THE DIFFUSION OF RENEWABLE ELECTRICITY TECHNOLOGIES
IN SMALL ISLAND DEVELOPING STATES: THE CASE OF THE
MALDIVES

BY

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Abstract

Globally, the production of electricity has been heavily reliant on non-renewable resources. The situation in Small Island Developing States (SIDS) is no exception. Most SIDS, such as the Maldives, are highly dependent on imported oil for electricity production. However, renewable electricity technologies (RETs) have the potential to decrease the cost of electricity, reduce vulnerability to external economic shocks, improve access to electricity in remote areas, increase energy security, and decrease greenhouse gas (GHG) emissions.

The existing literature fails to explain adequately the mechanisms through which the diffusion of RETs takes place, not least in SIDS. This study aims to improve our understanding of diffusion processes and thus explain why the diffusion of RETs in SIDS, such as the Maldives, has been so slow. The study draws on, and adapts, a systems approach, namely the technological innovation system (TIS) approach, in order to better understand the process of diffusion of RETs in SIDS. This study focuses on the Maldives. It applies a mixed methods approach and draws on qualitative and quantitative data from semi-structured interviews and a self-administered survey questionnaire. A six-step analytical process using the adapted TIS framework was applied to analyse the research findings.

The study reveals five main findings. Firstly, the distinct features of the Maldives impede their capacity for energy transformation. These include the geographical dispersion of islands over a large area, and the limited space available to install some of the mature RETs, such as solar PV and onshore wind turbines. Moreover, the lack of a renewable resource base, also contribute to these challenges. Secondly, the government and international development partners have been the most significant actors driving the diffusion of RETs in the Maldives. Thirdly, it is political and economic factors that mainly contribute to the slow diffusion of RETs in the Maldives, rather than technical constraints. There are too few policy measures in place to support the diffusion of RETs. Fourthly, the lack of information about the economic feasibility of RETs continues to be a barrier to the diffusion of RETs in the Maldives. Fifthly, the study improved the understanding of the dynamics of TIS functions in the Maldives.

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Abbreviations and Acronyms

AIMS	Atlantic Ocean, Indian Ocean, Mediterranean Sea and South China Sea
AOSIS	Alliance of Small Island States
FENAKA	FENAKA Corporation Ltd.
FIT	Feed-in Tariff
GDP	Gross Domestic Product
GHG	Greenhouse gas
IRENA	International Renewable Energy Agency
kW	Kilowatt
kWh	Kilowatt hour
MEA	Maldives Energy Authority
MEE	Ministry of Environment and Energy
MLP	Multi-Level Perspective
MoFT	Ministry of Finance and Treasury
MVR	Maldivian Rufiyaa
MW	Megawatt
OECD	Organisation for Economic Co-operation and Development
PPA	Power Purchase Agreement
PV	Photovoltaics
RETs	Renewable Electricity Technologies
RPS	Renewable Portfolio Standards
SIDS	Small Island Developing States
STELCO	State Electric Company Ltd.
TIS	Technological Innovation System
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNFCC	United Nations Framework Convention on Climate Change
UN-OHRLLS	United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and the Small Island Developing States

CHAPTER 1: INTRODUCTION

Electricity is essential for most contemporary economic activities. Globally, the production of electricity has been heavily reliant on non-renewable resources, most notably coal, oil and gas. Because of economic, environmental and energy security issues, it is becoming increasingly important to transform the production of electricity from the currently dominant system based on fossil fuels to a sustainable renewable energy system. However, there are challenges in making energy transitions. The transition from the existing means of electricity production to a system based on renewable energy has been slow, while there are economic, social, and environmental benefits of moving towards renewable electricity technologies (RETs) (Bretschneider, Cirilli, Jones, Lynch, & Wilson, 2017).

Most Small Island Developing States (SIDS) are blessed with an abundant supply of renewable energy resources for electricity production (Kuang et al., 2016). However, many of these SIDS, including the Maldives, are highly dependent on imported petroleum for electricity production (van Alphen, Hekkert, & van Sark, 2008; van Alphen, van Sark, & Hekkert, 2007).

RETs have the potential to reduce the cost of producing electricity in SIDS and reduce dependency on imported fossil fuel (Weisser, 2004b, 2004c). Transforming electricity generation from a fossil fuel-based system to RETs is a public policy issue because it is related to the rules and regulations, and actions of the government. There has been an increasing effort to improve the development, diffusion and implementation of RETs, but for many countries it has been a slow and unsatisfactory process (Negro, Alkemade, & Hekkert, 2012).

The purpose of this chapter is to introduce the research. This chapter begins by explaining the motivation for this research. Then it will explain the research problem, research questions, research methodology, delimitations of and contributions to research, and finally the structure of the thesis.

1.1 The Motivation for this Research

After completing my higher secondary schooling in the Maldives, I joined State Electric Company Ltd. (STELCO), the only state-owned electricity company in the country at that time. At that time the company was providing electricity to the capital, Malé, and a few other populous islands in the country. Electricity service in most of the outer islands was provided by community-based powerhouses and by independent power producers. Many outer islands did not have 24-hour electricity service. Since then there have been many changes to the sector. Now all the inhabited islands have electricity for 24 hours a day. In addition to STELCO, another government-owned company, FENAKA Corporation Ltd. (FENAKA), provides electricity to the outer islands, and the role of community-based powerhouses and independent power producers has diminished. Despite progress in coverage, electricity in the Maldives is still produced by using diesel-based generators. The fundamental issues of not making a profit from every island are still present because of cross-subsidised electricity tariffs, and the challenges in providing uninterrupted service remain high.

Over the years of my service with STELCO, I have witnessed the development and the challenges that have faced the sector. I have also contributed to the development of the company and the sector in managerial and operational capacities. I am passionate about developing the sector by providing sustainable and affordable electricity service to the public.

I understand many policymakers share this noble objective which is evident from the content of a number of national development plans in the past. I also see the distinctive situation of the Maldives and other SIDS, as compared to larger countries, in addressing the issue. The geographical, economic and social contexts of the island states place them in a different situation to many larger countries because of their remoteness and small size. Therefore a better understanding of the circumstances that are important in transitioning a technology, in this case RETs in SIDS, would be an important contribution to the literature, facilitate policy reform, and be helpful for practitioners.

1.2 Research Problem

At present, most of the world's energy requirements are met using fossil fuels (REN21, 2015, p. 27), and these include coal, oil, and gas. Fossil fuels are formed in the earth's crust by a natural process, over millions of years, through the decomposition of buried dead organisms. Currently, we are extracting the deposits millions of times faster than they were formed. There has been a large increase in world energy demand, and it is expected to grow over the coming years (BP, 2019a, p. 29). From the energy security perspective, there are concerns that at this rate of consumption, the world fossil fuel production may peak before 2025 and will decline rapidly after that (Mohr, Wang, Ellem, Ward, & Giurco, 2015, p. 120).

In SIDS, electricity production from fossil fuels is associated with a number of practical problems: high economic dependency on imported fossil fuel, the high cost of electricity, low levels of access to electricity, concerns about energy security, and challenges in meeting decarbonisation goals in electricity production.

Island states spend heavily on importing fossil fuels. The International Renewable Energy Agency's (IRENA) publication on spending on fossil fuels by island states in 2014 shows that the world, on average, spends about 4.6% of gross domestic product (GDP) on fossil fuels, while the figures are much higher for many SIDS, reaching over 10% for some of the countries. Figure 1.1 shows that even amongst SIDS the Maldives stands out, spending over 20% of its GDP (based on 2011 data) on the import of fossil fuels (IRENA, 2014).

Figure 1.1: Spending on Fossil Fuel Imports (percentage of GDP)

Source: (IRENA, 2014)

In recent years, the Maldives' expenditure on fuel (as a percentage of GDP) has increased. Table 1.1 shows that, in 2012, the Maldives spent 35% of its GDP on imported fossil fuels. This tremendous increase is partly due to the increase in international fuel prices.

Table 1.1: Fuel Expenditure in the Maldives (as a percentage of GDP)

Year	US\$ (million)	% GDP
2009	193.3	14
2010	245.0	17
2011	340.2	26
2012	474.6	35

Source: MoFT & UNDP (2014, p. 39).

Island states are also vulnerable to changes in oil prices because fossil fuel constitutes a large portion of their GDP. The Maldives is one of the top ten countries that experienced the largest increase in oil price vulnerability between 1996 and 2006 (World Bank, 2008, pp. 29–30). The oil price vulnerability index is calculated using indicators that reflect the country's economic performance, resilience of its economy, and the extent to which the country depends on imported oil.

The high price of diesel makes the commercial electricity tariff in small islands higher than the global average. The average commercial electricity tariff in the island states ranges from US\$ 0.33/kWh to US\$ 0.44/kWh (in 2012), while in EU member states the average tariff was about US\$ 0.26/kWh (in 2014) (Taibi, Journeay-Kaler, & Bassi, 2014, pp. 1,3). AF-Mercados EMI (2013a, p. 1) reported the average cost of electricity generation in the Maldives is more than US\$ 0.30/kWh, and reaches up to US\$ 0.70/kWh, making the electricity generation cost in the Maldives the highest in South Asia. Previous studies have provided some evidence that the introduction of renewable energy can reduce the cost of electricity generation in SIDS compared to the existing stand-alone diesel generators (Weisser, 2004b). Recent studies demonstrate that some forms of renewable generation are at grid parity, a condition “where the cost of renewables becomes the same or less than that of conventional sources,” (Jung, Kim, Moon, & Lim, 2018, p. 2).

Access to electricity is a problem for many SIDS. Dornan (2014) states that energy poverty is widespread in SIDS in the Pacific, and 70% of households in the Pacific SIDS do not have access to electricity, which is equivalent to the rates in sub-Saharan Africa, and slightly lower than low-income countries.

Energy security is a concern for the SIDS as well. They are largely dependent on imported fossil fuel to meet most of their energy needs since only a very few island states have fossil fuel reserves that can meet their energy requirements. They largely rely on sea transport to import fossil fuels. As a result, bad weather and disruptions to transport can have a significant impact on access to fossil fuels. Island states usually only have the capacity and the infrastructure to stock fossil fuels to meet their requirements for a few months and are dependent on the steady supply of fossil fuel.

The contribution of SIDS to global emissions of carbon dioxide (CO₂) and other GHGs is very low. However, they are among the first victims of climate change because of factors such as the geographical location, low elevation, coastlines, and climate conditions in these countries. One of the best option for reducing GHG emissions is to increase the use of renewable energy, particularly for electricity generation (Jefferson, 2008; Polzin, Migendt, Täube, & von Flotow, 2015). Renewable energy sources like solar power, wind power, hydroelectricity, biomass, geothermal energy, and marine energy can reduce the negative impacts of fossil fuel use on the environment and the economy. In order to limit their share of GHG emissions and to demonstrate to other countries that it is possible to achieve development by decarbonising, a number of SIDS have announced ambitious decarbonising goals. Achieving these goals can be facilitated by diffusion of RETs.

There are attempts to address many of these challenging issues in the sector, but success has been limited. The ineffectiveness of the approaches that aim to address the issues is not helped by the lack of understanding on why the diffusion has been slow. Chapter 3, section 5, elaborates this research gap. The lack of diffusion of RETs, the lack of understanding of the diffusion in the context of SIDS, and the lack of research on this phenomenon justify further research.

Lack of Diffusion of RETs

The growth of the use of renewable energy sources, or renewables, has been slow for most countries. For Organisation for Economic Co-operation and Development (OECD) countries, renewables in total energy supply increased from 6.2% to 7.1% from 1997 to 2008. During the same period, the UK's share increased only from 1% to 2.8%, the share of the US remained just above 5%, and only the EU (27) did relatively well with growth from 5.7% to 8.2% between 1994 and 2007 (Negro et al., 2012, p. 3837).

The diffusion of RETs in SIDS is lower than the global average. Electricity produced from renewable energy sources was 22.1% of global electricity in 2013 (REN21, 2014, p. 25), while IRENA's report on the energy profile of island countries in 2012 indicated the figure for most SIDS was below 10%, and for many SIDS it was closer to zero (IRENA, 2012b). Electricity produced from RETs in the inhabited islands in the Maldives is estimated to be below 1% of total electricity production (MEE, 2012, p. 16).

Lack of Understanding

The Maldives has stressed the importance of adopting sustainable energy policies since the sixth national development plan (UNDP, 2007, p. 3), and has also set a target of achieving 10% of its energy mix from renewable energy sources by 2010 (MPND, 2007, p. 16). The implementation of the plan has been constrained by a number of factors. The issues identified in a previous study include a limited partnership with private sector, an inadequate regulatory and policy framework, constrained access to finance, and a weak information sharing system (UNDP, 2007, pp. 4–16). It is important to understand whether these factors are continuing to hinder the diffusion of RETs.

Studies have identified a range of barriers to transforming the fossil fuel-based electricity sector to renewable energy technologies (Beck & Martinot, 2004; Dorf, 1984; Held et al., 2016; Negro et al., 2012; Painuly, 2001). We still do not know enough to understand why there is a low diffusion of RETs, particularly in the context of SIDS such as the Maldives. Alizada (2017) notes “there is a gap in the literature about the systematic studies of diffusion mechanisms, their links with different actors and with renewable energy policy adoptions” (p. 2). This necessitates investigating further the significant issues, as well as the important actors, affecting the diffusion of RETs in order to understand the diffusion mechanism.

The Need for Broader Research

There are a number of studies on the diffusion of renewable energy technologies in developed countries but few studies have been done to understand the policy measures applicable to promote the use of RETs in SIDS (Alves, Costa, & da Graça Carvalho, 2000; van Alphen, Hekkert, et al., 2008; van Alphen, Kunz, & Hekkert, 2008).

Small island states often do not get sufficient focus in research because in a number of ways they are so different from other advanced and developing countries. There are specific challenges in researching such states because of the absence of data, and moreover they do not play a significant role in international politics (Veenendaal & Corbett, 2014, p. 528). As a result, the slow diffusion of RETs in SIDS, including in the Maldives, has not been extensively examined.

There are some studies on the energy sector in the Maldives (AF-Mercados EMI, 2013a, 2013b; ECN, 2004; Fenhann & Ramlau, 2014; Journeay-Kaler & Taibi, 2015; MEE, 2012; SNC Lavalin & PA Government Services, 2010; UNDP, 2007), but very few on renewable energy (van Alphen, Hekkert, et al., 2008; van Alphen, Kunz, et al., 2008; van Alphen et al., 2007). Most of these studies have focused on the energy sector in the inhabited islands, while tourist resort islands are often not covered. Electricity production from tourist resorts accounts for 60% of national electricity production (MEE, 2012, p. 20). Hence, it is important to cover tourist resorts to obtain an in-depth understanding of the diffusion of RETs for the country.

In addition to understanding the key factors that affect the diffusion of RETs, it is important to understand how public policies contribute to the overall process of diffusion, and why the diffusion of RETs is rather slow. Theoretical approaches such as diffusion of innovation (E. M. Rogers, 2003), multi-level perspective (MLP) (Geels, 2002; Rip & Kemp, 1998), innovation systems (Edquist, 2006), and technological innovation systems (TIS) (Carlsson & Stankiewicz, 1991; Jacobsson & Bergek, 2004) can improve our understanding of the problem. However, there are few studies based on these frameworks on SIDS. An analytical framework based on a technological innovation system (TIS) approach may provide a better insight on the diffusion of RETs in SIDS, and its applicability can be explored by applying it in the context of SIDS.

1.3 Research Questions

The research problems present a number of potential questions to understand the issues. The problems can be explored from a technical and also economical perspective. However, this study is based on a public policy perspective and will explore the problems to provide a better understanding of the issues as to make a meaningful contribution to literature and practice of public policy. Hence, this study aims to understand why the diffusion of RETs is slow in SIDS, such as the Maldives, and to identify factors that are hindering and supporting the diffusion of RETs.

The primary research question this study seeks to answer is:

Why is the diffusion of renewable electricity technologies (RETs) slow in small island developing states (SIDS) such as the Maldives?

It also addresses the following two (secondary) research questions that arise from the primary question:

- 1) What are the factors driving and hampering the diffusion of RETs in the Maldives?
- 2) What policy interventions can improve this diffusion process?

1.4 Contributions to Research

This study makes two broad contributions to literature. Firstly, it makes an overall research contribution and contribution to the literature on the diffusion of RETs in the Maldives, and how that might be relevant to other SIDS. Secondly, this study makes a theoretical contribution in terms of identifying factors, actors, and the process by adapting the TIS framework to the context of the Maldives, which is similar to that of other SIDS. The study contributes to public policy in the Maldives by informing policymakers, donors, and international agencies interested in SIDS about important factors that are crucial for accelerating the diffusion of RETs in SIDS.

1.5 Research Methodology

This thesis is a case study of the diffusion of RETs in the Maldives. It uses a mixed methods approach and is based on qualitative and quantitative data. Qualitative data were collected from semi-structured interviews, and quantitative data were collected using a self-administered survey questionnaire. The two methods for data collection provide in-depth information on the perceptions and opinions of the stakeholders on RETs in the Maldives. Interviews were conducted in 2017 with a broad range of stakeholders including policymakers, experts working in the private sector, regulators, electricity service providers, and financiers. A six-step process was used to analyse both the quantitative and qualitative data using an adapted TIS framework.

1.6 Limitations of the Study

An important delimitation of this study is that it is restricted to understanding the diffusion of renewable *electricity* technologies (RETs) that are used for electricity generation, rather than all the renewable *energy* technologies that can be used for transportation, heating, and energy-efficient technologies in buildings. RETs are also referred to as technologies that are used to generate electricity from renewable energy sources (RES-E) (Batlle, Pérez-Arriaga, & Zambrano-Barragán, 2012; Held et al., 2016). Renewable energy technologies that are applicable to transportation, heating, and energy-efficient technologies in buildings are also important in the transition to a low carbon economy. In the same manner, technologies and practices that can improve energy efficiency and demand-side management are important to reduce environmental hazards and to increase energy security (Nogee, Clemmer, Donovan, & Deyette, 2002, p. 100). However, attempting to cover a vast range of technologies is too broad for this study.

The other delimitation of this study is that this single case study about the Maldives is based within the context of SIDS and is not broadly about developing countries. The distinguishing characteristics of SIDS justify focused research in their own context.

1.7 Structure of the Thesis

There are eight chapters in the thesis. The first two chapters give an introduction and background to the research. The next three chapters explain the theory and the methods used in the study, which are followed by the findings and discussions chapters that attempt to answer the research questions. The conclusions chapter wraps up the research.

CHAPTER 2: RESEARCH CONTEXT

2.1 Introduction

This chapter provides a background to the study by explaining the context of the research and gives supporting information for the reader to better understand and appreciate the issues presented in this case study. There are five sections in this chapter. After this introductory section, the next section will outline the distinguishing characteristics of SIDS. Section three will look at the use of RETs in SIDS, the potential of RETs, and the effort to improve the use of RETs by considering renewable energy targets and policies. As this study is based on a case study of the Maldives, section four will provide an overview of the Maldives, its electricity sector, and its use of RETs. Section five will conclude the chapter by highlighting the important aspects covered in this chapter.

2.2 The Small Island Developing States

Small Island Developing States (SIDS) are a distinct group of developing states that face special economic, social and environmental vulnerabilities. In 1992, during the United Nations Conference on Environment and Development (UNCED)—the Earth Summit held in Rio de Janeiro, Brazil—the United Nations (UN) recognised Small Island Developing States (SIDS) as a distinct group of developing states that face special vulnerabilities in achieving sustainable development¹.

There is no consensus on the list of countries that can be classified as SIDS. The United Nations Conference on Trade and Development (UNCTAD, 2018) claims that “the UN never established criteria to determine an official list of SIDS”. Different international agencies have listed a range of countries as SIDS based on the development circumstances of the countries. Fialho and Van Bergeijk (2017) presented six different lists of SIDS from six international organisations (see Table 2.1).

¹ Recognition of the circumstances of SIDS was specifically made at Agenda 21, Chapter 17G (Sustainable development of small islands) (UN, 1992).

Table 2.1: Six Different Lists of SIDS

	World Bank's small island exception	UNCTAD's unofficial list of SIDS	UNDESA's (SIDSnet) list of SIDS	AOSIS' members and observers	UNESCO's list of SIDS	UN-OHRLLS' list of SIDS
Since:	1985	1994 (?)	1997	1991	2008	2001
Number of countries in 2013	13	29	39	44	45	52

Source: Fialho and Van Bergeijk (2017, p. 108)

Fialho and Van Bergeijk (2017, p. 107) cited Carolina (2015) as explaining that the SIDS were then defined as “low-lying coastal countries that share similar sustainable development challenges, including population, limited resources, susceptibility to natural disasters, vulnerability to external shocks, and extensive dependence on international trade”, and this resulted in “inconsistency between the definition of SIDS and its acronym”. The most extensive number of countries documented under SIDS is presented in the United Nations Office of the High Representative for the Least Developed Countries (UN-OHRLLS) list of SIDS. Figure 2.1 shows SIDS in the UN-OHRLLS list located in the Atlantic Ocean, Indian Ocean, Mediterranean Sea and South China Sea (AIMS).

Figure 2.1: Small Island Developing States (SIDS) in AIMS

Sources: The population and land area are from *The World Factbook 2017* (CIA, 2018). The map was created using Tableau Software.

The UNCTAD's unofficial list of SIDS are more consistent with the criteria on islandness, Stateness, smallness, and developing country status (Encontre, 2004, p. 100). The list consists of self-governing island countries with a population less than 5 million. Table 2.2 lists UNCTAD's unofficial list of SIDS based on three different regions (AIMS; the Caribbean; and the Pacific) and with selected indicators of the countries. The list of countries shares more commonalities among the member countries than the diverse sets of countries presented in some of the other lists of SIDS.

Table 2.2: UNCTAD's Unofficial List of SIDS with Selected Indicators

Sources: SIDS members list is from (UNCTAD, 2018). The data on the SIDS are from *The World Factbook 2017* (CIA, 2018).

In many respects, SIDS are different from other landed and continental countries and face several additional developmental challenges. The distinct environmental, social, and economic features of SIDS increase their vulnerability, and many of these issues are discussed in the literature (Briguglio, 1995; de Vries, 1973; Streeten, 1993). Table 2.3 compiles the distinct features of SIDS that contribute to their vulnerability.

Table 2.3: Distinct Features of SIDS Leading to their Vulnerability

Geographic and Environmental	Social and Economic
<ul style="list-style-type: none"> • Small physical size • Remoteness • Geographical dispersion • Low resource endowment • Prone to natural disasters • Environmental fragility (climate change and sea level rise, threats to biodiversity, threats to freshwater resources, degradation of coastal environments, waste pollution, acidification of the oceans) 	<ul style="list-style-type: none"> • Small population • Limited ability to benefit from economies of scale • Small domestic market • Highly dependent on imports (including dependence on imported fossil fuels) • Little economic diversification • Limited labour base • Distance from market centres • Limited access to financial resources (dependence on external finance)

Sources: List compiled from Briguglio (1995), Ghina (2003), Hein (2004), and (UN-OHRLLS, 2015, p. 5).

There is also scepticism regarding vulnerabilities and special treatment for the island countries. This scepticism is often based on the economic growth rate and per capita income (Armstrong, De Kervenoael, Li, & Read, 1998; Armstrong & Read, 2002; Srinivasan, 1986). Based on a study on income, growth, and volatility outcomes, Easterly and Kraay (2000, p. 2013) argue “that small states are no different from large states, and so should receive the same policy advice that large states do” because lessons from growth experience are also applicable to small countries. On the other hand, Briguglio (1995, p. 1615) argues “the GDP or GNP per capita of these states often conceals” the vulnerability of these countries.

