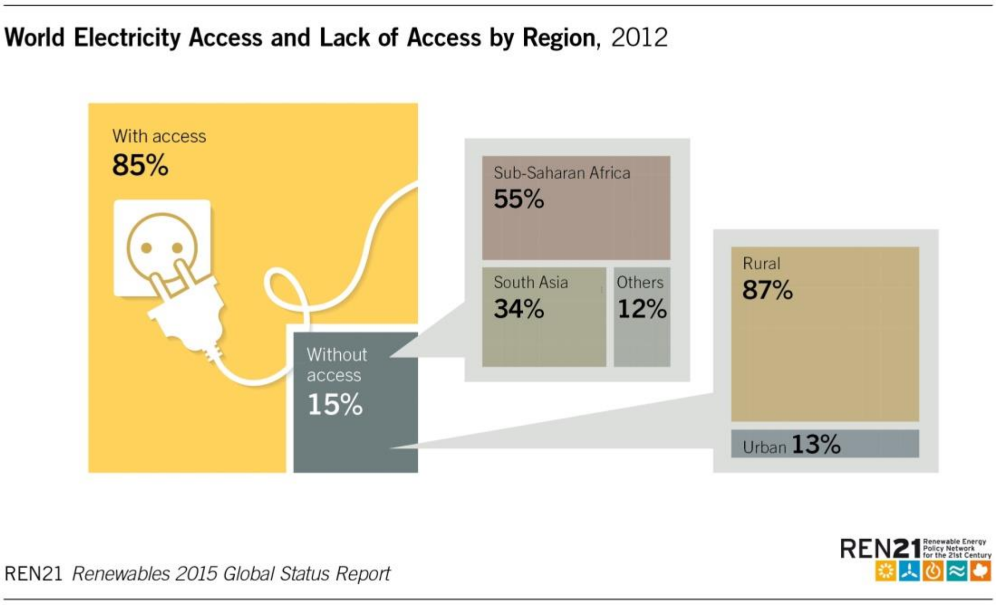
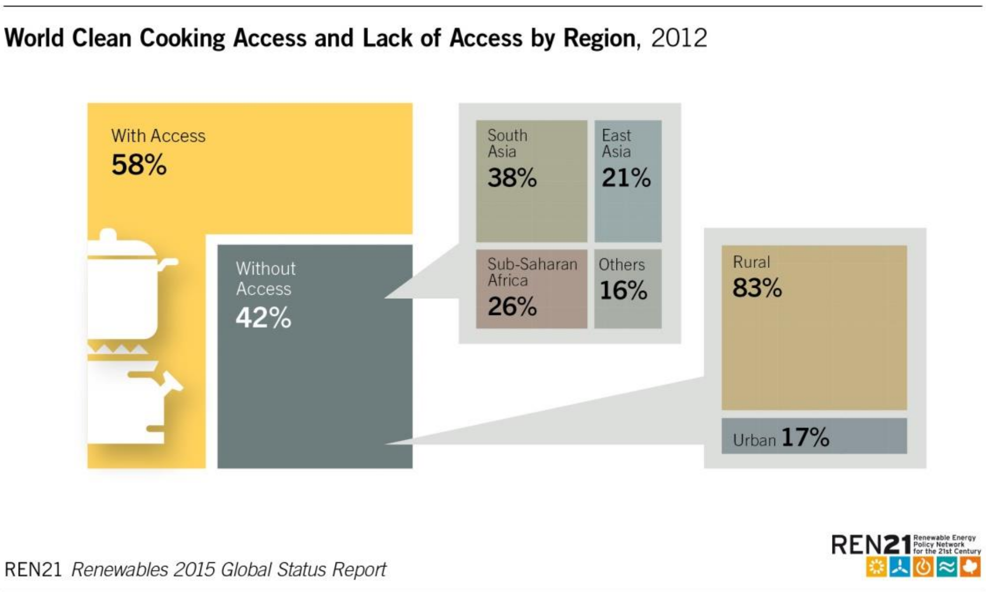


Figure 2-2 – World clean cooking access and lack of access by region (REN21 2016)



The residents of rural areas in developing countries are predominantly poor and are forced to spend significant portions of their income on obtaining fuel for cooking and lighting due to unreliable energy supply (Schäfer et al. 2011). Poor people in rural areas can spend almost as high as one third of their income on energy, mainly for cooking and lighting (K.C. et al. 2011). Lack of access to electricity exacerbates poverty as it does not allow industrial activities and prevents formation of jobs (WEO, 2001). Providing reliable energy access is a vital ingredient for reducing poverty and encourage socio-economic development (Kanagawa & Nakata 2008).

Many countries in South Asia are facing an energy shortage on a national level and are unable to meet their energy demands. This inability limits providing a reliable connection to rural areas which are often low on priority for electrification. Table 2-2 shows electricity access urban and rural regions in South Asia.

Table 2-2 Rural electricity access in South Asia (Kumar et al. 2010)

Country	Population without electricity (millions)	Electrification rate (%)		
		2013		
		Urban	Rural	Total
Bangladesh	60	90.2	29	41
India	237	96	74	81
Nepal	7	97	71.3	76.3
Pakistan	50	90.6	61.9	72.8
Sri Lanka	1	98.6	92.9	94

Rural areas in South Asia form one of the largest groups of people without any access to electricity and clean cooking energy (REN21 2016). More than 90% of the rural population and 45% of urban population in South Asia (REN21 2016) rely on traditional fuels for meeting their energy requirements such as cooking and lighting. India alone has more people without adequate energy access than any other country in the world (Bhattacharyya 2006a). Even though there have been attempts to provide energy access to more rural areas and more people have been connected, the net number of people without access to electricity has remained the same (Palit & Chaurey 2011b). To tackle this massive problem it is necessary that an innovative approach is adopted because traditional methods of providing electricity through the grid are very slow and often not cost effective due to low energy load and remoteness of rural areas. Decentralized Renewable Energy Systems have the potential to be an affordable and reliable method of increasing energy access in South Asia.

2.4 DECENTRALIZED RENEWABLE ENERGY SYSTEMS

Electricity delivery methods to urban and rural populations follow two ways, centralized and decentralized. In the centralized versions usually a national government entity such as a state owned utility, power ministry or rural electrification agency is responsible where they can act independently or together, and electricity is delivered primarily by grid extension. In a decentralized version the electricity is delivered with the help of isolated mini or micro grids running on fossil fuels or renewables and government and non-governmental entities such as cooperatives, private entrepreneurs, or community-based organizations are the initiators of the projects (Tenenbaum et al. 2014).

Decentralized energy not only offers a more sustainable and affordable model for rural electrification (Sharma 2007), it is also more in line with the urgent agendas of climate change; thus its effects are more suitable in the long term (Pereira et al. 2010). It has been suggested that due to harmful effects on the environment, the economies of developing countries are decoupled from fossil fuels and they should focus on the use of DRES (such as micro-grids) to provide energy access to its people and not rely on extension of the centralized grid (Stram 2016). Many developed nations are also moving towards a decentralized system due to its versatility and the advantage of being independent of centralized failures which would result in loss of power to large areas.

The role of sustainable decentralized renewable energy is very significant in providing energy to rural areas of developing nations (Nepal 2012). One of the major advantages of using DRES is the ability to avoid transmission and distribution losses. In March 2016 in India alone transmission and distribution losses were more than 20% (Central Electricity Authority 2014). A lack of electricity delivery infrastructure in developing regions like South Asia puts them in a most opportune position as this can be a chance for the developing world to leap frog into newer, more practical and eco-friendly technologies such as decentralized energy systems based on renewable sources (Kennedy & Basu 2013), by making most of decades-old developments made in decentralized and renewable technology (Williams et al. 2015)

Decentralized renewable energy systems (DRES) that generate and distribute energy independently of any centralised system, provide energy services to millions of people around the world, and numbers continue to increase annually (REN21 2016). Almost 26 million households or an estimated 100 million people in all—are served through off-grid renewable energy systems (Or DRES): some 20 million households through solar home systems, 5 million households through renewables-based mini-grids, and 0.8 million households through small wind turbines (IRENA 2015). Many projects in developing countries such as China, Laos, Kenya, and Vietnam have been successfully operating commercial ventures of DRES providing electricity to rural villages through solar, wind and hydro resources (World Bank 2008). The market for DRES is mainly located in developing countries (IRENA 2015) and the decentralized nature of RETs allows them to be matched with the specific needs of various rural areas. As discussed earlier an enormous proportion of the rural population remains without access to even basic electricity connections. Due to low load factors[12] along with dispersed populations, grid extension to rural areas remains expensive and unfeasible in most cases at least in the near future (Narula et al. 2012). It is desirable (but not feasible) to extend the grid to rural areas for electrification due to the ability of the grid to support large electric loads and its unlimited supply of power but research indicates that in many developing countries the current centralized electricity infrastructure is already strained and it is impractical to extend it to connect to rural electrification (Alliance for Rural Electrification 2009). Besides the decentralized nature of renewables, Decentralized renewable energy systems also have the advantage of clean sources of energy such as clean cooking stoves, biogas plants etc. (Palit & Bandyopadhyay 2016).

In addition, the energy requirement for rural households is very small, and can be met with DRES in most cases. The electricity load in a village can be classified into domestic, community and small scale industries. Domestic sector needs electricity for TVs, fans and compact fluorescent lamps. The agricultural needs include fodder cutting and crop threshing machines, and community centre requirements are for schools and village centres. Rural industrial loads could include potential for milk cooling and processing (Kanase-Patil et al. 2010). Thus logic would dictate it impractical to wait for the central grid

[12] Load factor is the ratio of energy being utilized to the maximum potential. A low load factor indicates lower utilization of available potential for producing energy

to provide energy access to rural regions (Palit & Bandyopadhyay 2016) when DRES are perfectly capable of meeting the energy needs of the rural population.

For the purposes of this study, DRES cover two categories: those used to provide energy for cooking and heating and those used to supply electricity. DRES used to produce energy for heating and cooking tend to do so by utilizing traditional fuels in new and improved ways such as in Improved Cooking Stoves or using renewable sources for cooking such as solar cookers. DRES that generate electricity can do so either as part of a stand-alone system or as a grid-based system, by way of connection to an independent mini-grid (UNCTAD 2010). Both mini-grid and standalone electricity supply systems can be implemented together to provide universal access to energy. The IEA predicts that if universal electrification is to be achieved by 2030 it can only be achieved with the help of decentralized energy systems, with 90% of these systems powered by renewables (IEA 2013). This suggests that it is completely possible to provide a long-term energy access to a rural population without relying on grid expansion. This study includes both type of systems under the same umbrella of DRES and does not make any distinction between individual or mini grid systems.

2.4.1 Micro grid

Micro grids, sometimes referred to as mini grids, is a mode of providing electricity where the renewable source of energy such as solar energy, micro hydel plants, is connected to a distribution network of overhead or underground wires running to each rural consumer household whereas in an individual system, the system only caters to a single household. Customer numbers usually range in the lower hundreds. Each household is provided with multiple energy sockets to meet their needs (Tenenbaum et al. 2014). These systems are more elaborate than individual systems and in a sense provide the closest alternate to grid electricity. The power source of such systems can be solar energy, mini (or micro)-hydel plants (MHPs), wind, producer gas engines etc. Some advantages of a micro-grid are (IRENA 2015):

1. Smaller project compared to grid extension, thus smaller investment
2. Provides electricity like a central grid
3. Can support integration into central grid

A mini grid has the advantage of being modular so further energy sources can be added and when the grid arrives, it can be integrated into the grid. In addition, mini grids can be set up quickly. Mini grids can support larger loads and thus can be used to generate revenue. Thus the use of mini or micro-grid is especially appropriate for locations where productive activities are already taking place (World Bank 2008). As described by the World Bank guide on DRES, a micro-grid setup usually follows three ways (World Bank 2008):

1. An isolated micro grid is operated by a private developer[13] which is attracted to the location, availability of large productive loads and subsidies. In this case the tariff is calculated with respect to the financial capability and willingness to pay of the user and the rest is covered by capital subsidy provided by the government to ensure profit for the private investor. To make the process smoother additional support in the form of technical assistance and training may be provided by the government. Since productive loads are the main

[13] In this study small power producers or private developers are referred to commercially-minded people that produce electricity by DRES and then sell this electricity to the user at a profit

incentive for the private developer, assistance may also be provided to the main potential user of the grid in establishing productive activities.

2. The second option is that if the place is too isolated, then the local community become the eventual owner of the system. This option means that more training must be provided to the local people to operate and maintain the DRES.
3. The third option is where the state owned utility or grid utility supplier is made responsible for running micro grids in rural communityies, and the government provides subsidies to offset the cost of lower amount being paid by the users. This method was successfully used to operate 700 centralized, isolated micro grids in China (World Bank 2008).

Various models of ownership and implementation of DRES that have been attempted in India for village electrification are as follows (Kumar et al. 2009):

1. State owned and operated.
2. State implemented and handed over to community organization for operation and maintenance
3. Community (users') organization owned and operated
4. Entrepreneur (private developer) owned and operated

Micro grids can be very successful if used correctly. For example currently over 200 isolated and grid connected micro grids supply electricity to almost 42 percent of rural Cambodian population, 120,000 customers, and all the investment came from the private investors (Tenenbaum et al. 2014).

2.4.2 Individual renewable energy systems

Individual systems are used where the main purpose is lighting (World Bank 2008) but in this study clean cooking energy systems have also been included under this heading.

2.4.2.1 DRES FOR LIGHTING

Examples of individual systems include Solar Home Systems (SHSs), Pico or Micro hydro systems less than 5 kW, biomass-based power plants and Wind Home Systems (World Bank 2008). Some portable units like solar lanterns contain a small LED lamp that is charged with solar energy during the day to provide illumination at night. There is good demand for Solar Lanterns in rural locations due to their affordability (World Bank 2008).

An example of a much more elaborate stand-alone system is a Solar Home System. It would normally consist of a few solar panels along with a charge controller and battery for energy storage. Peak wattage ranges from 10-100 Wp (Watt Peak). These systems are used to provide electricity to a single or several light bulbs and low power appliances like radios and TVs. SHS are also popular as a result of their limited maintenance requirement (World Bank 2008).

Table 2-3 provides example of SHS sold by Grameen Shakti, an independent organization which sells solar home systems to rural communities in India.

Table 2-3 Major types of Solar Home Systems installed by Grameen Shakti (Alam et al. 2003)

Capacity and number	Service	Major components
75 Wp	▪ 6 lamps each of 6 W capacity ▪ One 43 cm B&W television	▪ One 75 Wp panel ▪ One 130 Ah deep-cycle battery ▪ One charge controller ▪ Bulbs and other accessories
65 W_p	▪ 5 lamps each of 6 W capacity ▪ One 36 cm B&W television	▪ One 65 W_p panel ▪ One 100 Ah deep-cycle battery ▪ One charge controller ▪ Bulbs and other accessories
50 W_p	▪ 4 lamps each of 6 W capacity ▪ One 36 cm B&W television	▪ One 50 W_p panel ▪ One 100 Ah deep-cycle battery ▪ One charge controller ▪ Bulbs and other accessories

2.4.2.2 DRES FOR CLEAN COOKING ENERGIES

Biomass such as firewood, crop residues and dung, still stands as the major source of energy for poor households for cooking and heating in developing countries (Bensch et al. 2015). To put this into perspective, 18% of total global energy consumption comes from renewables and out of this 18%, 13% comes from biomass which is primarily used for heating and cooking (Kumar et al. 2010). As of the year 2003 in Bangladesh over 90% of the rural population relied on biomass to meet part of their energy requirements (Rofiqul Islam et al. 2008) and this figure is the same in many other developing countries (IEA 2006).

Hiremath (2011) has even suggested that it is possible to meet the cooking, lighting and rural industrial energy requirements of all Indian rural villages through biomass conversion alone which suggests that efficient use of biomass can play a potentially important role in the energy future of rural communities.

Although biomass sources like wood and crop residues are renewable, their use in homemade open fire stoves is inefficient (<10% efficiency) resulting in high consumption of fuel, and smoke production (Sarkar et al. 2003). The unsustainable use of biomass is leading to deforestation, a loss of biodiversity, loss of top soil, greater flood and land slide risk (Alliance for Rural Electrification, 2009). The effects of using biomass in traditional ways in open fires, does not only have negative health and environmental consequences but women who are primarily responsible for collecting biomass, spend large amounts of time collecting biomass, which prevents opportunities for revenue generation. Hence, traditional ways indirectly contribute to ongoing poverty in rural areas (Kumar & Mehta 2016).

Biogas plants and improved cooking stoves are two popular sources of renewable cooking fuel that help in alleviating some of the aforementioned problems (Alliance for Rural Electrification 2009). The clean or improved cooking stove has efficiency in the range of 25-30% (Sarkar et al. 2003) and can save millions of lives in South Asia by reducing indoor air pollution Figure 2-3.

Figure 2-3 Indoor pollution due to open stove (Zahnd & Kimber 2009)

Biogas burns cleaner, resulting in lower indoor house pollution, which will not only help to reduce health problems but it also has the benefit of taking the load off biomass resources which can help tackle deforestation. Slurry obtained as a by-product of biogas plants is a good source of fertilizer and can improve crop yields by 6-20%. The use of clean cooking sources like biogas and Improved Cooking Stoves have a positive social impact as they also free children and women's time spent on gathering fuel. Time can then be spent on education and productive activities (World Bank 2006a). Other clean cooking energy sources include biomass gasification plants and solar cookers.

Individual systems for lighting and cooking (World Bank 2008) are usually sold commercially with two business models:

1. One mode of selling is through dealers or distributors selling direct in the open market. The user can buy solar lanterns for instance by utilizing micro-credit facilities to off-set the initial high costs. In this method, the owner assumes all responsibility for the equipment after the lapse of the warranty period. Any operational or costs associated with replacements are also covered by the user.
2. Another method is a fee-for-service system where the user pays a fee for the use of the service and the equipment and the ownership remains with the supplier who is responsible for replacing any replacement parts, and maintenance over the length of the agreed contract.

2.4.3 Micro grids vs Individual systems

If there is a comparatively larger number of customers, implying a larger load, it becomes economically viable to connect the customers to a micro or mini grid (World Bank 2008). Although micro-grids benefit from grid like electricity, it should be kept in mind that establishing mini grids is more capital intensive and complicated than individual DRES systems like solar lanterns. Some populations would benefit immensely from even small use of DRES (Stram 2016). It has been shown that even providing a few kWh worth of electricity can have a strong effect on the quality of life (Painuly 2001; Masud et al. 2007). A relevant example would be the rural population in remote region of Nepal called Humla. These people have been living in such primitive conditions where soot from unsustainable unclean sources has resulted in diseases and low life expectancy (Zahnd & Kimber 2009).

2.5 DRES PROJECT EXAMPLE

A good example of a successful DRES project is the Rural Energy project for Rural Economic Development in Bangladesh. It was funded by the World Bank which along with implementing agency Infrastructure Development Corporation Limited (IDCOL) successfully disseminated 1.24 million Solar Home Systems that exceeded set targets. This project was based on an ownership model (where users pay a major share of the cost of the DRES) which was only partially subsidized by the government (World Bank 2014).

Figure 2-4 is used as an example to show how an institutional framework for a Decentralized Renewable Energy System such as a Solar Home System would function. IDCOL is an organization established by the government of Bangladesh, for providing off-grid energy access to rural regions. It works in coordination with partner organisations that are mostly NGOs. The partner organisations are the actual entities that contact with the rural communities and provide the Solar Home Systems, and IDCOL oversees implementation and operation of renewable energy projects and supports the renewable energy projects by performing functions such as: Selection of partner organisations, preparation of quality standards for SHS, selection of SHS suppliers, training for partner organisations and monitoring of their performance (Rahman et al. 2013).