The recognition of special disadvantages faced by SIDS has not been sufficiently materialized into international action. While there have been a number of international conferences in matters related to SIDS, many of these meetings “[turn] out be another amiable assembly unanimously expressing pious wishes and good intentions in favour of a nebulous group of countries” (Hein, 2004, p. 22). This lack of focus on issues related to SIDS has also contributed to the lack of data and studies on matters related to the island developing countries (UN-OHRLLS, 2015, p. 4).

2.3 Using RETs in SIDS

This section will first explain the current role and the potential of using RETs. Next, the policies and initiatives that are in place to promote the use of RETs are overviewed.

2.3.1 Potential of RETs

The negative impact of conventional electricity sources on island economies and the environment, coupled with the increasing availability and economic feasibility of RETs, is driving interest in RETs in SIDS. SIDS are increasingly adopting renewable energy targets and policies to utilise more renewable sources such as biomass, wind, sun, ocean, wave, hydropower and geothermal resources (UNEP, 2014, p. 28). However, the use of renewable energy sources in electricity production is still low in SIDS, and many are reliant on diesel generators to produce electricity (see Table 2.2).

The global use of renewable energy sources for electricity production has increased over the years, and the global renewable electricity capacity has more than doubled in the decade between 2007 and 2017 (REN21, 2018, p. 40). In 2017, 26.5% of global electricity was produced from renewable sources (see Figure 2.2). Hydropower constitutes over half of the renewable sources and is followed by wind power, bio-power, and solar photovoltaic (PV). The remaining sources of ocean power, concentrated solar power, and geothermal power account for 0.4% of total global electricity production.

Figure 2.2: Estimated Renewable Energy Share of Global Electricity Production (2017)

Source: REN21 (2018, p. 41)

Many SIDS have potential renewable resources that could increase the composition of renewable energy for electricity generation, but there are differences with the extent of available indigenous renewable energy resources, depending on the geography and geology of the islands (Singh, 2012, p. 263). Table 2.4 shows IRENA's assessment of renewable resource potential in 28 countries that belong to UNCTAD's unofficial list of SIDS.

The assessment clearly shows solar potential is high among all the countries, and wind potential is high or within medium range for most of the countries. The potential of ocean energy is mostly low or unknown. RETs associated with ocean energy are also less developed and are not among the mainstream technologies currently available for electricity generation. The renewable resources attached to more mature technologies, hydro, geothermal and biomass, also have limited potential in many SIDS. Only a third of the countries have good potential for geothermal power, while there is potential for hydropower in even fewer countries. Atoll states with very low elevation such as the Maldives do not have hydropower potential. A few countries have biomass potential.

The assessment of renewable energy sources shows that while SIDS largely lack indigenous fossil fuel reserves, their endowment of renewable resources is also limited to a few. Renewable resources that can easily provide baseload power such as hydropower, geothermal power, and biomass are available in few countries. The baseload power can provide electricity continuously and can offset the challenge of reliability or unavailability associated with intermittent energy sources such as wind and solar.

Table 2.4: Assessment of Renewable Resources in SIDS

Region	Country	Solar	Wind	Hydro	Biomass	Geothermal	Ocean
AIMS	Cabo Verde	High	High	Low	Low	Unknown	Low
	Comoros	High	Medium	High	Unknown	High	Unknown
	Maldives	High	Medium	Unknown	Medium	Unknown	Low
	Mauritius	High	High	Medium	Medium	Unknown	Unknown
	São Tomé and Príncipe	High	Low	Medium	Unknown	Unknown	Unknown
	Seychelles	High	Unknown	Unknown	Unknown	Unknown	Unknown
Caribbean	Antigua and Barbuda	High	High	Unknown	Unknown	Unknown	Low
	Bahamas	High	Medium	Unknown	Medium	Unknown	Low
	Barbados	High	High	Low	Low	Unknown	Low
	Dominica	High	High	Medium	Unknown	High	Low
	Grenada	High	High	Low	Low	High	Low
	Jamaica	High	High/Medium	Medium/Low	Low	High	Low
	St. Kitts and Nevis	High	High	Low	Low	High	Low
	St. Lucia	High	High	Low	Low	High	Low
	St. Vincent and the Grenadines	High	High	Medium	Low	High	Low
	Trinidad and Tobago	High	Medium/Low	Low	Low	Unknown	Low
Pacific	Federated States of Micronesia	High	Medium	Medium	Low	High	Medium
	Fiji	High	Medium	High	Medium	High	Medium
	Kiribati	High	Medium	Unknown	Low	Low	Medium
	Marshall Islands	High	Medium	Low	Unknown	Low	Medium
	Nauru	High	Medium	Unknown	Unknown	Unknown	Medium
	Palau	High	Medium	Low	Low	Unknown	Medium
	Samoa	High	Medium	Medium	Low	Medium	Medium
	Solomon Islands	High	Medium	Medium	Low	Medium	Low
	Timor-Leste	High	Medium	High	Medium	Medium/Low	Low
	Tonga	High	Medium	Unknown	Low	Medium	Medium
	Tuvalu	High	Medium	Unknown	Low	Unknown	Medium
	Vanuatu	High	Medium	Low	Low	High	Medium

Source: Compiled from the data presented in (IRENA, 2012b)

The SIDS have not been able to fully utilise the renewable resources that are available in these countries to generate electricity. Table 2.5 shows electricity production from renewable sources in 2017 in 28 countries that belong to UNCTAD's unofficial list of SIDS.

Solar power is produced in most of the countries followed by wind power. Hydropower and bioenergy are used in only very few countries. Even though almost a third of the countries have high geothermal potential, none of the countries produces electricity from geothermal sources. Among the list of SIDS, Fiji, Mauritius, Jamaica, Samoa, Dominica, and St. Vincent and the Grenadines have the largest installed capacity of hydropower. Only four countries are producing electricity using bioenergy: Mauritius, Fiji, Jamaica, and Vanuatu. The largest installment of wind capacity is in Jamaica, Cabo Verde, Mauritius, Fiji, and in Seychelles. The data demonstrates that the available renewable energy resources are not effectively utilised for electricity generation in most of the SIDS.

Table 2.5: Electricity Production from Renewable Sources in 2017 in SIDS

Source: Data obtained from (IRENA, 2018a)

However, the cost of generating electricity using RETs has tremendously decreased over the years, and for many technologies the costs are competitive even in comparison with conventional energy sources. Figure 2.3 shows the global levelised cost of electricity (LCOE) from utility-scale RETs for 2010 and 2017. The LCOE is the lifetime costs divided by the electricity produced over that period. This measure allows comparing technologies that have different life spans, capital costs, and capacities, as a single measure for cost comparison. The dashed lines on the graph show the global weighted average LCOE value for plants commissioned in both years. The band represents the fossil-fuel based electricity generation cost range. The global weighted average LCOE of utility-scale renewable energy is least from hydropower projects (US\$ 0.05/kWh), followed by onshore wind (US\$ 0.06/kWh), and bioenergy and geothermal projects (US\$ 0.07/kWh). IRENA (2018c, p. 14) points out that the global weighted average LCOE of utility-scale solar PV has fallen 73% since 2010, to US\$ 0.10/kWh for new projects commissioned in 2017.

Figure 2.3: Global Levelised Cost of Electricity from Utility-scale RETs 2010 and 2017

Source: (IRENA, 2018b)

The main drivers for the reduction in the cost of the technologies are associated with improvements in technology, competitive procurement, and the experience and the large base of international project developers (IRENA, 2018c, p. 14). The reduction in costs of the technologies and the increasing interest in SIDS in RETs have contributed to the recent improvements in the installation of RETs in SIDS. Figure 2.4 shows renewable energy progress in 24 countries on UNCTAD's unofficial list of SIDS. The data for the remaining four countries (Dominica, Jamaica, St. Kitts and Nevis, and Timor-Leste) are not available. Figure 2.4 (a) shows the total installed capacity of renewable energy sources from different technologies. There is an annual increment of the total installed capacity of renewable energy sources. As illustrated in Figure 2.4 (b) most of the additional installations are from solar, followed by bioenergy and wind.

(a) Total Installed Capacity of Renewable Energy Sources

(b) New Cumulative Renewable Energy Installations

Figure 2.4: Renewable Energy Progress in SIDS

Source: Data obtained from (IRENA, 2018d)

The growth of solar PV installation was slow in other regions of the world as well (see Figure 2.5) but started to make progress after 2007; understandably, most of this growth is in the OECD countries (see Figure 2.6). As indicated in Figure 2.4, the installed capacity of renewable sources has increased in SIDS as well, but the pace of this growth has been rather slow.

Figure 2.5: Solar PV Cumulative Installed Capacity

Source: Data obtained from BP (2019b)

Figure 2.6: Solar PV Energy Consumption by OECD and Non-OECD Countries

Source: Data obtained from BP (2019b)

2.3.2 Renewable Electricity Targets and Policies

There has been increased interest at a national and international level in supporting the use of RETs. The policy commitment and national targets have contributed to the improvements in the uptake of RETs.

There have been changes in these targets in the past few years. Table 2.6 shows renewable energy targets from 28 countries included in UNCTAD's unofficial list of SIDS. The 'Targets in 2012' are compiled from IRENA's 2012 report on use of renewable energy by SIDS. The 'Intended Nationally Determined Contributions' (INDCs) are GHG reductions that the signatories of the United Nations Framework Convention on Climate Change (UNFCCC) submitted to the United Nations Climate Change Conference held in Paris, France, in December 2015. Nationally determined contributions (NDCs) are an important part of the Paris Agreement. NDCs require that signatory countries to put forward their best efforts to achieve the targets.

Many SIDS have embraced more ambitious targets; aiming to incorporate a higher composition of renewable energy in meeting their energy needs, particularly in generating electricity. The economy-wide targets have been set as high as 84% of emission reduced by 2030 (e.g. Comoros). Tuvalu, Cabo Verde, and Samoa have targets to generate 100% of their electricity by 2025, and Fiji and Vanuatu aim to generate 100% renewable electricity by 2030. However, a few countries have also retracted their initial targets towards a more modest goal. For instance, the Maldives changed its carbon neutrality goal in the energy sector by 2020 to an economy-wide target of reducing 24% of emissions by 2030.

Table 2.6: Renewable Energy Targets by SIDS

Region	Country	Targets in 2012	Intended Nationally Determined Contributions (INDCs) Made in 2015	
			Economy-Wide Targets Target Type (Year)	Renewable Electricity Targets
AIMS	Cabo Verde	50% of electricity generation from renewables by 2020		100% renewable energy penetration rate between 2020-2025
	Comoros		-84% (2030)	Renewable energy will evolve from around 3% (2010) to almost 43% (2030)
	Maldives	Carbon neutrality in the energy sector by 2020 50% of electricity generation from renewables by 2015 60% of electricity generation from solar by 2020	-24% (2030)	
	Mauritius	35% of electricity generation from renewables by 2025	-30% (2030)	
	São Tomé and Príncipe		-24% (2030) ₂₀₀₅	Introduction of about 47% renewable energy in the national electricity system (34% hydro, and 13% solar PV)
	Seychelles	5% of electricity generation from renewables by 2020 15% of electricity generation from renewables by 2030	-29% (2030)	15% of energy supply to be met from renewable energy sources by 2030 (expected target in 2020 is 5%). The long term goal is to achieve 100% renewables.
Caribbean	Antigua and Barbuda			50 MW of electricity from renewable energy sources by 2030
	Bahamas		-30% (2030)	A minimum of 30% renewables in the energy mix by 2030
	Barbados	30% of electricity generation from renewables by 2012 10% of energy use from renewables by 2012 20% of energy use from renewables by 2026	-23 to -44 (2030) ₂₀₀₈	65% of total peak electrical demand from renewables by 2030
	Dominica		-44% (2030) ₂₀₁₄	Harness geothermal resources, and reduce emission from energy industries to -98.6% by 2030
	Grenada	20% of electricity generation and transport energy from renewables by 2020.	-40% (2025) ₂₀₁₀	10% electricity production from renewables by 2025 (10MW solar; 15MW geothermal; 2MW wind)
	Jamaica	20% of primary energy from renewables by 2030 15% of electricity generation from renewables by 2020	-10% (2030)	20% renewables in the primary energy mix by 2030
	St. Kitts and Nevis	20% of renewable capacity by 2015	-35% (2030)	50% renewables in electricity generation and the transport sector (wind: at least 7.6 MW; solar: at least 1,859MW; geothermal: at least 35MW; waste-to-energy: 0.5 MW)
	St. Lucia		-23% (2030)	35% renewables in electricity generation by 2025; and 50% by 2030
	St. Vincent and the Grenadines	30% of electricity generation from renewables by 2015 60% of electricity generation from renewables by 2020	-22% (2025)	Install a geothermal electricity generation facility
	Trinidad and Tobago		-15% (2030)	

Table 2.6 continues next page

Region	Country	Targets in 2012	Intended Nationally Determined Contributions (INDCs) Made in 2015	
			Economy-Wide Targets Target Type (Year)	Renewable Electricity Targets
Pacific	Federated States of Micronesia	Decrease the import and use of imported petroleum fuels by 50% by 2020 10% of electricity generation from renewables in urban centres and 50% in rural areas by 2020	-35% (2025) ₂₀₀₀	
	Fiji	100% of final energy from renewables by 2013		100% renewable energy by 2030
	Kiribati	10% of electricity generation from renewables	-61.8% (2030)	Renewable Energy targets (23%-100%) for individual islands by 2025
	Marshall Islands		-45% (2030) ₂₀₁₀	-55% emissions from electricity production by 2025. -66% emissions from electricity production by 2030
	Nauru	50% of energy demand from alternative energy sources (including renewables) by 2015		Implementation of a 0.6 MW solar PV system
	Palau	20% of primary energy from renewables by 2020		45% renewable energy target by 2025
	Samoa	20% of primary energy from renewables by 2030		100% electricity generation from renewable energy by 2025
	Solomon Islands	50% of electricity generation from renewables by 2015	-45% (2030)	Commissioning of hydropower (3.77 MW), solar (3.2 MW), and geothermal plants (20-40 MW).
	Timor-Leste	50% of electricity generation from renewables by 2020	(Timor-Leste has made a conscious decision not to have a target for emission reduction)	
	Tonga	50% of electricity generation from renewables by 2012 18% of energy generation reduced by 2020 compared to 2000		50% electricity generation from renewable sources by 2020 (70% by 2030)
	Tuvalu	100% of electricity generation from renewables by 2020	-60% (from the energy sector) (2025) ₂₀₁₀	100% renewables in electricity generation by 2020
	Vanuatu	100% of energy from renewables		100% share of renewable energy in electricity generation by 2030

Note: Economy-wide targets represent relative emission reduction compared to business as usual (%) or the absolute emission reduction compared to the base year (%). When it is later, then the base year is stated as a subscript.

Sources: Targets in 2012 are from IRENA's renewable energy country profiles (IRENA, 2012b).

Intended nationally determined contributions are from World Bank (2016), Climate Watch (2018), and UNFCCC (2018).

There are a range of policy instruments applied in developed countries to achieve the economy-wide renewable energy targets and the renewable electricity sector-specific targets. However, many SIDS do not have such policies to support the diffusion of RETs. Table 2.7 shows a list of renewable energy support policies and SIDS that have implemented different policies on the list. The support policies consist of regulatory policies, and fiscal incentives and public financing policies.

Table 2.7: Renewable Energy Support Policies

Region	Country	Regulatory Policies				Fiscal Incentives and Public Financing			
		Feed-in tariff/ premium payment	Electric utility quota obligation/RPS	Net metering/billing	Tendering	Investment or production tax credits	Reductions in sales, energy, CO ₂ , VAT or other taxes	Energy production payment	Public investment, loans, grants, capital subsidies or rebates
AIMS	Cabo Verde			X	X	X		X	
	Comoros								
	Maldives	X			X				
	Mauritius			R	X		X		X
	São Tomé and Príncipe								
	Seychelles			X		X	X		X
Caribbean	Antigua and Barbuda								
	Bahamas								
	Barbados			X			X		X
	Dominica								
	Grenada			X			X		
	Jamaica			X	X	X	X		
	St. Kitts and Nevis								
	St. Lucia			X			X		
	St. Vincent and the Grenadines			X					
	Trinidad and Tobago					X	X		
Pacific	Federated States of Micronesia			X*					
	Fiji					X	X		
	Kiribati								
	Marshall Islands						X		
	Nauru								
	Palau		X						
	Samoa								
	Solomon Islands								
	Timor-Leste								
	Tonga								
	Tuvalu								
	Vanuatu	X					X		

Note: X: Existing national (could also include sub-national); X*: Existing sub-national (but no national); R:

Revised (one or more policies of this type).

Source: REN21 (2018, pp. 64–67)

Most of the financial incentives adopted by SIDS provide tax reductions, and only a few countries have established loans and capital support schemes. As a regulatory policy, net metering is adopted by most countries, but it accounts for only a third of SIDS. The assessment of the support policies within SIDS indicates that there are few policy schemes applied by these countries, and many countries are yet to establish appropriate policies to support the intake of renewable energies.

2.4 The Maldives as a Case Study

This section will provide an overview of the Maldives, the electricity sector, and RET use in the country. This background information will provide the context of the case study.

2.4.1 Country Overview

The Maldives is an archipelago of low-lying islands in a double chain of coral atolls located in a north to south direction across the equator on the Laccadives-Chagos submarine ridge in the Indian Ocean (Figure 2.7). This chain is 860 km long, and the width varies between 80 to 120 km from east to west (MEEW, 2006, p. 7). The Maldives consists of about 1,192 small islands, which are grouped into 26 natural atolls, and divided for administrative purposes into 20 atolls (MEE, 2012, p. 19). Among these islands, only 187 are inhabited, and 135 are self-contained tourist resorts (MoFT, 2018).

Figure 2.7: Map of the Maldives

Source: Ministry of Environment and Energy

The islands in the Maldives are small, and the terrain is flat. The total land area of the Maldives is about 300 km², and the average size of the islands is 25 hectares (MEE, 2012, p. 19). The largest island is barely 6 km² (MEEW, 2006, p. 19). Maldives is also one of the lowest lying countries in the world, where 80% of the landmass is less than one meter above sea level (CIF, 2018), and no single point is higher than 2.3 meters above mean sea level (MEE, 2012, p. 19).

The Maldives has a tropical climate, with little variation in temperature throughout the year; temperatures range from 25°C to 31°C. The country experiences two monsoon periods: the southwest monsoon (wet season), which lasts from May to November, and the northeast monsoon (dry period), which lasts from January to March (MEE, 2016, p. 2). The annual rainfall over the country varies between 1,779 – 2,218 mm per year (MEE, 2016, p. 2), and the Maldives on average receives over 2,700 hours of sunshine each year (MEE, 2012, p. 19).

The estimated population of the Maldives in 2017 was 359,608 (MoFT, 2018). The largest population center is the capital, Malé, and the second largest population center is Addu City in the south. One third of the population lives in Malé, which has an area of about 2 km² (MEE, 2012, p. 19). The rest of the population is dispersed across the outer islands. Figure 2.8 displays the distribution of the population in inhabited islands as per 2014 census data. This shows that 27% of the islands have fewer than 500 people, and only five islands have over 5,000 (MoFT, 2017, p. 7).

The Maldives has the highest GDP per capita in the South Asian region with GDP per capita of US\$ 10,536 (current) in 2017 (World Bank, 2018). Tourism and fisheries are the largest industries of the economy. The two sectors contribute approximately 40% of national GDP and are the main source of foreign exchange earnings (MEE, 2012, p. 21).

Figure 2.8: Number of Inhabited Islands by Population Size

Source: (MoFT, 2017, p. 7)

2.4.2 Electricity Sector

The provision of electricity in the Maldives started in 1949 with a 6kW diesel generator set installed in Malé (MEE, 2012, p. 24). Electricity was initially provided to the presidential palace and a few other government buildings and later expanded to the entire population in Malé. At first electricity service was provided directly by a government agency such as the Department of Electricity, and the Maldives Electricity Board (MEB). The MEB provided electricity to Malé and few other outer islands. Later, in 1997, the MEB was converted to a government-owned company, State Electric Company Ltd. (STELCO) (STELCO, 2018a).

STELCO provided electricity to Malé and some of the most populous islands in the country. Electricity service to the remaining islands was provided by island development committees and private providers. In 1997, only seven inhabited islands did not have any electricity service, and by 2006 all inhabited islands had some form of electricity, and most of them had a 24-hour power supply (MPND, 2007, p. 94). Maldives achieved universal access to electricity in 2008 (MEE, 2017c, p. 69).

The Maldives does not have one single electricity grid. Each island (inhabited islands, tourist resorts, and industrial islands) has its own electricity grid and a single electricity service provider. In 2009, the new government formed six government-owned regional utility companies to provide electricity and other utility services to the inhabited islands. However, the subsequent government in 2012 dissolved the regional utility companies and formed a single company, FENAKA Corporation Ltd. (FENAKA) to provide these services to all the inhabited outer islands (FENAKA, 2018). Now, FENAKA provides electricity service to most of the outer islands, Malé Water and Sewerage Company Pvt. Ltd. (MWSC) provides electricity to one inhabited island, island councils provide electricity to four inhabited islands, and a private company provides electricity service in one inhabited island, while STELCO provides electricity service to 35 islands that include Malé and nearby islands (MEE, 2017a, p. 10).

The use of electricity is on the rise and is expected to follow this trend in the short-run. The rate of increase in electricity consumption is associated with the increased electrification of islands, a rising number of high-rise buildings, increased use of air conditioning, and growth in the tourism sector. The tourism sector uses more than half of the electricity used in the country (MEE, 2016, p. 47). Most of the electricity consumed in the inhabited islands is in the capital city. Electricity generation for the greater Malé region (the capital Malé, Hulhumalé, and Villingili) accounts for about 60% of total electricity generated in all the inhabited islands (MEE, 2017a, p. 12). Electricity production in Malé has increased by 71% from 2005 to 2014; this accounts for an average of about 7.1% increase per annum (MEE, 2017c, p. 69).

Almost all the electricity generated in the Maldives is from diesel generators, and imported fuel is mostly used for electricity generation (MEE, 2012, p. 25). Fuel imports have been increasing (see Figure 2.9), and diesel constitutes the largest portion of imported fuel (see Figure 2.10). This increased dependency on imported fuel increases the vulnerability of the country to change in international fuel prices. Limited demand due to the small size and limited capacity to store fuel further increases this vulnerability. The Ministry of Environment and Energy stated in its latest island electricity data book that with a 28 metric ton (MT) storage capacity the country could only meet ten days of national requirement (MEE, 2017a, p. 10). This necessitates importing fuel twice or thrice a month.

Figure 2.9: Maldives Total Fuel Imports

Source: (MEE, 2017a, p. 13)

Figure 2.10: Maldives Oil Imports

Source: (MEE, 2017a, p. 13)

The cost of electricity production is largely dependent on the cost of fuel and the size and quality of the electrical system. A 2012 assessment of LCOE from diesel generators in the Maldives showed it varies between US\$ 0.31–0.46/kWh around the country (MEE, 2016, p. 53). The high cost of fuel makes electricity production in most of the islands inefficient. Production is cost-effective only in larger islands, where it is possible to achieve economies of scale. The existing electricity tariff approved by the Maldives Energy Authority (MEA) ranges from US\$ 0.14–0.50/kWh (MEE, 2017a, p. 12). The high cost of electricity necessitates cross-subsidising electricity to make it less expensive for residential consumers. The electricity tariff has three categories: residential, businesses, and government. Government and business tariffs are higher than the residential consumer tariff. In 2009, a revision of the electricity tariff introduced an electricity surcharge in addition to the kWh rate to meet the cost of production because of the fluctuations in fuel price. This increased the cost of electricity, and the government introduced a subsidy to residential consumers, which increased the economic burden on the government's budget.