Figure 2-4 Sample Institutional framework for DRES (Rahman et al. 2013)

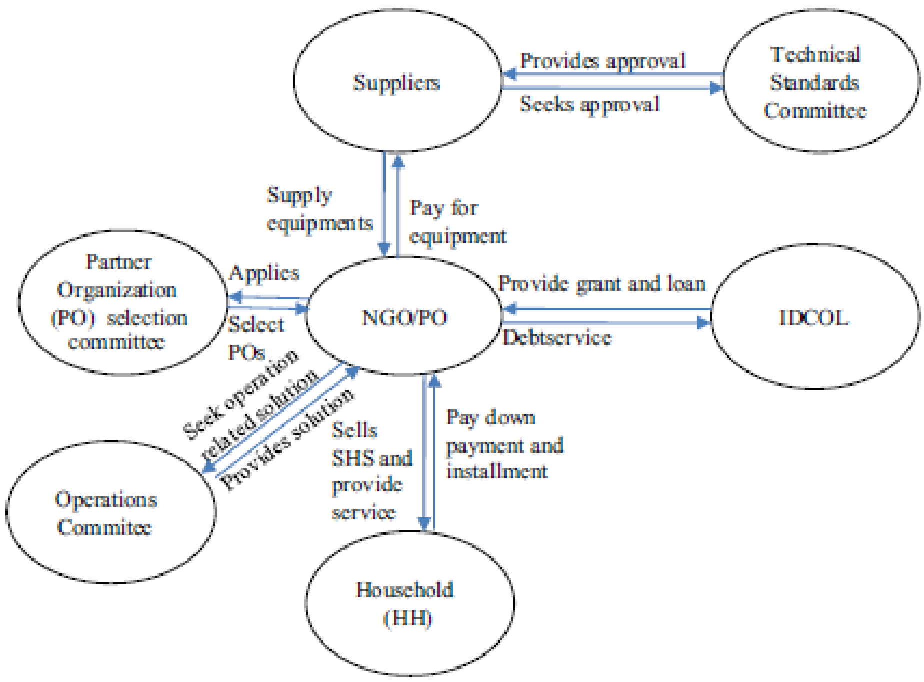
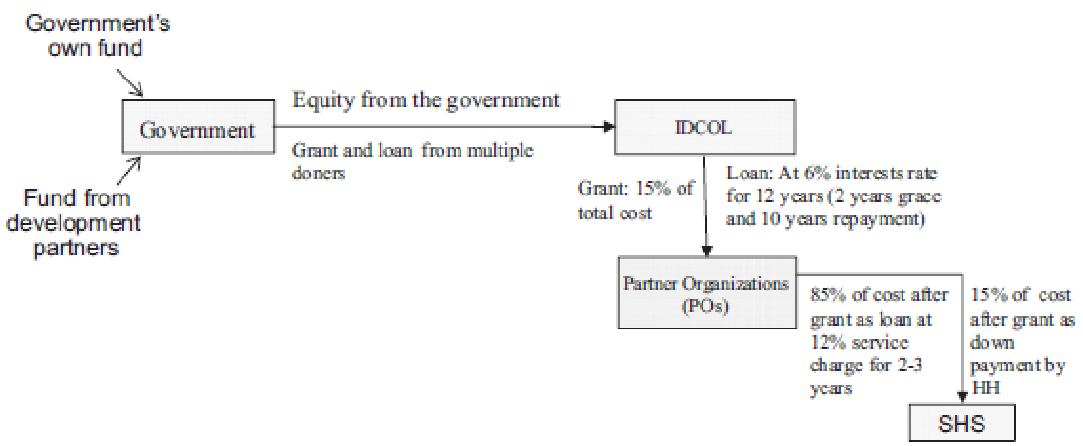


Figure 2-5 Sample financial framework for DRES (Rahman et al. 2013)



The financial framework for this example is given in figure 2-5. The government and development partners such as the World Bank provide funds for the Solar Home System (SHS) program. There is no subsidy in the program and IDCOL transmits 15% of these funds to partner organizations as grant and the rest of the funding is in the form of low interest loans. The partner organizations then provide the SHS at low interests to the users.

2.6 PREVIOUS STUDIES

Authors such as Painuly (2001) and Jacobsson & Johnson (2000) have suggested analytical frameworks to analyse the diffusion or penetration of renewable energy systems. The analytical framework suggested by Painuly (2001) suggests literature review as one of the ways for barrier analysis in addition to preparing questionnaires for stakeholders (such as manufacturers, users, NGOs and policy makers) in order to gain their perspective about potential barriers to renewables. Painuly (2001) also provides a list of barriers in his paper based on a literature review, but no specific methodology is followed to identify the barriers.

Two research papers which discuss barriers to Decentralized Renewable Energy Systems (DRES) in South Asia are by Yaqoot (2016) and Palit (2011b). Yaqoot et al. (2016) discusses barriers to decentralized renewable energy on a national level and does not focus on rural communities in South Asia. Palit & Chaurey (2011) discuss off grid rural electrification in South Asian rural communities but exclude non-electricity generating DRES sources such as biomass which remains the largest source of energy (for cooking and heating) for rural communities of South Asia. The major lacking feature of all these studies is a lack of a systematic methodology for explaining how the barriers were derived.

The current study partially resonates with previous studies using literature as data sources but it has three different features not fulfilled by any other research. Firstly, this study aims to include clean cooking energies under the umbrella of DRES. Secondly, this study focuses on the challenges to DRES in rural areas only and thirdly this research utilizes a systematic method of reviewing, drawing inferences and concepts from the study of the barriers.

2.7 SUMMARY

It is naïve to assume that electricity is a panacea for energy requirements of the developing world, but access to clean and sustainable energy is an essential ingredient for socio-economic development. Rural areas are still greatly dependent on traditional fuels for their energy requirements and clean cooking energies can offer various monetary, health and social benefits. More than 50% of South Asia remains without access to reliable source of energy which includes electricity and clean cooking energies. The problem is even more pressing and challenging on many levels because it is concentrated in rural class who are mostly poor. Decentralized renewable energy systems (which include RETs and traditional fuels) not only offer a swift and affordable method for providing energy access to locations without electricity and clean cooking energy but DRES use also help in alleviating the environment effects of using conventional fuels.

Thus, it is necessary to understand why despite the potential of DRES for energy access in a developing region like South Asia, is it still not widespread? This study aims to discover the barriers to decentralized renewable energy access which are further discussed in Chapter 4.

3. RESEARCH APPROACH AND METHODOLOGY

The objective of this research was to systematically review Decentralized renewable energy systems in peer reviewed and grey literature covering the five countries selected for this study to reveal major themes and implications and to also carry out a comparison of the barriers in peer-reviewed and grey literature.

The study was exploratory in nature and aimed to answer the research objectives from the data and findings gathered during the course of the research. The research aims did not entail proving hypotheses (or quantifying relationships between variables) which are features of a quantitative or fixed design approach (Robson 2002; Montello & Sutton 2012).

A qualitative approach was selected to carry out this research which is explained by Robson (2002) as an approach that entails repeated review and modification of the design, as new data and findings are obtained, resulting in the continuous development of the research design as the research progresses. As written content was the source of the data, it was necessary to adopt an approach that would enable a qualitative analysis of the written content (peer reviewed and grey literature on barriers to DRES in South Asia). A method was needed to enable analysis of documents in a systematic way that would lead to development of concepts and identification of latent themes within the text. Content analysis was able to meet the research objectives as it offered a structured way to analyse the information in written text and enable development of concepts (Robson 2002).

3.1 METHODOLOGY: CONTENT ANALYSIS

Content analysis has existed for centuries with the earliest application to theological studies in the 17th century (Krippendorff 2013). Content Analysis started off as a purely quantitative method, but it was popularised as a qualitative method in the 20th century for the analysis of non-news material and propaganda analysis in newspapers during the World Wars (Berelson 1952; Krippendorff 2013).

Content analysis is a research method which can utilize any form of communication including written text (Marshall 1999) and as put by Holsti (1969) is 'any technique for making inferences objectively and systematically identifying specified characteristic of messages'. Krippendorff (2013) defines content analysis as a "research technique for making replicable and valid inferences from texts (and other meaningful matter) in the contexts of their use". Content analysis is also defined by Weber (1990) as a method that employs a specific set of steps to deduce information that is not otherwise apparent in the text. One of the prominent merits of using content analysis is its unobtrusive and unreactive nature compared to other methods such as participatory forms of researches where the presence of the researcher can influence the data (Marshall 1999).

Content analysis can be carried out with either quantitative or qualitative approach. The main feature of the quantitative approach involves measuring the frequency of keywords or the length of an article or any other quantitatively measurable feature of a text, to draw meaningful inferences from text and their comparisons. For example counting recurring words through the campaign speech of candidates can give an idea to their inclination or things which are important to them (Krippendorff 2013). However, in a quantitative approach there is undoubtedly a loss of the context in which information is presented. Authors such as Kracauer (1952) and Holsti (1969) support the qualitative capability of content analysis and assert that in most cases qualitative analysis is necessary to extract in-depth meaning which quantitative analysis alone is unable to do .

An interpretive two-stage research design utilising the qualitative content analysis approach was employed critically to examine barriers to Decentralized Renewable Energy systems in South Asia. The qualitative content analysis approach involves organising the data into categories on the basis of themes, concepts or similar features, from which new concepts are developed, conceptual definitions are formulated and relationships among concepts are examined (Miles et al. 2014). The categories are developed with an inductive approach which calls for the categories to be developed based on the intrinsic characteristics in the data as opposed to a deductive approach where the categories are based on previously based theories or concepts (Mayring 2004). This constant comparative method requires the comparison of all the items of data that have been assigned to the same category. The aim is to clarify the meaning of the categories that have emerged as well as to identify subcategories and relations among categories (Krippendorff 2013; Miles et al. 2014). The use of a qualitative content analysis approach for analysing secondary material, results in data being uncovered progressively through reading and annotation of the material which leads to the natural creation of categories, thus uncovering pertinent data for the study (Krippendorff 2013).

3.2 ATLAS.ti: COMPUTER AIDED QUALITATIVE CONTENT ANALYSIS

The use of computer aided software brings with it the distinct advantage of quickly repositioning and displaying data in various settings to allow revelation of elements of interest (Weber 1990). It also speeds up the analysis which would otherwise be time-consuming (Krippendorff 2013).

Atlas.ti was used for qualitative data analysis and it offers tools to manage, extract, compare, explore, and reassemble meaningful pieces from large amounts of data in creative, flexible, yet systematic ways (Friese 2013). Some mechanics of the software are as follow:

Unit of analysis: An integral part of Content Analysis is the unit of analysis. A unit of analysis can be a word, a sentence, a paragraph, or the whole document itself. The purpose for determining a unit of analysis is to divide the research data into discrete parts. For example if the source of data is interviews, individual interview transcripts could form the unit of analysis or the interviews could be divided on the basis of the gender of the individuals and so on.

A problem that was identified in the initial phase of the research was the selection of the unit of analysis. Initially single words or incomplete phrases were selected and made part of the code that fitted the scope of the research, but this caused the original meaning to be rendered nebulous due to a loss of context. This is where it is relevant to explain semantic validity which means ensuring that the meaning of the unit of analysis, whether it is a word or phrase, remains unaltered during analysis, as it was in the context of the original text. Moreover it must prevent attrition of the original meaning and prevent reduction to a dictionary meaning (Krippendorff 2013). To preserve semantic validity, instead of selecting individual sentences or phrases that explained a particular barrier, complete sections of text that explained the background and implications were decided as the unit of analysis in order to satisfy semantic validity.

QUOTATIONS: The ATLAS.TI software allows you to select continuous segments or snippets from the documents which are referred to as ‘quotations’ and this is the first step after setting up the software. In the software it enables you to select a sentence, words or incomplete phrases which are called ‘quotations’. These quotations are stored in a dedicated part of the software and can be accessed independently from the main document. It is possible to print these quotations only and if needed, see the quotation in the original document.

CODES and CATEGORIES: Allotting units, or segments of text, keeping in view the suitability to the research aims, ‘labels’ or ‘categories’ is a key aspect of content analysis (Holsti 1969). In the context of Atlas.ti, this process is called coding.

Coding is the process of applying labels to quotations which can either be descriptive or conceptual. In the initial stages of Content Analysis the codes are numerous and descriptive but the codes are refined throughout the analysis and become fewer and more conceptual as the analysis proceeds (Friese 2012). The refining process of the codes can involve merging or recoding by thinking about the code in relevance to the research aims. In some cases, it can be seen how certain codes overlap and can be merged into a more abstract code. This process of refining code is part of the coding process itself (Friese 2012). Coding is accompanied with defining the code in detail which ensures that newly formed codes are aligned with old ones and there is no ambiguity about the meaning of the code.

The codes formed are then put under main categories or themes. Categories are high level codes which means they are broader in scope and meaning as compared to individual codes. There are two main ways of arriving at categories: inductive and deductive coding (Krippendorff 2013). In inductive coding the data is used to form the categories whereas in deductive coding the categories are based on previous information such as making themes from a brief review of the literature under study. An inductive approach for coding was selected in this research and no prior categories were made before the coding process. The purpose of the categories is to give structure to the codes and promote thinking about the data on a more conceptual level (Friese 2012).

FREQUENCY (OR GROUNDNESS): Refers to the number of quotations that are labelled under a single Code. For example, if ten different quotations referring to high initial costs of DRES are coded under the heading, “DRES too expensive”, the frequency would be ten in this case.

MEMOS: Memos enable recording of the thinking process and can be helpful during the analysis of the data to develop ideas and concepts. The memo function allows the researcher to note down thoughts, hunches or reflections during the analysis process, which have been called “containers for ideas” (Friese 2012). Atlas.ti also enables connection of these memos to specific codes and quotations.

3.3 METHOD

The method used in this study is broadly based on the NCT (NOTICE-COLLECT-THINK) model for computer aided qualitative content analysis (Friese 2013). The model suggests three different processes for computer aided qualitative content analysis, namely Noticing, Collecting and Thinking. A visual representation of this model can be seen in Figure 3-1. It should be noted that as indicated by the two-way directional arrows in the figure, the content analysis process is not sequential and there is constant moving back and forth between the different components of this model. The three processes of the model used in this study are described below and this description is followed by the two stages of coding which makes use of these three processes.

I. Noticing

The noticing process involves marking or highlighting pieces of text in written text that are relevant to the research. In the case of this study it meant marking or highlighting sentences or phrases that discussed challenges to Decentralized Renewable Energy Systems in the literature. This marking or highlighting can take the form of Quotations or these Quotations could be converted to Codes by applying labels to them. The Codes can be descriptive or conceptual. The Quotations or Codes do not have a role in the analysis at the noticing stage but the purpose of this step is to 'record' information for later analysis.

ii. Collecting

During the noticing period a large number of Quotations and Codes are accumulated. The 'Collecting' process refers to the actual coding process where the Codes are refined in light of the research questions. The refining process involves deleting quotations or codes and merging or making new codes to subsume codes with lower frequencies which are based on similar characteristic of the data. The number of codes is reduced from a large number of codes with low frequencies to a smaller number of Codes with broader meanings.

iii. Thinking

The thinking process is where the refined and now structured codes are evaluated in terms of the research questions. A number of tools such as Memos, network diagrams and querying tools in Atlas.ti are used to make more sense of the data. This process can also be construed as a visual way of thinking, organizing and analysing the data.

Stage 1 Coding: Descriptive level analysis

Following Friese (2012)**,** two stages have been used in the coding process. The first stage is described as a 'descriptive level analysis'. The aim of this stage is to explore the data and to apply the processes of Noticing and Collecting (as described earlier).

Labels (called Codes) were applied to segments of the document (called Quotations) that explained or mentioned a barrier to DRES. For example, if a barrier implied that DRES were not adopted due to being expensive, a Code "too expensive" would be assigned to the quotation. This process is continued to make more new Codes until a saturation point is reached and no new Codes are formed and signifies the end of the first stage of the coding. In the second step, categories are formed to give more structure to the codes and to systematically divide and display all the codes. Taking Institutional barriers as an example, all the barriers that were related to an organized group of people or entities responsible or involved in DRES projects such as government organizations, non-government organisations, donor bodies etc., were clumped together under the category of 'Institutions'. At this point in the coding process, the codes evolve from merely describing the highlighted text to a more conceptual form and simpler codes identified in earlier stages of the research are condensed into broader meaning Codes and concepts. Analysing the list of codes in this manner, it was possible to classify the codes into different categories such as Social, Monetary, Technical or Institutional which are discussed in detail in Chapter 4.

Figure 3-2 shows an example of a structured code list.

Figure 3-1 – **The NCT model qualitative content analysis** (Friese 2013)

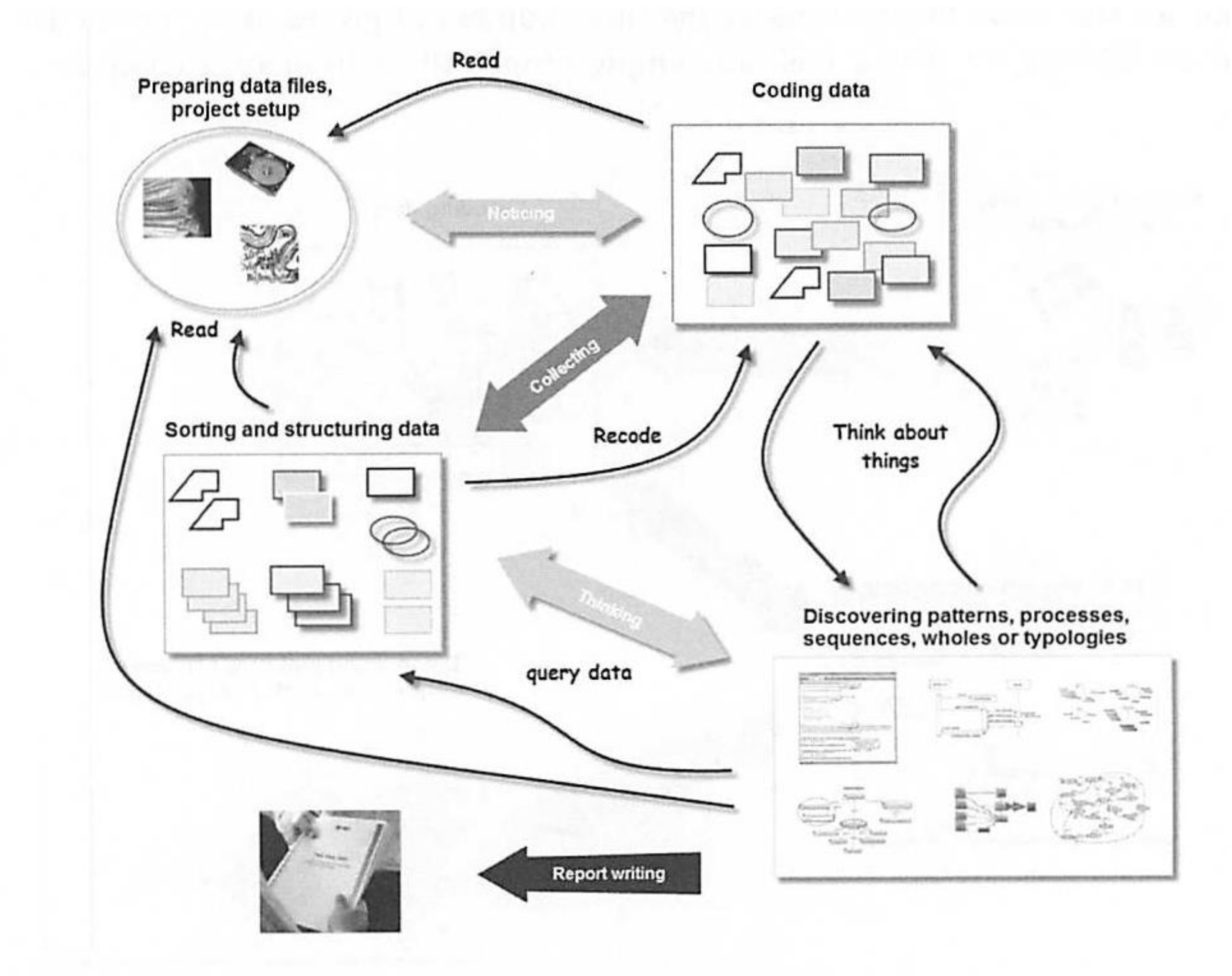
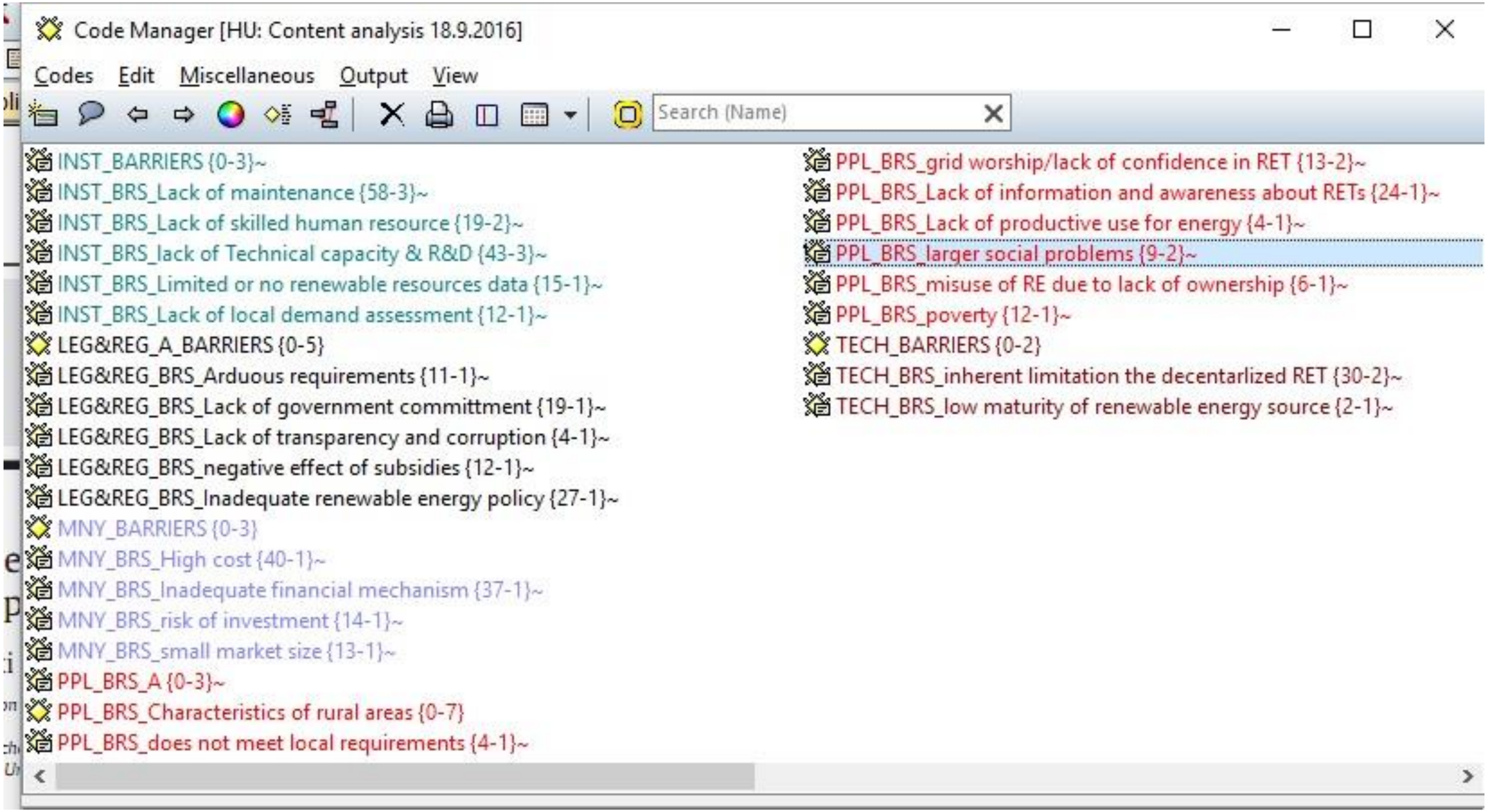


Figure 3-2 Example of structured codes as viewed in Atlas.ti



Stage 2 coding: Conceptual level analysis

In the second stage the previously developed structure of coding was applied to the remaining documents in the study. The second coding stage is a way of validating the first coding stage (Friese 2012) as no new codes form at this stage. If new data was encountered that did not fit the framework, then revisions were made to the coding structure. The advantage of such a coding structure is that it allows the data to be systematically accessed for analysis.