2.4.3 Renewable Electricity Technologies

The increase in the cost of diesel-based generation and the reduction in the cost of RETs is the justification for installation of RETs. Studies also show that transitioning to a hybrid system of renewable energy and diesel-based generation is more economical than the existing means of electricity production (ADB (Asian Development Bank), 2015). The cost of producing electricity using solar PV has become lower than it is from diesel generators. In 2012, the cost of diesel-based electricity production in large electricity consuming islands was US\$ 0.35/kWh, while the cost of producing electricity from solar PV was US\$ 0.23/kWh, and solar PV was also competitive with battery storage (MEE, 2012, p. 40). The solar PV module prices have decreased by 81% since the end of 2009, and the global weighted average LCOE of utility-scale solar PV has fallen by 73% between 2010 and 2017 (IRENA, 2018c, p. 16).

Initial assessment of the availability of renewable resources indicates that the Maldives has a high potential for solar energy, and medium potential for wind and biomass energy (IRENA, 2012b). One of the most promising renewable resources for electricity generation has been solar since the Maldives is blessed with an abundance of sunshine throughout the year. The Maldives is also located on the equator, and solar declination is not an issue around the year (MEE, 2012, p. 38).

The early use of solar PV in the Maldives was limited to use for navigation lights and telecommunications systems. Since 1989 the national telecommunications provider has used solar PV to provide electricity to the repeater stations of the national digital microwave antenna systems (MHAHE, 2001, p. 44). Data provided by the Ministry of Energy and Environment shows that solar PV installation remained the same until 2006 (see Table 2.8). The 34.30kWp solar PV installed in 1995 is solar PV installed on telecommunication towers. The installed capacity reached 100kWp only in 2009 and crossed a megawatt-peak in 2012. The pace of solar PV growth has been remarkably slow even though the national development plans emphasised the need to increase the use of renewable energy in the Maldives. The Maldives development plan as early as 2001 committed to making use of alternative energy sources (Government of Maldives, 2001, p. 22).

Figure 2.11 shows the growth of solar PV in the Maldives, indicating the annual increment by both the government and the private sector. The government projects are installations implemented by the government under various donor-funded projects. The private installations include installation by a telecommunications company, electricity consumers, tourist resorts, and electric utilities. The installation of solar PV has only started to increase in the last few years. The increase in government projects is contributed to by donor supported programmes and government engagement in these projects. The increment in private sector contribution in 2012 was caused by STELCO's solar PV project. The 2014 increment in the private sector was contributed to by 960kWp² of solar PV installed by Gasfinolhu tourist resort.

² The size of a solar PV system is given a rating in kilowatts peak (kWp), and it is the peak power of the panel.

Table 2.8: Solar PV Installed in the Maldives

Year	Government Projects	Private Projects	Total (Year)	Total Installed (kWp)
1995	-	34.30	34.30	34.30
1996	-	-	-	34.30
1997	-	-	-	34.30
1998	-	-	-	34.30
1999	-	-	-	34.30
2000	-	-	-	34.30
2001	-	-	-	34.30
2002	-	-	-	34.30
2003	-	-	-	34.30
2004	-	-	-	34.30
2005	-	-	-	34.30
2006	17.80	-	17.80	52.10
2007	20.00	-	20.00	72.10
2008	-	1.80	1.80	73.90
2009	-	70.00	70.00	143.90
2010	11.10	11.20	22.30	166.20
2011	-	18.20	18.20	184.40
2012	395.00	744.92	1,139.92	1,324.32
2013	305.00	123.60	428.60	1,752.92
2014	1,063.99	1,222.80	2,286.79	4,039.71
2015	-	17.00	17.00	4,056.71
2016	2,656.20	33.20	2,689.40	6,746.11
Total	4,469.09	2,277.02		

Source: Data provided by the Ministry of Environment and Energy (MEE)

Figure 2.11: Growth of Solar PV in the Maldives

Source: Data provided by the Ministry of Environment and Energy (MEE)

The government projects were carried out with the support of bilateral and multilateral donor assistance. Climate Investment Funds (CIF) has recently supported a few projects that will potentially increase RET capacity in the Maldives. CIF supported projects include: Preparing Outer Islands for Sustainable Energy Development (POISED) (the World Bank is the lead agency for this project); and the Accelerating Sustainable Private Investments in Renewable Energy (ASPIRE) Program (ADB is the lead agency for the project). The POISED project had installed 2,500kWp of solar PV by the end of 2016. The other larger projects implemented by the government include: Project for Clean Energy Promotion in Malé (740kWp, with a grant from Government of Japan); Clean Energy for Climate Mitigation Project (558kWp, supported by the World Bank-managed Climate Change Trust Fund (CCTF)); and Support for the Climate Neutrality Strategy of the Maldives (327kWp, supported by Germany). The largest private installment of solar PV includes 960kWp installed by Gasfinolhu tourist resort, and 613kWp installed by STELCO in six islands through a power purchase agreement (PPA).

2.5 Summary

This chapter explained the classification of SIDS, their distinguishing characteristics, and demonstrated that SIDS share many common vulnerabilities and development challenges. For comparison, this study focused on UNCTAD's unofficial list of SIDS because the countries on this list share more common characteristics. Many SIDS are endowed with renewable energy resources even though renewable energy sources are limited. There is also the economic potential of transforming the electricity sector to renewable energy sources. In recent years, there has been increasing interest in transforming the energy sector in SIDS, but the diffusion of RETs has been slow.

The Maldives is considered appropriate for a case study in this research, as it can improve the understanding of the diffusion of RETs in SIDS, and in the last few years there have been increasing efforts to increase the use of RETs. The Maldives shares many common characteristics with other island countries, but the country also has unique features.

CHAPTER 3: LITERATURE REVIEW

3.1 Introduction

The purpose of this chapter is to review the literature and identify the research gap that necessitates answers to the research questions. There are eight sections in this chapter.

The next section will explain how the literature review is conducted and the research focus of this study. The following three sections will explain the three main areas in this literature review: the diffusion of RETs; renewable electricity policy; and SIDS. The remaining part of this chapter will explore studies about the Maldives and will demonstrate the research gap.

The third section will explore studies on the diffusion of RETs to understand how energy transition to a low-carbon system has taken place in the past. It also explores studies explaining the motivation to adopt RETs. Fourthly, renewable electricity policies are explored to improve the understanding of both the barriers and the driving policies that affect the diffusion of RETs. Fifthly, the studies on SIDS are explored to review the barriers and driving policies within the SIDS. Sixthly, the studies on the barriers and driving forces supporting the diffusion of RETs in the Maldives are further examined to assess the current understanding of the diffusion of RETs in the Maldives. Seventhly, the research gap for the study is demonstrated, and the justification for the study is presented. Finally, this chapter will conclude by summarising the important insights from the literature review.

3.2 The Research Focus

The three main areas in this literature review are the diffusion of RETs, renewable electricity policy, and SIDS. These three areas cover the broad subjects that fall within the research questions. Figure 3.1 shows the focus of the research by depicting that it occurs at the intersection of the three main areas of this research. This research explored relevant literature in these three areas.

Figure 3.1: Areas of Research Focus

In order to examine the literature on the diffusion of RETs, the following aspects were explored: the theories and approaches employed to study the diffusion of RETs; studies on the transition of energy systems; the broad factors related to the transition of energy systems; and the motivations to adopt RETs. The theoretical approaches employed to analyse the diffusion of RETs are introduced in this chapter, but they are elaborated on in the following chapter (analytical chapter), because the strengths and weaknesses of the approaches are examined in creating an adapted analytical framework for this study. Studies on energy transition are explored to understand different perspectives on the duration of energy transitions. In searching for broad factors related to energy transition, the concepts of path dependency, carbon-lock-in, entrapment in the technological system, and of systemic problems are explored. Additionally, studies explaining the justification for adopting RETs and minimising the use of technologies based on fossil fuels are also reviewed in this part of the literature review.

In reviewing the literature on renewable electricity policy, two broad subjects are reviewed. They are studies on the barriers to the diffusion of RETs, and then the policies that drive the diffusion of RETs. The studies consist of assessments on the diffusion of RETs in developed countries as well as developing countries. This review documents the lists of barriers and policy measures and categorises them according to studies into meaningful groups. The assessment of barriers and drivers with respect to RETs also attempts to understand the most significant barriers and important policy measures identified in other studies.

This study is based within the context of SIDS. The literature review explores a broad range of studies related to SIDS. Firstly, studies to understand the research context by exploring the special circumstances of SIDS, including renewable energy potential and renewable electricity generation in SIDS. These are explained in the previous chapter (research context) based on a review of relevant literature. Secondly, the literature review on SIDS explores the barriers and the drivers affecting the diffusion of RETs in SIDS.

This study is based on a case study in the Maldives. Hence, a broad range of literature focused in the Maldives is reviewed, and this includes grey literature. The review also explores quantitative data on electricity production in the Maldives that was obtained from the Ministry of Environment and Energy (MEE). The review of these data and an overview of the country, the electricity sector, and RETs in the Maldives are presented in the previous chapter (research context). The studies based on the Maldives are further analysed to understand the barriers and policy drivers identified in those studies which analysis is presented in this chapter.

In order to demonstrate the research gap, this study reviewed the literature as mentioned above with an aim of understanding the research gaps identified in those studies and the recommendations provided for further studies.

The following sections will present the findings from the studies based on the literature review approach just explained above.

3.3 Diffusion of RETs

The diffusion of RETs is instrumental for low carbon transition. The first part of this section explains that early action in supporting RETs is required to expedite the transition to a low carbon energy system, and technological development is not sufficient to transform the energy sector. The second part of this section explains the diffusion of technologies. It then demonstrates that the diffusion of RETs are tied to a sociotechnical system that has locked up the energy system to one based on fossil fuels, and that this inhibits the transformation to a low-carbon energy system. The third and the final part of this section explains different motivations for adopting RETs that drive the energy transition.

3.3.1 Energy Transition

Energy transition is defined as “the change in the composition (structure) of primary energy supply, the gradual shift from a specific pattern of energy provision to a new state of energy system” (Smil, 2010, p. vii). The world’s energy system has transformed from preindustrial dependence on renewable resources, such as wood biomass, to the industrial era with coal, and then to other fossil fuels. More recently, energy transition has resulted in starting to use renewables for electricity generation.

Energy transitions have resulted in changes in the fuel, the technology employed, the services provided, and the environmental impacts of the use of the resources (O’Connor, 2010, p. 1). The transition has also resulted in electrification and increasing use of electricity. In the energy transition, the electricity sector has also undergone a transition, with the restructuring of the electricity sector, technological change in electricity generation, and the evolution of the electricity grid.

There are two broad perspectives on the duration of the transformation of the energy system. The predominant view is that such transitions took a very long period in the past, and for the present system based on fossil fuels to transform to renewables will also be a “prolonged, multidecadal process” (Smil, 2016, p. 194). The opposite perspective is that technological transition has not always been prolonged, and that many transitions have taken place in a relatively short period (Sovacool, 2016, p. 202).

Sovacool (2016, p. 212) acknowledges that most transitions have been “path dependent rather than revolutionary, cumulative rather than fully substitutive”, and anticipates that this will continue to be the case. The path dependency and cumulative aspect of transformational changes mean that early action supporting RETs is instrumental in accelerating the pace of energy transformation.

The difficulty in energy transition is underlined by the fact that businesses and governments continue to invest in conventional technologies even where cost-competitive technologies are available (Pfeiffer & Mulder, 2013, pp. 285-286). This demonstrates that renewable energy transition is unlikely to take place on its own, but rather requires policies supporting this transition (Arent, Arndt, Miller, Tarp, & Zinaman, 2017, p. 4). Low-carbon energy transition is stalled not necessarily because of the lack of technology, but because of the lack of political and institutional support, and social awareness (Sovacool & Watts, 2009, p. 107). These factors are intertwined in forming the energy system and affect the diffusion of technologies such as RETs.

3.3.2 Diffusion of Technologies

Diffusion studies have been conducted in many disciplines, including economics, marketing, sociology, and public policy (Meyer, 2004, p. 59; Tidd, 2010, p. 5). Many of these studies focus on specific aspects of the diffusion of technologies. Economists apply econometric models on the diffusion of new products and processes to explain past behaviour, while in marketing models are used to examine buyer behaviour. In rural sociology diffusion is examined using statistical surveys (Tidd, 2010, pp. 5–6), and diffusion is also studied using statistical surveys in public policy studies, including with respect to public health issues. The use of agricultural technologies have been studied using qualitative studies and statistical surveys.

In the pioneering work on diffusion, Joseph Schumpeter in 1912 proposed a linear progression approach to diffusion proposing that it progresses from invention to innovation, and then to diffusion (Sarkar, 1998, p. 131). Early studies on technological diffusion were focused on invention and innovation. In initial studies on diffusion, the inventors and innovators were regarded as ‘the heroes’ in the technological development, whereas the adopters or imitators were considered as some ‘ambiguous figures’ (Silverberg, 1991, p.

67). Most of the modern work on technological diffusion applied the logic of epidemiological theories, which aimed to analyse the spread of disease, and these models emphasised that diffusion results in the spread of information (Karshenas & Stoneman, 1995, p. 270).

Diffusion of a technology is described as “the spread of use and/or ownership of new technology” (Karshenas & Stoneman, 1995, p. 265). The modern work on diffusion argues that the diffusion of technologies such as RETs does not follow a linear path, and that there are interrelated aspects that affect the diffusion of the technology.

Technological development and cost-effectiveness of technologies are important drivers in the diffusion of RETs, but they are not enough to drive the transition to renewable energy. An important question in energy transition is why some technologies are successful in overtaking existing technologies. O’Connor (2010, pp. 16–19) argues that supply constraints of the resource, cost, and performance advantages of the technology, and policy decisions that affect technological preferences, are important factors.

There are a number of factors that run in parallel that contribute to the slow pace of energy transition (Jefferson, 2008, p. 4116). This is because energy is not only a technological and economic phenomenon, but it is also fundamentally a social issue, and energy systems are interrelated with social, economic, and political aspects of society (Miller, Richter, & O’Leary, 2015, p. 29).

The intertwined nature of the energy system is referred to as a socio-technical system (Bolton & Foxon, 2015; Geels, 2004; Labussière & Nadaï, 2018), and also as techno-institutional complexes (TIC) (Unruh, 2000, 2002; Unruh & Carrillo-Hermosilla, 2006). Socio-technical systems “refer to the fact that individual technical artefacts or innovations are not operating in isolation”, and “it is not the individual artefact or innovation as such that has an effect, but its interplay with and embedding in other technical and non-technical elements in society and the economy” (Borrás & Edler, 2014, p. 1). The development and diffusion of large technology systems such as RETs are hampered by entrapment in the technological system (Walker, 2000), carbon lock-in (Unruh, 2000, 2002; Unruh & Carrillo-Hermosilla, 2006), and systemic problems (Negro et al., 2012).

The sociotechnical process of the energy system favours existing technologies based on fossil fuels, and this path-dependent process disadvantages carbon-saving technologies. This creates technological ‘lock-in’, where technology is entrapped in a technological system; and this is caused by social, legal, organisational, and political commitments (Walker, 2000, pp. 833, 845). Negro et al. (2012, p. 3838) argue that lock-in is caused by systemic problems that include problems with the market structure, infrastructural problems, institutional problems, interaction problems, and capabilities problems. The technological and institutional mechanisms that lock the energy system to technologies based on fossil fuels is described as ‘carbon lock-in’ (Unruh, 2000, p. 817).

The politics of the incumbent energy actors is also a significant factor in perpetuating the status quo and blocking attempts from renewable energy actors in spreading their role in the energy system. Smink, Hekkert, and Negro (2015, p. 87) note the incumbents have the economic resources to hinder, delay or even water down strict environmental regulations. In addition to obtaining fossil fuel subsidies, the network of power of the fossil fuel industry is also broadly embedded within state institutions that are mandated to support energy transformation (Newell & Johnstone, 2018, p. 77). The incumbents influence the institutions by interacting with policymakers, the general public and social movements by influencing the public debate and lobbying policymakers (Smink et al., 2015, p. 95). Geels (2014, p. 35) also observed from his study in the UK electricity system that the incumbent energy actors use different forms of power (instrumental, discursive, material and institutional) to resist climate change-related pressures for transformation.

Unruh (2000, p. 828) argues that for a technology to be dominant in the market, the path-dependent process is instrumental since it can create “technological cul-de-sacs”. The path-dependent process involves the historical circumstances of technology involving technological, organisational, industrial, social, and institutional factors.

Table 3.1 lists types and sources of technological lock-in within the techno-institutional complex (Delrio & Unruh, 2007). This suggests that the existing technological architecture, organisational routines, industry standards, system socialisation, and government policies (such as subsidies that support generation using fossil fuels) can hinder market entry and the development of RETs.

Table 3.1: Types and Sources of Technological Lock-in

Type of lock-in	Source
Technological	Dominant design, standard technological architectures
Organizational	Routines, hierarchies, customer-supplier relations
Industrial/System	Industry standards, technological interrelatedness, value chain relations
Societal	System socialization, adaptation of preferences and expectations
Institutional	Government policy intervention, legal frameworks, departments/ministries

Source: Delrio and Unruh (2007, p. 1501)

Carbon lock-in inhibits the diffusion of carbon-saving technologies such as RETs, even when the technologies become environmentally and economically advantageous (Unruh, 2000, p. 817), and this delays technological transition (Unruh & Carrillo-Hermosilla, 2006, p. 1186).

Unruh and Carrillo-Hermosilla (2006, p. 1189) also argue that developing countries are becoming “carbon copies” of industrialised countries, since they are following the same development path, and this prevents the developing countries from leapfrogging carbon-intensive technologies. This also raises the question of why economically attractive technologies are not automatically adopted, but the adoption decision is not a simple cost-benefit decision. There are a multitude of factors that affect the decision to adopt a given technology. Uncertainty, lack of financial means, and the anticipation that better technologies may be available in the future are important factors that can encourage a wait and see approach where adopters want to see how the market develops (Kemp & Volpi, 2008, p. S16). This makes the diffusion of RETs a more complex process.

3.3.3 Motivations for Adopting RETs

The demand for electricity is increasing because of the increase in the world's population, the increase in consumption in the growing economies, industrialisation, urbanisation, as more people switch from non-commercial fuels such as biomass to modern energy, and as more people are getting access to electricity (Mukherjee & Sovacool, 2012, p. 173). There are concerns about meeting this demand using conventional means of generating electricity which use fossil fuels, because of the impact on the environment, because of energy security, and for economic reasons. There are different views on the role of foreign direct investment (FDI) on the diffusion of RETs. Doytch and Narayan (2016, p. 295) have argued that FDI generally discourages the consumption of unclean energy, while Pfeiffer and Mulder (2013, p. 286) argue that higher levels of FDI appear to delay the diffusion of non-hydro renewable energy. Different countries are motivated to adopt RETs for many of these reasons, including climate change, security of supply, and cost competitiveness of RETs (Held et al., 2016, p. 34). Table 3.2 shows different motivations for adopting RETs among countries.

There is growing recognition of the urgency of addressing climate change. RETs are instrumental in reducing greenhouse gas (GHG) emission. Lifecycle GHG emissions from RETs are much lower than conventional power plants (IPCC, 2011, p. 18). Energy security is also an increasing issue since the prospect of fossil fuel depletion is increasing (Mezher, Dawelbait, & Abbas, 2012, p. 315), and oil reserves are concentrated in only a few and mostly volatile countries (Jordan-Korte, 2011, p. 1). RETs are becoming economically attractive, and in some cases equally competitive with technologies based on fossil fuels, even without subsidies and factoring in external costs from the conventional system. Some of these issues are more important in some countries than they are in others.

Table 3.2: Motivations for Adopting RETs

Consideration	Details
Economics	
Reducing energy imports	Fossil fuel imports impact national budgets as they drain foreign reserves. Changes in fuel prices in the international market also affect the local economy. On the other hand, RETs use indigenous resources create local jobs, and contribute to the economy. RETs also have the potential to provide electricity to remote areas where grid access is difficult.
Reducing fuel price fluctuations	
Strengthening local economies	
Improving energy access	
Security	
Diversifying energy supply	The oil price hikes in 1973/74 and 1979/80 initiated security concerns for depending on foreign oil reserves. Diversifying energy supply has become important to reduce dependency on fossil fuel imports, and to avoid disruption to supply because of international events. The disruptions in supply can have an impact on political stability. The increased use of fossil fuels are also driving the world nearer to peak oil, and there are increasing concerns with respect to fossil fuel depletion.
Improving the reliability of energy	
Fossil fuel depletion	
Environmental	
Fewer GHG emissions	Increasing evidence of anthropogenic climate change and the impact of GHG emissions has increased efforts to mitigate climate change. RETs provide an alternative energy system with lower negative externalities than systems based on fossil fuels. RETs create fewer GHG emissions and minimise localised pollution from electricity generation. The use of RETs reduces the large quantity of water required for many thermal generators. RETs is also considered a safe alternative to nuclear power generation.
Minimising localised pollution	
Lower negative externalities	
Less water use	
Reducing and eliminating the risk of nuclear power	

Sources: Jordan-Korte (2011, p. 220); Mezher et al. (2012, p. 315); Neuhoff (2005, pp. 88–89); Sovacool and Watts (2009, p. 99); Unnerstall (2017, pp. 21–25)

From an environmental perspective, to address climate change mitigation, the role of developing countries is becoming important because of their growth trajectories. However, developing countries face many development challenges and then having to prioritise mitigation efforts over other development aspirations is an additional challenge. Arent et al. (2017, p. 11) argue that energy transition does not impede the growth of developing countries, while Pfeiffer and Mulder (2013, p. 285) note adoption of RETs also provides developing countries with an opportunity to “‘leapfrog’ over developed countries”.

However, Arent et al. (2017, p. 11) acknowledge that there are “practical and ethical arguments” for developed countries to support the developing countries to make the transition to renewable energy.

As explained above, by identifying different motives for the adoption of RETs, this review demonstrates that there are pressures to change the energy pathways, both for the developing countries and for the developed countries. These pressures were evident in the past, particularly at the times of oil shocks (Araújo, 2014, p. 113). In order to address these issues, there has been increasing effort to transform the energy trajectory and to increase the use of RETs. Nevertheless, low-carbon energy transition continues to struggle, and renewable electricity policies attempt to address these problems.

3.4 Renewable Electricity Policy

This research is situated within the context of public policy and is based on renewable electricity policy. This section explores the diffusion of RETs from a public policy lens and aims to improve the understanding of this public policy issue, the lack of the diffusion of RETs, by exploring the literature on the barriers to the diffusion of RETs, and then the policies that are driving the RETs. The first part of this section explores different barriers, by classifying the barrier categories, and then identifies the key barriers that are affecting the diffusion of RETs. The second part of this section explores different policies that support and incentivise the diffusion of RETs. The analysis of these drivers showed that it is rational for the government to intervene to support RETs, and that no single policy measure may be sufficient to improve the diffusion of RETs.