The last stage of the Qualitative Content Analysis entails looking at this coded structure and categories and assessing it in terms of how it can answer the research questions. This is called a conceptual level analysis. Tools such as network views in the form of memos and ideas noted down through the research were put together to understand the relation between codes and categories.

3.4 SAMPLING

Peer-reviewed and grey literature on barriers to Decentralized Renewable Energy Systems were used as two data sources. Academic literature included research papers obtained from peer reviewed journals whereas grey literature in the scope of this study refer to literature freely available on the internet in the form of country government websites, NGOs, donor and development agencies such as the World bank working in the area of Decentralized Renewable Energy Systems in South Asia. These two different sources were selected to analyse the difference in approach, if any, in discussion of barriers to decentralized renewable energy systems in the respective type of literature. It was also intended to assess practical implications of this difference.

The scope for collection of journal articles was limited to peer-reviewed journals but no attempt was made to include or exclude any specific journals. The collection of peer-reviewed literature was carried out by searches of keywords on bibliographic databases and journal collections EBSCO, ProQuest & Science Direct. The key words used were “decentralized” AND “[names of countries in study]”, “challenges” AND “renewable energy”, “rural” AND “electrification”, “off-grid” AND “rural”, “decentralized” AND “barrier”. The same keywords were employed in looking for grey literatures on the internet by using the search engine Google. In addition, a technique called “The Snowball Technique” (Ridley 2012) was adopted where bibliographies of previously selected articles were consulted to identify new sources of data.

Due to varied nature of the documents available, a purposive sampling was adopted to ensure that both peer-reviewed and grey literature was in line with the research objectives. The criteria for the purposive sampling were as follows:

1. The source must discuss energy access (electricity sourced from renewables or clean cooking energy) in a rural setting
2. The paper must discuss barriers to Decentralized renewable energy systems
3. The paper must be based in one of the five South Asian countries in the study

Although it was desired that all the documents met all three criteria but due to shortage of such documents the criteria were relaxed. A document was selected only if it met the third criterion and either of the first two criteria of the sampling.

All documents included in the study originated in the period 2000 - 2016. Fifty articles were selected in this study which included thirty four peer-reviewed articles and sixteen grey-literature articles.

It is necessary to point out that some bias might have been introduced as a result of this sampling technique. As grey literature was searched in English language, it is possible that documents in languages other than English, relevant to the research might have been overlooked. This is especially applicable in this study as many countries in South Asia use languages besides English as their official language. Grey-literature was sourced from publicly available online resources. This technique restricts documents to only those that are available online and thus excludes relevant data that might not be available online. Although care has been taken to make sure that all the relevant keywords were used to track down all peer-reviewed and grey- literature pertaining to the study, it is possible that some documents utilized other terminologies to refer to Decentralized renewable energy systems which subsequently would not have appeared in the search results.

3.5 LIMITATIONS & RELIABILITY

Content analysis as a method has been criticized as a simple and supplementary method (Weber 1990; Robson 2002). However, the proponents of content analysis deem it suitable as any other main method if objectivity, reliability and validity are ensured (Krippendorff 2013). These three characteristics are distinguished features of the suitability of any method lies in its ability to successfully answer the research question (Krippendorff 2013)

Marshall (1999) cites that the range of subjective understanding can that can be developed from a text as a weakness of Content Analysis but not all cases are susceptible to high levels of subjectivity due to the objective or factual nature of the data. An explanation for low levels of bias in this study is the use of manifest content, as opposed to latent content which poses more problems related to inference and reliability (Krippendorff 2013). A complete lack of bias on the researcher's part although wanted, is not possible but a high level of objectivity can be maintained by self-awareness of the researcher's bias (Robson 2002).

The limited number of documents in the study and a comparatively lower reliability as compared to quantitative methods has been regarded as a limitation for a qualitative method like Content Analysis (Montello & Sutton 2012). Intra-coder reliability is suggested as a test for reliability in Content Analysis (Krippendorff 2004) where one or more person codes the same piece of data. The level of agreement in the codes is used as a measure of reliability. In this study an adapted method for reliability was achieved by partial self-recoding of the documents. After 50% of the documents were coded, the first 10% of the documents were re-coded and the resultant codes were compared with the initial codes. The results showed a >90% match with the original code which indicated a high degree of reliability of the coding method.

3.6 SUMMARY

Qualitative content analysis was selected and used as a method to achieve the objectives. The use of this method allows an immersion in the data and allows in-depth analysis of the barriers to DRES in South Asia. Such an approach had been previously missing where past literature had relied on a "literature review" format. Coding is the essence of a content analysis method which follows an iterative cycle of "thinking" about the data. It is during this cycle that greater understanding of the data leads to development of concepts and ideas which are discussed in more detail in Chapter four and Chapter five.

4. SYSTEMATIC REVIEW & ANALYSIS

The first part of this chapter discusses the barriers obtained from the analysis of the material drawn from both peer-reviewed and grey literature about the five main countries with which this study is concerned. The barriers have been categorized into five main themes as discussed in detail in Sections 4.1 – 4.5. Table 4-1 summarises these main five themes along with some examples. The chapter ends with observations, learnings and implications of these barriers.

Table 4-1 List and definitions of barriers to Decentralized Renewable Energy Systems

Barrier Title		Definition
1	Institutional barriers	This section contains the barriers to Decentralized renewable energy systems (DRES) associated with organized entities such as government organisations, power utilities responsible for rural electrification, NGOs, etc. Some examples of barriers are • Inadequate planning, installing and maintaining DRES • Top down approach • Lack of research and development • Lack of skilled human resource in the region
2	Legal and regulatory barriers	This section discusses all challenges associated with policy and regulations such as • Difficult and lengthy approvals for DRES • Lack of transparency in decisions of regulatory bodies such as subsidy grants etc. • Negative effect of subsidies • Inadequate renewable energy policies
3	Monetary barriers	This section discusses some of the financial reason such as • High initial costs associated with DRES • Lack of financing for rural users and developers • Perceived risks in investing in DRES
4	Social and People-related barriers	These are the barriers associated with the people, mainly rural communities utilizing DRES. Some examples include: • Lack of customisation of DRES per local requirements • Lack of awareness & acceptability of DRES • Lack of productive use of DRES • Larger social problems such as gender inequity
5	Technological barriers	Technical barriers include: • Site specificity of some DRES • Lack of suitable sites for renewable energy technologies has been quoted as barriers for DRES.

4.1 INSTITUTIONAL BARRIERS

An inadequacy or absence of function performed by an organized entity such as government bodies, entrepreneur managed Decentralized Renewable Energy Systems (DRES) and NGOs, which acts as a barrier to utilization of DRES is referred to an institutional barrier in this study. Some institutional functions may include: deciding which communities will be electrified, selection of renewable energy technologies, planning, building and maintaining renewable energy systems, etc. The barrier and its definition are presented in Table 4-2.

Table 4-2 Institutional barriers definitions

Barrier	Definition
Lack of long term viability	Absent or ineffective measures by institutions such as maintenance or availability of spare parts etc. to ensure that the DRES achieves its intended life
Lack of information and promotions	Absent or ineffective methods in institutions to disseminate information such as: monetary and health benefits of clean cooking energy to users and private developers, guidelines and financial incentives etc. for investing in DRES
Lack of technical knowledge R&D	Absent or ineffective institutions to develop low-cost DRES as per user needs, establish quality control of DRES, gather reliable renewable resource data
Lack local demands assessment	'Top down' approach of institutions where demands, habits, financial capacity are not assessed in design and selection of DRES
Lack of skilled human resource	Absence of local technical and management expertise for DRES projects
Inadequate networking & coordination	Absent or ineffective facilities and platforms for coordinating between institutions

These barriers will be explored in more detail in sections 4.1.1 to 4.1.6. A summary of the institutional barriers along with implications and suggested actions is provided in section 4.8.

4.1.1 Lack of maintenance

Lack of maintenance has been quoted as one of the main reasons why DRES fall into disuse (Committee for Promotion and Dissemination of Renewable Energy in Bangladesh 2000; K.C. et al. 2011; Amjid et al. 2011). An example from the literature raised the following: A project of Improved Cooking Stoves (ICS) in India failed because there was a lack of service plan and users discarded their ICS after it developed defects (Bhattacharya & Jana 2014). In a DRES project in Bangladesh based on biogas plants, only 32% of installed plants were functioning after one year due to lack of appropriate maintenance and technical knowledge (Islam et al. 2014) and another biogas pilot project only had 50% plants functioning after a few years (Mondal et al. 2010). In this last example, inadequate maintenance was cited as a barrier as contracts were awarded to private contractors who had poor performance which resulted in the rural community reverting to kerosene, their previously used cooking fuel.

4.1.2 Lack of information and promotions

Evidence in literature shows that due to insufficient demonstration and promotional activities institutions are not successful at motivating and educating users and private investors about the availability of DRES and its ability to produce electricity for hospitals, community centres etc. (Mirza et al. 2003; Grameen Shakhti 2006; Rofiqul Islam et al. 2008; Amjid et al. 2011; Gurung et al. 2013; Luthra et al. 2015). Low penetration of improved cooking stoves (ICS) in India has been attributed to lack of widespread effort on part of the agencies/institutions (Alam et al. 2003). The author does not elaborate on the nature of the widespread effort that is missing but it is inferred that there was a lack of promotions that reached a larger part of the targeted rural population.

Similarly, there is an overwhelming lack of information and education among users and developers that DRES like ICS can raise biomass efficiency (Grameen Shakhti 2006; Mondal et al. 2010; Waheed Bhutto et al. 2014) and the rural population is unaware of the potential cost savings of using DRES in the long run when compared to fuels like kerosene (Rofiqul Islam et al. 2008). Rural communities are also unaware of the health risks associated with indoor pollution due to inefficient use of biomass (K.C. et al. 2011).

Analysis of literature also indicates that there are too few agencies promoting the use of RETs at the rural level (Grameen Shakhti 2006; Amjid et al. 2011; Rahman 2012). There is no central source for reliable low cost information on how best to implement DRES (Gurung et al. 2012) and information is scattered among various public sectors, R&D centres and academia (Rofiqul Islam et al. 2008). This lack of information about government subsidies, finance sources, knowledge of other working projects, technical knowledge and equipment suppliers (Rofiqul Islam et al. 2008; Gurung et al. 2012; Rahman 2012), along with a lack of knowledge of the advantages of using DRES has prevented stakeholders (users and developers) from taking an active interest in DRES projects (Luthra et al. 2015). Analysis of literature gives evidence that promotional campaigns for DRES are poorly designed and unable to inform the general public about the benefits of DRES (Christian Aid 2012). Thus a lack of detailed and reliable source of information has led to a lack of confidence in adopting DRES (Luthra et al. 2015). The lack of information is not limited to users and developers but it extends to industrial and financial institutions (Mondal et al. 2010).

4.1.3 Lack of technical R&D

Analysis of the literature reveals a severe lack of research and development in Renewable energy technologies (RETs) (Gurung et al. 2012; Chaudhary et al. 2014; Luthra et al. 2015). Authors Chauhan & Saini (2015) say that there is not enough funding by the government to research low cost renewable technology. Local manufacturing and assembly of DRES is limited in the region (Rofiqul Islam et al. 2008; SREDA n.d.) which is attributed to a lack of materials and relevant skills to manufacture DRES to desired specifications (MNRE 2015). DRES is imported which have high initial costs (Waheed Bhutto et al. 2014; Luthra et al. 2015). K.C. (2011) cites an absence of dedicated organizations for researching and developing DRES specific to local economic and geophysical conditions.

There is a lack of quality control and standards for DRES (Islam & Islam 2005; SREDA n.d.). Authors Islam, Rahman and Chauhan (2008; 2012; 2015) say that due to lack of quality control and technical standards, DRES are of low quality and have low reliability. An example of unregulated technical standards for DRES is found in Nepal where Solar kit sellers were in large numbers but the quality and design was found to be poor (MNRE 2015).

There is insufficient reliable information on renewable energy resource potential such as solar insolation, wind speeds, water flow etc. (Rofiqul Islam et al. 2008; Mondal et al. 2010; Islam et al. 2014; Nayyar et al. 2014; Chauhan & Saini 2015). Evidence shows that a lack of information has impeded decision making at the energy policy level and has also hampered investor decisions (Zaidi & PCRET 2009; Rauf et al. 2015).

4.1.4 Lack of local demand assessment

Literature analysis shows that a lack of regard for local energy requirements, habits and technical capabilities when designing and installing DRES is a source of failure of DRES (Gurung et al. 2013). Lack of inappropriate selection of RET can result in low confidence in DRES (Rofiqul Islam et al. 2008). A relevant example is where biogas digesters were installed in Nepal but the poorest could not benefit from the subsidy provided by the government for biogas digesters because they did not have sufficient livestock to gather manure for the digesters (K.C. et al. 2011).

Literature gives evidence of a focus on DRES like Solar Home Systems for increasing rural energy electrification but selection of this technology does not address the most common need of rural population, cooking energies (Bhattacharyya 2006b). Another example is that of a family sized solar reflector type cooker which was installed in India but failed due to being unsuitable for the family because the size was not sufficiently large (Sarkar et al. 2003; Mondal et al. 2010). An unsuccessful improved cooking stove project did not consider the size of utensils (which did not fit the small openings of the new stoves), different food preparation habits, lack of dual functionality of space heating and cooking and inability to use locally available biomass and industrial residue (K.C. et al. 2011).

4.1.5 Lack of skilled human resource

A large number of studies point to the institutions' lack of experience in handling and managing DRES due to a lack of technical expertise required for successful installation and maintenance of DRES (Mirza et al. 2003; Islam & Islam 2005; Grameen Shakhti 2006; Zaidi & PCRET 2009; Sheikh 2010; Gurung et al. 2011; Gurung et al. 2012; Waheed Bhutto et al. 2014; SREDA n.d.). An example of such failure could be found in Pakistan where solar panels were set up in villages in the 1980s but the project failed due to lack of technical expertise (Mirza et al. 2003; Sheikh 2010; Waheed Bhutto et al. 2014; Rauf et al. 2015). It is unclear in this example as to what purpose the technical expertise serves and it has been assumed that it refers to a lack of technical expertise of the government agency to operate and maintain the DRES. Another improved cooking stoves project stalled due to shortage of skilled manpower (MNRE 2015). Literature also cites that due to an absence of local technical expertise, expensive private consultation teams from outside the region had to be hired which further elevated cost for providing DRES to rural areas (South Asia Regional Initiative for Energy & SARI 2002).

Bhattacharyya (2006b) cites another important lack of expertise namely lack of ‘managerial skills’ for DRES as one of the main reasons why improved cooking stoves have not become popular among the rural poor. K.C. (2011) says that community based biogas plants suffer from management problems due to conflicts in sharing. There is also a dearth of professional expertise and associated service companies such as consultants, contractors and equipment suppliers (Rauf et al. 2015; MNRE 2015). Islam (2005) says that there is limited expertise in the field of marketing and management skills when it comes to DRES which has been attributed to a lack of trainings available in the country (Waheed Bhutto et al. 2014; MNRE 2015; Luthra et al. 2015; SREDA n.d.). Chauhan (2015) says that skilled work force are not willing to work in rural areas because of low salaries.

There are limited courses and vocational training at universities and technical institutions that train manpower to work with DRES (K.C. et al. 2011), and especially for developing low cost RET solutions for rural areas (Gurung et al. 2012).

4.1.6 Inadequate coordination

Literature analysis suggests that there is inadequate coordination among donor agencies, energy companies, distributors, micro-finance institutes, ministries, government agencies and research institutions (Rofiqul Islam et al. 2008; Mondal et al. 2010; Rahman 2012; Gurung et al. 2013; Rauf et al. 2015) but further explanation of the type of coordination that was desirable was not elaborated by the authors. On a smaller scale there is a lack of communication between project owners, developers and equipment suppliers (Chauhan, Saini 2015). Expansion of the central grid to rural areas without prior planning and lack of communication has created frustration among private developers, as rural users choose to abandon DRES once their area is connected to the grid (Schnitzar et al. 2014). There is also an absence of linkages between various stakeholders which are necessary components for technological transfer such as links between universities, Research and Development institutes, chambers of commerce and industries, poverty reduction agencies and institutes developed for technology transfer (Shah et al. 2011). The author does not elaborate on desirable 'linkages' to support this barrier.

4.2 POLICY, REGULATORY & POLITICAL BARRIERS

Barriers due to policies and regulations dictating the use of DRES are explained in this section. For the sake of simplification, no distinction has been made between policy and regulatory barriers and they are both treated the same. Table 4-3 lists the barriers in this section and its definitions. These barriers are discussed in more detail in sections 4.2.1 – 4.2.5.

Table 4-3 Legal, policy and regulatory barrier definitions

Category	Definition
Ineffective renewable energy policy or regulatory framework	Absent or ineffective policies and regulations that specifically address DRES by providing guidelines for implementation, financial support, promote private investment,
Arduous requirements and delays	Regulatory DRES project licensing and subsidy disbursement that are subject to lengthy approval times, complicated and impractical procedures
Corruption and politics	Policies and regulation that do provide clear description for selection and license grant for operating DRES leading to misuse of subsidies etc.
Lack of subsidies	Barrier to DRES due to lack of subsidies itself, difficult and lengthy procedure for subsidy allotment etc.
Lack of government commitment	Actions and inactions that are detrimental to the development of DRES in the region

4.2.1 Ineffective and inadequate renewable energy policy and regulations

Evidence from literature shows that some pilot projects based on DRES were launched with success but the projects were not scaled up (Mondal et al. 2010; World Bank 2014) due to unclear policies and future plans. No specific example of a project was provided by the literature. Inadequate renewable energy policies that lack clarity (Amjid et al. 2011; Waheed Bhutto et al. 2014) and fail to provide support in the realisation of DRES projects hamper expansion of DRES (Zaidi & PCRET 2009; Mondal et al. 2010; SREDA n.d.). Inadequate allocation and release of funds by regulatory bodies despite being dictated by renewable energy policies (Chauhan & Saini 2015) have also been cited as barriers to DRES.