3.4.1 Barriers to the Diffusion of RETs

The barriers referred to in this study are the political, economic, technical, social, and other factors that inhibit the diffusion of RETs. Studies have identified broad categories of barriers to the diffusion of RETs, and these categories include: sociotechnical, management, economic, policy (Karakaya & Sriwannawit, 2015); technical, economic, social, political (Zhang, Shen, & Chan, 2012); costs and pricing, legal and regulatory, market performance (Beck & Martinot, 2004; Urme, Harries, & Schlapfer, 2009); economic and financial, market, awareness and information, technical, and behavioural (Reddy & Painuly, 2004); market failure, market distortions, economic and financial,

institutional, technical, social-cultural-behavioural, and others (Painuly, 2001). Table 3.3 shows the main barrier categories, subcategories and a list of studies that identify the barriers and barrier categories with respect to the diffusion of RETs. The studies in Table 3.3 show there have been a number of studies over the years on the barriers to the diffusion of RETs and they have identified a range of categories. Most of these broad categories of problems identify economic, non-economic, and institutional barriers.

Table 3.3: Studies Identifying Barrier to the Diffusion of RETs

Barrier Categories	Subcategories	Studies
Political	Policies	Dulal, Shah, Sapkota, Uma, and Kandel (2013, p. 304); Wilkins (2002, p. 122); IEA & OECD (2001, p. 13); Sovacool (2009, p. 1530)
	Regulatory Framework	Nygaard and Hansen (2015, p. 17); Sovacool (2009, p. 1530); Reddy and Painuly (2004, p. 1434); Beck and Martinot (2004, pp. 366–369); Wilkins (2002, p. 122); IEA & OECD (2001, p. 13); Dulal et al. (2013, p. 304)
	Institutional Capacity	Nygaard and Hansen (2015, p. 17); Suzuki (2013, p. 164); Dulal et al. (2013, p. 304); Wilkins (2002, p. 122); IEA & OECD (2001, p. 13); Painuly (2001, pp. 79–81)
Economic	Costs	Beck and Martinot (2004, pp. 366–369); Painuly (2001, pp. 79–81); Dulal et al. (2013, p. 304)
	Financial	Nygaard and Hansen (2015, p. 17); Suzuki (2013, p. 164); Sovacool (2009, p. 1530); Reddy and Painuly (2004, p. 1434); Wilkins (2002, p. 122); IEA & OECD (2001, p. 13); Painuly (2001, pp. 79–81); Dulal et al. (2013, p. 304)
	Market Failure	Nygaard and Hansen (2015, p. 17); Painuly (2001, pp. 79–81); Suzuki (2013, p. 164); Dulal et al. (2013, p. 304); Neuhoff (2005, p. 88); Reddy and Painuly (2004, p. 1434); Beck and Martinot (2004, pp. 366–369)
Technical	Technological Constraints	Nygaard and Hansen (2015, p. 17); Suzuki (2013, p. 164); Dulal et al. (2013, p. 304); Reddy and Painuly (2004, p. 1434); IEA & OECD (2001, p. 13); Painuly (2001, pp. 79–81)
	Infrastructure	IEA & OECD (2001, p. 13); ; Wilkins (2002, p. 122)
Social	Human Capacity	Nygaard and Hansen (2015, p. 17); Dulal et al. (2013, p. 304)
	Public Apathy and Misunderstanding	Nygaard and Hansen (2015, p. 17); Dulal et al. (2013, p. 304); Sovacool (2009, p. 1530); Reddy and Painuly (2004, p. 1434); Wilkins (2002, p. 122); IEA & OECD (2001, p. 13); Painuly (2001, pp. 79–81)

There are different methods of exploring barriers to the diffusion of RETs, and most of the studies are based on a literature review, obtaining stakeholders perspectives, and developing case studies. In order to understand the barriers to RETs and to develop measures to overcome the barriers, Painuly (2001, pp. 77–78) suggested performing a literature survey on similar projects and case studies, as well as making site visits to obtain insights from the field and interact with stakeholders to obtain their perspectives. Zhang et al. (2012) studied the diffusion of solar energy use in Hong Kong based on a literature review, data collection from research reports, a questionnaire survey, a case study, and face-to-face interviews with experts in the industry. The use of different approaches improves the breadth and depth of data and allows the researcher to validate the data across different methods.

The barriers affecting the diffusion of RETs can be analysed at different levels. Disaggregating barriers at different levels provides a detailed description of the barriers, and gives a better insight into why the barriers exist, clarifies their significance, and makes it easier to take measures to address the barriers (Nygaard & Hansen, 2015, p. 20). On classifying barriers to the diffusion of RETs, Painuly (2001, p. 78) has suggested disaggregating them at four different levels: broad categories; barriers within categories; elements of barriers; and dimensions of barriers.

The survey questionnaire used in this study is based on the assessment of the barriers identified in this literature review. The literature review identified four broad categories of barriers: political, economic, technical, and social. The four categories of barriers are further explained below.

The political barriers consist of policies, regulatory frameworks, and institutional capacity. The lack of or weakness of these aspects inhibits the policy direction and the capacity to support the diffusion of RETs. Wilkins (2002, p. 123) identified the following seven barriers related to national policies and programmes as the factors that inhibit the diffusion of RETs:

1. Lack of clear government plans and targets for renewable energy development
2. Lack of appropriate fiscal policies and support mechanisms (taxes, duties, pricing, etc.)
3. Unclear and changing grid electrification plans
4. Lack of access to the grid
5. Lack of integrated planning for energy and development
6. Lack of consistent policy
7. Lack of focus on and ownership of renewable energy development.

Weak policy directions contribute to the lack of a regulatory framework and the institutional problems (the written rules and regulations, and social norms and values). Negro et al. (2012, p. 3844) argue in their study on why renewable energy diffuses slowly that the most recurring barrier is the lack of stable institutions. The policies also affect the economics and cost of the technologies.

The absence of externality costs, which are the costs imposed on society but not included in private supplier calculations in pricing systems based on fossil fuels, can be argued to distort the pricing of the energy system and provide an undue advantage to the fossil fuel sector. Renewable energy is more expensive than the conventional fossil fuel energy because of the absence of externality costs for conventional energy generation (Sovacool, 2008; Urmees et al., 2009). Sovacool (2008, p. 25) also notes that if renewable energy technologies compete with fossil fuel energy generation systems, by taking into account the external costs, then RETs will offer the cheapest means of electricity generation.

The cost of RETs is also associated with the level of maturity of the technology. The level of challenge is different for technologies at different levels of maturity in terms of technology development, costs, and market penetration (Held et al., 2016). As the technologies mature and achieve economies of scale, the cost also decreases.

Technological constraints such as intermittency of renewable energy sources (e.g. wind and solar) pose challenges in providing a steady supply of electricity to meet electricity demand. The intermittent nature of many RETs makes them unsuitable to use as a single source of electricity without an electricity storage facility. Hence, a hybrid system using conventional sources along with RETs are economical in many cases. F. Chen, Duic, Manuel Alves, and da Graça Carvalho (2007, p. 1890) argue that the intermittency barrier and the associated issues are more significant in the island energy system. Technical issues such as “grid connection constraints and lack of grid capacity” also add to the challenges of RET adoption in growing markets (Nasirov, Silva, & Agostini, 2015). The increase in technological development has been able to overcome many such challenges but RETs have yet to overcome some of the social barriers and achieve acceptance of the technologies.

There is broad acceptance of RETs. However, social acceptance of RETs is still a constraint in implementing some projects, such as securing a site for wind energy projects because of issues such as the visual impact on the landscape. Wüstenhagen, Wolsink, and Bürer (2007, p. 2683) note from Carlman’s (1982) work that issues related to social acceptance were considered as residual questions and were bundled under “non-technical” factors. Nevertheless, unlike most generation based on fossil fuels, RETs are based closer to consumers and this raises the question of the “backyard”, or “not-in-my-back-yard” (NIMBY), issue (Wüstenhagen et al., 2007, pp. 2684, 2686). Many of these barriers are common across the industrialised countries and developing countries including the SIDS.

There are also context-specific barriers because of the national and local characteristics of the countries. The state of the development of the country also creates different socio-economic conditions, and this may be different in developing countries compared to the industrialised countries. Table 3.4 lists barriers to the diffusion of RETs in developing countries that are attributed to the development state of these countries. In addition to sector-specific challenges, developing countries including the SIDS share common disadvantages because of weak policies; lack of financial, institutional, and human resources capacity; a less attractive business environment; and lack of availability of technologies.

Table 3.4: Barriers to the Diffusion of RETs in Developing Countries

Factors	Explanation
Policies	Lack of policy frameworks and facilitating legislations (e.g. energy and land use plans)
Financial Capacity	Lack of financial capacity to invest in RETs and to allocate funds to support the sector
Institutional Capacity	Lack of institutional mechanisms, government agency capability to regulate or promote technologies, and planning capability in general
Human Capacity	Lack of appropriately trained human resources, and management experience
Business Environment	Investment risk (real and perceived) due to political and economic instability and corruption
Technology	Low technical capabilities of domestic firms, and availability of appropriate technologies

Source: Adapted from Wilkins (2002, p. 121), and Singh (2012, p. 256)

These attributes in developing countries result in the lack of an enabling environment for private sector investment in RETs, and this is a key barrier to the diffusion of RETs (Suzuki, 2013, p. 159). To improve the diffusion of technologies in developing countries, both the transfer of technologies and the human resources capacity of the countries should also be improved (Wilkins, 2002, p. 174). This also requires government intervention, and support schemes to improve the diffusion of RETs.

The following section will first provide the rationale and justification for government intervention to support RETs, and then will explore different policies available to support the sector.

3.4.2 Policies Driving RETs

The current carbon trajectory is not expected to transition to low carbon technologies without government policies and intervention. (McDowall, 2018, p. 244). The higher cost of RETs and other factors such as grid structure makes it “virtually impossible for them to grow without regulatory intervention” (Batlle et al., 2012, p. 212). Moreover, without government support, RETs will diffuse at a less than optimal rate (Jordan-Korte, 2011, p. 219).

The market-based approaches cannot be expected to solve these system problems, since they can generate systematically weak performance and result in “systemic failure” (Smith, 2000, p. 94). This system failure justifies policy intervention (Negro et al., 2012, p. 3837). The market mechanism alone is not sufficient to increase the use of RETs because markets are not able to internalise emission costs, and overcome the structural barriers to the diffusion of RETs (Dulal et al., 2013, p. 305; Menanteau, Finon, & Lamy, 2003, p. 800). Unruh (2000, p. 828) reports from the work of Hohmeyer (1988) that the failure to internalise the environmental damage caused by fossil fuel distorts the price of fossil fuel by a factor of three or more. Sovacool (2008, p. 18) also argues that if electricity costs account for externalities, then the cost of RETs will be lower than conventional technologies.

Government intervention has been effective in changing relative costs, incentivising innovation (Groba & Breitschopf, 2013, p. 2), and correcting market failure. This has been the case even though there is a risk of government failure, and the potential misallocation of resources because of imperfect information and political capture (Jordan-Korte, 2011, pp. 4-5). There are a range of policy measures and tools that governments can apply to support the diffusion of RETs and to correct the system failures, but what may be missing is the political will to implement them (Sovacool & Watts, 2009)

Table 3.5 lists studies that have identified different policies that can be applied to support the diffusion of RETs. The policy measures include policies applied for market pull and technology push and consist of price-based and quantity-based approaches that include regulations, incentives, and financing to support the diffusion of RETs.

Table 3.5: Studies Identifying Policies that Support the Diffusion of RETs

Study	Broad Policies
Groba and Breitschopf (2013, p. 19)	Market pull policies that include: market-based (tax, trading); command and control (standards); and voluntary (investment and generation promotion); and technology push policies
Mezher et al. (2012, p. 317)	Feed-in tariffs; quotas; bidding tendering; tax credit; subsidies/rebates; and net metering
Sovacool and Watts (2009, pp. 104–106)	Promote energy efficiency; eliminate subsidies; standardize and certify; implement feed-in tariffs; provide grid interconnection and metering; streamline permitting and planning; distribute information
Beck and Martinot (2004, pp. 370–376)	Price-setting and quantity-forcing policies; cost reduction policies; and public investments and market facilitation activities
Menanteau et al. (2003, pp. 802–803)	Price-based and quantity-based approaches that include: feed-in tariffs; competitive bidding processes; and green certificates
Painuly (2001, pp. 85–87)	Energy sector liberalization; guaranteed markets; economic/financial incentives; government investments; information and awareness campaigns; standards and regulations; institutional measures; research and development; facilitating measures; and moral and ethical considerations
Nogee, Clemmer, Paulos, and Haddad (1999, pp. 22–43)	Renewable portfolio standards (RPS); public benefits funding; net metering; fair transmission and distribution rules; fair pollution rules; consumer information; putting green customer demand to work

Market pull policies use price-driven and quantity-driven technology specific, and non-technology specific, approaches to incentivise investment and generation using RETs (see Table 3.6). The price-based approaches are focused on incentivising green power generators and investments by providing subsidies and tax incentives, and offering attractive rates through schemes such as feed-in tariffs and net-metering. Quantity based schemes are focused on targets for renewable sources that include national targets or quotas, quota systems in combination with green certificates, and tendering to generate a designated quantity using RETs (Menanteau et al., 2003, pp. 799–800).

Table 3.6: Market Pull Strategies and Policies to Support RETs

Market pull policies		Technology specific (direct)		Non-technology specific (indirect)
		Price-driven	Quantity-driven	
Market-based	Investment Incentives	<ul style="list-style-type: none"> • Investment subsidies • Tax credits • Supportive tax policy • Tenders (price) 	<ul style="list-style-type: none"> • Tendering systems for investment grants (quantity) • Quotas (capacity) 	
	Generation Incentives	<ul style="list-style-type: none"> • Feed-in tariffs • Premium feed-in tariffs 	<ul style="list-style-type: none"> • Energy portfolio standards (quotas) in combination with tradable green certificates <ul style="list-style-type: none"> • Tendering systems for long-term contracts 	<ul style="list-style-type: none"> • Environmental taxes • Emission trading
Command and control		<ul style="list-style-type: none"> • Technology and performance standards • Authorization procedures 		

Source: Adapted from Groba and Breitschopf (2013, p. 19)

Technology push policies use incentives to drive the development and supply of technologies, and these include: public research and development (R&D) spending; tax credits to invest in R&D; support for education and training; financing demonstration and pilot projects; and technology exhibitions (Groba & Breitschopf, 2013, p. 19). There is also a perception that a technological revolution could decouple economic development from its impact on the environment (Peters, Schneider, Griesshaber, & Hoffmann, 2012, p. 1296).

There is increasing consensus that disruptive technologies (technologies that are radical and far-reaching) may not be enough for low carbon-transition (McDowall, 2018, p. 244). In addition to progress in science and technological development, the demand for the unmet need in the market is important in driving technological change. There is a wide agreement among scholars that technical change is caused by both the supply side (technology push) and the demand side or market pull, and they must exist simultaneously (Nemet, 2009, p. 701; Peters et al., 2012, p. 1296). This therefore justifies technology push and market pull policies.

There are a range of potential policy measures available for governments. However, the links between government policy choices and RET development are not well established and are sometimes contradictory (Shrimali & Kniefel, 2011, p. 4727), and little is known about the dynamics of policy choices and the diffusion of RETs (Schaffer & Bernauer, 2014, p. 15). Shrimali and Kniefel (2011) found in their study on the effectiveness of government policies on the diffusion of RETs based on 50 US states that some of the policy measures like RPS have been successful in promoting RETs. However, its impact has been mixed for different technologies. It has produced positive results for geothermal and solar energy, while negative results for combined renewables, wind, and biomass.

The policy measures identified in Table 3.5 can be broadly categorised into four types: targets and obligations; investment incentives; market facilitation activities; and discouraging measures. The policy measures in the list are used in the survey questionnaire of this study to determine the respondents' perceptions of the most important policy measures with respect to the diffusion of RETs in the Maldives (see Table 5.7). The four categories of policy measures are further explained below.

Targets and Obligations

National renewable energy targets indicate the government's commitment to increasing the use of RET. REN21 (2015, p. 87) notes national "targets remain the most prevalent indication of support to renewable energy in the power sector". Obligations require generation of the designated amount of electricity using RETs. There are different schemes to enforce such targets in different countries; for example, Renewable Portfolio Standard (RPS) in the USA; Renewables Obligation (RO) in the UK; Mandatory Market Share (MMS) in China; and renewable quotas in European countries (Mezher et al., 2012, p. 316).

Investment incentives

Different incentive schemes that are targeted to investment (loans, grants, subsidies, private sector funding), tax (tax credits, tax reductions), and tariffs (feed-in tariff (FIT), net metering) are crucial to reduce the cost of RETs investments and to make them more economical. Among the policy measures, net metering and FIT have been widely used. In net metering, a single meter is used to measure the electricity used by the consumer from electric utilities and the electricity fed into the grid through home-based solar PV systems. In FIT, the electric utility allows private producers to sell the renewable electricity they

generate back to the electricity grid. When the market price is sufficiently low, the role of investment incentives becomes less significant for the uptake of RETs.

Market Facilitation Activities

The government can support market facilitation through a number of activities: supporting customer education on RETs, human resource capacity building, improving technical capacity within the country, organisational capacity building, and supporting technology transfer. The government can also initiate public-private partnership projects, improve legislation supporting RETs, and provide easy access to the grid to increase private sector investment. Electricity sector reform and energy liberalisation are also seen as applicable approaches that support private sector engagement and improve RETs uptake. However, Weisser (2004c, p. 124) argues that there is insufficient evidence that privatisation alone can stimulate RETs uptake.

Accommodating independent power producers (IPP), and facilitating power purchase agreements (PPA), will allow private sector entry to the power sector, and they may contribute to the diffusion of RETs. However, Weisser (2004c, p. 104) also argues that this does not guarantee an increase in the contribution of RETs. The Natural Resources Defense Council (NRDC) report on direct foreign investment flows to renewable electricity in developing countries also illustrates that IPPs do not lead to more RETs (H. Chen & Schmidt, 2017). Nevertheless, private sector entry to electricity markets and access to the electricity grid are considered important factors in studies on the diffusion of RETs (Alagappan, Orans, & Woo, 2011, p. 5100; Painuly, 2001, p. 86).

Discouraging Measures

Removing subsidies for conventional sources of energy generation, and pricing the cost of electricity accurately are argued to be among the most important policy mechanisms to promote RETs (Sovacool, 2009, p. 1259). This includes removing subsidies for fossil fuels that are granted in order to reduce the cost of electricity.

There is no agreement on what is the most effective and efficient policy to promote the use of RETs. Jordan-Korte (2011, p. 5) argue FIT and RPS are the two main forms of policy measures that are used. The two approaches are based on price and quantity respectively.

While there are many policy measures to support the diffusion of RETs, many studies have highlighted the importance of implementing policies that holistically address the problem, rather than individual and isolated measures to improve the diffusion of RETs (Polzin et al., 2015; Richards, Noble, & Belcher, 2012; Sovacool, 2009). Polzin et al. (2015) studied the policies that are most effective to induce investment in renewable energy in Organisation for Economic Co-operation and Development (OECD) countries. They found that a policy mix, instead of single policies, is most effective in tackling market failures in the renewable energy sector. However, there are also challenges in designing mixed policies, and they do not necessarily assure the intended outcome (Trencher & van der Heijden, 2019, p. 43). Richards et al. (2012, p. 691) note that to overcome the barriers to RETs, one single approach that focuses on the technological, social, political, or economic factors in isolation solely does not produce sufficient results. Rather, the problem requires a multidimensional approach that addresses the sources of the barriers. Sovacool (2009, p. 1539) also argues that “no single-policy mechanism is a panacea”; and that policies should be implemented comprehensively and not individually.

Renewable energy policy formulation takes place at local as well as at national level, and the policy formulation occurs in cycles, and it takes place within the context of broad public, political and institutional context. In a study on policy challenges for renewable energy deployment in the Pacific Island Countries, IRENA found that the international development partners, and the local energy stakeholders play an important role in influencing the government in formulating energy policies, but the role of NGOs and industry association has not been equally significant (IRENA, 2012a, p. 13). The limited resources including the institutional, human, fiscal and materials are barriers to policy making in any context, and these are considerable issues in the case of SIDS (IRENA, 2012a, p. 9). The different circumstances of the SIDS necessitate context-based study to understand the barriers that hinder the diffusion of RETs in those island states, and the applicability of different policy drivers. The following section will explore the diffusion of RETs in SIDS.

3.5 The Diffusion of RETs in SIDS

The analysis of the special characteristics and features of SIDS in the diffusion of RETs is the third aspect of this research. There are only a few studies on RETs in SIDS. Some of these studies have focused on the economics of electricity supply (Weisser, 2004a, 2004b), renewable solutions for island states (F. Chen et al., 2007; Shirley & Kammen, 2013), power sector reform (Weisser, 2004c), case studies on the energy sector in different island states (Duic, Alves, Chen, & da Graça Carvalho, 2003), and barriers for RETs (Jafar, 2000). There are many common barriers across industrialised countries and developing countries including the SIDS, but SIDS encounter specific barriers because of national and local characteristics of the countries. Many studies on the use of renewable energy in islands are based on islands that belong to developed countries (Duić & da Graça Carvalho, 2004; Praene, David, Sinama, Morau, & Marc, 2012). There is also literature by international organisations and regional agencies on RETs in SIDS (Journeay-Kaler & Mofor, 2013; Taibi et al., 2014).

In this section, first the barriers to the diffusion of RETs within SIDS is explored. Next, based on relevant studies, the driving forces and appropriate measures to support the diffusion are analysed.

3.5.1 Barriers in SIDS

Most studies on the energy sector in SIDS highlight that SIDS are dependent on imported fossil fuel while they have an abundant supply of potential renewable energy sources, and that RETs can be economically attractive for SIDS (Blechinger, Seguin, Cader, Bertheau, & Breyer, 2014; Niles & Lloyd, 2013; Weisser, 2004b). However, the use of RETs has been low in SIDS (Blechinger et al., 2014; Jafar, 2000; Weisser, 2004b).

The challenges identified in studies on the use of RETs in SIDS include inadequate policy and regulatory frameworks (UN DESA, 2010, p. 20; Weisser, 2004b, pp. 128–129); lack of financing (Taibi et al., 2014, p. 4; UNEP, 2014, p. 29); lack of human and institutional capacities (Dornan, 2015, p. 491); UNDP (United Nations Development Programme) (2010, p. 54), and technical problems (Jafar, 2000, p. 308).

The four broad barriers identified above (inadequate policy, lack of financing, lack of capacity, and technical problems) are also pressing issues in many advanced economies, albeit to a different extent. These challenges are exacerbated in SIDS because of their special circumstances such as remoteness from a mainland, small population, small economy, and dependency on international markets. In many SIDS, the issues related to policy, finance and capacity are particularly pressing challenges. SIDS have established one of the most ambitious renewable energy targets in the world (Dornan & Shah, 2016, p. 759), but “sustained, consistent long term policy outlooks to support achieving targets are often absent” (Timilsina & Shah, 2016, p. 653). The special circumstances of many SIDS also raise the costs of infrastructure (Lucas, Fifita, Talab, Marschel, & Cabeza, 2017, pp. 46–47), and increase the financial burden to support RET projects. The absence of knowledge about the techno-economic potential of renewable hybrid systems in the islands (Blechlenger et al., 2016, p. 675), and the gap in technical data, resource assessments, and local capacity affects policy decisions (Timilsina & Shah, 2016, p. 653).

An increasing number of SIDS are embracing ambitious policy targets in respect of the use of RETs (see section 2.3.2 on renewable electricity targets and initiatives), while in many SIDS there are inadequate mandatory policies and regulatory frameworks to achieve those objectives.