Mini-grids have the potential for providing grid-quality power enabling productive activities but there is an absence of dedicated policies that guide and optimize the installation of mini-grids (Chaudhary et al. 2014; World Bank 2014).

There is a lack of a policy and regulatory framework to support commercialization of RET and most projects are technology-driven where the focus is to assess the technical capability of the technology (Islam & Islam 2005). Policies are not market oriented and only support technical research and development of RETs, which are not then tested for commercial viability (Rofiqul Islam et al. 2008) and hence do not have supporting financial mechanisms (Shah et al. 2011). Literature analysis also shows that there is a lack of regulations that protect the interests of private investors in the renewable energy sector (Zaidi & PCRET 2009).

DRES projects fail to become part of the mainstream energy planning at the government level when policies are not based on proper renewable energy resource assessment and planning (Rofiqul Islam et al. 2008) and when there is a lack of information about potential users and their energy requirements (Alam et al. 2003). Literature also shows that some regions have renewable energy policies that encourage larger capacity DRES by offering more financial assistance and subsidies to bigger projects. Thus they do not account for the socio-economic landscape of rural population and result in marginalization of the very poor (Gurung et al. 2012).

While attempts have been made to incorporate electricity-producing DRES, policies that guide the efficient use of traditional fuels such as biomass remain lacking. Almost all rural populations utilize various forms of traditional fuels to meet their cooking needs but there is no specific and definite policy that mandates the promotion of efficient and clean use of traditional fuels (IDEA, n.d.).

4.2.2 Arduous requirements and delays

Literature analysis shows that the control of resources is often centralized with the local rural population exerting little control on plans made for fulfilling their energy requirements (Christian Aid, 2012). Authority for license approvals (for setting up a mini-grid for example) and allotting subsidies in South Asian countries often lie in these inefficient centralized government structures which suffer from bureaucratic hurdles and red tape (Mainali & Silveira 2011; Nepal 2012; Gurung et al. 2013). In some cases the impractical requirements for subsidy eligibility such as a low power allowance (of maximum 120 W) for each household and a requirement for at least 10% productive use[14] can make

[14] Productive use refers to the use of DRES for commercial activities that generate revenue

it difficult to be eligible for subsidies and actually acts as a barrier instead of promoting DRES (Mainali, Silveira 2011).

Furthermore, government approvals for use of land and physical infrastructure calls for unnecessary and complicated procedures which further delays DRES project (Cust et al. 2007; Rahman 2012; Chauhan, Saini 2015).

4.2.3 Corruption and politics

Existing DRES related regulations lack clarity, raise the possibility of corruption and are open to alternate interpretation (Cust et al. 2007). Politicians have made use of this lack of transparency for achieving their own vested interests such as approving licenses for relatives (Gurung et al. 2013; Luthra et al. 2015) taking bribes for project approvals or as a means of garnering votes. In some cases, installation of DRES in rural locales was target-, budget- and subsidy-driven in nature and customer preferences were overridden so specifications could meet the government requirements (Bhattacharya & Jana 2014).

Literature suggests that there is a lack of accountability for poor performance (Bhattacharya, Jana 2014). Banks are reluctant in long term investment due to bad governance (World Bank, 2014). Corruption in political circles is another factor that has impeded the dissemination of DRES in India (Luthra et al., 2015). Political leaders for their own agenda can extend central grid power lines to villages which can become a barrier in the promotion and implementation of RETs (Grameen Shakhti, 2006). Political turmoil and frequent changes in political system have been cited as barriers to private investments in rural DRES (K.C. et al., 2011; Nepal 2012; Gurung et al., 2013; Bhattacharya, Jana, 2014; World Bank, 2014; Rauf et al., 2015).

4.2.4 Subsidies

Subsidies which are not administered properly, without planning for the post-subsidy period have acted as a barrier to DRES (Rahman et al. 2013). Biogas projects launched in Pakistan based on subsidies did not prove to be feasible after subsidies were removed, which resulted in the failure of the project (Waheed Bhutto et al. 2014).

There is a lack of decentralization of the subsidy decision-making authorities to a local district or provincial level, and instead they appeal to a single central regulatory body (Mainali & Silveira 2011). Absence and delays in the acceptance of DRES-based projects and subsidies are a source of demotivation for private investors (Rofiqul Islam et al. 2008; Mondal et al. 2010; Mainali, Silveira 2011; Chauhan, Saini 2015; Luthra et al. 2015).

Literature analysis also shows that subsidized DRES projects can cause market distortions (Rahman 2012). Government subsidized projects often provide energy access to the poor with little or no margins i.e. the projects can take form of social service rather than a commercial venture. This demotivates private investors as they cannot compete and invest in projects that are not commercially viable (Cust et al. 2007; Bhattacharya & Jana 2014).

Another aspect of an improper implementation of subsidies is where the main focus of the private project developers shifts to only grant or subsidy rather than providing a reliable DRES for improved rural energy access, due to mismatched priorities. As a result deterioration of quality, poorly run and monitored projects ensue (Pohekar et al. 2005; MNRE, 2015).

4.2.5 Lack of government commitment

The political commitment to establish an effective renewable energy policy is absent (Sarkar et al. 2003) and the role of DRES in the socio-economic growth is not recognized by governments (Shah et al. 2011; Rauf et al. 2015). Subsidized conventional sources of energy such as oil and gas (Rofiqul Islam et al. 2008) and heavily subsidized agricultural sector also shows a of a lack of political commitment to RETs (Chauhan & Saini 2015).

The government is often focused on the expansion of the central grid rather than DRES as a means of increasing rural energy access (Rauf et al. 2015; Committee for Promotion and Dissemination of Renewable Energy in Bangladesh 2000).

4.3 MONETARY BARRIERS

Barriers due to monetary reasons are discussed in this section. Table 4-4 lists the monetary barriers and its definitions. These barriers are discussed in more detail in sections 4.3.1 – 4.3.3.

Table 4-4 Monetary barriers

Category	Definition
High cost and low demand	This category includes barriers stemming from high initial costs of DRES and also their low demand
Inadequate financial mechanisms for funding DRES	No proper methods in place to provide money to invest in DRES projects
Barriers to private investment	DRES depend a great deal on private investments and hurdles in getting these investments is discussed in this category

4.3.1 High cost & low demand

As mentioned in Chapter 1 and 2, the majority of the population without energy access live in the rural regions of South Asia. DRES have been utilized to provide energy access to this targeted rural population but these communities are composed mainly of poor people with limited financial resources. Despite the technical viability of DRES, required initial investments are relati v ely high (Mirza et al. 2003; Sarkar et al. 2003; Pohekar et al. 2005; K Hossain, Badr 2007; Rofiqul Islam et al. 2008; K.C. et al. 2011; Mainali, Silveira 2011; Nepal 2012; Gurung et al. 2013; Waheed Bhutto et al. 2014; Chauhan, Saini 2015). These high initial costs coupled with low load factors[15] further drive up costs, as fixed costs are divided

[15] Load factor is the ratio of energy being utilized to the maximum potential. A low load factor indicates lower utilization of available potential for producing energy

among a smaller number of people (Gurung et al. 2012; Rahman et al. 2013). A low electric load (which is often the case in rural areas) makes the electricity per unit more expensive as the initial large investment is spread over a smaller number of users. Loads can be as low as 50% in Micro-hydel Plants (Gurung et al. 2012) which effectively doubles the price of electricity. The energy demand is quite low because of a lack of modern appliances, and only peaks during evenings which leads to requirement for high peak components and other equipment. This in turn raises cost (Rahman et al. 2013). The resulting higher costs are often not affordable by the poor of rural regions, without financial assistance. Low plant load factors can push privately-invested ventures which depend on generating revenue for operation and maintenance into failure.

Analysis of the literature shows that a small market size for DRES is also responsible for high initial costs (SREDA n.d.). The use of DRES is not widespread, with limited demand by rural users, and DRES sellers are scattered and few in numbers (Alam et al. 2003; Rahman 2012). The local market is small due to limited local production and largely dependent on imports (Christian Aid, 2012). The small market size prevents the advantage of economies of scale (Mondal et al. 2010). Even with falling international prices of DRES, regional costs of DRES have not fallen (Nepal 2012). It is a vicious cycle where there are limited imports due to fewer people buying DRES (Sarkar et al. 2003) which causes the prices to stay high and as a result high prices of DRES retard market growth. Sarkar (2003) also says that many people still consider DRES a novelty which results in a low demand.

Developers who already operate mini-grids are not keen on scaling up (Schnitzar et al. 2014). Luthra (2015) says that private DRES developers are smaller in size and they do not possess the human and financial resources to attract a large number of consumers. Price distortions due to government-subsidized DRES projects has also adversely affected the market size (Islam and Islam, 2005; Rahman, 2012).

4.3.2 Inadequate financial mechanism for funding DRES

Source of financing or a financing mechanism is often one of the major barriers in implementing DRES (Grameen Shakhti 2006; Christian Aid 2012). Grameen Shakti in India is a good example of a micro-credit insititution which provides micro credit to rural population but there is widespread dearth of such financing mechanisms (Rai 2004; Rofiqul Islam et al. 2008; Mondal et al. 2010; Rahman 2012; Chaudhary et al. 2014).

DRES projects have been scrapped after successful testing and operation because there was no adequate financial mechanism in place to ensure financial viability (Mondal et al. 2010; Rahman 2012). Such failures highlight the need of the financial viability of DRES projects.

Literature analysis shows that some credit institutions charge considerably higher interest rates which deter people and DRES developers from investing in rural electrification. Long term financing with soft loans are absent for developers. Financial institutions are biased against and have limited experience of financing DRES projects (Islam & Islam 2005; Grameen Shakhti 2006; Rahman 2012; SREDA n.d.). This bias can be explained by a lack of willingness to invest by the banking sector because of the perceived high risk of default by customers and lack of confidence in the usefulness of such investments (SREDA n.d.).

Furthermore, the terms of the credit are often stringent with high interest rates causing many non-government organisation to fail in replicating (by providing a competing power tariff) what the government is able to achieve with subsidies (Cust et al. 2007; Rofiqul Islam et al. 2008; Gurung et al. 2012).

Developing countries do not possess the financial and technical resources to solve the rural energy problem (Gurung et al. 2013; Rauf et al. 2015). DRES are often linked to national budgets (Mondal et al. 2010) which can complicate the allocation of funds (Rofiqul Islam et al. 2008; Rahman 2012) as limited national budgets also address other issues. Devaluation of currency has limited the potential benefit Nepal could reap from internationally falling prices (Nepal 2012).

4.3.3 Barriers to Private investment

The limitation of financing options faced by rural users also extends to the developer and local entrepreneur who often have no access to loans and credit for setting up a DRES project. Government institutions promoting rural based renewable energy technologies often have weak institutional framework for financial management which causes hesitance in investors, as they feel there is a risk of losing their investment (Chauhan & Saini 2015). The author does not elaborate this point and it is assumed that government agencies do not have enough incentives for private investors.

Literature analysis shows that many investors deem the DRES market to be small and immature (Gurung et al. 2012). There is strong evidence that DRES without financial incentives hold little attraction for private investors due to low margins, small returns and the lack of purchasing power of rural people, which adds to the risk of investment (Islam & Islam 2005; Bhattacharyya 2006b; Gurung et al. 2012; Nepal 2012; Gurung et al. 2013).

Bad debts due to insolvent rural energy access projects also deters banks from giving out loans (Mainali & Silveira 2011). Literature gives a possible explanation of this problem faced by DRES developers because of bill payments recovery issues especially when locally-nominated community members are unable to collect payments due to caste system found in rural areas (Schnitzar et al. 2014). Private investors are also discouraged by political turmoil, bank scams and the weak economy of the host countries (World Bank 2014)

4.4 SOCIAL AND PEOPLE RELATED BARRIERS

Barriers due to societal norms and people are discussed in this section. A list of the barrier categories and its definitions are given in Table 4-5. These barriers are discussed in more detail in sections 4.4.1 – 4.4.7.

Table 4-5 Social barriers

Category	Definition
Poverty	Limited ability of potential users to utilize DRES due to low income
Incompatible with local needs and customs	Inherent design fault of DRES limits its use, such as small improved cooking stoves that cannot accommodate large cooking utensils etc.
Lack of awareness and training	1. Limited or no information about availability, financing etc. of DRES 2. Loss of operation of DRES due to lack of appropriate training to operate and maintain DRES S
Grid worship	The perception of DRES as being inferior to grid electricity
Lack of productive use	Limited or no tangible benefit derived from DRES such as being able to process crops, run small industries etc. for revenue generation
Low involvement of rural community	Limited or no input of the community in the initial planning and operation of DRES

4.4.1 Low income/Poverty

The target of DRES are rural people who are often poor and do not have the capacity to purchase these technologies (Alam et al. 2003; Rai 2004; Rahman et al. 2013; Luthra et al. 2015). The limited spending ability of rural denizens creates reluctance in many investors (Gurung et al. 2013). Literature suggests that some remote areas suffer from extreme poverty and people in these areas need additional financial assistance despite subsidies from the government (World Bank 2006b). K.C. (2011) has cited a problem with DRES in Nepal where the government has been sponsoring biogas plants for rural inhabitants. A lack of research into appropriate technology selection is suggested in this case, as the very poor who do not possess cattle (which is a source of dung, the fuel for biogas digesters) cannot afford a biogas plant and are thus marginalized.

4.4.2 Incompatible with local needs and customs

Failure to address local needs and customs can also cause failure of DRES. For example solar cookers are ill equipped to handle frying food which is an integral part of local cuisine in Nepal (K.C. et al. 2011). Sometimes the design of the equipment makes the cooking process inconvenient (Waheed Bhutto et al. 2014; Pohekar et al. 2005) such as the need to cook outside when using solar cookers. Some Improved Cooking Stoves are unable accept the large size of local utensils or require special types of fuels not available locally (K.C. et al. 2011). DRES that provide a central charging station for rechargeable batteries incur the inconvenience of carrying batteries, which is a to deterrent adoption of DRES (Committee for Promotion and Dissemination of Renewable Energy in bangladesh 2000)

4.4.3 Lack of awareness and training

There is a lack of awareness among rural population and private developers about the benefits of DRES as results of limited promotions and campaigns. This has also been discussed in section 4.1.2.

Islam (2008) points out the availability of potential biogas plant technology in Bangladesh, but there is low adoption due to a lack of awareness of the existence of such technology among potential users. On the other hand lack of training arrangements for people in rural areas who are in charge of maintaining renewable energy equipment is also a barrier (IDEA n.d.). A lack of training and understanding on how to operate a DRES efficiently can also demotivate users who lose interest and confidence in the system after it does not perform well (Alam et al. 2003).

4.4.4 Grid Worship & lack of confidence in DRES

People show a general resistance to adopt new technology and are not confident of their benefits (Alam et al. 2003; Pohekar et al. 2005; Waheed Bhutto et al. 2014). A strong incentive is required to move people towards this technology, which is currently missing (Rofiqul Islam et al. 2008).

Absence of warranty of components by institutions is also another barrier to adaptation of DRES by local masses (World Bank n.d.). DRES systems like solar lanterns or Solar Home Systems are financed over a period of years and if there is no arrangement for replacement or repair of a faulty system, will prevent users from adopting this technology.

There is a superior social status associated with the use of modern fuels like kerosene and technologies like Improved Cooking Stoves are perceived as old fashioned (IDEA n.d.).

There is an overwhelming lack of confidence in DRES in the rural regions where people perceive DRES as being inferior to central grid electricity. Due to this reason the rural population is keen for grid expansion and politicians have been known to exacerbate this negative perception by making commitments to extending the grid into rural areas, which further deters people from accepting or investing in DRES (Rahman et al. 2013). Some rural communities believe that accepting the introduction of DRES could actually preclude or delay the arrival of the grid (World Bank n.d.). Rural communities prefer the grid due to its unlimited supply potential even though the grid is often very unreliable, sometimes with limited few hours of operation (Schnitzar et al. 2014). Micro grids or DRES are often perceived as temporary solutions until the grid arrives. An example of grid worship by local inhabitants is the case of WBREDA (mini-grid developer in India) where the renewable energy based mini-grid was abandoned by users due to connection of the village to the central grid. People residing in villages lose interest in paying for mini-grid connections due to news of central grid extension and have also been observed pressing politicians for grid extension (Schnitzar et al. 2014).

4.4.5 Lack of productive use & revenue generation

DRES are often tied to only lighting and cooking and are unattractive (Bhattacharyya 2006b; K.C. et al. 2011) as they already have access to free energy source such as firewood for meeting their lighting and cooking needs.

There is lack of opportunities for productive uses of DRES (such as drying fruits, removing rice husk, other small enterprises etc.) which either generates revenue or saves time (Gurung et al. 2012). The lack of connection or integration of DRES with revenue generation has been cited as a barrier from widespread use of renewable energy among the poor (K.C.

et al. 2011). DRES Developers are of the opinion that it is not possible to operate a profitable mini-grid unless there are commercial activities taking place in the area under consideration for DRES installation (Schnitzar et al. 2014)

4.4.6 Lack of ownership due to low involvement of people

No community involvement and participation in DRES projects by developers fail to instil a sense of ownership causing abandonment and under-utilization of DRES and petty disputes (Cust et al. 2007). Fee for service program (where a user only pays for use of electricity and no upfront payment for connection is required) do not perform well, with the DRES project falling into disuse due to lack of interest on behalf of the users (World Bank 2014). Fee for service is often not cost effective as bills collection from remote and scattered locations is often time and resource consuming.

A lack of ownership causes neglect and abuse by the users (World Bank 2014) where the DRES is dismantled and sold off. Literature analysis shows that DRES projects such as mini-grids operate on low power and theft and over-usage are significant challenges faced by developers. Consumers disregard rules set by the developer, bypass electricity meters and use incandescent bulbs instead of low power bulbs which can overload the system. It is difficult to monitor consumption at individual customer level due to limited investment capital (Schnitzar et al. 2014).

Schnitzar et al. (2014) holds opposite views where he considers community involvement as barriers. DRES, mainly mini-grids, often utilize village electrification committees[16] (VECs) for tariff collection, resolving disputes, controlling theft but in cases where VECs do not

[16] Nominated members in a rural community that participate in DRES implementation and coordination with the developer

function effectively and are unable to resolve disputes, deliver correct maintenance, and control overuse, they can act as barriers to the success of DRES (Schnitzar et al. 2014). Another example of a failure of community involvement is where cooperatives (partnerships between local people and developers) responsible for collecting payments started demanding a share from collection money. In other cases cooperative elections (to elect locals to lead the cooperatives) became a political contest and rivalry ensued and as a result the cooperatives had to be dismantled (Schnitzar et al. 2014).

4.4.7 Other problems

Rural regions in South Asia face social problems such as gender inequity and poverty which hamper the adoption of DRES (Rai 2004). Conflicts between rebel factions within developing countries have been a challenge in operating mini-grids in some regions in India, endangering the institution personnel working in those areas (Schnitzar et al. 2014; MNRE 2015). Rural communities are often dispersed and have poor communication facilities which increases the cost installation and maintenance of DRES (Grameen Shakhti 2006). Institutions are unable to operate and maintain DRES equipment in remote areas due to bad terrain and lack of communication facilities (Rahman et al. 2013; Chauhan & Saini 2015).

4.5 TECHNOLOGICAL BARRIERS

Barriers due to technical limitations are discussed in this section. A list of barrier categories and definitions are given in Table 4-6. These barriers are discussed in more detail in sections 4.5.1 – 4.5.2.

Table 4-6 Technological barriers

Category	Definition
Intermittency	Low or limited performance of DRES due to variation in renewable energy resources
Other barriers	Such as necessity of a specific site for installation of some DRES like Micro hydel power MHP etc.

4.5.1 Intermittency

DRES such as solar cookers and photovoltaic based projects suffer from intermittent energy generation which has been cited as a barrier to adoption of DRES (Pohekar et al. 2005; Gurung et al. 2012; Waheed Bhutto et al. 2014). Due to intermittent nature of RET it is difficult to satisfy peak demands and a backup storage (such as a battery) is required which is itself a challenge due to prohibitive costs. These high storage costs reduce the financial feasibility of rural mini-grid projects (Luthra et al. 2015; Chauhan & Saini 2015).

Literature analysis shows that there is insufficient information on how inter-seasonal variation of the RET will affect output (Alam et al. 2003). Sometimes local conditions make it difficult for some technologies to operate. Biogas plants require ambient temperatures of 35-37 degree Celsius and access to water to operate optimally but in mountainous regions (as in Nepal) it is more difficult to operate biogas plants due to cold weather and lack of access to water. The river flow is seasonal and discharge varies leading to variation in peak electricity production using Micro hydel plants. In the case of solar PV it is often not appropriate for use in mountainous regions which do not get ample sunlight thus affecting electricity production. Solar devices such as solar cookers are also not effective in the long harsh winters of some areas such as mountainous regions of Nepal (K.C. et al. 2011).

4.5.2 Other barriers

Many technologies like Micro Hydel Plants (MHP) are site specific and cannot be used at every location (K Hossain, Badr, 2007; Mainali, Silveira, 2011).

Improved Cooking Stoves cannot provide heating at the same time as cooking and only limited to use specific type of biomass which deter people from adopting them as rural population often utilize stoves as space heaters (K.C. et al. 2011).

Lack of innovation has also been discussed as DRES developers such as Husk Power Systems in India are running successful micro-grids on rice husk gasification, but there is no replication of its design indicating there is a lack of innovation in the field (Schnitzar et al., 2014) to utilize other potential sources of fuel. Some technologies such as the rice husk gasification currently being utilized on rural mini-grids require more maintenance, increasing costs (Schnitzar et al. 2014).

4.6 REFLECTION: IMPLICATIONS AND ACTIONS

Before proceeding with this section, it is important to highlight that a general lack of specific and real-world examples with details based on case studies or field experience, was apparent during the analysis of the barriers.

It was observed during the analysis and categorisation of the barriers, some of the barriers overlapped categories and could not always be distinctly identified with a single category. For example, it is possible to categorize the Institutional barrier of "lack of maintenance" as a social one where there is a lapse in maintenance not due to an absence of institutional arrangement but due to a dispute among members of the community or lack of involvement of the community. "Lack of local demand assessment" and "Lack of community involvement" have been categorised as an institutional and social barrier but a "lack of community involvement" could be due to a "lack of local demand assessment". Thus, these two problems are actually related and depend on each other and addressing one of these problems will have an effect on the other. "Lack of productive applications" of DRES could very well be a product of "Lack of skilled human resource" in institutions, to integrate productive activities with DRES. This relationship between barriers also explains why some of the barriers appear in more than one category.

It can be inferred that due to this cross over of barriers into various categories, the categories themselves are not independent of each other. For example, Institutional success is not independent of the success of other categories. Thus, it can be further inferred that neither the categories nor the barriers are independent of each other and the barriers and categories are part of an interconnected mesh, that characterizes rural energy access programs based on DRES. Thus, it can be concluded that even a barrier in only one 'category' can adversely affect the performance and longevity of a DRES project.

An artificial scenario based on some of the examples encountered during the analysis of the literature is constructed below, further to demonstrate the interrelation of the barriers and categories. Relevant barriers have been put in square brackets.

An NGO intends to setup a micro-grid (a type of DRES) based on micro hydel power (MHP) to provide a few hours of electricity for lighting in the evening for a rural community. The NGO does not intend to generate a profit, but wants the project to be financially self-sustaining (after initial investment) by charging a fee-for-service to cover operating and maintenance costs. A license from the regulatory body is required to operate a mini-grid, which takes months to process **[Regulatory barrier - delays]**. Capital subsidy to cover part of the equipment costs takes additional time **[Regulatory barrier – delays]**. There is limited local technical expertise for installing the micro-grid and the NGO has to hire a foreign firm **[Institutional barrier- lack of skilled human resource]**. The residents of the village are required to apply for connection after commissioning of the micro-grid but many people are reluctant to pay because the mini-grid can only provide lighting which they already obtain by collecting and burning free wood **[Institutional barrier – lack of local demand assessment] [Social barrier – lack of productive activities]**. A few months into the project some wires and equipment are stolen **[Social – lack of ownership]**. In addition, the installed MHP is of low quality standard **[Institutional – lack of technical standards]** and there are frequent breakdowns that require further investment for maintenance and replacement of parts which was not initially built into the feasibility of the project. The residents are responsible for operating the DRES but have insufficient knowledge and training **[Social –**

Lack of awareness and training] and the DRES often does not work leading to customer dissatisfaction. A year after installation of the micro-grid, the central grid is extended to the area by the power company **[Regulatory – Lack of dedicated policy for DRES][Institutional - inadequate coordination]**. The locals abandon the micro-grid connection and switch to the grid because of its lower cost **[Social barrier – grid worship]**. The DRES is abandoned and project owner loses all initial investments. In this example, the DRES was threatened by multiple factors and it was necessary to address all Institutional, regulatory, monetary and technical barriers to ensure the sustainability of the project.

As discussed, the sustainability of a DRES project consists of a web of interacting barriers among the main categories which raises difficulty in understanding and solving DRES projects. A weakness in one area can snowball and affect other areas over time. Only a holistic view of the DRES projects can help in assessing the barriers. Drawing on the interdisciplinary nature of the barriers, an attempt has been made to discuss key areas for action that would strengthen rural energy access through DRES.

4.6.1 Capacity development

Literature analysis reveals that the bulk of the barriers belong to the institutional category which suggests that the current institutions need significant attention and development to effectively execute their role in rural energy access. Institution building and enhancement is a key aspect of capacity development which seems to be lacking, and which requires greater attention from programme planners and developers. Institutions created at different levels are varied in scope and complexity and include national renewable energy agencies, private entrepreneurs, or a simple village committee responsible for operation and maintenance of a DRES project. Literature analysis also suggests that monitoring of

DRES projects from planning to execution is another component of capacity development that perhaps deserves increased emphasis from programme planners. More effort is to be devoted to monitoring programme implementation and results, by different actors, using participatory approaches and diverse means to feed input back into programme management at district and national levels to improve and strengthen programme implementation and development impact.

Capacity development has been suggested as a prerequisite in order to sustain energy access in developing countries (Clemens et al. 2010). A definition relevant to this study is as follows: "Capacity development is a broad concept. It encompasses the process through which the abilities of individuals, organizations, institutions, and communities to perform functions, solve problems, and set and achieve objectives in a sustainable manner, are obtained, strengthened, adapted, and maintained over time", (Clemens et al. 2010, pg. 72).

The analysis of the barriers suggests that capacity development is needed in the following areas.

1. At government level: increase political commitment to increase use of DRES for rural energy access by formulating effective market-oriented policies, increase accountability and eliminating political influence from regulatory bodies by establishing independent regulatory bodies free from political influence
2. At regulatory level: develop and implement regulations that facilitate speedy DRES development, deregulation for small DRES developers, provide attractive incentives to private developers, and ensure quality monitoring of DRES against set technical standards

3. At organisational (national rural agencies, private developers and NGOs) levels to: impart training in technical skills for selection of appropriate technologies, maintenance and operation, provide management skills to private developers of DRES, launch and maintain effective promotions and demonstrations to popularise DRES, training in methods to monitor and build these learnings into plans.
4. At community level: provide technical training for operation and maintenance, develop entrepreneurship skills for productive activities, develop rural information points for free and reliable information regarding DRES

Prior to capacity development it is necessary to carry out a capacity development assessment where a planned assessment of the current capabilities of actors at all stages would become part of an action plan (Clemens et al. 2010). Pursuing this capacity development plan would enhance the capabilities to help achieve the target of rural energy access using DRES.

4.6.2 Technological R&D

Analysis of the barriers suggests that financial investment is needed in technical R&D to address barriers such as lack of technical and quality standards. An absence of technical standards and quality monitoring would threaten the reliability and functional life of DRES which would only exacerbate rural energy access in an already small market. On the other hand, the technical and quality standards should not be so stringent that DRES become very expensive and unfeasible.

Investment in local Research and Development can assist in the development of DRES which are low cost, meet user and geographical requirements, as locally developed technology would be cheaper than importing DRES. Investment in local R&D could also contribute to development of indigenous innovative solutions such as low cost durable batteries which could contribute further in reducing initial costs. Technical R&D institutes would also function to monitor renewable energy source data such as discharge rate of rivers, solar insolation and wind speeds, which is essential in planning policies, selection of appropriate technology.

Hybrid renewable energy systems, HRES, use a combination of renewable energy technologies to tackle the intermittent nature of many renewable energy sources. HRES offer a reliable and sustainable method of delivery quality electricity to remote locations where grid electricity would be too expensive. HRES are especially applicable for micro grid applications as they can withstand much higher loads (Mohammed et al. 2014). HRES offer a solution to the limitation of RET due to intermittent nature and seasonal variation (World Bank, 2008). In a micro grid setting it is possible to use a combination of different technologies utilizing solar, MHP, biomass and biogas to come up with the most cost effective solution to counter intermittency of a single renewable source (Kanase-Patil et al. 2010). All these actions require that investment in R&D is carried out specifically for developing DRES but it is necessary that these technologies are developed with a user centric approach; user demand and habits should be the focal point of all DRES development.

4.6.3 Productive activities[17]

Donor and development institutions such as such as the World Bank stress that productive activities linked with DRES ensure long term functioning of the DRES (Clemens et al. 2010).

[17] Productive use as used in the context of this study can be defined as agricultural, commercial and industrial activities, powered by renewable energy sources, which generate income (Lecoque et al. 2015)

The use of productive activities is not only beneficial to the user but it also has positive consequences for private DRES developers. Increased load factor due to productive activities (in case of micro-grids) can increase financial feasibility due to greater utilization of the capacity of the plant. Even if profit generation is not the objective of a DRES project, as is the case in government based projects, productive activities can enable the socio-economic development of the people (Kumar et al., 2009; Glemarec, 2012). Revenue generation from productive activities could also translate to increased equity of the rural community which would increase ownership and sense of participation. DRES projects that mainly rely on subsidies for operation and maintenance are not financially sustainable and literature analysis showed that DRES projects have collapsed in the past upon subsidy withdrawal. Productive activities could act as an exit mechanism from dependence on revenue subsidy, by letting the DRES become financially sustainable.

Commercial activities that generate revenue in rural communities offer an important opportunity for incentivizing and increase the willingness and increasing financial capacity of rural communities. Productive activities that generate revenue possess a tangible benefit for the user as opposed to consumptive purposes like lighting (previously being met by burning wood which came at no cost) enabled by a DRES.

It is possible to increase the load of a micro-gird by utilizing anchor users such as a rural industry which forms the bulk of the load. Mobile-phone towers can serve as anchor customers if this does not entail lengthy approvals from the regulatory body (Tenenbaum et al. 2014). This increased load factor utilizing the capacity, makes DRES more financially feasible. Lecoque et al. (2015) discusses the benefits of productive use of DRES based on six case studies of DRES application for rural use in Africa. Some of these benefits could be equally applicable in the South Asian context and are summarized below:

- Stronger local economy – the presence of a reliable energy access based on DRES can enable rural communities to move beyond traditional professions such as farming and can give rise to new entrepreneurial activity
- Increase in jobs – new expertise will be required for installing, operating and maintaining DRES installed in the region.
- Improved health and sanitation – An indirect benefit of DRES enabled by productive applications is that people can have access to community health centres, information on how to prevent malaria and other diseases can be communicated by radio, television, mobile phone texts etc.
- Gender equity – Productive uses can be used to empower women by enabling them to earn money through small businesses

4.6.4 Financing

The centre or focal point of DRES projects are rural communities who are predominantly poor (Painuly, 2001). Specialized institutions such as micro-finance institutions (MFIs) can help in assisting of financial viability of the equipment as the rural poor do not have the capability to pay for the high initial costs of DRES (Glemarec, 2012).

Besides MFIs, subsidies have an important role in implementation of these systems. Analysis of the literature provided examples of DRES projects that relied on initial capital donations with no plans in place ensuring future financial sustainability. One-off subsidies actually act as barriers and a subsidy in the form of Output Based Aid is more successful in ensuring the long term viability of DRES projects. Output Based Aid (OBA) refers to subsidy which is linked to the performance of the projects. It has been proven to be highly effective in the success of DRES (Glemarec 2012). It is also suggested that the process for subsidies disbursement should be transparent and devoid of political influence so as to prevent any misuse of the subsidies. As discussed in the previous section DRES projects supported with productive activities have better prospects of losing their dependence on subsidies.

As government led projects are often fully or partly subsidized (Schnitzar et al. 2014) care should be taken that such projects do not cause market distortion and discourage private investment. Evidence suggests that fully subsidized DRES are not successful in the long term (Tenenbaum et al. 2014) because they fail to create a sense of ownership in the users.

An example of an innovative financing technique (also discussed in previous section) is where financial viability of a DRES project can be improved by using “anchor” customers. (Tenenbaum et al. 2014) cites an example in Africa where telecom companies owned mobile phone towers were used as anchor customers to provide a sufficient enough electric load to increase the financial viability of the DRES project.

The role of private investors is important in developing countries and it is recommended to facilitate private sector investment in DRES projects, by helping to reduce the (perceived) risks on the regulatory, technological, political and market development level, as well as by taking part in financing, for example through grants and soft loans.

Glemarec (2012) gives the following four recommendations to lower initial costs of DRES: (i) eliminate taxes and tariffs on clean energy devices; (ii) reduce subsidies on fossil fuels and subsidize part of the upfront and operation costs; and (iii) promote entrepreneurship and income-generating activities by the new end-users of these energy services.

Glemarec (2012) also discusses an encouraging and relevant example of a currently widespread use of technology, the mobile phone. Industry watchers were sceptical that the mobile phone would ever become common among the poor of the world such as the sub Saharan and South Asian population where landline connections had grown very slow. The initial cost of the phones alone was thought to be insurmountable for people living on very low income levels. But through innovative business models this industry has expanded rapidly in the developing world with South Asia being the fastest growing market for mobile phone subscriptions. This example just goes to show that with the right incentives, tangible benefit for the users and enabling environment newer technologies could thrive. This real-life example also suggests that the potential of private investment is subject to an environment that is conducive to private investment. Decentralized renewable energy systems are set in a similar environment with relatively expensive technology being targeted at the same rural population. This analogy suggests that with the right factors in place it is possible to make DRES viable for the poor.

4.6.5 User centric approach

The approach to DRES implementation should be user centric which means that the function of the DRES should be based on the cultural requirement, financial capability etc. of the user. Local demand assessment is not only necessary to ascertain practical aspects such as cooking habits, cultural norms etc. but it also necessary to assess latent factors such as willingness of the user to pay for DRES (Kumar et al. 2009). A user centric approach, which involves community participation, in planning DRES not only increases ownership in the user but it also ensures that the physical aspects such as energy requirements and compatibility with compatibility with cultural norms are understood by DRES implementer. Community participation has been recognized as an important factor contributing to the success of rural electrification (Urmee and Harries 2011). It is suggested that every user should be a member of a rural cooperative [18] and has the right to be involved in the decision-making and policy-making practices of the cooperative through their elected representatives. This membership practice gives users a feeling of ownership in the cooperative and encourages them to protect the DRES from thieves and abuse.

It is important to understand that once electricity is available, users tend to increase their usage by buying more appliances and initial assessments of energy demand may not hold (Louie et al. 2014) thus a user centric approach based on community participation can make sure that increased requirements of energy are accounted for in the lifetime of the project.

4.6.6 Policy and Regulatory

In analysis of the literature, it is suggested that policies, which specifically support and chart guidelines for DRES as a source of rural energy access, need to be developed. DRES specific policy implementation should promote development in DRES by providing a one-stop solution under, for example, a ministry of rural energy, where all aspects of DRES project for rural energy access can be dealt with and where clear and transparent guidelines (about licensing, regulations etc.) for NGOs and developers to set up and operate their business can be imparted. A central Information repository (in the form a website) operated by the regulatory body, could also act as a solution to lack of information, which would not only outline information about financial incentives such as subsidies and licensing requirements etc. but also data on renewable energy potential in different areas of the country. Rural information centres placed at strategically placed areas could make use of pilot projects

[18] A group of citizens residing in rural communities that take part in DRES development projects (Mignon & Rüdinger 2016)

and demonstrations to explain the monetary and health benefits (in case of Improved cooking stoves) of using DRES.

Some proponents support deregulating[19] private developers for a period of five years until developers have matured their delivery models (but annual reporting and customer complaints to be monitored) after which regulations can be implemented (Tenenbaum et al. 2014). Even in such a situation safeguards should be in place, in the form of light-handed regulations, to ensure that a quality service at a reliable price is offered to the rural communities.

In terms of subsidies, the purpose of regulations should be to facilitate the implementation of DRES by timely disbursement of subsidies. A centralized government structure is one where the majority of the authority to make decisions remains in the central government and there is a lack of provincial or smaller decision making power and autonomy. Smaller autonomous state level bodies capable of making decisions for the local rural population could also possibly solve the lengthy process of licensing and subsidy disbursement.

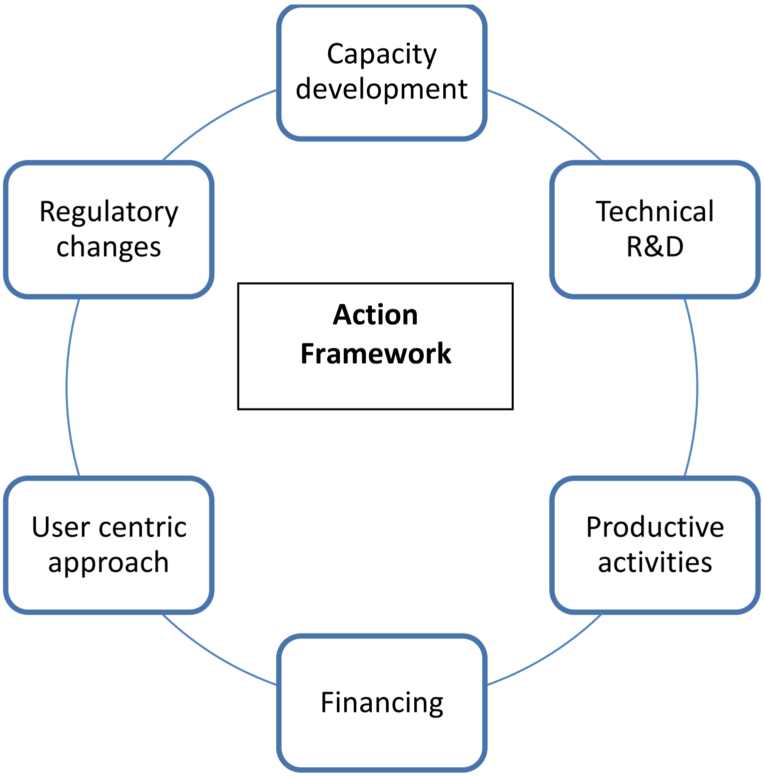
As suggested by Palit (2016), an exit strategy should be built into the regulatory framework for off-grid investors so that their investment does not get lost. Such a strategy could offer an option to DRES developers to connect to the main grid in case of operating a micro-grid (Colmenar-Santos et al. 2016).

[19] Deregulation refers to where private DRES developers do not need licensing or approvals in order to implement a DRES system.

4.7 ACTION FRAMEWORK & SUSTAINABLE RURAL ENERGY ACCESS

The suggested actions in sections 4.6.1-4.6.6 are visualized here as a framework for addressing current barriers to DRES in rural South Asia (Figure 4-1).

Figure 4-1 Framework for addressing current barriers to DRES in South Asia



An important inference that can be drawn from the interdisciplinary nature of the barriers is that only realization of the problem of rural energy access as a whole can lead to long lasting DRES projects. Akinyele (2016) says that off grid rural electrification projects in Africa are built based on considerations of design, cost and installation without consideration of the long term viability of the projects, showing that focus only on specific aspects of a rural energy access project is not limited to South Asia.

To assess the problem of rural energy access on a holistic level, the concept of Sustainable Rural Energy Access has been suggested to refer to the long-term sustainable use of DRES to achieve energy access. The concept of sustainability here does not refer to the sustainable nature of renewable energy sources but instead the word 'sustainability' has been used to refer to the effectiveness of institutions, the practicality of regulations, the ease of financing and solutions to social concerns in delivering affordable, reliable and long-lasting rural energy access projects. In other words, sustainability in the context of this study refers to the sustainability of all facets (as proposed in this study as four areas of institutional, regulatory, monetary and social) of a rural energy access project. Sustainable Rural Energy Access is further discussed in Chapter 6.

4.8 SUMMARY OF BARRIERS

The main barrier categories obtained after literature analysis were discussed in this chapter to propose a plan for addressing these barriers. A summary of the implications of these barriers along with suggested actions to counter these barriers is provided in the sections below.