There are weak financial incentives to support the use of RETs. The absence of market support mechanisms for RETs is also identified as an important problem in the development of RETs (Jafar, 2000; Weisser & Garcia, 2005). In many SIDS, RET projects are primarily funded by development partners, and there is a trade-off in using development assistance for such projects (Dornan, 2015, p. 491). This raises the question if development assistance from donors should be prioritised for poverty alleviation projects rather than for RET projects. The difficulty of accessing finance and the cost of financing hampers the deployment of RETs (Taibi et al., 2014, p. 4), and many SIDS are reliant on development partners for investment in RETs (Dornan, 2015, p. 501).

The lack of human and organisational capacity is a development challenge in many sectors in SIDS including the energy sector. The lack of availability of skilled people to manage RETs is a constraint in the energy sector (Jafar, 2000; Taibi et al., 2014). Jafar (2000) argues many RET projects in SIDS funded by donor assistance have failed because there was little consideration given to skill development and operation and maintenance of these systems, and the projects had a short-term focus

The technical problems identified in the studies include the intermittent nature of renewable energy sources and inadequate energy storage technologies (F. Chen et al., 2007; Journeay-Kaler & Mofor, 2013; Urmee et al., 2009; Weisser & Garcia, 2005). Some of these technical issues, including the intermittent nature of renewable electricity, and inadequate energy storage technologies, are not confined to SIDS. The intermittent nature of renewable energy sources affects the power quality and reliability of diesel-based grids and presents some technical uncertainties (Weisser & Garcia, 2005). Weisser and Garcia (2005) argue that to reduce the disruptive effect additional costs may be incurred and this can limit the penetration of these technologies. Jafar (2000) also noted that some of the problems in deploying renewable energy were the result of technical failures during the initial installation of solar PV systems. The technical problems include inappropriate design, unreliable components, improper installations, and poor maintenance.

3.5.2 Driving Policies in SIDS

There are strong arguments for government intervention to support the use of RETs, particularly in developing countries, since the RETs market is small and the consumers are poor, and without government intervention the diffusion of RETs is “highly questionable, if not impossible” (Dulal et al., 2013, p. 309).

There are a number of studies on policy measures to support renewable energy in developed countries, while there is a lack of studies on the suitability of these policies for SIDS. Van Alphen, Kunz, and Hekkert (2008, p. 1961) argue that many studies on developed countries may not be directly transferable to SIDS, because the economic, social, and geographical characteristics of SIDS create specific challenges that often differ from developed countries. In a study on barriers to the penetration of RETs, Painuly (2001, p. 77) also emphasised that barriers for RETs can vary across countries, and it is important to understand contextual factors.

The studies on policy drivers to support the diffusion of RETs in SIDS have also identified relevant policy measures to overcome the barriers mentioned in the previous section. The three broad policy measures from the studies are: establishing RETs targets that are required by law (Taibi et al., 2014, p. 4; UNEP, 2014, p. 29); providing financial incentives (Blechinger et al., 2016, p. 685; Taibi et al., 2014, p. 4); and building human and organisational capacity (Dornan, 2014, p. 726; UNDP (United Nations Development Programme), 2010, p. 55).

The laws and regulations in respect of the policy objectives are instrumental in achieving the policy objectives. Many SIDS lack holistic and long-term energy policies and models to support RETs (Weisser, 2004a, pp. 1320–1321). Establishing strong policy ambition has been successful in driving the diffusion of RETs. In a study on RETs in European islands, F. Chen et al. (2007, p. 1890) argue that RETs are most developed in islands where they are trying to achieve 100% of electricity requirement from RETs. Along the lines of policy instruments, if the government targets are stipulations and explicit regulations with penalties for not achieving them, then they can be viewed as sticks, if not they may be more like sermons. These policy objectives need to be supported by financial incentives to make investment in RETs more attractive. Policy measures to improve human and organisational capacity are also important to strengthen the technical capacity of the people, as well as the regulatory aspects of the energy sector.

As a policy issue, restructuring of the electricity sector has also become an important consideration in respect of the diffusion of RETs. The electricity sector has been restructured in many industrialised countries, while in many SIDS electricity services continue to be provided by state-owned electric companies. In a review of renewable energy development in 14 markets in developed countries, Alagappan et al. (2011) analysed the impact of market structure (restructured vs. not structured), feed-in tariffs (FIT) (present vs. not present), transmission planning (anticipatory vs. reactive), and transmission cost allocation between renewable generators and grid operators (high vs. low for generator). The study found market restructuring is not a primary driver for renewable energy development; however the use of FIT, anticipatory transmission planning, and the renewable generator assuming most of the costs of interconnection are important drivers in renewable energy development.

Weisser (2004c) studied electricity sector reform in SIDS to understand its implications for the diffusion of RETs. The study was based on electricity sector reform programmes in different countries including SIDS, and review of academic literature. This study concluded that full privatisation of the power sector cannot be encouraged, and that there is no conclusive evidence that it led to economic development in SIDS (Weisser, 2004c, p. 124). Beck and Martinot (2004, p. 378) also stated in their study on renewable energy policies and barriers that restructuring of the electricity sector in the 1990s had both positive and negative influences on RETs.

3.6 Studies on the Maldives

There are few peer-reviewed academic papers on renewable energy in the Maldives (Ali, Shafiullah, & Urmee, 2018; Jung et al., 2018; Liu, Mei, Wang, Shao, & Xiang, 2018; van Alphen, Hekkert, et al., 2008; van Alphen, Kunz, et al., 2008; van Alphen et al., 2007). However, the government (MEE, 2012; MHE, 2010) and international development partners, often in collaboration with the government, have prepared studies (AF-Mercados EMI, 2013a, 2013b; ECN, 2004; Journeay-Kaler & Taibi, 2015; SNC Lavalin & PA Government Services, 2010; UNDP, 2007) to understand the use of renewable energy in the Maldives.

IRENA, in its renewable energy roadmap for the Maldives, recognised the lack of studies in the sector and recommended energy policies be fully reviewed in order to identify specific barriers that are holding back the development of renewable energy in the Maldives (Journeay-Kaler & Taibi, 2015, p. 15). Van Alphen, Hekkert, et al. (2008, p. 164) in their study on RETs in the Maldives also stressed the need for further studies “to assess local needs, perceptions, resources as well as the existing economic, institutional, financial, and political frameworks”. These studies reaffirm the need for further studies to examine the barriers within the sector, and to identify potential policy measures to overcome them.

3.6.1 Barriers in the Maldives

The studies on RETs in the Maldives identified many of the common challenges that are identified in other SIDS. Many studies on the energy sector in the Maldives have emphasised the following four aspects as key barriers to the diffusion of RETs in the Maldives. Firstly, the lack of policy direction and regulatory obligations. Secondly, there remain concerns on the economics of RETs and whether the deployment of a renewable system is economically feasible (Jung et al., 2018). Thirdly, there are also questions on the appropriate composition of RETs that can be economically incorporated to the grid (Ali et al., 2018, p. 31). Fourthly, the availability of space for solar PV installation also remains as a concern (MEE, 2012, p. 40).

IRENA's renewable energy roadmap for the Maldives states renewable energy deployment in the Maldives is limited by policy and regulatory barriers, and national energy policy should promote renewable energy in tourist islands (Journey-Kaler & Taibi, 2015, pp. 2–6). The tourism industry represents almost half of the country's electricity consumption, while there is a lack of focus on resort islands (Journey-Kaler & Taibi, 2015, p. 4; MEE, 2012, pp. 107–108). Van Alphen, Hekkert, et al. (2008, p. 164) also argue that the diffusion of RETs is limited not only because of techno-economic issues but also by non-technical barriers, and their assessment of barriers and drivers in the Maldives renewable energy sector shows the blocking mechanisms for the development of RETs are more powerful than the inducement mechanisms. The study identified a number of barriers for the development of RETs in the Maldives: lack of information; insufficient capabilities; political and economic barriers; lack of understanding of local needs; business limitations; and institutional limitations.

The cost of solar PV modules has reduced significantly over the years, and installing solar PV on new buildings and retrofitting it to existing buildings has become feasible around the world, including in the Maldives (Ali et al., 2018, p. 31). However, there are questions on the economics of incorporating RETs fully to meet electricity requirement in the islands (van Alphen et al., 2007, p. 1650), even though it is possible to generate 100% of electricity from RETs (Sovacool & Watts, 2009, p. 95).

Hybrid systems incorporating RETs are economical (van Alphen, Kunz, et al., 2008, p. 1960), and increasing studies are supporting this assessment. In a study based on an inhabited island in the Maldives, Mohamed (2012) demonstrated that a diesel hybrid system incorporating RETs was economically and environmentally advantageous compared to a diesel-only system. The diesel-solar PV hybrid system with storage has become economically attractive for small island countries (Wijayatunga, George, Lopez, & Aguado, 2016, p. 274). A recent study based on one of the most populous islands in the Maldives, Hulhumalé, showed that the DG (diesel generator)/PV/battery hybrid system is the most economical compared to the DG/PV or DG-only system, and that the payback is only 4 to 5 years (Ali et al., 2018, p. 31).

The availability of roof space has been often cited as a barrier for solar PV in the Maldives, while an assessment by the Ministry of Environment and Energy (MEE) of “randomly selected islands” shows that existing roof space can meet between 30% to 80% of electricity demand in the islands (MEE, 2012, p. 40). The small size of the islands and the limited availability of space in many inhabited islands reduces the potential for having solar farms within the island. As an alternative to address the space availability, a solar energy company operating in the Maldives has started to offer a floating solar solution on the lagoons of the islands, but so far there have been only a few installations (Swimsol, 2019).

3.6.2 Driving Policies in the Maldives

Many studies on policy measures to improve the diffusion of RETs in the Maldives have emphasised the importance of private sector participation (Hameed, 2015, p. 57; van Alphen, Kunz, et al., 2008, p. 1964). Private sector involvement is limited by a number of factors including the difficulty of obtaining finance, high-interest rates, and lack of knowledge on the economic and technological feasibility of RETs (van Alphen, Hekkert, et al., 2008).

Based on a study of two renewable energy projects implemented in the Maldives, Van Alphen, Kunz, et al. (2008, p. 1961) argued that there is not sufficient support for local entrepreneurial activities to support the diffusion of RETs. Van Alphen, Hekkert, et al. (2008) assessed renewable energy projects implemented in the Maldives by Global Environment Facility (GEF), the United Nations Development Program (UNDP), and the

European Commission to determine if they have strengthened the local renewable energy innovation system. The analysis of the study was based on TIS. The study concluded that the projects have addressed most of the functions of the innovation system and development of RET seems promising. However, it recognised that enough attention was not paid to the development of local entrepreneurs and the creation of market activities. Hence, there is a risk of stagnation of technology transfer after the projects are completed. The study also recognised the importance of creating an autonomous renewable energy market that is not dependent on foreign aid.

Electricity sector restructuring is one of the approaches for private sector entry to the sector. Many developed countries have restructured the electricity sector to increase its efficiency and performance, and to facilitate private sector involvement. Electricity sector restructuring has been done by commercialising government managed operations, privatising the industry, and unbundling services (allowing different service providers to generate, transmit, and distribute electricity) (Weisser, 2004c). Nevertheless, some of the studies claim that there is no clear evidence that electricity sector restructuring in SIDS can ensure improvements in the diffusion of RETs. Weisser (2004c, p. 124) also argues there is insufficient evidence to show that privatisation leads to increased use of RETs.

3.7 Knowledge Gap and Research Justification

Renewable energy sources are becoming technologically and economically viable option for generating electricity. However, they have been tapped only to a small fraction of their potential (Painuly, 2001; Urmee et al., 2009). Researchers have questioned and tried to analyse why RETs diffuse so slowly, and what drives renewable energy development (Alagappan et al., 2011; Negro et al., 2012). The literature review on the diffusion of RETs, renewable energy policies, and the diffusion of RETs in SIDS demonstrated that there is *lack of diffusion* of RETs, *lack of understanding* of why the diffusion is slow, and *insufficient research* examining the diffusion of RETs, particularly in SIDS such as the Maldives. This knowledge gap justifies this research, and the gaps are further explained below.

It has been difficult to say farewell to fossil fuels, while fossil fuel is causing global climate change and irreversible changes to the environment (Hoffert, 2010). Over the years there have been increasing efforts to improve the use of locally available renewable resources and to reduce dependence on imported fossil fuel, but “renewable energy sources continue to struggle to be adopted into the mainstream of the energy mix” (Ince, Vredenburg, & Liu, 2016, p. 700). Assessment of resources suggests that there are sufficient renewable resources for large-scale deployment of RETs (Neuhoff, 2005, p. 88), but studies on SIDS show the use of RETs “lags far behind its potential” (UNDP, 2010, p. 54)

The slow diffusion is increasingly baffling since many RETs have become technologically mature and economically competitive compared to traditional electricity generating technologies (Weisser, 2004c, p. 122). It is a paradox that RETs are technologically and economically competitive, and reduce carbon emission, but are not adopted more rapidly, and government policies are not aggressive enough to promote them (Unruh & Carrillo-Hermosilla, 2006, p. 1185).

The market failures and the barriers that hinder the development and diffusion of RETs are often cited as the reasons for the slow diffusion. The ‘system failures’, ‘system imperfections’, or the ‘systemic problems’ are also recognised as factors that contribute to technological lock-in by favouring the status quo, and present a hurdle for RETs to penetrate the energy system (Negro et al., 2012, p. 3837).

Nevertheless, not enough “is known about “‘why’” or “‘how’” adoption occurs or fails to occur” (Meyer, 2004, p. 63). Similarly, Kemp and Volpi (2008, p. S18) argue in a study on the diffusion of clean technologies that “we have only a partial understanding of clean technology diffusion”. We need a better understanding of the diffusion of the technologies to help develop more realistic business plans and policies to support the diffusion (Tidd, 2010, p. 3). Wilkins (2002, p. 148) also argues, “There is no ‘one fits all’ solution to successful technology transfer”, and identification of the barriers should be done on a by country-by-country basis since the circumstances differ across the countries. This justifies and calls for country-based case studies to explore and understand the diffusion of RETs in respective countries.

There is increasing recognition that additional research is necessary to understand the diffusion of RETs, particularly in developing countries. In a study on the diffusion of renewable energy technologies in developing countries, Pfeiffer and Mulder (2013, p. 286) argued that most of the existing studies on the diffusion are based on developed countries:

[A]lthough investments in energy-saving or environmentally friendly technologies have received considerable attention in the field of environmental and energy economics, to date few studies have focused specifically on the diffusion of RET [renewable energy technologies], and these studies consider almost exclusively developed countries.

There is little peer-reviewed literature on RETs in the Maldives. Some of the recent studies on the Maldives electricity sector have only reviewed previous studies (Journeay-Kaler & Taibi, 2015), and it is not evident if stakeholder perspectives have been obtained to understand the barriers in the market and to assess the applicability of different policy measures. The studies on SIDS and the Maldives have not extensively explored the significance of barriers and policies in the energy system in order to understand the diffusion of RETs in the Maldives. This study aims to address this research gap and contribute to knowledge by improving understanding of diffusion of RETs in SIDS, and particularly in the Maldives.

3.8 Summary

The analysis of the diffusion of RETs shows the energy system is locked in to a system based on fossil fuels, and policy initiatives are needed to transform the energy system to rely on low carbon technologies. There are also important causes and motivations to take action to transform the energy sector.

The review of renewable energy policy demonstrated that there are a range of barriers that are inhibiting the diffusion of RETs, and that there is justification for government intervention to support the diffusion of RETs. Studies on the effectiveness of the policy measures show that no single measure is sufficient to overcome the barriers but that a holistic approach is needed to address diffusion of RETS in the energy system.

To date, there have been few studies of the diffusion of RETs in SIDS. Such studies as there are reveal an urgent need to improve the diffusion of RETs in order to reduce the dependency on expensive and polluting fossil fuels. The challenges in implementing RET projects include technical problems, weak incentives, issues related to donor-assisted projects, and a lack of private sector investment. In many SIDS policies to address these challenges and to drive the diffusion of RETs are lacking or poorly designed.

The literature review demonstrates that there is a lack of diffusion of RETs and only a limited understanding of why diffusion is slow in SIDS. This justifies additional research to address these gaps in knowledge. The literature review has made it clear that there are multiple drivers and barriers for the diffusion of RETs, and this requires choosing an analytical framework that can account for a wide range of influential factors at different scales.

CHAPTER 4: ANALYTICAL FRAMEWORK

4.1 Introduction

The purpose of this chapter is to explain the theoretical approach and the analytical framework used in this study. There are challenges in explaining the diffusion of RETs in SIDS using existing theoretical frameworks. There is a need for an overall framework based on multiple linked entities, their motivations, and interactions with each other, informing a country-level analysis of the diffusion of RETs. This chapter explores the existing approaches to studying the diffusion of RETs and modifies an existing framework to better understand the diffusion of RETs in SIDS.

The chapter consists of four sections. The next section explains four competing theoretical frameworks that may be used to study the diffusion of RETs. The following section explains the analytical framework for this study adapted from the technological innovation systems (TIS) framework. The analytical framework used in this study combines the strengths of the competing frameworks to enhance the applicability of TIS to understanding the diffusion in SIDS. Before concluding, the application of the adapted TIS for the analysis is also explained.

4.2 Approaches to Studying the Diffusion of RETs

Different academic disciplines have tried to understand and explain the process of diffusion by using different criteria and theoretical frameworks (Greenhalgh et al., 2005). Research on diffusion is highly interdisciplinary. Most diffusion studies are from the fields of business economics, innovation studies, and business management (Sriwannawit & Sandström, 2015, p. 1637). Different models using economic analysis have also been analysed to examine variables and their roles in the diffusion of innovation. Most of these have been used to explain the past behaviour of the diffusion of innovation rather than to predict future diffusion (Meade & Islam, 2006, p. 521).

The focus of this study is not on the invention, but the diffusion of innovation (i.e. RETs in SIDS). Early theorists of innovation, such as economist Joseph Schumpeter, maintained the distinction between *invention* and *innovation* (Robertson, 1967). E. M. Rogers (2003) defined an invention as “the process by which a new idea is discovered or created” (p. 475), and innovation as “an idea, practice, or object that is perceived as new by an individual or other unit of adoption” (p. 12). Diffusion, however, is the process by which changes occur, and “by which innovations spread from one locale or one social group to another” (Brown, 1981, p. 1).

Theories about the diffusion of innovation are broadly grouped into the following four perspectives: the neoclassical economic perspective, the sociological approach, the multi-level perspective, and the systems approach including technological innovation. These approaches are explained below.

4.2.1 Neoclassical Economic Perspective

In the early studies on diffusion, neoclassical economists explained profitability as the main driver of diffusion (Griliches, 1957; Mansfield, 1961). Profitability increases the number of firms using an innovation. According to this approach *market failures* are the main reason for the slow diffusion of RETs (Negro et al., 2012). There is a market failure when the allocation of goods and services is not socially optimal. Poor regulations on RETs relative to other energy sources, high initial investment for RET projects, and uncertain returns on RET projects contribute to market failure.

Two approaches are suggested to address market failure in RETs (Negro et al., 2012, p. 3837). One is to reduce the cost of technology by increasing support for research and development (R&D), and the other is to increase the cost of conventional sources of production by taxing them.

The neoclassical approach based on market failures does not fully explain how much subsidization is needed and where the subsidies should be given to rectify the problem (Smith, 2000, p. 85). There is no consensus on what the appropriate policy or policy mix should be to address market failure since the implications for diffusion are different for different environments (Delaportas, 2016, p. 102).

The oversimplifying nature and the reliance on profitability and externalities are seen as major weaknesses of the neoclassical framework (Delaportas, 2016). Later studies recognised that, in addition to profitability, the characteristics of the adopters are important in determining the diffusion of innovation (Gold, 1981).

4.2.2 Sociological Approach

The sociological approach to explaining the diffusion process recognises that in addition to profitability there are other factors at work. E. M. Rogers (2003, p. 5) defines diffusion as “the process in which an innovation is communicated through certain channels over time among the members of a social system”, and explains that it is a special type of communication, where the messages are concerned with new ideas (innovation). Four theories are widely used to explain Rogers’s diffusion of innovation – *the innovation decision process*, *individual innovativeness*, *the rate of adoption*, and *perceived attributes* (Surry & Farquhar, 1997).

The innovation decision process is extensively used to explain the process of diffusion (see Figure 4.1). The theory suggests that diffusion takes place over a period of time and the process has five distinct stages: (i) knowledge, (ii) persuasion, (iii) decision, (iv) implementation, and (v) confirmation (E. M. Rogers, 2003, pp. 20–21). Knowledge or information about the innovation is first communicated, and then adopters are persuaded about the benefits of the innovation. When adopters decide to adopt, they implement the decision and confirm their decision to adopt was appropriate.

Figure 4.1: Innovation Decision Process

Source: (E. M. Rogers, 2003, p. 170)

Individual innovativeness theory states that individuals differ in terms of innovativeness and categorises people on their degree of innovativeness and hence willingness to adopt an innovation. The differences are represented in a bell-shaped curve, where most of the people are in the middle range and a few are at both ends of the curve (see the bottom panel of Figure 4.2). Innovators are the first adopters of innovation, and are followed by early adopters, early majority, late majority and at the tail of the curve the laggards who are the last to adopt an innovation (E. M. Rogers, 2003, pp. 22 - 23).

The rate of adoption theory explains that the adoption process starts slowly because just a few take it up and follows a rapid growth phase because of high total use until growth reaches the new stabilised level (at maturity stage), and starts to decline on its final stage. The pace of adoption of innovation can be depicted by an S-shaped curve (E. M. Rogers, 2003, p. 23) (see the top panel of Figure 4.2).

Figure 4.2: Diffusion Curves

Source: (Meade & Islam, 2006, p. 520)

Perceived attributes theory states that potential adopters' adoption of innovation is related to their perception of the innovation, and lists five significant attributes: relative advantage, compatibility, complexity, trialability, and observability (E. M. Rogers, 2003, pp. 15 - 16). When innovation is seen favourably regarding those attributes, then diffusion is likely to be faster. Relative advantage is the extent to which an innovation is better than the existing technology, and this is based on the perception of the adopter based on economic profitability and social aspects of the innovation. Compatibility of the innovation relates to the extent to which the innovation is consistent with the adopter's values, past experiences, and expectations. Complexity determines the degree to which an innovation is difficult to understand and use. Trialability is the extent to which innovators can experiment within a limited scope, and observability is the degree to which the results of the innovations are visible to others.

There are a number of shortcomings in the Rogers diffusion of innovation theory and its application to technological innovation (Lyytinen & Damsgaard, 2001). The approach considers the diffusion process in terms of distinct discrete stages, but technologies do not diffuse in a homogeneous and linear sequential order. Diffusion processes take time, and the historical events of the process also influence the decision. These factors are not elaborated in Rogers's sociological approach.

Rogers's approach is widely used in diffusion studies (e.g. Dearing (2009); Nooteboom (1994)). However, it is not often used in studying the diffusion of RETs, probably because of its "inability to account for the impact of the environment in the diffusion process" (Delaportas, 2016, p. 22). The theory also does not explain the interaction of the determinants of diffusion.

4.2.3 Multi-level Perspective (MLP)

The multi-level perspective (MLP) is a "middle-range framework for analysing socio-technical transitions to sustainability" (Geels, 2011, p. 24). MLP is used to explain long-term technological changes that fulfill societal functions such as transportation, housing, communication, and energy needs (Geels, 2005b). Based on insights from evolutionary economics and technology studies, MLP provides a different perspective on how technological transitions take place (Geels, 2002). The approach was originally developed by Rip and Kemp (1998) and the theory was elaborated on by Geels (2002) and others (Whitmarsh, 2012)³.