4.8.1 Institutional

Table 4-7 Institutional barriers, implications & actions

Institutional barriers	Implications	Action

Lack of maintenance	Short life of projects	Performance monitoring, maintenance plans and access to spares & repair service
Lack of promotions and demonstrations	Lack of awareness Low confidence in DRES	Capacity development, knowledge repository & rural information access points
Lack of technical R&D on DRES related areas	Expensive imported technologies, incompatible with local requirements	Investment in DRES research institutions: reducing cost, indigenous design, technical standards, renewable energy data
	Unreliable and low quality equipment	
	Incomplete and unreliable data on renewable energy potential	
Lack of local demand assessment	Slow uptake or rejection of DRES by user	Training on selection of appropriate and practical technology based on user centric approach
Lack of skilled human resource	Expensive international experts from outside region	Capacity development of policy makers, developers, users More DRES courses at university and technical colleges
	Inefficient institutions focusing on DRES education	
	Poor operation and maintenance	
Lack of inter organization coordination Lack of knowledge transfer between institutes	Unutilized and wasted resources Gap between knowledge and application, lack of common platform	Central contact for coordination e.g. Dedicated rural energy access agency

4.8.2 Regulatory

Table 4-8 Regulatory barriers, implications & actions

Policy and regulatory barriers	Implications	Action
Ineffective and inadequate policies and regulatory framework for DRES	Low private investment in DRES due to lack of commercialization and market of DRES Lack of guidance on DRES operation Low incentive for private DRES developer Low dissemination of DRES	Policies that are based on resource assessment and user centric Detailed policies that specifically address DRES like mini-grids, improved cooking stoves etc. Market and commercial oriented policies for DRES that encourage and protect private investment
Arduous requirements and delays	Low motivation for private investment	Deregulation / Light handed regulations to speed up DRES penetration Decentralization of authority
Corruption and politics	Lack of confidence and low private investment, low international donations Short life of projects	Depoliticization of DRES institutions – independent institutions Performance based subsidies
Subsidies: Absence of subsidies, difficult and delayed approvals of subsidies, no post-subsidy plan, market distortion	DRES not financially viable Frustration and reduced motivation to invest from private sector Short life of DRES projects	Strategic and quick dispatch of capital and revenue subsidies Simplified and transparent procedure Market and commercial oriented policies for DRES
Lack of government commitment	Low knowledge and understanding of potential of DRES	Capacity building Remove subsidy on fossil fuels

4.8.3 Monetary

Table 4-9 Monetary barriers, implications & actions

Monetary barriers	Implications	Actions
High initial costs & small market size	Lack of indigenous production Lack of demand	Research and development for low cost and practical solutions
Weak supply base	Low demand / Lack of awareness / Low financial incentives	Marketing and promotion of DRES
Lack of dedicated entities for financing DRES developers	Low investments in DRES	Dedicated financing institutions for DRES
Low load factors	Financial viability is absent	Research and development for low cost and practical solutions, productive activities
High interest rates	No dedicated incentive for DRES	Dedicated financing institutions for DRES
Lack of organizations for specialized financing of the disadvantaged and developers		Dedicated financing institutions for DRES
Perception of high risk in DRES investments	Lack of regulatory support	Simplified regulations and support for investors
Lack of private investment	Low penetration of DRES	Simplified regulations and support for investors
Bad debts from developers and consumers	Lack of assurance of investment	Dedicated and specialized financing institutions for DRES

4.8.4 Social

Table 4-10 Social barriers, implications & actions

SOCIAL BARRIERS	Implications	Actions
Low income & poverty	Low purchase power of user Reluctance of investments by de	Micro-financing Develop productive uses of DRES
Lack of knowledge of benefits, funding sources, cost effectiveness for DRES	Low demand and investments in DRES	Effective promotions and demonstrations
Resistance to new technology	Lack of demonstration and pilot projects	Effective promotions and demonstrations Community in
Lack of productive use for revenue generation	Low incentive for adopting DRES	Develop productive uses of DRES
Poor demonstration	Ignorance of benefits of DRES	Effective promotions and demonstrations
Lack of proper training to operate DRES	Short life of DRES projects	Community capacity development
Vandalism and theft	Low return on private investments	Community involvement
Grid worship	Lack of knowledge of cost effectiveness of DRES	Effective promotions and demonstrations
Community involvement: Village electrification committee	Lack of ownership/source of disputes	Community involvement

4.8.5 Technological

Table 4-11 Technological barriers, implications & actions

Technological barriers	Implications	Actions
Intermittency of DRES	Lack of confidence in DRES use	Selection of appropriate and practical technology based on resource availability, Hybrid solutions
Storage requirement is expensive	High cost of equipment	Hybrid solutions, Investment in DRES research: reducing cost, indigenous design, technical standards, renewable energy data
Seasonal variation effect	Lack of knowledge of available annual renewable energy data	Hybrid solutions
Specific site requirements	Inherent limitation	Selection of appropriate and practical technology based on resource availability
Unsuitable local conditions for optimum use	Inappropriate technology selection	Selection of appropriate and practical technology based on resource availability
Lack of innovation	Lack of technical R&D on DRES	Investment in DRES research: reducing cost, indigenous design, technical standards, renewable energy data

4.9 LIMITATIONS OF THE FRAMEWORK

The analysis of the barriers seems to have been limited by the same issues experienced by researches studied: a lack of specifics, generalization and repetition. It is suggested that the resulting framework is limited in real world application because of a lack of primary research that discuses barriers to DRES. There is a lack of literature that specifically focuses on the use of DRES in a rural context by evaluating real-case studies and field data. This study aims to go further by analysing this deficiency in the literature which is discussed in Chapter Five.

4.10 CONCLUSION

The crossover of the barriers across the four main categories is one of the key findings of this study. The limitation of not being able to distinctly categorize barriers shows that the scope of these barriers is interdisciplinary and thus it can be inferred that interdisciplinary focus and cooperation is necessary for sustainable rural energy access. Such an interdisciplinary approach can enable development of integrated strategies which go beyond providing purely institutional, monetary, regulatory and technical solutions.

Keeping in view the interdisciplinary nature of the barriers, a framework for action which addressed all the barriers analysed in this study was proposed. A new concept of sustainable rural energy access is also introduced which emphasises the sustainability of all the different dimensions in rural energy access projects.

Lastly, as pointed out at several instances in the chapter, the peer-reviewed literature often failed to provide contextual details about the barriers due to lack of reference to specific case studies or field work. This limitation is discussed in more detail in Chapter 6.

5. RESEARCH TO PRACTISE

Two sources, peer-reviewed and "grey literature" were used to analyse the barriers and challenges to Decentralized Renewable Energy Systems (DRES) in South Asia. During the analysis of the data, it was observed that the peer-reviewed literature had certain limitations such as lack of specific focus on DRES and use of abstract language. Another major difference in the barriers discussed in peer-reviewed paper and the grey literature was the lack of discussion of specific cases and actual experience which provided contextual detail of barriers. Many of the "grey" literature, which originated from NGOs and developmental agencies such as the World Bank, was in the form of project assessments and reports based on actual case studies and field data analysis.

The argument being made is not that grey literature uniquely adopts an appropriate method in their assessment of challenges to DRES but that grey literature often offered a perspective of assessing the problem in its institutional and social context. These deficiencies in peer-reviewed literature can act as barriers in real world application of the literature for sustainable rural energy access. The different features of peer reviewed and grey literature are discussed in detail in this chapter.

In the first section an attempt has been made to highlight the characteristics of each type of source by using examples and comparison. These findings are then discussed in the light of broader research in the second section.

5.1 OBSERVATIONS AND FINDINGS

In the following sections, two predominant deficiencies in the peer-reviewed literature are highlighted.

5.1.1 Lack of focused research

Lack of specificity is explored in this section. The argument being made in this section is that most of the peer reviewed literature does not address barriers that specifically focus on decentralized renewable energy systems to increase rural energy access. Instead, barriers to off-grid, grid-connected, renewable energy sources are explored in general, without specific reference to rural communities and they are often generalized and discussed together with findings rarely based on real-world research.

An example of a real-world regulatory barrier for mini-grid operators in Bangladesh given in a report by World Bank discusses how the current regulatory policies do not have exit strategies for private mini grid operators (World Bank 2014). When the central grid is extended to a rural location previously supplied electricity by a private mini-grid operator, the users will in most cases switch to the central grid due to its unlimited capacity, as opposed to the limited load bearing capacity of mini-grids. The electricity supplied from the central grid is cheaper than electricity from the micro-grid which further shifts users away from the micro-grid. The investor will be left with “stranded assets” in the form of abandoned equipment and will then lose his investment. This is a good example of well-defined barriers to DRES and explains how inadequate regulations can affect future investors in DRES. Schnitzar’s (2014) report realizes the lack of discussion of real-world problems and challenges, and discusses specific challenges and barriers that are faced by Decentralized Renewable Energy System users and developers by covering seven case studies of mini-grid operators in India. An example of the barriers in the report discusses a common element of theft and overuse of electricity which causes breakdowns and extra maintenance for the system. The financial costs to monitor and control individual consumer consumption by installing individual meters at each user points are prohibitive and impractical. Few peer reviewed papers give such real world examples that explain these barriers.

An analysis framework is adopted to substantiate this argument. The literature from both sources was checked against the following criteria.

1. Decentralization of RETs – The paper made a deliberate effort to discuss the challenges specific to decentralized nature of RETs and did not combine DRES with grid connected renewable energy technologies
2. Case studies – refers to the in-depth exploration of real life examples of DRES use. This criterion is fulfilled if challenges are discussed by citing real life examples DRES (not necessarily personally observed by the authors)
3. Field experience – refers to presence of methodologies that called for interaction and observations with rural users and developers in the form of surveys, questionnaires etc.
4. Rural context – refers to the exploration of specific challenges emanating from a rural setting

Detailed results of the application of this framework can be found in ANNEX Tables 9-1 and 9-2.

Table 5-1 Percentage of documents matching theme criteria

Type of literature	Decentralization of RETs	Case studies / Specific examples	Field experience based study	Rural context
Peer reviewed	44%	32%	18%	47%
Grey	31%	65%	35%	59%

Table 5-1 shows that as in the analysis framework, both sources show that there is a lack of focus on all central themes part of the analysis framework. Peer reviewed literature fared worse than the grey literature in all areas except for the theme of 'Decentralization of RETs'.

5.1.2 Lack of depth and use of abstract and high level concepts

An issue that was faced in the analysis of the barriers for making a framework in the previous chapter was that challenges highlighted in both sources did not discuss details such as background and context. Tenenbaum (2014) in 'How Small Power Producers and Mini-Grids Can Deliver Electrification and Renewable Energy in Africa' discusses how high level conceptual terms are used by many authors in the context of Africa which results in failure of communication. Example of abstract, high-level concepts given by the author are "institutional and regulatory ecosystems," "enabling environments," "non-cost-reflective tariffs," or "flawed governance mechanisms." A similar use of high level and conceptual terms has been observed in research studies in South Asian context. Authors cited barriers such as that the "financial mechanism was weak" without offering further explanation as to what was lacking in the mechanism. Another example is cited by Rahman (2012) and Rauf (2015) who discuss the lack of widespread use of Renewable energy technologies in Bangladesh and Pakistan due to a 'lack of financial awareness'. Mondal et al., (2010) cite, a 'lack of good coordination between different agencies' and 'project approvals is lengthy and difficult' as barriers to RETs in rural areas of Bangladesh. Rahman, (2012) when referring to failed DRES project in Bangladesh, says that the 'financial mechanism was not successful'. More detailed examples with direct passages from literature are present in the Annex in Table 9-3.

The above-mentioned barriers are broad and can have multiple interpretations in the context of DRES usage in rural areas and authors in peer-reviewed papers often did not explain these concepts further. A lack of financial mechanisms can range from barriers in obtaining subsidy form the government to lack of micro-credit facilities for the rural population. All these cited barriers are limited as instruments for understanding the sustainable rural energy access problem in South Asia.

The lack of depth due to use of abstract and high level language was found to be more dominant in the peer reviewed literature. The grey literature often provided more detail and insight into barriers to sustainable rural energy access. Table 5-2 offers a comparison between barriers from peer-reviewed and grey literature sources.

Another observation was that many of the challenges found in peer reviewed papers were found to be repeated using same or similar words over the years in different articles. The results of the analysis, to detect repetition, is shown in Table 5-3.

Table 5-2 Comparison of barriers from peer-reviewed and grey literatures

Peer reviewed source	Grey literature source
"The major barriers for solar energy development in Pakistan are the initial cost and **institutional weaknesses**.", (Mirza et al. 2003).	Renewable energy research, development and implementation in Pakistan, have been hampered by a lack of institutional support and poor definition of mandates and responsibilities amongst those organizations that do exist for the purpose . . . there were a number of disparate bodies set up with limited objectives and there was little coordination amongst different players. As a result, the few initiatives taken, principally with respect to biomass, solar and wind energy applications have not been able to progress beyond the pilot or technology demonstration phase. Because of the absence of a systematic approach to renewable resource deployment, local community-level and distributed energy demand and supply options have not been properly assessed, aspects where renewable energy options can offer attractive applications, nor has the commercial exploitation of renewable power been properly evaluated, which would involve coordinating with agencies and utilities involved in such operations. The impact of such weak institutional arrangements has been to further marginalize renewable options, instead of finding ways of incorporating these into the mainstream energy planning and supply mechanisms. (Zaidi & PCRET 2009)
Main constraints to widespread utilization of solar PV technologies are - high initial cost of PV system - inadequate renewable energy policy (in fact the government has not properly realized the need of RET) - unawareness in local communities - Inadequate availability of technical know-how. (Khan & Latif 2010)	A lack of general awareness, technological knowledge, and detailed information on the available renewable potential and energy markets in the country seriously impedes consideration of alternative energy options in the decision-making process, at both the national policy-making and investor-planning levels. Many mature technologies, and suitable areas of applications, especially in remote locations, have not been properly assessed for implementation in Pakistan because of ignorance of relevant technical and cost considerations or the absence of sound data on which to devise renewable energy solutions. Thus, the need for increasing the availability of technical information, education, and data collection on local conditions and resources has been identified

	as a way of facilitating an improved appraisal of renewable energy options. (Zaidi & PCRET 2009)
Main constraints to widespread utilization of solar PV technologies are - high initial cost of PV system - inadequate renewable energy policy (in fact the government has not properly realized the need of RET) - unawareness in local communities - Inadequate availability of technical know-how. (Khan & Latif 2010)	Capacity building in RE technology promotion remains low due to the fact that only two departments have been established in the public sector. These departments have limited skilled staff for dissemination and installation of RE projects. There is low capacity of the public sector for dissemination and development of RE technology due to limited technical manpower. Therefore, communities have less awareness of clean energy technologies. The government initiatives for low carbon development are not well disseminated to the public, largely due to limited resources and poorly designed campaigns (Christian Aid 2012)
Another striking example of technology push failure is mentioned in Sarkar et al. (2003)—family-size reflector type solar cookers were developed and implemented in rural areas. After implementation, these solar cookers were found not to be acceptable to the local population. In contrast, much larger cookers were found to be more acceptable in local community kitchens. (Mondal et al. 2010)	Sizing of biogas plant is very important factor for success and failure of biogas plants. If the plant is oversized rawer material is required to feed the plant so more labour is required as well. There is a chance of underfeeding of the plant that causes the poor performance of the plant. If the plant is undersized the produced gas will not fulfil the household energy demand. So they have to depend on other fuel. Due to this the users become frustrated and they take less care of the biogas plants that result poor performance of the plants. During sizing of biogas plant the biogas organization considers the family size and animal population. The daily consumption of biogas also depends on some others important parameters such as cooking habit, type of food to be cooked and economic status of the households. These parameters can also vary from household to household to some extent. These parameters are not considered by the biogas organization for sizing the biogas plants. (Mahdi et al. 2012)

The main hurdle in dissemination of solar cooker are resistance to acceptance as it is a new technology, intermittent nature of sun- shine, limited space availability in urban areas, higher initial costs and convenience issues. (Waheed Bhutto et al. 2014)	System I consists of a 8-watt lantern, 3-watt incandescent lamp and 6 watt peak (Wp) module. In System II, there is a 12-volt (60 AH) battery to light two 8-watt fluorescent tubes and to run a TV/Tape and in system III, there are two 12-volt batteries (60 AH each) to light two 8-watt and one 13-watt fluorescent tubes and also to run a fan and a TV/Tape. The batteries for these systems are charged at solar charging stations. Three solar charging stations have been set up in the project area… Since the same battery is circulated among the different consumers, the maintenance of the batteries is severely affected, so much so that within one year more than 100 batteries has been put out of commission. Hand/head carrying of batteries containing sulfuric acid weighing about 15 kgs is sort of hazardous and a kind of drudgery. This is disliked by the consumers. (Committee for Promotion and Dissemination of Renewable Energy in Bangladesh 2000)n
Municipal solid waste could also be an important source of biogas production, which is found very limited application. Fig. 11 shows a simplified model of biogas dissemination in rural Bangladesh. However, previous research conducted by the authors in [43] found that as of July 2009, 32% of the total installed biogas plants are not working due to **lack of appropriate maintenance and technical knowledge**.", (Islam et al. 2014)	Since the same battery is circulated among the different consumers, the maintenance of the batteries is severely affected, so much so that within one year more than 100 batteries has been put out of commission. As per specification, the durability of these batteries is 3-5 years. It is suggested that, in order to check this bad maintenance, batteries with code numbers be assigned to individual consumers. (Committee for promotion and dissemination of renewable energy in bangladesh 2000)

“Economic, financial and financing barriers • Below loan-run marginal cost pricing and price distortion. • High initial capital costs. • Financial institution biases and unfamiliarity with financing solar PV projects. • Lack of access to credit and appropriate financing mechanisms for solar PV. (Rahman, 2012)	Bangladesh has compromised the Bank’s support for mobilizing long-term private investment in the generation sector due to serious governance issues, which has come in the way of realizing a least cost expansion of the sector which can lead to lower power generation costs and decreased need for government subsidies. This situation continues to mask the significant achievements made in expanding rural and off-grid electrification country-wide, and remains a critical constraint to further grid expansion and a significant fiscal risk. While the off-grid expansion still offers potential to expand electricity access to rural areas, sustainable development of the sector depends upon Bangladesh restoring the path of least cost development in the sector. The Bank has a critical role to play in this regard through broadening and deepening reforms in the sector. (World Bank 2014)
Due to lack of low purchasing power of rural people and lack of viable and sustainable RETs financing mechanisms, the private sector is reluctant towards investing in renewable energy in Nepal (Gurung et al. 2013)	A parallel effort by REB using a fee-for-service approach for SHS did not fare well as it was not cost-effective for the REB/PBSs to undertake bill collection or perform maintenance in dispersed locations. Also a lack of ownership of the asset resulted in neglect and even abuse of the systems by the users. (World Bank 2014)

Table 5-3 Examples of repetition in peer reviewed papers

Quotation from article	Date		Date
"…a later outlook was presented by (Mirza et al. 2009); concluding that the existing infrastructure remained unable to advance the status of solar energy in Pakistan, although a comparative picture of the countries in the region painted by Roy [18] gives an encouraging outlook for Pakistan. The present status of solar energy technologies, lack of policy instruments to integrate the techno-economic and socio-political behaviours and actions, and inconsistencies of the government policies present the major barriers to the significant utilization of the solar energy." (Sahir & Qureshi 2009)	2009	"…a later outlook was presented by (Mirza et al. 2009) concluding that the existing infrastructure remained unable to advance the status of solar energy in Pakistan. However a comparative picture of the countries in the region painted by Roy [41] gives an encouraging outlook for Pakistan. More recently Sahir and Qureshi [42] discussed that the present status of solar energy technologies and they were of the opinion that lack of policy instruments to integrate the techno-economic and socio-political behaviours and actions, and inconsistencies of the government policies present the major barriers to the significant utilization of the solar energy.", (Waheed Bhutto et al. 2014)	2014
Main constraints to widespread utilization of solar PV technologies are - high initial cost of PV system - inadequate renewable energy policy (in fact the government has not properly realized the need of RET) - unawareness in local communities - inadequate availability of technical know-how. (Khan & Latif 2010)	2010	According to Khan and Latif [45] the main constraints to widespread utilization of solar PV technologies are: • high initial cost of PV system, • inadequate renewable energy policy, • unawareness in local communities, • inadequate availability of technical know how. (Waheed Bhutto et al. 2014)	2014
In the early 1980s, eighteen PV stations were set up by the government in different parts of the country for village electrification, with an installed capacity of nearly 440 kW. However, because of lack of technical know-how and follow up, these systems have not performed as required. (Mirza et al. 2003)	2003	In the early 1980s, 18 PV stations were set up by the government in different parts of the country for village electrification, with an installed capacity of nearly 440 kW. However, because of lack of technical know-how and follow up, these systems have not performed as required (Waheed Bhutto et al. 2014)	2014

Use of biogas digesters in rural households, after a promising start, has stagnated due to withdrawal of external subsidies. (Government of Pakistan, 2006)	2006	Use of biogas digesters in rural households, after a promising start, has stagnated due to withdrawal of external subsidies. (Waheed Bhutto et al. 2014)	2014
Renewable energy based provision of modern energy services is dealt with by various ministries, agencies and institutions, making good coordination between them a necessity to efficiently make use of limited human and financial resources in the country. There is provision lengthy and difficult process for permission. Dependency on the national budget for implementation of activities, which creates uncertainties in allocation of project financing as well as time delays associated with decision-making. Limited spatial distribution of suppliers limits access to RETs. (Rofiqul Islam et al. 2008)	2008	Thirdly, renew- able energy based provision of modern energy services is dealt with by various ministries, agencies, and institutions in Bangladesh. Establishing a good coordination between them is a necessity for efficient use of limited human and financial resources in this area. Fourthly, the process for project approval is lengthy and difficult. Fifthly, many RET implementation activities are dependent on national budgets, which creates uncertainties in allocation of financing as well as time delays associated with decision making. (Mondal et al. 2010)	2010
Technical barriers • Lack of standards and quality control for solar PV equipment. • Lack of domestic manufacturing. • Difficulties offirm dispatch in utility grid operations. • Bulk procurement of solar PV technologies is limited due to the current small market for solar PV based modern energy services. Hence the (technical) infrastructure to support solar PV development does not exist. • Local manufacturing and/or assembly of solar PV components are currently very limited, although the knowledge, skills, expertise and facilities are available in the country. • Limited technical capacity to design, install, operate, manage and maintain solar PV based		Technical: There is a lack of standards and quality control for renewable energy equipment. We have a great lacking of domestic manufacturing. Bulk procurement of RETs is limited due to the current small market for renewable energy based modern energy services. Hence the (technical) infrastructure to support renewable energy development does not exist. Local manufacturing and/or assembly of RET components are currently very limited, although the knowledge, skills, expertise and facilities are available in the country. Limited technical capacity to design, install, operate, manage and maintain renewable energy-based modern energy services, mainly as a result of lack of past activities in this new field (Rofiqul Islam et al. 2008)	

modern energy services, mainly as a result of lack of past activities in this new field (Rahman 2012)			
Government budgets for subsidizing RE projects are limited as the demand for financing the various national priority areas (health, education, disaster management, etc.) is great. (Mondal et al. 2010)		Government budgets for subsidizing RE projects are limited as the demand for financing the various national priority areas (health, education, disaster management, etc.) is great. (Rahman 2012)	
An important obstacle to RET diffusion is the high costs. Especially initial investment costs are high. The currently small and dispersed size of the renewable energy market does not facilitate benefits such as economies of scale. Furthermore, currently there are no dedicated financing mechanisms for renewable energy activities within most financial institutions (Mondal et al. 2010)		The high upfront cost at the end user level for solar PV is a major barrier to the increased use of solar PV sources for the provision of modern energy services. The currently small and dispersed size of the solar PV market in Bangladesh does not facilitate benefits such as economies of scale. No dedicated financing for solar PV activities exists with financial institutions now. The (Rahman 2012)	
Availability of renewable energy resources is very site specific, requiring detailed analysis of local specific conditions, both in terms of solar irradiation and wind speed and in terms of cultural characteristics and specific demand (Mondal et al. 2010)		Availability of solar PV resources is very site specific, requiring detailed analysis of the local specific conditions (Rahman 2012)	
A central information point does not exist, instead information is scattered among various sectors; e.g. public sector, development assistance, R&D centers and academia. (Rofiqul Islam et al. 2008)		Availability and access to existing solar PV resource information is not centralized, rather it is scattered among various sectors; e.g., public sector, development assistance, R&D Centres and academia (Rahman 2012)	

Human Resource Barriers • Limited expertise in business management and marketing skills • Limited in-country capacity for renewable energy data collection and analysis. • Lack of expertise and services in system design, installation, operation and maintenance of renewable energy technologies. • Limited in-country capacity for renewable energy project development. (SREDA n.d.)		Human resource barriers • Limited expertise in business management and marketing skills. • Limited in country capacity for solar PV data collection and analysis. • Lack of expertise and services in system design, installation, operation and maintenance of renewable energy technologies. Limited in-country capacity for renewable energy project development. (Rahman 2012)	

Tables 9-1, 9-2, 9-3, 5-2 and 5-3 suggest that in many cases the grey literature offered a perspective on barriers to DRES that was grounded in actual experience whereas peer-reviewed literature remained limited due to use of secondary sources and lack of real case study analysis. These observations show that there is an element of 'recycling' of much of the material in peer-reviewed literature.

5.2 FINDINGS AND IMPLICATIONS

Following points summarize the observations made from analysing both grey and peer-reviewed papers.

1. Distinct topics such as grid and off-grid, individual home systems and mini-grids, were often found not treated differently in both grey and peer-reviewed literature. Grey literature was often based on primary research and relied on actual experiences whereas peer-reviewed literature often relied on secondary sources. Few peer-reviewed papers discuss specific and real-world examples of barriers and challenges of DRES.
2. There was a predominant use of abstract and high level concepts in peer-reviewed literature to discuss barriers. Grey literature used more simple and specific language with details to explain barriers. Same examples of DRES project failures and challenges are quoted by different authors over a period of several years.

This study suggests that academic resources such as peer reviewed papers in the attempt of providing a guideline to successful implementation of DRES by highlighting specific barriers are grossly inadequate in quantity and quality. There is a lack of focus on actual case studies and field research and there is a gap between the academic world of researchers and NGOs, private entrepreneurs, funders like IEA and World Bank. It is being argued here is that there is a lack of appropriately focused and structured research to identify the barriers and their solutions for sustainable rural energy access.

The use of high level and abstract terminologies with broad connotations would generate low value to potential users of this information such as developers and policy makers. On the other hand, it is also inferred that there is a lack of ground level experience of researchers, and a gap between the actual people who are implementing this project and the people who are researching it. The practitioners composed of developers, policy and regulation makers, financiers, banks, do not make use of these research findings because of its lack of practical application. This inaccessibility of research to practitioners suggests a vacuum between the researchers and decision makers which poses a significant obstacle to the penetration of DRES in South Asia.

Sustainability Education has progressed from research on theory and policy issues to empirical research in the form of case studies (Stevenson 2004). Case studies call for making detailed and in-depth observations of a phenomenon (such as barriers to sustainable rural energy access) in all its complexity and as close to the people as possible (Kyburz-Graber 2004). This approach was observed to be missing during the literature analysis as most of the peer-reviewed papers reviewed the current renewable energy potential in a region in a 'descriptive style study'. Thus the use of properly designed case studies can fill the gap of a lack of in-depth studies on barriers to DRES.

Without bringing together all stakeholders into an interactive session, queries and concerns of stakeholders cannot be answered. Methodologies such as participatory action research can potentially solve this gap and assert that the understanding and improvement of practice strongly depends on inquiry and practice. In participatory action research cases, practitioners are viewed as contributors in generation of knowledge and not only recipients (Stevenson 2004). Sustainable rural energy access can benefit from knowledge generated by participative action, which will facilitate viewing the problem from different perspectives. Bradbury (2003) also says how studying with people and not studying people can yield practical real-world solutions

Another implication of this study is the value stored in grey literature. Although “grey” literature does not focus on requirements such as references and methodology it can yield useful information, as analysed in this study. The same was realized by Benzies (2006) who discussed that grey literature actually offered more information to support preparing guidelines in an area of medicine. This study suggests that research on sustainable rural energy access in South Asia can also benefit by being complemented with “grey” literature produced by NGOs, independent bodies, financiers etc.

Thus in the light of the above discussion, it is suggested that the research quality on sustainable rural energy access as indicated by the above findings and the findings in the previous chapter, can be improved upon by the following steps:

1. Participatory case studies
2. Holistic interdisciplinary research
3. Complementing academic research with grey literature sources

5.3 CONCLUSION

Analysis of the peer-reviewed and grey literature showed that there is a lack of primary research which involves all stakeholders in a rural energy access project. Research grounded in real cases can inform decisions pertaining to policies, regulations, financing mechanisms, understanding social dynamics affecting technology uptake, and can prove to be an indispensable tool for making practical decisions.

The academic literature which discusses barriers to DRES is largely populated with country-based reviews which address the potential of renewable energy sources for electrification and rarely focus on the implementation, real world problems and detailed outcomes of a sustainable rural energy access projects. Various studies exclusively discuss financial and technological viability of DRES while others chiefly review policy and institutional issues. Holistic studies that analyse different aspects of sustainable rural energy access and investigate the impact of reforms on the uptake of DRES or try to assess the drivers of success in the context of particular case studies remain rare. Multifocal research across technological, institutional, social and financial boundaries is more likely to overcome the general failure to capitalize on past research to generate replicable frameworks and models for sustainable rural energy access.

It is suggested that research on sustainable rural energy access which is based on field studies and case studies has an important role to play in addressing the sustainable rural energy access. The analysis of the study suggests that there is a need to change the research approach to address the problem of low rural energy access.

6. DISCUSSION

In this section, wider implications of the study are discussed and a basic conceptual model for sustainable rural energy access is introduced. In the second part, the implications of the dominant research approach in the literature (sample) have been discussed.

6.1 SUSTAINABLE RURAL ENERGY ACCESS

A concept of sustainable rural energy access is introduced which refers to the sustainability of all the different dimensions in rural energy access projects such as institutions, policies and regulations, monetary and social dimensions. Each individual aspect that is a part of and supports a rural energy access program [20] needs to be sustainable in order to achieve sustainability of the whole project. (Louie et al. 2014 pg. 71), defined sustainability in the context of small-scale off-grid energy development as ‘‘the perceived potential for a system or project to endure, build a self-perpetuating capacity within a community, and ultimately reach the end of its predetermined life span or evolve into another beneficial form”. Therefore, in the context of this study adding renewable cooking energy, sustainable rural energy access is viewed as the capability of decentralized renewable energy (DRES) systems to continually generate electricity and clean cooking energy for the intended households within the rural community, over the lifespan of DRES.

Decentralized renewable energy systems have the technical potential for providing energy access to rural regions but as this study indicates the multi-dimensional rural energy access problem is fraught with barriers which are a complex mix of interrelated and

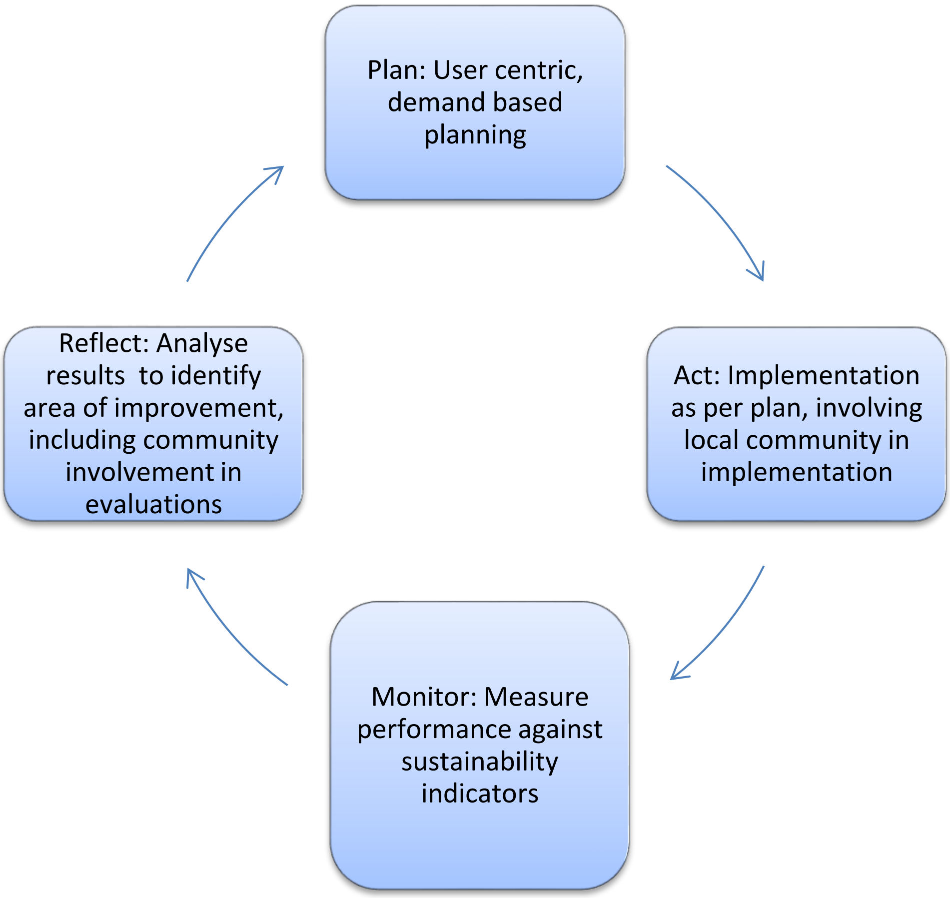
[20] National or privately led programs to provide electricity and/or clean cooking fuels to rural communities

interdependent areas. Thus, concentrating efforts on a single dimension of rural energy access program without conscious realization of its inter-related nature and also ignoring possible beneficial synergistic effects of integrated solutions (such as capacity development, productive activities etc.) could contribute to unsustainability and failure of rural energy access programs.

The lack of treatment of rural energy access in South Asia on a holistic level necessitates the need for a reorientation of approach towards decentralized renewable energy systems for rural energy access. It is suggested that the rural energy access vision be driven by an interdisciplinary goal of "sustainable rural energy access" where all aspects of rural energy access are integrated into a single objective. A conscious realization of an integrated approach with cooperation between institutional, financial, social, regulatory aspects to solve rural energy access problem should make better use of available resources. Based on this study it is suggested that such holistic approach appears to be missing from rural energy access programs in South Asia.

A holistic approach in the form of a basic conceptual model for sustainable rural energy access is introduced in Figure 7-1.

Figure 6-1 Conceptual model for sustainable rural energy access in South Asia



It is suggested that successful sustainable rural energy access is a complete cycle with the following parts:

1. Plan – This step involves a user centric and demand based approach based on case-studies and field based research of the actual energy needs of rural denizens
2. Act – This part of the cycle refers to installation and operation of DRES projects through appropriate delivery models (like fee based service, micro-financing etc.)

3. Monitor – feedback and performance monitoring of DRES using indicators derived from field data
4. Reflect – analysing feedback results to integrate into planning stage

Literature analysis shows evidence of the first two stages of planning and action in the form of planning and implementation of rural energy access projects but analysis of the barriers show the last two parts of this conceptual model involving monitoring and reflection (such as use of sustainability indicators, capacity building, community involvement) have been largely overlooked and need to be addressed.

It is evidenced in this study that there is a lack of monitoring of progress of rural energy access programs besides the need for capacity development. In other words there is a lack of a formal feedback mechanism which integrates lessons learnt from implemented projects back into the planning stage for improvement.

Ilskog (2008) and Mainali (2014) proposes methodology for devising sustainability indicators for assessing rural electrification progress based on field data. Development of meaningful indicators is a crucial part of the monitoring and evaluation of programmes.

The last part of the proposed cycle to approach sustainable rural energy access is using the results of these sustainability indicator studies to produce the basis for reflection and finally changes in the plan to improve the system under question (or to inform the planning of other programmes) to generate an ongoing cycle of improvement and development in the implementation of DRES. This concept can help understanding of the real world problems that undermine sustainable rural energy access on a holistic level.

Summarising this discussion, it is suggested that the rural energy access problem in South Asia be addressed through the lens of "Sustainable rural energy access" so DRES projects are able to be useful to the target communities for the intended lifetimes of the projects and in order for DRES to be able to play their part in the socio-economic development of rural communities.

6.2 RESEARCH TO PRACTISE

The discussion on the role of research to support sustainable rural energy access brings us to the second part of this study where wider implications of the gap between research and practice are discussed.

Findings in Chapter 6 suggest that the current dominant research approach in assessing challenges to DRES in South Asia is based on reviews and other methodologies based on secondary sources that do not include primary research with stakeholders (for example, policy makers, international financiers, DRES project developers, village committees and individual users) in the research process. If research is intended to contribute to the improvement of rural energy access, but occurs without adequately considering the concerns and questions of the stakeholders (or practitioners working in rural energy access programs), then a gap between research and practice can be inferred. This gap in current research approach results in a one-sided perspective on the rural energy access problem that might meet academic standards of publishing but fails to produce useful and transferable knowledge and thereby live up to its potential for improving and extending individual or institutional practices.

Evidence of the gap between research and practice is also found in two very different disciplines, that of accounting (Inanga and Schneider, 2005) and medicine (Bero et al., 1998). This indicates that the gap between academic research and practice is an endemic problem which suggests that the pressing research imperative to carry out research for peer-reviewed publication, which are not easily accessible to potential user groups, needs to be questioned on the whole.

Inaga's assertion is that accounting research is inadequately related to practitioner and user needs because of a lack of meaningful and constructive communication between and among researchers, practitioners, and users (Inanga and Schneider, 2005). These observations could equally be applied to studies of Distributed Renewable Energy Systems, as shown by this research. A possible solution lies in research that blurs the boundary between researchers and practitioners. In situations where the researcher and the researched work together, as in the principles of Action Research (Bradbury and Reason 2003) the knowledge generated is likely to offer a somewhat different perspective to that of the 'remote' academic researcher. In other words, the focus of the research needs to shift from 'on' the people to 'with' the people with the participants becoming generators of knowledge rather than just recipients of it. Similarly, the planning and implementation of DRES should take place 'with' the local communities rather than being just something done 'to' the communities.

Such participatory evidence-based research approaches could add value to decisions made for development in various areas including sustainable rural energy access. It is also suggested that an indirect consequence of reducing the gap between research and practice by involving policy and decision makers in real-world research could open doors to an unmet (and as yet unimagined?) demand by policy makers for research with practical implications. (Ferguson, 2005) gives some recommendations on bridging the gap between research and practise such as:

- Researchers and practitioners should articulate and acknowledge each other's differences in approaching and addressing problems
- Invest time in understanding each others' interests, differences and priorities
- Both parties should realize that scientific and practical knowledge depend on each other and each is weakened without the other
- Build the partnership incrementally. Practise patience and allow room for mistakes in the beginning.

In summary, a detailed analysis of the peer-reviewed and 'grey literature' shows that the peer-reviewed literature is dominated by reviews of existing articles often exhibiting recycling of case studies, in contrast to the grey literature which demonstrates greater connection with stakeholders involved in DRES projects, often identifying different and more detailed challenges. This draws into the question the impact of the peer-reviewed literature, and highlights the need for greater primary research to be carried out to understand the detailed contextual barriers to the sustainable implementation of DRES and ultimately influence sustainable rural energy access, in order to greater bridge the gap between research and practice.

Studies by Schafer (2011) and Louie (2014) reach similar conclusions about interdisciplinary nature and more research which further gives importance to pursue this areas. It can therefore be suggested that answers to real world problems such as sustainable rural energy access lie in rigorous evidence based interdisciplinary research, which transcends traditional academic disciplines, while applying interactive and participative methodologies which focus on assessing the problem in its original environment. It is surmised that when research is carried out with this vision, it can achieve its purpose of not only making original contributions but contributions that make a difference in the real world.

6.3 LIMITATIONS & CHALLENGES OF THE STUDY

Different types of technologies like mini-grid, individual systems and renewable cooking systems have been merged in this study due to paucity of literature on each type of systems. It has been assumed that the techno-socio dynamics involving all these different types of DRES systems are the same.

Although “grey” literature provided an alternative source of information to explore the challenges of Sustainable Rural Energy Access, there are difficulties with ascertaining the reliability of this literature due often to the absence of clear methods and references, with only limited reports produced by large and ‘recognisable’ organisations such as the World Bank.

Content analysis was selected as the method for this study to derive challenges and issues inductively and not rely on pre-set categories. However, in some of the literature the authors themselves have already categorised barriers and challenges, which might have biased the final coding and categorisation process.

A limitation of this study was it assumes that the literature is representative of the challenges and the current progress on DRES in South Asia and it is therefore possible that the literature is not representative of both the whole range of different barriers and challenges and not representative of either the issues experienced across the whole of the countries examined, or the South Asia region in general.

The proposed framework (presented in Figure 4-1) is based on an investigation of literature barriers to Decentralized Renewable Energy Systems for rural energy access in South Asia. The proposed framework is based on a detailed analysis of the key peer-reviewed and “grey” literature covering the five selected South Asian countries. However, the review of the literature has not been exhaustive and there may be additional elements within the literature which have not been accessed. There may for example, be literature, "grey" literature in particular, that is not accessible online, or in English, or literature which is no longer supported online. This study highlights the need for greater analysis and use of the grey literature and primary research with key stakeholders, which was beyond the scope of this study, involved in both successful and unsuccessful DRES projects. The framework presented provides a basis that can be built upon by further work.

7. CONCLUSION

The use of Decentralized Renewable Energy Systems offers a relatively quick and reliable method of increasing energy access among the rural population in South Asia. Despite the encouraging technical, and in many cases financial feasibility, the use of DRES faces a range of barriers in its implementation. A systematic analysis of the barriers was carried out utilizing Qualitative content analysis and resultant categories of the barriers were formed, namely institutional, regulatory, monetary, social and technological.