The MLP framework consists of two transition concepts, *multi-phase* and *multi-level* (Geels, 2005a). The multi-phase nature of technological transition is depicted by an S shape curve, explaining that transition phases are non-linear and consist of phases that move from one dynamic equilibrium to another. The multi-level aspect of technological transition explains that transition of technology takes place with an interaction between the three levels: *landscape* (macro-level), *regime* (meso-level), and *niche* (micro-level) (Geels, 2002).

The landscape consists of slow changing external factors that may take decades to change, while regimes maintain the stability of the existing technological development by regulations and standards, adaptation of life style to technical system, and sunk investment in machines (Geels & Schot, 2007, p. 400). Niches act as 'protected spaces' for radical novelties and contribute to the generation and development of radical innovation (Geels, 2005b, p. 684).

³ Some of the other systems approaches, such as strategic niche management (SNM), and transition management (TM), also use MLP and have evolved as policy-centric frameworks (Kemp, Rotmans, & Loorbach, 2007; Schot & Geels, 2008). SNM and TM approaches look into the role of visions, development of actor-networks, and scaling up niche innovations.

Landscape represents the external factors (macro level) that affect the regime but are beyond the influence of the meso-level actors. Climate change is an example of an external factor that influences the development of energy systems, and is beyond the control of the regime actors (Kern & Smith, 2008). Changes at the macro level can put pressure on the regime level, and may also reinforce the status quo.

Regime (the socio-technical regime) is situated between landscape and niche and constitutes a patchwork of regimes that are aligned with each other by rules. The sub-regimes within the patchwork of regimes include the user and market regime, industry regime, science regime, policy regime, culture regime, and technology regime (Geels, 2002). The current status quo is configured within these regimes to maintain its structure. In a fossil fuel-driven electricity generation environment, the regimes provide stability for technological development. Studies on change at technological regimes place emphasis on incremental changes (Kern & Smith, 2008, p. 4094).

Niches provide protected space for innovations, and take place at the micro-level of the socio-technical system. Niche actors such as entrepreneurs and start-ups support innovation projects rather than existing projects. These novel projects can provide systematic change and may become dominant technologies at the regime level (Dóci, Vasileiadou, & Petersen, 2015).

The dynamic patterns of socio-technical transition are conceptualised in MLP, which is based on the concept that system innovation occurs through interactions between developments at the three levels, and that transitions often take place with interaction between two or more levels: “(a) niche-innovation build up internal momentum, (b) changes at the landscape level create pressure on the regime, and (c) destabilisation of the regime creates windows of opportunity for niche-innovations” (Geels, 2011, p. 29).

The MLP framework has been applied mostly in Organisation for Economic Co-operation and Development (OECD) countries. Recently the framework has also been applied to a developing country, Indonesia, for evaluating the promotion of renewable energy (Marquardt, 2014). Marquardt (2014, p. 92) states that the transitional theoretical framework “follows the Eurocentric paradigm of a very positive attitude towards bottom-up support”, and there are limitations on its application to developing countries.

The MLP framework has also been criticised for the lack of attention to geographical scale and overlooking power and politics. The transition towards a sustainable energy system will involve interactions of actors, networks and institutions across different spatial context. The lack of attention to local diversity and institutional contexts makes it difficult for MLP approach to explaining why niches in some places emerge while it is not the case in other places (Raven, Schot, & Berkhout, 2012, p. 67). The relationship between the policymakers and the incumbents are also not conceptualised in MLP framework to understand the dynamics of power and politics. Policymakers and incumbent firms form a core regime level alliance because of their mutual dependencies, and they often resist fundamental change (Geels, 2014, pp. 26–27).

The MLP approach is more complex than the innovation systems approach to diffusion of innovation, and it positions energy transition within broader developments. For this reason some experts feel that it fails to focus on the specifics of the energy system (Araújo, 2014). MLP is also not powerful in explaining the role of actors, networks, and institutions, and the approach is largely confined to the niche level in the analysis of emerging technologies (Markard & Truffer, 2008). The MLP framework has been largely applied to study the transformation of innovation that has taken place in the past, and it also overemphasises the role of niches (Genus & Coles, 2008).

4.2.4 Innovation Systems

The presence of multiple actors, institutions, and networks, and the influence of the social environment, make the process of diffusion a complex process. It is not possible to unlock the system by isolating a single factor (Negro, Suurs, & Hekkert, 2008, p. 59).

The innovation systems approach took a new perspective and recognised the complementarities of other factors, and proposed to examine the structural elements of a system (Jacobsson & Johnson, 2000). Innovation system theory evolved from the traditional ‘linear model’ of ‘technology push’ and ‘market pull’, or ‘basic research – applied research – development – diffusion’ model, to a systematic model that better explains the interaction of actors (Al-Saleh & Vidican, 2013). The late 1980s and early 1990s saw the emergence of innovation systems concepts (national, regional, sectoral, and technological innovation systems) (Markard, Hekkert, & Jacobsson, 2015).

The innovation systems approach has also been identified as a well-suited approach to explain the diffusion of technology (Musiolik & Markard, 2011; Schmidt & Dabur, 2013) since it takes the rationale for policy intervention from the limited ‘market failures’ approach to a more appropriate ‘systematic failures’ approach (Al-Saleh, 2011).

Innovation systems are defined as “the network of institutions in public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies” (Freeman, 1987, p. 3). The literature on innovation systems argues that innovation and diffusion are both individual and collective acts, where the individual and firms are interconnected in an innovation system, and technological change is a component of the economic system (Jacobsson & Bergek, 2004). Innovation systems theory recognises the complex environment in which innovation occurs, and provides greater recognition of the institutional environment in which the innovation takes place (Hudson, Winskel, & Allen, 2011).

The innovation system is made up of three main structural elements: *actors* (and their competencies), *networks*, and *institutions* (Jacobsson & Bergek, 2004). The structural components contribute to the overall functions of the development, diffusion, and performance of the system (Bergek, Hekkert, & Jacobsson, 2008). Actors consist of organisations and individuals involved in the transfer of emerging technology (Jacobsson & Bergek, 2004). Networks consist of the interactions between actors and institutions, and they represent modes of transfer of tacit and explicit knowledge. For example, a network or coalition of firms, associations, and research communities (Al-Saleh & Vidican, 2013). Institutions constitute Acts, regulations, and norms and values that affect the interactions and decisions of the system. Institutions can influence the decisions of the actors. Similarly, the actors also have some discretion to influence the institutional structure (Musiolik & Markard, 2011).

The positive interaction of the structural elements in the innovation system supports the diffusion of innovation since it leads to the development of the system. In the systems approach, the systematic interrelated nature of the innovation process is analysed. The approach identifies the processes and components that are most important for policy intervention (Jacobsson & Bergek, 2011).

Innovation systems can be examined at the national, regional, sectoral, or technological level, and they all involve the creation, diffusion, and use of knowledge (Carlsson, Jacobsson, Holmén, & Rickne, 2002). The boundaries of the systems determine the factors that are endogenous and exogenous to the innovation process, and every system serves a different explanatory purpose.

National innovation systems theory (Edquist, 1997; Freeman, 1987; Lundvall, 2010; Nelson, 1992; Porter, 1990) is used to explain how interactions between nationally bounded institutions support and facilitate diffusion of innovation. In regional innovation systems (Asheim & Isaksen, 1997; Cooke, 2001) the focus is regional. The sectoral system of innovation (Breschi & Malerba, 1997) looks at the rate and type of innovation and the organisation of innovative activities in sectors (Malerba, 2005).

The innovation systems approach is criticised for its simplistic approach to diffusion because it overlooks the dynamics of the innovation system. It is considered difficult for policymakers to extract sufficient practical guidelines from the innovation systems approach when it is based only on the structural components (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008).

The technological innovation systems (TIS) extends the innovation systems framework. In addition to the structural elements in the innovation systems, TIS incorporates functional activities, and this allows us to understand the dynamics of the system. The dynamics of the system is referred to as the internal and external pushes and pulls (Bergek et al., 2015, p. 52). The various functional activities of the TIS allows to aggregate those pushes and pulls and the influences on the performance of the TIS.

Technological Innovation Systems (TIS)

The TIS approach is proposed as an appropriate framework for studying the diffusion of RETs (Jacobsson & Bergek, 2004, 2006; Jacobsson & Johnson, 2000), and it has been used to study the diffusion of RETs in many industrialised countries (Bento & Fontes, 2015; Hekkert, Harmsen, & de Jong, 2007; Jacobsson & Lauber, 2006). However, there are only a few studies in developing countries using the TIS approach (Gosens, Lu, & Coenen, 2015), and among them some are focused on a particular technology within RETs (Agbemabiese, Nkomo, & Sokona, 2012; Tigabu, Berkhout, & van Beukering, 2015a,

2015b), while others have studied the entire sector or several technologies (Dantas, 2011; Gebreeyesus & Sonobe, 2012; van Alphen, Hekkert, et al., 2008). Since TIS is not widely used in developing countries, the use of TIS in this study will help to develop the approach and contribute to the development of the framework.

The TIS approach extends the innovation systems framework. This approach consists of structural elements (actors, networks, and institutions), and the functional activities (often referred to as ‘functions’) that can determine system performance (Jacobsson & Bergek, 2006).

Methodologically, TIS is a clearer approach to studying the complex concept of innovation systems (Gosens & Lu, 2013), and it is used more widely in the study of sustainable energy technologies. TIS can identify a diverse set of system weaknesses, and also the processes and components which are the most important for policy intervention (Jacobsson & Bergek, 2011).

TIS was originally defined by Carlsson and Stankiewicz (1991, p. 94) as “a network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology”. TIS is based on a non-linear model of innovation and recognises the complex and interdependent nature of the technological transition. It recognises that systems can fail not only because of market imperfections but also when there is system-wide failure (Negro et al., 2012). The approach recognises that path and innovation and diffusion of new technologies are dependent on the existing environment.

The structural elements are the fundamental parts in an innovation system. The role and contribution of these elements can impact the performance of the system (system performance). It is difficult to determine the impact of structural elements directly on system performance. Hence the structural components are supplemented with a process focus, and are represented by functions (Bergek, Hekkert, et al., 2008).

Functions in the innovation system focus on the most important processes for technology development and diffusion (Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007; Jacobsson & Bergek, 2004), since innovation systems theory was seen as too static, and as lacking

sufficient attention to the micro level. The functions are necessary processes to build up TIS. The functions may also be considered as criteria to evaluate the performance of TIS. Hekkert, Suurs, et al. (2007) defined the role of functions in TIS as being “to identify, understand, and compare the crucial activities in technology specific innovation systems”. The functions should stand on their own as relevant processes that contribute to the development and diffusion of the innovation system. The functions are particularly important in evaluating the performance of the system at the formative stage of technology diffusion since data on market diffusion are limited at the pre-mature stage (van Alphen, 2011, p. 24).

The functions of the technological system also serve as an intermediary between the structural elements of the system and its performance. In order to understand the performance of the technological system, the functions can be analysed (Jacobsson & Bergek, 2004, p. 818). Besides the pure analysis of the barriers to the diffusion of renewable energies, the functions of the innovation system allow analysing the diffusion of a technological system via policy measures (Schmidt & Dabur, 2013). The functions in a technological system are not independent of each other, and a change in one of the functions can have an impact on another (Jacobsson & Bergek, 2004).

The seven functions widely used in TIS are: entrepreneurial activities (F1), knowledge development (F2), knowledge exchange (F3), the guidance of the search (F4), market formation (F5), resource mobilisation (F6), and creation of legitimacy (F7). Table 4.1 provides a description of the functions and some of the criteria used to measure their performance. The roles of the functions are further explained below based on the descriptions by Hekkert, Negro, Harmsen, and Heimeriks (2011) and by Gosens and Lu (2013). Different functional activities are proposed in studies using TIS. However, most of them recognise the role of knowledge, entrepreneurship, social acceptance, resources, public support, and markets (Delaportas, 2016). The list of functions proposed by researchers for the TIS approach has been revised and refined several times. Bergek, Hekkert, et al. (2008) proposed seven functions in their revised work and agreed that their list of functions might require further revision when this provides new insight into system dynamics.

Table 4.1: Description and Performance Criteria of TIS Functions

Description	Performance Criteria
Function 1: Entrepreneurial Activities	
Entrepreneurs are essential for a well-functioning innovation system.	Intensity of new entrepreneurial activity, diversification and exploration of new applications, variety of technological experimentation
Function 2: Knowledge Development	
Mechanisms of learning are at the heart of any innovation process, where knowledge is a fundamental resource.	Research and testing performed, the number of patents held, the evolution of the knowledge base
Function 3: Knowledge Exchange	
The exchange of relevant knowledge between actors in the system is essential to foster learning processes.	Number of learning/educational seminars and summits, size of the network system and industry associations
Function 4: Guidance of the Search	
The processes that lead to a clear development goal for the new technology.	Expectations of actors, incentives created for uptake, established government targets or objectives, articulated consumer demand
Function 5: Market Formation	
The creation of a market for the new technology.	Phase of the market, niche markets, uptake projections and policy uptake inducements
Function 6: Resource Mobilisation	
Financial, human and physical resources are necessary basic inputs for all activities in the innovation system.	Availability and accessibility of materials, skills and labour, volume and quality of education and training, deployment capacity
Function 7: Creation of Legitimacy	
Innovation is uncertain. A certain level of legitimacy is required for actors to commit to the new technology and execute investments, take adoption decisions etc.	Presence of lobby organisations and activities, consumer and institutional expectations, establishment of technological legitimacy

Sources: Description from Reichardt, Rogge, and Negro (2017, p. 1218), and Performance Criteria from Hudson et al. (2011, p. 300)

Entrepreneurial activities function (F1) constitutes the presence and activities of entrepreneurs in the system since they are important to transferring knowledge of RETs into business opportunities. The entrepreneurs' role is to translate new knowledge, networks, and markets into new business opportunities.

Technology transfer function (F2) constitutes the level of access to technology for local use, either through demonstration projects, foreign aid, or through an established relationship with manufacturers and suppliers.

Knowledge exchange function (F3) constitutes the level of RETs knowledge exchange within the country, so that people are informed about the potential benefits of the use of RETs and about the opportunities that are available locally.

Guidance of the search function (F4) constitutes the significance of the direction given by the government for the use of RETs. Hekkert and Negro (2009, p. 586) explain guidance of the search (F4) as “the activities within the innovation system that can positively affect the visibility and clarity of specific wants among technology users”. It is done through government targets, regulations, and through administrative mechanisms to support RETs. An example of such an activity is the announcement of a policy goal to mandate electric utilities to generate a designated percentage of electricity using RETs within a specified period. Guidance of the search can positively affect the confidence of the actors, and that may influence further investments in the technology.

Market formation function (F5) constitutes the activities that support the creation of demand by reducing the cost of investments and maintenance, and by increasing supply of RETs through easy access to suppliers. It involves activities that contribute to the creation of demand, or the provision of protected space for the new technology.

Resource mobilisation function (F6) constitutes the allocation of physical, human, and financial resources to support RETs. These resources are important to facilitate and support the development of TIS.

Creation of legitimacy function (F7) constitutes attitudes towards RETs, and the level of networking established within RETs service providers. RETs can be resisted by incumbent service providers reliant on technologies based on fossil fuels. For the development of RETs, they have to have legitimacy in the incumbent regime. The functional activity can be determined by the level of growth of interest groups, the attitude towards RETs, and the extent of lobbying activities by RETs service providers.

There is no single standard that determines the performance of each function, and several indicators are used to evaluate the performance of the functions. Analysis of the functions is usually based on expert opinion of the performance of the functions, diagnostic questions, and indicators relevant for each of the functions (van Alphen, 2011, p. 25). As more system functions are fulfilled, it will result in better performance of the system – development, diffusion, and implementation of new technologies.

System changes take place when thresholds of certain functions are reached in the system. Change is caused by cumulative causation or “motors of innovation” as a result of the sequence of events of the functions (Suurs & Hekkert, 2009, p. 1006). Positive interaction of the functions creates momentum and overall positive efficiency of the system, and stimulates a structural change in the innovation system (Coenen & Díaz López, 2010, p. 1155). Hence, it is important to understand the sequence of the processes that can accelerate the diffusion of innovation.

Functions influence other functions, and create non-linear interaction between functions, and affect the overall performance of the system. These dynamics may also be considered as important processes and conditions for structural change (Hekkert, Suurs, et al., 2007). The performance of individual functions, and the interaction between the functions, are also important in understanding the diffusion of technology, since the positive interaction of well-performing functions can support virtuous cycles enabling the diffusion of new technology (van Alphen, 2011, p. 24). For example, a government’s announcement of its renewable energy targets and commitment to RETs (guidance of the search, F4) can have the effect of legitimising an increased allocation of resources to support RETs (resource mobilisation, F6). Individual functions are strengthened through this interaction, and such positive interactions between the functions can help to improve the development and diffusion of RETs.

Similarly, a system that is in decline in the development and diffusion of RETs may be in a vicious cycle, where the negative development of a function can contribute to the limited progress of other functions and decrease the diffusion of RETs. For example, removing subsidies for new technologies can result in a vicious cycle of events, since it can reduce entrepreneurs’ investments, which can further decrease expectations of the innovation, and may result in additional reduction in subsidies (Negro et al., 2008).

The role of the functions can also change at different phases of development of the system (Hekkert, Suurs, et al., 2007). In the early phase of innovation, some actors may play a more important role than others. For example, the significance of government support to reduce the cost of technology, and to accommodate it within the current environment, will be more important in the early stages than in the later stages.

Some of the weaknesses identified in the TIS approach are based on its lack of analysis of the system's landscape. Hence, it can be considered myopic in identifying the processes that result in transitions of technological systems, where there are impacts from the external environment (Markard & Truffer, 2008). The limitations of the analysis of contextual factors may also cause influential processes to be missed in the analysis since the analysis of the landscape is less systematic.

The TIS approach also appears to suggest that the technology developed will be later diffused in the same system (Delaportas, 2016, p. 111). However, for developing countries, particularly SIDS, the circumstances can be different because they are dependent on the import of technologies. Additionally, resource availability is not given explicit consideration in the approach. This may not apply to all sectors since the import of technology from a place where the resources are available may provide the solution (Delaportas, 2016, p. 112). Nevertheless, for the use of RETs, the availability of renewable resources within the country is important.

Markard et al. (2015) notes six criticisms of the TIS approach. First, these are based on the perception that the TIS approach downplays the external context factors. Second, clearly defined boundaries are absent. Third, the geographical issues are not sufficiently covered. Fourth, the question on the usefulness of TIS to analyse transition process. Fifth, the perception that TIS is not providing sufficient attention to the politics of transition, and sixth, the limits of TIS approach in providing policy recommendation.

In responding to this criticism, Markard et al. (2015) argue that that TIS has not ignored the contextual factors, but the contextual structures, boundary setting, and the spatial boundaries need to be further elaborated. Markard et al. (2015) also acknowledge that the TIS was not designed initially as a transition framework, but it explains the key process of socio-technical transition. Similarly, the politics of transitions are already addressed in the analysis of advocacy coalition and political networks. In response to the issue on policy recommendation, it is noted that TIS is frequently used to provide policy recommendations, but it does not need to be in support of a particular technology at the expense of the others.

The TIS and MLP frameworks are built on closely related concepts as they share common theoretical roots and analyse similar empirical phenomena in the study of technological change (Markard & Truffer, 2008). The two approaches offer two perspectives to analyse technological change. The TIS approach allows us to examine the weakness of the system and identify areas to make improvements. MLP takes a broader approach than TIS to understanding technological change by looking at societal processes. The starting point for the MLP framework is how societal change can be created, while the TIS approach examines the success and failures of a particular technology based on the performance of the (whole) technological system. The framework incorporates the role of the landscape and external factors to the system, and acknowledges the role of external shocks and disruptive changes to the system (Markard & Truffer, 2008). MLP is helpful in understanding the complex interplay of different forces between macro-, meso-, and micro-levels in creating transformational changes.

The TIS approach has been used in many studies and provides a systematic approach for the analysis to derive policy recommendations. Many of these studies are based on technologically advanced countries with a focus on the innovation of RETs. Applying the adapted TIS framework in this study helps to improve the understanding of its applicability in SIDS context to analyse the diffusion of RETs.

TIS is better suited to address the research questions for this study because it is narrower and has a more focused approach than some of the other socio-technical approaches. Additionally, considering its strengths and the weaknesses, TIS has more analytical power, because it provides a better understanding of innovation systems with its analysis of structural components and additionally of the functional processes of systems (Markard & Truffer, 2008).

In order to improve the analysis of TIS, new studies are suggesting additional indicators that can be used to assess the TIS performance (Miremadi, Saboohi, & Jacobsson, 2018). New studies are also attempting to improve the understanding of the life cycle stages of TIS development since this will help in formulating public policies supporting the technology (Markard, 2018). An increasing number of studies recognise the importance of understanding the dynamics between different functions within the innovation system and external structures (Wicki & Hansen, 2017).

Recent studies using the TIS have attempted to extend the TIS framework by bringing insights from the MLP framework (Edsand, 2017; Raven & Walrave, 2018; Walrave & Raven, 2016; Walz, 2018) to address the boundary issue of TIS and to improve the understanding of the dynamics of TIS. The TIS framework delimits the innovation system based on the actors and their activities alone, but they are not sufficient for understanding the performance of the system. Hence, additional studies are complimenting the TIS by incorporating landscape factors related to the diffusion of new technologies (Edsand, 2017). In order to improve the understanding of the dynamics of the TIS, recent studies have attempted to address ‘transitional failures’ (Raven & Walrave, 2018), and incorporated the concept of ‘transition pathways’ (Walrave & Raven, 2016, p. 1833) to understand the dynamics driving the innovation system (Walz, 2018, p. 277).

Among the recent studies using the TIS framework, only limited studies can be found focused on SIDS (T. Rogers, 2016). New studies based on TIS approach continue to use the framework to identify barriers for the diffusion of RETs (Edsand, 2017). Most of the studies using TIS are based on European countries (Kanda, Río, Hjelm, & Bienkowska, 2019; Lukkarinen et al., 2018; Magnusson & Berggren, 2018; Miremadi et al., 2018), and only a limited studies on developing countries (Walz, 2018), and/or remote communities (Karanasios & Parker, 2018).

4.3 Analytical Framework for this Study

TIS is the basis for the development of the analytical framework since TIS is applied to study complex systems such as the diffusion of RETs. In order to improve the applicability of the framework to SIDS, attempts have been made to address two aspects. Firstly, the limitations of the TIS approach in explaining the diffusion of RETs has been addressed by incorporating the strengths of other theoretical frameworks. Secondly, the characteristics of SIDS that were applicable to the framework were incorporated so that the framework would address the special circumstances of SIDS.

In order to address these issues, the following three changes were made to the TIS framework: incorporating the landscape element; changing the functional activity, F2 of the TIS; and strengthening the analysis of the creation of legitimacy function (F7). These changes aimed to address the limitations of TIS and its applicability to SIDS.

4.3.1 The Adapted TIS Framework

Figure 4.3 shows the adapted analytical framework that is used in this study to study the diffusion of RETs in SIDS. The additional elements added to the framework (Landscape and F2 – Technology Transfer) are shaded dark grey in the figure. The three broad components of the framework are the landscape, structural elements, and functional activities. These components are explained below.