Two key concepts emerged during the categorization and data analysis. The first concept was that the barriers are interdisciplinary and that they could not be completely allotted to the categories that were developed during the content analysis process. This finding indicated that a divided approach that was only focused on individual categories would be unable to solve the rural energy access problem. Thus it was necessary that the barriers be addressed under a unifying concept of sustainable rural energy access, which encompassed all areas that affect a rural energy access program. The second key finding of the study was that the peer-reviewed literature on the barriers is one sided because stakeholders are not involved in the research process for analysing barriers and devising solutions. This lack of participative approach suggested a gap between researchers and practitioners.

These two implications hold real world consequences in the sense that if research is poised to answer the rural energy access problem then it is currently lacking right now and the current approach to research barriers to DRES holds little value to practitioners in the field of Decentralized renewable energy systems. Thus a major conclusion of this study is that in addition to barriers identified in the literature to DRES, another major barrier lies in the current research approach in analysing these barriers which lacks an interdisciplinary and participative approach to solve the rural energy access problem

Finally, considering the temporal nature of fossil fuels, the versatility that renewable energy has to offer and the global trend towards decentralized energy generation, DRES have a significant role to play in the energy future of the world if adequate steps are taken to solve the barriers to its implementation.

7.1 FURTHER STUDY

It is suggested that the framework outlined in Figure 4-1 and the conceptual model for Sustainable rural energy access in Figure 6-1 are built upon using further inputs and insights from stakeholders which was beyond the scope of this study. The characteristic of action research being grounded in practical experiences, developed in partnership with stakeholders (Stevenson 2004), seems appropriate in filling the current gap between academic research with practical application in developing a robust framework for sustainable rural energy access. This could take the form of an interdisciplinary participatory action research that brings together technical experts on DRES, potential users from the rural population, private investors and developers, non-profit organizations and NGOs, financial institutions like banks, government officials responsible for policy and regulatory decisions and international organizations with agendas of increasing energy access to rural regions like World Bank, Alliance for rural electrification etc.

A consequence of high quality research with practical applications would be to enable rapid and easy access to this information, which can be utilised by those involved in the planning, developing, implementation, and monitoring and evaluation of such projects. The article in Nature by (McKinnon et al. 2015) comments on a visual tool developed by International

Initiative for Impact Evaluation (a non-governmental organization that promotes evidence-informed policies and programmes for development) that gathers all the primary studies and grey literature in an area and displayed them in a pictorial form, called evidence maps. These evidence maps not only systematically consolidate current research but also identify areas that need more research. It is hoped that the use of such innovative tools could also assist in organizing knowledge to address problems like sustainable rural energy access in South Asia and other developing regions.

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9. ANNEX

Table 9-1 Theme analysis of Peer-reviewed literature

Author(s)	Journal/Organisation	Year	Title	Focus on following themes for sustainable rural energy access			
				Decentralization of RETs	Case study	Field experience based study	Rural context
Alam Hossain Mondal, Md.; Kamp, Linda M. & Pachova, Nevelina I.	Energy Policy	2010	Drivers, barriers, and strategies for implementation of renewable energy technologies in rural areas in Bangladesh ”An innovation system analysis”	No	Yes	No	Yes
Alam, Mozaharul; Rahman, Atiq & Eusuf, Muhammed	Energy for Sustainable Development	2003	Diffusion potential of renewable energy technology for sustainable development: Bangladeshi experience	No	No	No	Yes
Islam, Md. Tasbirul; Shahir, S. A.; Uddin, T. M. Iftakhar & Saifullah, A. Z. A.	Renewable and Sustainable Energy Reviews	2014	Current energy scenario and future prospect of renewable energy in Bangladesh	No	No	No	No
K Hossain, A. & Badr, O.	Renewable and Sustainable Energy Reviews	2007	Prospects of renewable energy utilisation for electricity generation in Bangladesh	No	No	No	No
Rahman, Md Mizanur; Paatero, Jukka V.; Poudyal, Aditya & Lahdelma, Risto	Energy Policy	2013	Driving and hindering factors for rural electrification in developing countries: Lessons from Bangladesh	Yes	Yes	No	Yes

Author(s)	Journal/Organisation	Year	Title	Focus on following themes for sustainable rural energy access			
				Decentralization of RETs	Case study	Field experience based study	Rural context
Rahman, Mohammad Ziaur	Renewable and Sustainable Energy Reviews	2012	Multitude of progress and unmediated problems of solar PV in Bangladesh	No	Yes	No	No
Rofiqul Islam, M.; Rabiul Islam, M. & Rafiqul Alam Beg, M.	Renewable and Sustainable Energy Reviews	2008	Renewable energy resources and technologies practice in Bangladesh	No	No	No	No
Sarkar, M. A. R.; Ehsan, M. & Islam, M. A.	Energy for Sustainable Development	2003	Issues relating to energy conservation and renewable energy in Bangladesh	No	No	No	No
Bhattacharyya, Subhes C.	Energy Policy	2006	Renewable energies and the poor: niche or nexus?	Yes	No	No	Yes
Chaudhary, Ankur; Krishna, Chetan & Sagar, Ambuj	Climate Policy	2014	Policy making for renewable energy in India: lessons from wind and solar power sectors	No	No	No	No
Chauhan, Anurag & Saini, R. P.	Renewable and Sustainable Energy Reviews	2015	Renewable energy based off-grid rural electrification in Uttarakhand state of India: Technology options, modelling method, barriers and recommendations	Yes	Yes	Yes	Yes
Kulkarni, Sanjeev H. & Anil, T. R.	Strategic Planning for Energy and the Environment	2015	Status of Rural Electrification in India, Energy Scenario and People's Perception of Renewable Energy Technologies	Yes	Yes	Yes	Yes

Author(s)	Journal/Organisation	Year	Title	Focus on following themes for sustainable rural energy access			
				Decentralization of RETs	Case study	Field experience based study	Rural context
Luthra, Sunil; Kumar, Sanjay; Garg, Dixit & Haleem, Abid	Renewable and Sustainable Energy Reviews	2015	Barriers to renewable/sustainable energy technologies adoption: Indian perspective	No	No	No	No
Pohekar, S. D.; Kumar, Dinesh & Ramachandran, M.	Renewable and Sustainable Energy Reviews	2005	Dissemination of cooking energy alternatives in India - A review	Yes	No	No	No
Quadir, Shaikh Abdul; Mathur, S. S. & Kandpal, Tara Chandra	Energy Conversion and Management	1995	Barriers to dissemination of renewable energy technologies for cooking	Yes	No	No	No
Rai, Saroj	Energy for Sustainable Development	2004	Sustainable dissemination of solar home systems for rural development: experiences in Nepal	Yes	Yes	Yes	Yes
S.C. Bhattacharya, Chinmoy Jana	International Journal of Applied Engineering Research	2014	Renewable energy in India: Historical developments and prospects	No	No	No	No
Gurung, Anup; Ghimeray, Amal Kumar & Hassan, Sedky H. a	Energy Policy	2012	The prospects of renewable energy technologies for rural electrification: A review from Nepal	Yes	No	No	Yes
Gurung, Anup; Gurung, Om Prakash & Oh, Sang Eun	Renewable Energy	2011	The potential of a renewable energy technology for rural electrification in Nepal: A case study from Tangting	Yes	Yes	Yes	Yes

Author(s)	Journal/Organisation	Year	Title	Focus on following themes for sustainable rural energy access			
				Decentralization of RETs	Case study	Field experience based study	Rural context
Gurung, Anup; Karki, Rahul; Cho, Ju Sik; Park, Kyung Won & Oh, Sang Eun	Energy Policy	2013	Roles of renewable energy technologies in improving the rural energy situation in Nepal: Gaps and opportunities	Yes	No	No	Yes
Mainali, Brijesh & Silveira, Semida	Energy	2011	Financing off-grid rural electrification: Country case Nepal	Yes	Yes	No	Yes
Nepal, Rabindra	Renewable and Sustainable Energy Reviews	2012	Roles and potentials of renewable energy in less-developed economies: The case of Nepal	Yes	Yes	No	Yes
Surendra, K. C.; Khanal, Samir Kumar; Shrestha, Prachand & Lamsal, Buddhi	Renewable and Sustainable Energy Reviews	2011	Current status of renewable energy in Nepal: Opportunities and challenges	Yes	No	No	Yes
Abbas, Tauqeer; Ahmed Bazmi, Aqeel; Waheed Bhutto, Abdul & Zahedi, Gholamreza	Renewable and Sustainable Energy Reviews	2012	Greener energy: Issues and challenges for Pakistan-solar energy prospective	No	No	No	No
Sahir, Qureshi	Renewable and Sustainable Energy Reviews	2009	Assessment of renewable energy resources potential in Pakistan and identification of barrier to their significant utilization	No	No	No	No
Amjid, Syed S.; Bilal, Muhammad Q.; Nazir, Muhammad S. & Hussain, Altaf	Renewable and Sustainable Energy Reviews	2011	Biogas, renewable energy resource for Pakistan	Yes	No	No	Yes

Author(s)	Journal/Organisation	Year	Title	Focus on following themes for sustainable rural energy access			
				Decentralization of RETs	Case study	Field experience based study	Rural context
Ghafoor, Abdul; ur Rehman, Tanzeel; Munir, Anjum; Ahmad, Manzoor & Iqbal, Muhammad	Renewable and Sustainable Energy Reviews	2016	Current status and overview of renewable energy potential in Pakistan for continuous energy sustainability	No	No	No	No
Mirza, Umar K.; Mercedes Maroto-Valer, M. & Ahmad, Nasir	Renewable and Sustainable Energy Reviews	2003	Status and outlook of solar energy use in Pakistan	No	No	No	No
Nayyar, Zeeshan Alam; Zaigham, Nayyer Alam & Qadeer, Abdul	Renewable and Sustainable Energy Reviews	2014	Assessment of present conventional and non-conventional energy scenario of Pakistan	No	No	No	No
Rauf, Omer; Wang, Shujie; Yuan, Peng & Tan, Junzhe	Renewable and Sustainable Energy Reviews	2015	An overview of energy status and development in Pakistan	No	No	No	No
Shah, Asif A.; Rashidi, Roshan S.; Bhutto, Arabella & Shah, Ambreen	Renewable and Sustainable Energy Reviews	2011	The real life scenario for diffusion of renewable energy technologies (RETs) in Pakistan â€“ Lessons learned through the pilot field study under physical community	Yes	Yes	Yes	Yes
Sheikh, Munawar A.	Renewable and Sustainable Energy Reviews	2010	Energy and renewable energy scenario of Pakistan	No	No	No	No
Dominguez-Dafauce, Luis Carlos & Martin, Francisco Marcos	International Journal of Energy and Environmental Engineering	2015	Sustainable and renewable implementation multi-criteria energy model (SRIME) case study: Sri Lanka	No	No	No	No

Author(s)	Journal/Organisation	Year	Title	Focus on following themes for sustainable rural energy access			
				Decentralization of RETs	Case study	Field experience based study	Rural context
Miller, Damian & Hope, Chris	Energy Policy	2000	Learning to lend for off-grid solar power: Policy lessons from World Bank loans to India, Indonesia, and Sri Lanka	No	Yes	Yes	Yes

Table 9-2 Theme analysis of grey literature

Author/Organization	**Nature of organisation**	**Year**	**Title**	**Country**	**Following themes addressed**			
					Decentralization of RETs	**Case studies / Specific examples**	**Field experience based study**	**Rural context**
World Bank	Funding and development agency	1994	Bangladesh: Rural Electrification and Renewable Energy Development	Bangladesh	**No**	**Yes**	**No**	**Yes**
Committee for promotion & dissemination of renewable energy in Bangladesh	Independent organisation	2000	Bangladesh Renewable Energy Newsletter	Bangladesh	No	Yes	No	No
Islam, A. K. M. Sadrul & Islam, Mazharul/ ISESCO Science And Technology Vision	Independent organisation	2005	Status of renewable energy technologies in Bangladesh	Bangladesh	No	Yes	No	Yes
Grameen Shakhti	Non-government organization working on energy access	2006	Renewable Energy Technologies in Bangladesh Country Status	Bangladesh	No	No	No	Yes

Mahdi, T. H.; Hasib, Z. M.; Ali, M. & Sarkar, M. A. R./	2nd International Conference on the Developments in Renewable Energy Technology (ICDRET 2012)	2012	An aspect of biogas plants at Pabna district in Bangladesh	Bangladesh	No	Yes	Yes	No
World Bank	Funding and development agency	2014	PROJECT, PERFORMANCE ASSESSMENT REPORT, The Peoples' Republic of Bangladesh	Bangladesh	Yes	Yes	No	Yes
SREDA	Government agency	2014?	Sustainable and Renewable Energy Development Authority (SREDA) of Bangladesh Role and Responsibility	Bangladesh	No	No	No	No
Cust, James; Singh, Anoop & Neuhoff, Karsten	Working paper	2007	Rural Electrification in India: Economic and Institutional aspects of Renewables Rural Electrification in India Economic and Institutional aspects of Renewables	India	Yes	Yes	Yes	Yes
D. Schnitzar, D. Lounsbury, J. Carvallo, R.	Working paper	2014	Micro-grids for Rural Electrification : A critical review of best practices based on seven case studies	India	Yes	Yes	Yes	Yes

Deshmuck, J. Apt & Kammen, D./ United Nations Foundation, UC Berkley								
UNDP	International development programme	2015	Decentralised Energy Solutions	India	Yes	No	No	Yes
Global partnership on output based aid	Development agency	2006	Nepal Biogas Support Program	Nepal	No	Yes	Yes	Yes
World Bank		2006	Project Information Document: Nepal Biogas Programme	Nepal	No	Yes	Yes	Yes
South Asia Regional Initiative for Energy & SARI	Regional Development programme	2002	Rural Energy Services Best Practices	Nepal, Sri Lanka	Yes	Yes	Yes	Yes
PCRET	Government agency	2009	Renewable Energy Report (Pakistan)	Pakistan	No	No	No	No
Christian Aid	Independent organization	2012	Low-carbon South Asia : Pakistan	Pakistan	No	Yes	No	No
IDEA		2014?	Energy for Sustainable Development Sri Lanka - A Brief Report with Focus on Renewable Energy \& Poverty Reduction	Sri Lanka	No	No	No	No

Table 9-3 Quotations from peer-review papers

Quote from peer-reviewed paper	Author and year of publication	Observation
"…a later outlook was presented by Mirza et al. [40] concluding that the **existing infrastructure** remained unable to advance the status of solar energy in Pakistan."	(Waheed Bhutto et al. 2014).	Possible implications of infrastructure can be technical, financial or institutional which was not further elaborated on by the author.
"More recently (Sahir & Qureshi 2009) discussed that the present status of solar energy technologies and they were of the opinion that lack of policy instruments to integrate the **techno-economic and socio-political behaviours and actions, and inconsistencies of the government policies** present the major barriers to the significant utilization of the solar energy."	(Waheed Bhutto et al. 2014).	In this example the author fails to clarify the terms such as techno-economic, socio-political behaviours and the specific inconsistencies that might be present in the government policies.
"According to Khan and Latif [45] the main constraints to widespread utilization of solar PV technologies are: • high initial cost of PV system, • **inadequate renewable energy policy**, • **unawareness in local communities,** • **inadequate availability of technical know how**."	(Waheed Bhutto et al. 2014).	The last three points do not explain the specific shortcomings of the policy such as whether the policy does not support private investors or there is a lack of clarity or if the policy is too vague itself. Unawareness in local communities again fails to clarify whether the information is targeted at users or possible private investors. Technical know-how is a broad term and can also be divided into technical knowledge of the potential rural communities if self-maintenance by users is targeted or institutions or private investors. It could also refer to a lack of technical expertise to effectively plan such projects to address topics such as choosing the right technology, following a least-cost model.
"The main hurdle in dissemination of solar cooker are resistance to acceptance as it is a new technology, intermittent nature of sun-shine, limited space availability in urban areas, higher initial costs and **convenience issues**.",	(Waheed Bhutto et al. 2014).	The lack of convenience is not further elaborated whether this is due to having to cook outdoors or whether the solar cookers are not compatible with the cooking utensils.
"About seven solar stations were installed in the late 1980s for village lighting by different agencies in various parts of HKH region. These systems, with a total capacity of 234 kW, are not in operation nowadays because of **maintenance problems**",	(Mirza et al. 2003).	The type of system is not clear whether contractors were hired for maintenance or the users were themselves were responsible for it or whether the institution failed in keeping up with it.

"The major barriers for solar energy development in Pakistan are the initial cost and **institutional weaknesses**.",	(Mirza et al. 2003).	The use of the term Institutional weakness is a broad term and institutional weakness can be construed as due to lack of skilled human resource, lack of experience renewable energy technologies and its management, no dedicated agencies or bodies for dealing with rural energy access etc.
"Solar energy technologies in Pakistan have not been exploited on a large scale for a number of reasons, such as fear of the high cost of solar energy technologies, **lack of motivation and incentives**, and inadequate demonstration of effective use of the technologies.",	(Mirza et al. 2003).	The lack of motivation can be directed at the rural population or on the other end the private entrepreneurs. The action plan for either case would be very different.
"It is a bitter truth that the main institutions concerned with this sector exhibit an **absence of coordination and unanimous decisions related to the development and improvement of investment in renewable energy source**. This lack of organization between relevant agencies of government of Pakistan (AEDB, NEPRA, MoW & P, MoP & NRS etc.) hinders the utilization of these sources.",	(Rauf et al. 2015)	Absence of coordination is not explained with relevance to actual institutions.
"Fifthly, many RET implementation activities are dependent on national budgets, which creates uncertainties in allocation of financing as well as time delays",	(Mondal et al. 2010).	The relation of budget allocations in national budget is not clear here.
"Another striking example of technology push failure is mentioned in Sarkar et al. (2003)—family-size reflector type solar cookers were developed and implemented in rural areas. After implementation, these solar cookers were found not to be acceptable to the local population. In contrast, much larger cookers were found to be more acceptable in local community kitchens.",	(Mondal et al. 2010)	No explanation for the failure of solar cookers is offered
"Furthermore, the use of biomass energy by rural households and industries is often inefficient because of lack of knowledge, affordability and acceptability of new technology, and lack of cost-effectiveness.",	(Alam et al. 2003).	Lack of knowledge could refer to a lack of maintenance training or operation which is not explained by the author
"Up to December 2002, about 300,000 households were provided with improved stoves. The penetration rate is slow because of the absence of a massive effort, which should include	(Alam et al. 2003)	"Absence of massive effort" is ambiguous

site-specific and biomass-specific designs of the stoves. A massive effort and strong GOB policy are needed to take improved stoves to a larger proportion of rural households.”,		
1. “Municipal solid waste could also be an important source of biogas production [51], which is found very limited application. Fig. 11 shows a simplified model of biogas dissemination in rural Bangladesh. However, previous research conducted by the authors in [43] found that as of July 2009, 32% of the total installed biogas plants are not working due to lack of appropriate maintenance and technical knowledge.”,	(Islam et al. 2014)	In highlighting this failure the author fails to define who was responsible for the maintenance and what type of technical knowledge was required.
“The subsidy, if not administered properly, causes problems; for instance, it can create opportunities for politicians to intervene, which destroys impartial management practices. The subsidy often makes the program prone to unfair practices for restoring connections that have been cut off due to a lack of payment, to stealing power or other illegal activities, and to people bypassing the criteria for the selection of areas”,	(Rahman et al. 2013)	Examples of unfair practices are not clear
“As for solar cookers, family-size reflector type cookers were developed but have not been found to be acceptable. A much larger and modern imported reflector cooker is more acceptable in a community kitchen.”,	(Sarkar et al. 2003)	The reason for failure of the solar cookers was not supplied.
“Economic, financial and financing barriers • Below loan-run marginal cost pricing and price distortion. • High initial capital costs. • Financial institution biases and unfamiliarity with financing solar PV projects. • Lack of access to credit and appropriate financing mechanisms for solar PV.	(Rahman 2012)	Reasons for biases and lack of appropriate financing mechanisms are not explained further.
Biogas technology pilot project under BCSIR: The biogas technology pilot project was implemented by the Institute of Fuel Research and Development (IFRD), Bangladesh Council of Science and Industrial Research (BCSIR), a state-owned	(Mondal et al. 2010).	This real world example of a failure of pilot project does not highlight the reasons for failure of the project.

research organization. The main objective of the project was to popularize biogas among rural population for meeting primary household energy needs for cooking and lighting. The project was aimed to establish a total of 5000 household scale biogas plants in 64 districts of the country. The project was set up to last for 3 years, from July 1995 to June 1998. The project approval procedure, which generally follows a lengthy administrative process in Bangladesh, took a long time and the project was finally approved in February 1996. By June 2000, a total of 4664 biogas plants were constructed. Different studies found that about 50% of the biogas plants are presently not working (Ali, 2005).",		