Figure 4.3: Framework to Study the Diffusion of RETs in SIDS

Landscape

The TIS approach is enhanced by including landscape as an analytical factor. The MLP approach recognises the role of contextual factors, termed the landscape, and its influence on the development and the diffusion of RETs; these are not present in the TIS framework. Local events and international events can accelerate the diffusion of RETs. Understanding what the potential contextual factors are that can influence the diffusion of RETs in SIDS will strengthen the analytical capability of the approach. Three aspects of the landscape are analysed to obtain a broad view of the environment in which the energy system functions. In the adapted TIS framework, the term “landscape” is used not only to describe the global transformations and influences (the external developments), but also to include the physical geographical attributes of the Maldives (natural renewable resource endowment, and economic and social development of the country).

Firstly, the natural renewable resource endowment is analysed. Different countries have different endowments of renewable resources. The availability and the quality of renewable energy resources within the country is instrumental in determining the cost of RETs and potential investment in RETs (Freitas, Dantas, & Iizuka, 2012). Steady availability of renewable resources can increase the adoption of RETs.

Secondly, the economic and social development of the country is analysed. The economic and social development of a country affects the level of resources available for investment in RETs (Freitas et al., 2012). As economies grow, they can provide more resources to invest in RETs. Economic growth and the level of access to electricity can be useful indicators to assess the resources available to support RETs.

Thirdly, the external factors that can impact the functioning of the system are analysed. Energy systems are dependent on external developments, specifically the supply of fossil fuels, and the availability and prices of the technologies. This also includes changes in exchange rates and financial flows, including foreign aid. Most SIDS are dependent on foreign aid and donor assistance for development projects. External developments that affect the supply and cost of technology have a significant impact on the adoption of new technologies in technology recipient countries. SIDS are almost entirely dependent on international trade to meet their domestic consumption.

Structural Elements

The structural elements of the TIS are actors, networks, and institutions. The role of the actors within the system is evaluated in order to understand the significance of different actors. In analysing the diffusion of RETs in SIDS, the role of international development partners is important, as they play an important role in providing resources, technology, and technical assistance to the energy sector. Many SIDS are dependent on foreign aid and donor assistance for development projects, including many pilot projects and commercial-scale projects. Hence, their role in the diffusion of RETs in SIDS is analysed within the structural components of the innovation system.

Networks

Network analysis looks into relationships in the network of nodes and ties. The nodes are individual actors within the network and ties represent the relationship established between actors. The analysis of the network indicates the central players (actors) in the system and the links between the players.

Institutions

Institutions are the rules of the game. They include formal and informal regulations. The formal regulations are also referred to as ‘hard institutions’ and consist of written regulations including Acts, rules, and standards. Informal regulations are referred to as ‘soft institutions’ and consist of informal rules including social norms and values, and willingness to share resources with other actors in the system. Analysis of institutions indicates whether there are strong or weak regulatory regimes in the system, and related social factors that stakeholders view as important in affecting the diffusion of RETs.

Functions

The functions or the functional activities of the TIS make it easier to assess the performance of the system. In this study, two changes are made to the functions of the TIS framework.

Firstly, instead of a widely used function, knowledge development (F2), a more appropriate function for the SIDS context, technology transfer, is used in this framework. Van Alphen et al. (2008) also argue that the functions used in the TIS approach cannot be used without modifications in SIDS (like the Maldives), because the framework is based on industrial economies. The emphasis of the knowledge development function on the creation of new scientific knowledge domestically is not applicable to SIDS, because of their limited capacity and resources to perform this function. New technologies and products are often imported into SIDS.

Van Alphen et al. (2008) argue that it is more appropriate to assess the local capacity to adapt to new technologies. They propose replacing the knowledge development function (F2) with the ‘creating adaptive capacity’ function, but the suggested functional activities of the creating adaptive capacity function are also largely examined in the guidance of the search function (F4), since this function also analyses the capacity of institutions to support RETs.

This study uses technology transfer (F2) as an alternative functional activity to knowledge development. The technologies used in RET projects are transferred from overseas inventors or manufacturers and suppliers. Hence, it is appropriate to consider technology transfer as a separate function in the process of the diffusion of RETs in SIDS. The technology transfer function can be analysed based on the ease of obtaining technologies from overseas. This may be assessed by the availability of RETs in the local market, the number of private businesses selling the technologies, and the ties of private local businesses with manufacturers and suppliers of RETs.

Secondly, to improve the analysis of the creation of legitimacy (F7) function, additional aspects identified in Rogers's sociological approach are incorporated. The framework for this study has incorporated the perceived attributes of RETs (relative advantage, compatibility, and complexity) when analysing the creation of legitimacy function (F7). Rogers identified the perceived attributes as the most important variables that determine the rate of adoption of innovations. However, these attributes are not directly evaluated in the TIS approach. Among the five attributes identified in Rogers' diffusion of innovation, relative advantage, compatibility, and complexity of the technology can be analysed from user perspectives in the context of the creation of legitimacy (F7).

The remaining two attributes, trialability and observability, are broad concepts applicable to the technology. Therefore, the three attributes (relative advantage, compatibility, and complexity) are incorporated in the analysis of the creation of legitimacy (F7) to determine the perception of RETs in SIDS. Assessing the relevant perceived attributes of RETs in comparison to the existing method of electricity generation provides a better understanding of the perception of RETs.

4.3.2 Applying Adapted TIS

This study used a six-step process to analyse the diffusion of RETs in SIDS using TIS. Different analytical approaches are used in TIS studies. A six-step approach was proposed by Bergek, Jacobsson, et al. (2008), and the same approach with an additional functional activity was used by Gosens et al. (2015). Hekkert et al. (2011) proposed a five-step process in their manual for TIS analysts.

This study modified the approach of Hekkert et al. (2011) to align it with the research question for the study and to seek an in-depth assessment of the diffusion of RETs. Figure 4.4 shows the scheme of the analysis that was used for this study. The six-step analytical process used in this study is explained below.

Figure 4.4: The Scheme of Analysis for the Theoretical Framework

Source: Adapted from Hekkert et al. (2011, p. 4)

Step 1: Landscape

The analysis of the landscape of the innovation system provided a broad perspective on the system environment and the external factors that influence the performance of the system. In the analysis of the landscape, three factors were studied: external factors, natural resource endowment, and economic and social development.

Step 2: Structure

In this step, *actors*, *networks*, and *institutions* (structural factors) were identified from analysis of semi-structured interview responses, in order to determine their roles, capacities, and contribution to the diffusion of RET.

The analysis of the structural components of the system allows performing the analysis of the functional activities. The functions in TIS are more evaluative in character compared to the system structure, and they are analysed in step 3.

Step 3: Functions

The analysis of the seven functions indicates the performance of the system. To analyse the functional performance of the system, each of the seven functional activities was analysed separately. Different diagnostic questions were asked for each function in the semi-structured interviews.

Step 4: Development phase

The development phase shows the level of development that the system has reached. In order to determine the development phase, information from the analysis of the previous two steps is used. The development phase of the functions is assessed based on the performance of the functions. The functions are examined to understand the factors supporting and hindering the diffusion of RETs. The structural components and functional activities are insufficient and weak in the early stages of development. The dynamics of the structural components and functions change over different periods of development. The three broad categories of development phases are: the early formative stage; the growth stage when the system structural components and functions are well established; and the maturity stage where the system is finally stabilised.

The analysis of the structural components (their roles, capacity, and contribution) and the functional activities (performance of the functions) provides information on the status of the development of different functions.

Step 5: Identify system failures

The analysis of functional activities (step 3) showed the poorly performing activities that are acting as barriers to the diffusion of RETs, and highlighted the causes of these barriers. The causes of barriers can be within the structural components (step 2) or landscape (step 1). For example, if the entrepreneurial function is poorly fulfilled in the system, then it may indicate the need for the increased presence of private actors within the system.

The following steps were performed to identify the system failures. First, poorly performing functions were identified. Second, for each function, the structural components (actors, networks or institutions) that form a barrier to the development of the system were identified. The landscape may influence the performance of the structural components, and it was also analysed in this process. Finally, the relationship between the cause and the

barriers was analysed to determine if the cause is related to the absence of structural components or the quality of those components. The analysis may also indicate if the structural component has implications for other functions within the system.

Identifying system failures and the structural cause for functional barriers shows the necessary areas for policy action. The analysis of applicable policy instruments helps to improve our understanding of necessary policy instruments to address system failures, and it will provide additional information to answer the research questions.

Step 6: Policy instruments

The sequence of steps in the analysis provided a clear picture of the drivers and barriers in respect of the diffusion of RETs, and showed, particularly in step 5, the system failures that need to be addressed by policy action.

The policy options identified in the study are obtained from the survey, interview and the literature that has been reviewed in this study. The quantitative questionnaire provided information on respondents' opinions in respect of appropriate policy measures applicable in the Maldives. The interviews also identified perceptions of appropriate policy measures and provided an in-depth understanding of their application.

4.4 Summary

This chapter reviewed theoretical approaches to the diffusion of innovation by explaining the neoclassical economic perspective, sociological approach, multi-level perspective, and systems approach including TIS.

There are limitations to the direct application of these approaches to understanding the diffusion of RETs in SIDS. The neoclassical and sociological approaches provide a linear understanding of the diffusion of innovation and fail to incorporate the complexity of the societal environment in which innovation and diffusion take place. Nevertheless, these approaches provide important insights into the process of diffusion of innovation, particularly with respect to the determinants of the diffusion of innovation. The MLP approach provides a much broader perspective on the transformation of technology, but it is more difficult to operationalise. Also, MLP has been largely applied to understand the historical development of technological transformations.

The system approaches are more comprehensive and applicable to studying the diffusion of innovation in SIDS since they reflect the complexity in which RETs are developed and diffused in a society. However, the emphasis on the development of technology is not applicable to SIDS since they import technologies and are not generally involved in the development of these technologies domestically.

The analytical framework for this study is an adapted TIS framework. This framework attempted to address the gaps identified in the analysis of the existing theoretical approaches and attempted to improve understanding of why the diffusion of RETs is slow in SIDS. This study used a six-step process to analyse the diffusion of RETs, which was based on the analytical framework. The process used to address the research questions is explained in the following chapter on research methodology

CHAPTER 5: RESEARCH METHODOLOGY

5.1 Introduction

The purpose of this chapter is to outline the research strategy and the techniques applied to answer the research questions of this study. In order to answer the research questions, a pragmatic research paradigm is considered most appropriate. This study is based on a case study of the Maldives and used a mixed methods approach for data collection and analysis. To collect primary data for the research, semi-structured interviews and a self-administered survey questionnaire were used. The analytical process to answer the research questions included thematic analysis and quantitative data analysis (see Figure 5.1). The processes followed to answer the research questions are explained in this chapter.

Figure 5.1: Research Methods Map of the Study

This chapter consists of nine sections. After this introductory section, the following sections include: research paradigm; case study research strategy; methodology; research validation; methods of data collection; data analysis process; ethical considerations; and finally the conclusions.

5.2 Research Paradigm

All research is “guided by the researcher’s set of beliefs and feelings about the world and how it should be understood and studied” (Denzin & Lincoln, 2008, p. 31). It is important “to be aware of the implicit worldview that researchers bring to their studies” (Creswell & Clark, 2007, p. 21). This “worldview” (Creswell & Clark, 2007, p. 21; Guba & Lincoln, 1994, p. 105), “basic belief system” (Guba & Lincoln, 1994, p. 105), or “way of looking at the world” (Punch, 2014, p. 14) is the research paradigm, and it affects how we go about conducting research.

In the social sciences, there are different and competing paradigms that guide research (Willis, 2007, p. 8). In a pragmatic paradigm, the research question is more important than the underlying method (Punch, 2014, p. 304). In order to answer the research questions for this study, it is felt that the most appropriate approach is to obtain broad sets of data without being confined by methodological restrictions. By taking a pragmatic position, the researcher is not confined to the limitations imposed by the postpositivist or the constructivist view on research but can select different approaches for the research methodology. Postpositivism view that objective reality is out there in the world, and it can be observed and measured, typically by quantitative research. Whereas, constructivism view that reality is subjective, and it is co-created with the interaction of the investigator, and it is typically researched by qualitative approach.

Each study also has implicit assumptions that the researcher makes about reality (ontology), how knowledge is obtained (epistemology), and the methods of gaining knowledge (methodology). In this study, I take the view that the reality of diffusion is RETs is very complex and different actors have different perspectives based on how they interpret the phenomenon. Their (different) perceptions and opinions constitute the main source of knowledge in this study, and this data has been obtained via a mix of qualitative and quantitative interview methods.

5.3 Case Study Research Strategy

A case study is defined as “a research strategy which focuses on understanding the dynamics present within single settings” (Huberman & Miles, 2002, p. 8). Case studies are ideal to “understand complex social phenomena”. They are also useful for when the research questions require an “in-depth” description of some social phenomena; and for when the research questions seek to explain some present circumstance and use “how” and “why” questions to understand social phenomena (Yin, 2014, p. 4).

The case study approach provides the flexibility to use different data collection methods. Eisenhardt (1989, p. 534) notes that “case studies typically combine data collection methods such as archives, interviews, questionnaires, and observations”, because the evidence for the case may be available from qualitative and quantitative data.

Case studies can make a significant contribution to research, particularly in the following three ways (Punch, 2014, p. 124):

1. There can be valuable learning from an in-depth understanding of a case in its own right. The case might be “unusual, unique or not yet understood”.
2. As in much social research, an in-depth study of a case study can provide a deeper understanding of the complex problems.
3. The case study can provide an important contribution by combination of other types of research.

The three contributions can be related to the three types of case studies identified by Stake (1995, pp. 3-4): intrinsic, instrumental, and collective. In the intrinsic case study, the case is studied because the researcher is interested in having a better understanding of that case. In the instrumental case study, the case is studied to get a better insight into an issue or to refine a theory; and in the collective case study, a group of cases are studied to understand about a phenomenon (Punch, 2014, p. 121). Every case will have some similarities and uniqueness compared to other related cases, and case studies are conducted to study their uniqueness and commonality.

This study aims to explore and develop a deeper understanding of the issue of the diffusion of RETs in SIDS, based on a case study in the Maldives, and the research is applicable as an intrinsic case study.

5.3.1 Case Selection

Case studies may be a single case or a multiple case study. While there are some advantages of doing multiple case (or comparative) studies over single case studies (or classic case studies), single case studies can also provide “significant contribution to knowledge and theory building by confirming, challenging, or extending theory” (Yin, 2014, p. 51). Single case designs are justified when the case is critical, unusual, common, revelatory, or is a longitudinal case (Yin, 2014, p. 51). In these circumstances, multiple case study design may also not be applicable. There are also challenges in using multiple case studies because of the time and resources required, and it may be “beyond the means of a single student or independent research investigator” (Yin, 2014, p. 57).

This study will examine the diffusion of RETs at a country level, and in a single country, the Maldives. Many studies on the energy sector in SIDS have been based on single country case studies. In a study on increasing renewable energy sources in island energy supply, Duić and da Graça Carvalho (2004) based their study on a Portuguese island, Porto Santo. Duic et al. (2003) also studied the potential of the Kyoto Protocol Clean Development Mechanism (CDM) in the transfer of RETs to SIDS using a case study of Cape Verde. explain that, to simplify the example of the transfer of technology to SIDS through the CDM, one energy system was selected.

In this study, the Maldives is selected for the study for the following reasons. The Maldives has some unique characteristics compared to the other SIDS, such as universal access to electricity, while it shares many common features with other SIDS. As a developing country, the developmental context of the Maldives is similar to many SIDS and shares many geographical and demographic similarities. The use of RETs is also at its early stages in the Maldives as it is in most of the other SIDS. In-depth familiarity with the case is important in selecting a case for the study. The researcher’s ability to access data because of local knowledge and experience of the Maldives has provided a valuable contribution to this study.

5.3.2 The Relevance of the Findings

There has been a somewhat disapproving attitude towards case studies, usually based on the generalizability of the findings; with remarks such as “That’s only a case study” (Punch, 2014, p. 124), or “You cannot generalise from a single case” (Flyvbjerg, 2006, p. 219). Punch (2014, p. 124) argues the lack-of-generalizability criticism is often “a ‘knee jerk’ reaction to the case study”. In response to such criticisms, Yin (2014, pp. 20 - 21) argues that the findings from case studies are “generalizable to theoretical propositions and not to the populations or universes”. Case study research provides analytical generalization, and the aim of generalization is not the same as experimental research since the sample selected is too small to represent the larger population.

This study acknowledges the limitations of the study in broadly generalizing the findings across all SIDS. Additionally, among the RETs, the study is focused on solar PV, because at the time of data collection solar PV happens to be the only RET in use in the Maldives, and most of the available data relates to solar energy. The Maldives is also a solar-rich country, but many islands have limited space to install a large amount of solar PV within the island. Hence, there are limitations in generalizing the study to other SIDS with high wind resource. At the same time, the findings of this study may apply to many other SIDS that share common characteristics in terms of population, resource availability, and economic development.

5.4 Methodology

This study used a mixed methods approach. In order to answer the research question, this study used qualitative data from interviews to improve the understanding of the phenomenon, why the diffusion of RETs is slow in SIDS such as the Maldives. Similarly, a quantitative survey questionnaire is used to perform a statistical analysis of the perception of relevant stakeholders on factors driving and hampering the diffusion of RETs in the Maldives.

5.4.1 Mixed Methods

A mixed methods approach is used in this study because it is better suited to answering the research questions and to obtain different and multiple perspectives.

In selecting the type of mixed methods research design, there are three important factors related to the use of qualitative and quantitative data. The three factors are the *timing* (the order in which the collected data will be used; whether it will be concurrent or sequential), the *weighting* (the relative weighting of the two types of data; whether they will be given equal weight or unequal weight), and the *mixing* of data (how the data sets will be mixed; whether the two types of data sets will be merged, whether one will be embedded within the other, or whether both will be connected) (Creswell & Clark, 2007, pp. 79 - 84).

This study used concurrent triangulation design and collected and analysed the qualitative (interview) and quantitative (survey questionnaire) data concurrently to converge the findings. The purpose of the design is “to obtain different but complementary data on the same topic” (Morse, 1991, p. 122). In this study qualitative data are more important because a broader range of issues were identified using the qualitative method. Quantitative data were collected only to investigate two broad factors; barriers and policies. Both methods were used in parallel, during the same timeframe. The data from the two approaches were mixed by merging results during the interpretation of the data. The knowledge obtained from the review of literature has also been used in the TIS analysis.

Figure 5.2 shows a visual model for the mixed method design procedure used in this study. This study collected qualitative and quantitative data by using semi-structured interviews and a self-administered survey questionnaire. As a product of qualitative data, the semi-structured interview questions provided qualitative data, interview transcripts, and audio records of the interviews. The transcripts were coded and analysed for patterns, trends, and themes. Quantitative data was generated from the responses to the self-administered survey questionnaire. The analysis of the data provided mean scores, distribution of responses, and descriptive statistics on respondents’ perceptions of the overall degree of importance of different barriers and policies. The findings from both approaches are integrated to obtain answers to the research questions. The two methods for data collection and analysis provided more in-depth information on the perceptions and opinions of the stakeholders of RETs in the Maldives.

Figure 5.2: Visual Model for Concurrent Triangulation Design Procedures

Source: Adapted from Creswell and Clark (2007, p. 46)

5.4.2 Methodological Triangulation

Triangulation is described as “the combination of two or more theories, data sources, methods or investigators in the study of a single concept”, and it aims to “provide confirmation and completeness of data by overcoming the biases” that are inherent in single approach studies (Halcomb & Andrew, 2005, pp. 71 - 72). The argument for confirmation is a more challenging issue (Shih, 1998), and Fielding and Fielding (1986, p. 33) argue that the purpose of combining methods and theories in studies should not be to achieve “objective” truth but to attain depth and breadth to the analysis.

There are four basic types of triangulation: data (use of different data sources), investigator (use of multiple observers), theory (use of alternative theories), and methodological (use of different data collection methods, either within-methods or between-methods) (Denzin, 1989, p. 237). While there are different types of triangulation in research, many studies focus on the triangulation of methodology (Jones & Bugge, 2006). The fundamental argument for the use of triangulation of methods is that the weakness of individual methods is compensated for by the strengths of the other methods (Jick, 1979).

There are also limitations in the application of triangulation because it requires additional resources, and while the use of different methods can strengthen the research by complimenting the advantages of each method, bias-checking of the methods may also compound the sources of errors (Halcomb & Andrew, 2005, p. 79). A challenge is also presented when the analysis from both approaches does not corroborate, and the differences may be a result of poor design, or it might be giving an additional insight to the research problem (Halcomb & Andrew, 2005).

The researcher is aware of these limitations and has followed a methodological process to minimise such issues by explaining how the data from different methods will be used in the analysis of this study (see Figure 5.2). Methodological triangulation is used in this study as it aims to deepen the understanding of the phenomenon under study. Differences in results obtained from the two approaches will be examined to improve the understanding of the research problem.

5.5 Research Validation

Validity and reliability do not carry the same connotations in quantitative and qualitative studies (Creswell, 2014, p. 201; Hesse-Biber, 2010, p. 86). Qualitative analysis is often more probed about the validity and reliability of the findings. Quantitative researchers can be critical about the approaches to qualitative research and the validity of the data, because of the absence of the measures that are prevalent in quantitative studies, such as “quantitative measurement, explicit controls for various validity threats, and the formal testing of prior hypothesis” (Maxwell, 1992, p. 279).

Yin (2014, pp. 45, 48) proposes some analytical processes, including pattern matching and explanation building, to ensure internal validity. In this study, the interview transcripts are coded as per predefined code in order to identify emerging themes from the study. The TIS framework allows looking for different aspects of the diffusion of RETs even before starting to do the analysis. Aspects related to the structural components and functional activities of TIS are pre-coded for the analysis (see Appendix G – Provisional List of Codes). The analysis of the findings is documented and explained. The study has also used direct quotes from the participants as it can increase the credibility of the findings. The survey data is analysed by calculating the mean score for the factors listed in the survey and the key factors are ranked accordingly.

Reliability tests attempt to determine if the study employed an operational procedure that minimises errors and bias in the data collection and analysis so that the same results can be achieved when the study is repeated. Yin (2014, p. 49) suggests two approaches: using case study protocol and using a case study database. In this study, to allow audit trails of the data, the analytical process of the research is clearly stated (see section 5.7). Procedures followed in the collection, and the analysis, of data were well documented and followed established procedures. The analysis of this research is based on an analytical framework that provided a structural guide for the analytical process. The coding and theming of the data were performed using precoding and descriptive and pattern coding, and the documents are available for external scrutiny (further explained in section 5.7.1).

5.6 Methods of Data Collection

The TIS analysis is performed using the qualitative data obtained from the semi-structured interviews, the quantitative data obtained from the self-administered survey questionnaire, and the data obtained from the review of the literature. The interview data has allowed performing the thematic analysis to improve the understanding of different aspects identified in the framework. Similarly, the quantitative data enabled ranking respondents' perception of different barriers and drivers of the diffusion of RETs in the Maldives. The literature review provided important insights into the landscape of the analysis, and it also allowed to cross-reference aspects identified from the interview data.

5.6.1 Interviews

In a case study interviews are one of the most important sources of information (Yin, 2014, p. 110). This study used semi-structured interviews as the main means of data collection. The interviews provided information about the historical context of the development of the sector, important initiatives that have taken place, and the key players and important factors that have contributed to the implementation of previous projects. It allowed a more in-depth look at the experience and ideas of the stakeholders on the barriers and appropriate policies and way forward to accelerate the uptake of RETs. The use of semi-structured interviews also allowed the researcher to ask specific questions formulated before the interview, and to follow up with additional questions when new ideas were brought up during the interview.

The interview questions (see Appendix A) were formulated to obtain information about the landscape (external factors, natural resource endowment, and economic and social development), the structural components (actors, networks, and institutions), and the functional activities of TIS that are relevant to the diffusion of RETs in the Maldives.

Purposive sampling was used for selecting the interviewees and survey respondents. Well-informed interviewees can provide insight into the research problem, shortcut to prior history, and help to identify other sources of evidence that can be useful for the research (Yin, 2014, p. 113). The two principal aims in purposive sampling are ensuring that all relevant subject matter is covered and that there is diversity in the selection of the sample so that the relevant characteristics can be explored (Ritchie, Lewis, & Elam, 2003, p. 79). Sample selection for this study meet these two aims: interviewees were from different areas that are relevant to the electricity sector, and were selected based on their expertise in their area of work and the varied information they were likely to provide.

Potential interviewees were identified before starting field work, and additional interviewees were approached during the data collection. The interviewees are senior officials from their respective areas. The researcher is well acquainted with many senior officials and national experts within the energy sector. This familiarity has allowed reaching many of the prominent officials in the country. Additionally, the interviewees also suggested some other potential interviewees. The number of interviewees is large enough because the interviewees include the people working directly in the energy sector, as well as others working in fields related to energy sector or contribute to the development of the sector, e.g. educational institute, commercial bank, and an NGO. Before conducting the interviews, each interviewee was provided with an information sheet on the study (see Appendix B), which explained the purpose of the research and how the information that interviewees provide will be used. The interviewees were also requested to sign a form providing their consent to the interview (see Appendix C). The information sheet and the consent to interview were provided in both English and Dhivehi (the local language). All the interviewees signed the consent form printed in English.

In order to arrange the interviews, some of the potential interviewees were contacted by email. Other potential interviewees were approached directly by phone because it was easier to reach them by phone and some of their email contacts were not initially available.

Those contacted by phone were provided with the same information as those contacted by email. The interviewees were contacted in English and Dhivehi, and they were informed that they might choose any language for the interview. The interviews with Maldivians were conducted in Dhivehi. The interviewees were also given the opportunity to clarify any questions that they may have regarding the interview and about the study. The interviews were conducted during a field trip to the Maldives, from January to April in 2017.

A total of 33 people were interviewed from four broad areas of work: government, electric utilities, businesses, and institutes. The role of the interviewees is as shown in Table 5.1. The interviewees from the government sector included informants from government ministries, the electricity regulator, and local government agencies. Interviewees from electric utilities included informants from the two government-owned electric utilities (STELCO and FENAKA). Interviewees from the business sector included informants from tourist resorts, RET service providers, and support services to the electricity sector. Interviewees from institutes included a respondent from an academic institution, a financial institution, and an NGO.

Table 5.1: Role of Interviewees

Area of Work	Code	No. of interviewees
Government	GOV	8
Government ministries, the electricity regulator, and local government agencies		
Electric Utilities	UTI	11
Government owned electric utility companies		
Businesses	BUS	11
Tourist resorts, RET service providers, and supporting services		
Institutes	INS	3
Academic institutions, financial institutions, and non-governmental organisations		
Total		33

To maintain the confidentiality of the interviewees, the interviewee's details are coded according to the area of their work (e.g. GOV1, GOV2, UTI1, BUS1, etc.). All the interviewees agreed to the recording of interviews. The duration of the interviews lasted on average about an hour. Most of the interviews were conducted at the interviewees' workplaces', although due to the availability of the interviewees, a few were conducted at agreed places outside the interviewee's work organisation.

Some of the challenge with interview data are the limitations respondents have in recalling events, poor and inaccurate articulation of events, and the personal bias an individual may have towards an event. These problems can be addressed by corroborating information with other sources of evidence (Yin, 2014, p. 113). In this study, literature was reviewed to corroborate some of the issues discussed in the interviews.

5.6.2 Survey Questionnaire

A self-administered survey questionnaire (see Appendix D) was used to obtain quantitative data. The use of a self-administered survey questionnaire allowed the researcher to reach out to more survey respondents than the number of interviewees since the researcher did not need to meet the respondents in person. The survey questionnaire assessed respondents' perceptions about different barriers and policies that are limiting the diffusion of RETs in the Maldives, and determined the most significant barriers and policies according to respondents. The survey questionnaire also obtained information about the type of the respondent's primary work organisation and the role of the respondent in the organisation.

The survey questionnaire was formulated in English, but a Dhivehi translation was also used to obtain accurate information from respondents who preferred to complete the questionnaire in Dhivehi. The researcher is aware that when the same survey questionnaire is used in two different languages there will be potential for bias if there is a discrepancy in meaning. Hence, measures were taken to minimise such bias. Before finalising the survey questionnaires, the English and Dhivehi questionnaires were shared with a Dhivehi language expert and an energy sector expert in the Maldives to obtain their opinion about the accuracy of both translations. The experts did not identify any issues with the translation.

The two questions in the survey questionnaire are derived from the literature analysis. The barriers derived from the literature in Table 5.6, and the policy measures in Table 5.7 both derive from the literature on diffusion of RETs. The barriers in Table 5.6 are also categorized according to different functional activities, and it has allowed assessing the perception of the performance of different functional activities (see Table 7.3). The policy measures are grouped into four categories to assess the perception of the importance of different policy measures (see Table 7.6).

Before starting most of the interviews, the interviewees were requested to complete the self-administered survey questionnaire. A separate information sheet about the survey questionnaire was provided to the respondent (see Appendix E), and written consent to participate in the survey was also obtained separately (see Appendix F). The information sheet and consent to survey questionnaire were also prepared in both English and Dhivehi, and the respondents were given a choice to select either. Requesting the interviewees to complete the survey questionnaire enabled targeting the survey questionnaire to relevant stakeholders. Among the 33 interviewees, eight were not able to complete the survey questionnaire because of their schedules.

Additional participants were approached to obtain more completed survey questionnaires. The additional participants were also selected on the same basis as were the interview participants; in consideration of the relevance of their work organisation, and their expertise in the sector. These additional respondents were reached by either meeting with them directly, through their work office, or by sending them an email requesting that they complete the survey questionnaire. In all cases, the researcher explained to the respondents about the research and provided the information sheet and consent form for survey participants. Thirty-five additional potential respondents were approached, but only 25 provided completed questionnaires. As a result, quantitative data is available for 50 respondents. The role of the survey respondents, which information respondents provided in question 3 of the survey questionnaire, is shown in Table 5.2.

Table 5.2: Role of Survey Respondents

Area of Work	No. of Survey Respondents	%
Government (GOV) Government, local government agency, and the electricity regulator	9	18%
Electric Utilities (UTI) Electricity service providers	19	38%
Businesses (BUS) Tourist resorts, private businesses, and RET suppliers	14	28%
Institutes (INS) Academic institutions, financial institutions, multilateral organizations, and non-governmental organizations	4	8%
Others	1	2%
Missing (no response)	3	6%
Total	50	100%

There are different response biases in self-reporting administered survey questionnaires, and these may be intentional or accidental. Before conducting the analysis, the data was cleaned to identify entry errors and illogical answers. The entries were checked to find if any single respondent has made remarkably different choices than the rest. For example, if any respondent marked all the barriers as ‘extremely significant’ or ‘not at all significant’ or for all questions marked the same rank. By observing the pattern of responses to the survey questionnaire, the researcher did not observe any non-sincerely completed questionnaire. The selection of the respondents may have contributed to minimising the effect of non-sincerely completed responses. The respondents for the survey were selected based on their expertise and knowledge on the sector and was chosen from a focused segment. Many of them are familiar with the researcher, as well. Hence, the respondents probably have taken the survey attentively.

5.7 Data Analysis Process

The data analysis for the study involved thematic analysis of interview data, and quantitative analysis of survey data.

5.7.1 Thematic Analysis

Thematic analysis is widely used as a qualitative analysis method. Braun and Clarke (2006, p. 79) define thematic analysis as “a method for identifying, analysing and reporting patterns (themes) within data”. In qualitative inquiry, the data is often coded to identify the themes and concepts that emerge from the data. Coding attaches “meaningful labels to data chunks” (Miles & Huberman, 1994, p. 89), and it speeds up the analysis (Miles & Huberman, 1994, p. 65). Theming is not something that often directly emerges from the data, but is “an *outcome* of coding, categorization, and analytic reflection, not something that is, in itself, coded” (Saldaña, 2013, p. 175, emphasis in original).

All the interviews in this study, except two, were conducted in Dhivehi and they were transcribed into Dhivehi with the help of transcribers. The other two interviews were conducted in English. The researcher listened to the recording of the interviews several times, and read through the transcripts and translated them into English for transcription coding and data analysis. Recorded interviews were referred to from time to time during the analysis to ensure the accuracy of the context and meaning of the text. The researcher found the 33 interviews in this study could be coded using Microsoft Word (Word), rather than using separate qualitative data analysis software. For the provisional coding, the “New Comment” feature under the “Review” tab of Word was used. For additional coding and themes, a master document was created in Word compiling all the interviews, and different “Styles” of headings were used to categorise and list the themes that emerged from the interview data. These features in Word provided an easy approach to code and manage the interview data.

There is a range of coding profiles that can be used to analyse qualitative data, and these may be followed in different cycles. In this study, three coding profiles (provisional coding, descriptive coding, and pattern coding) were used in two coding cycles. The provisional codes are related to the TIS framework components. The three approaches to coding were used because they allowed systematic analysis of the findings. The coding cycling was iterative, and interview transcripts were read again to ensure completeness of coding and to ensure all important information was included in the analysis. As Saldaña (2013, pp. 60 - 61) has advised, the coding system for this study is based on the research question, the answers that the study is seeking, and the methodological needs of the study.

In the first cycle of coding, provisional coding and descriptive coding were used to analyse the data. The provisional list of codes was formulated based on the adapted TIS framework used in this study (see Appendix G). Table 5.3 shows an example of provisional codes used for a functional activity: technology transfer (F2). The provisional codes identified major categories and subcategories of interest for each component of the framework. The questions in the semi-structured interviews were formulated with the aim of obtaining information about all the aspects of the framework, and it helped to identify appropriate codes for different structures and functions of the framework. In the first cycle of coding, in addition to the provisional list of codes, the researcher also kept an open mind in order to identify different aspects relevant to the study that were not exactly captured by the pre-defined codes and the descriptive coding used.

Table 5.3: An Example of Provisional Codes for a Component of the Framework

Component of the Framework	Category	Sub-category
Technology transfer (F2)	Availability of RETs	Factors Affecting Availability
		Relationship with Other Functions
		List (Types) of Activities

Descriptive coding informed the second cycle of coding. Descriptive coding summarises the basic topic of the passage in a short word or a phrase, and assists in answering questions such as “What is going on here?” (Saldaña, 2013, p. 88). It is also used to “document and categorize the breadth of opinions stated by multiple participants” (Saldaña, 2013, p. 7). Table 5.4 shows an example of descriptive coding derived for a response to a research question.

Table 5.4: An Example of Descriptive Codes Derived for Responses to a Question

(Q7) How easy is it to obtain renewable electricity technologies from overseas?	
<i>Code</i>	Excerpt from Interview
<i>Easy to Obtain</i>	“It is not difficult to obtain the technology from overseas. The largest suppliers of solar PV and wind turbines are from China. It is easy to trade with Chinese companies since they are willing to supply even small quantities. Many of the solar PV products are also imported from China”. [BUS 7]
	“Solar PV products are readily available on the Internet, and you can find the suppliers easily with a Google search. If you use an established local business, it will be easy to obtain after sales and maintenance service”. [UTI 1]
<i>The Question of Quality</i>	“It is easy to obtain the technology, but it may take a while to understand if what we are getting are quality products”. [GOV 4]
<i>Attending Trade Fairs</i>	“Now it is easy to obtain the technologies. Many are reliant on Chinese companies. We meet with the suppliers at trade fairs in both Dubai and Germany.... We obtain the contacts through the internet or by visiting the trade fairs”. [BUS 5]
<i>Make it Available at the Island Level</i>	“The renewable energy products need to be available from different locations within the country, and not only within the capital Malé. At the moment, all the businesses are based in the capital”. [GOV 3]

In the second cycle of coding, the codes generated from the descriptive coding process helped to develop a range of codes that were then put into broad categories according to their similarities and differences. Table 5.5 shows an example of patterns derived from the codes for the purpose of assessing the role of businesses, residential consumers, and electric utilities. The patterns derived from the codes around assessing the role of the other actors are also provided in the respective section in 6.5.

Table 5.5: An Example of Patterns Derived from the Codes

Codes	Patterns
“Dominant Role of the Service Provider”	<p>The Absence of a Good Business Model</p> <p>Lack of Information</p>
“Difficulty to Disband Diesel”	
“Utilities Unable to Position Themselves in RETs Use”	
“Loss of Revenue to Utility”	
“Access to Grid”	
“Reliability of RETs”	
“Lack of Knowledge About RETs”	
“Lack of Awareness”	

In this second cycle of coding, pattern coding was used to develop major themes from the data. Miles and Huberman (1994, p. 69) explain pattern codes as “explanatory or inferential codes, ones that identify an emergent theme, configuration, or explanation. They pull together a lot of material into more meaningful and parsimonious units of analysis”. This coding process has helped to develop themes from the data and provided a systematic approach to address the research questions.

5.7.2 Quantitative Analysis

Quantitative data for the study was derived from the survey questionnaire. The survey questionnaire consisted of two broad questions: barriers to the diffusion of RETs, and policy measures that can improve the diffusion of RETs. The list of barriers and policy measures in the questionnaire were based on the literature review (see section 3.4). These questions aimed to assess the significance of different barriers and the importance of different policy measures from the perspective of the respondents. Table 5.6 shows a list of barriers used in the survey questionnaire and the respective barrier categories and sub-categories. The code within the parenthesis of the barriers is the barrier code used in the survey questionnaire.

Table 5.6: Barrier to the Diffusion of RETs

Barrier Categories	Sub-categories	Barriers
Political	Policies	Lack of government plans to improve the diffusion of RETs (B9)
		Government subsidies for fossil fuel based generation (B17)
		Lack of regulatory obligation to increase the diffusion of RETs (B10)
	Regulatory Framework	Difficulty for private businesses to enter the renewable electricity market (B1)
	Institutional Capacity	Administrative delays in issuing permits to start renewable electricity projects (B11)
		Lack of support from existing electricity providers to increase the use of renewable electricity (B12)
Economic	Costs	High initial investment costs required for renewable electricity technologies (B13)
		High maintenance costs required for RETs (B14)
	Financial	Lack of government support schemes to promote the diffusion of RETs (B16)
		Lack of international aid to support RETs (B5)
	Market Failure	Lack of local suppliers of RETs (B15)
		Lack of renewable electricity projects (B4)
		Lack of interaction between local businesses and international manufacturers and suppliers of RETs (B6)
Technical	Technological Constraints	Lack of space to install RETs (B18)
	Infrastructure	Limited grid capacity and infrastructure to connect RETs (B19)
Social	Human Capacity	Lack of trained people to implement renewable electricity projects (B8)
	Public Apathy and Misunderstanding	Lack of information about RETs (B7)
		Perceived unreliability of RETs (B3)
		Lack of interest by private businesses to use renewable electricity (B2)
		Lack of recognition from businesses of the benefits of using RETs (B20)

Similarly, Table 5.7 shows the list of policy measures used in the survey questionnaire and their respective policy types. The policy code used in the questionnaire is in parenthesis. The list of policy measures in the questionnaire helped to identify relevant policy measures that respondents thought were important to address the slow diffusion of RETs. The policy measures were also grouped by different policy types. The broad policy types provided an overview of the relevant policy types that respondents regarded as most relevant to improve the diffusion of RETs.

Table 5.7: Policy Types and Measures to Support the Diffusion of RETs

Policy Type	Policy Measures
Targets and Obligations	Instituting national targets to generate electricity from renewable sources (P1)
	Government obligations on electricity service providers to generate a designated level of electricity from renewable sources (P9)
Investment Incentives	Availability of public loans for renewable electricity projects (P2)
	Availability of grants for renewable electricity projects (P3)
	Government subsidies for renewable electricity projects (P4)
	Tax incentives for renewable electricity projects (P5)
	Availability of a tariff incentive such as feed-in-tariff (P7)
	Availability of a tariff incentive such as net metering (P8)
Market Facilitation Activities	Educating the public about the impact of fossil fuels on the climate (P10)
	Training people to provide the necessary skills for renewable electricity projects (P11)
	Improving interaction between local businesses and international manufacturers and suppliers of renewable electricity technologies (P12)
	Allowing private electricity producers easy access to electricity grid (P13)
	Providing information about renewable electricity technologies (P14)
Discouraging Measures	Eliminating subsidies for fossil fuel based electricity generation (P6)

The list of barriers in the questionnaire was also associated with the seven functional activities of the analytical framework used in this study. The barriers corresponding to different functions were classified in the order of their relevance to a given function (see Table 5.8). Most of the barriers listed in the questionnaire are attributable to one of the seven functions, through some can be seen as being applicable to more than one function. The decision to place a barrier against a given function is based on the order of relevance as judged by the researcher.

Table 5.8: Barriers Related to Different Functions

Functions	Barrier Codes
F1: Entrepreneurial Activities	B1, B2
F2: Technology Transfer	B6, B15
F3: Knowledge Exchange	B7, B8
F4: Guidance of the Search	B9, B10, B11, B12
F5: Market Formation	B4, B13, B14
F6: Resource Mobilization	B5, B16, B17
F7: Creation of Legitimacy	B3, B18, B19, B20

The questionnaire also contained two questions on the demographics of the respondents – the type of organisation which the respondent primarily works at, and his/her role within the organisation. Analysis of the two demographic questions, along with the ranking of the barriers and policies, provided insight into differences that people within different sectors viewed about the listed barriers and policies.

The lists of barriers and drivers in the questionnaire were evaluated by calculating the average score for each of the barriers and drivers and then by ranking the barriers and drivers separately. The barriers with the lowest average score were the most significant (since 1 equals extremely significant, and 5 equals not at all significant). Similarly, the drivers with the lowest average score were most important.

The responses on barriers and drivers were also cross-tabulated with the respondent's demographic details. This provided information about different perspectives on the barriers and policy measures across people within different organisations. The results of the survey questionnaire were also compared with the responses to the interview questions to determine their consistency.

5.8 Ethical Considerations

The ethical considerations required by the Human Ethics Policy and Human Ethics Guideline of Victoria University of Wellington were followed during data collection and analysis of data. The interview process and the completion of the survey questionnaire started after obtaining the University's Human Ethics Committee's approval for the research⁴.

Interviewees and survey respondents were informed of the purpose for and the proposed use of the data collected from the interviews and surveys. The information sheets provided to the research participants informed them of the research process and how the information provided would be used in the study. The information sheet was provided to respondents before the interviews and before they were requested to complete the survey questionnaire. The interviewees' and survey participants' written consent to participate in the study was obtained by their signing of the consent form.

⁴ Application reference: 0000023650.

The interview transcribers also signed a confidentiality agreement in which they agreed to keep the information confidential (see Appendix H). The personal details of the research participants have been kept confidential in the study, and only codes representing the area of work of the participants are used to represent the information that they have provided.

5.9 Summary

This chapter explained how the research methodology was used to answer the research questions. A pragmatic approach was used since this is the most appropriate way to answer the research questions and provides wider options of tools to collect and analyse data. The use of mixed methods allowed the use of qualitative and quantitative data. The mixed methods approach provided the opportunity to gain the benefits of the two approaches, and this methodological triangulation minimised the disadvantages in using any one of them.

The use of a case study approach facilitated the collection of comprehensive data that were required for the study. The Maldives has some similarities, and unique features, compared to the other SIDS, and presents an ideal case to understand the phenomena of slow diffusion of RETs in SIDS. The researcher also explained the considerations that were given to ensure the validity and reliability of the study in terms of both the qualitative and quantitative data.

The methodology followed in this study allowed collection and analysis of data required for the adapted TIS framework. The knowledge obtained from the literature provided insights into the landscape of the TIS framework. The qualitative data provided in-depth knowledge to assess the structural components and functional activities of TIS and improve the understanding of the diffusion of RETs in the SIDS, such as the Maldives. The quantitative data allowed ranking the perceptions of the respondents on different barriers and drivers to the diffusion of RETs.

The methods of data collection – interviews, and a survey questionnaire – were described by explaining how these data were used to answer the research questions. In order to analyse the data, this study used thematic analysis for the data obtained from interviews, and quantitative analysis for the data obtained from the survey questionnaire.

CHAPTER 6: FACTORS AFFECTING DIFFUSION OF RETs

6.1 Introduction

This chapter attempts to answer the research two sub-questions: (1) what are the factors driving and hampering the diffusion of RETs in the Maldives, and (2) what policy interventions can improve the diffusion process. This chapter has two objectives. First, the perceptions of experts are analysed to assess significant barriers and important policy measures that affect the diffusion of RETs in the Maldives. Second, data from interviews with stakeholders in the Maldives are analysed to examine the most important actors in the diffusion of RETs in the Maldives and the factors that are affecting these actors.

The analysis from this chapter is also related to the TIS analysis in the next chapter. The assessment of the barriers in this chapter contributes to the analysis of the development phase of the functions in the TIS framework, and the ranking of the drivers contributes to the assessment of policy instruments. The findings from this chapter about the role of actors contribute to the analysis of the TIS framework and are elaborated in chapter 7.

This chapter consists of seven sections. After this introductory section, sections 6.2 and 6.3 present the findings from the survey questionnaire on the significance of different barriers and the importance of different policy measures. Section 6.4 explains the important actors, and section 6.5 details the key factors affecting those important actors. Section 6.6 discusses the findings in relation to other SIDS, and section 6.7 concludes by summarising the chapter findings.

6.2 Barriers

The literature review (in section 3.4.1) identified the different classifications of barriers used by scholars to identify the factors that contribute to the slow diffusion of RETs. These include political, economic, technical, and social barriers. Twenty barriers were listed in the survey questionnaire and also include an open-ended question to obtain additional input from the survey respondents.

The findings from the survey questionnaire are presented in Table 6.1. The mean score for each barrier was calculated on the basis of the score the respondents gave for the barriers, and the barriers are then ranked in ascending order of the mean score; low scores indicate high significance because 1 is most significant, and 5 least significant. Mean scores cluster into five groups. In Table 6.1 the three most significant barrier groups are marked by solid ovals and the bottom two groups are marked by dotted ovals. The open-ended question received nine responses, and these included many of the barriers already listed in the questionnaire, such as: difficulty in obtaining low-interest loans; lack of financial support; lack of space; and lack of awareness. In addition, a respondent also emphasised the lack of showcase projects as an important barrier.

The most significant barriers identified by the respondents in order of significance are high initial investment costs (B13) and lack of regulatory obligations (B10). The next set of barriers which closely follow these include lack of government support schemes (B16), lack of trained people (B8), lack of support from electric utilities (B12), lack of government plans (B9), and administrative delays (B11). The third set of barriers include lack of space to install RETs (B18), the difficulty of private sector entry (B1), lack of grid capacity and infrastructure (B19), and lack of recognition from businesses of the benefits (B20).

The above-mentioned barriers highlight the significance of the financial burden on investors who wish to set up RET systems in comparison with continuing to use their existing diesel-based generation system. The ranking of the barriers also highlights the capacity of the government in both pushing for a more active increment of RETs by way of regulatory obligations, and also supporting such initiatives with government support schemes. The lack of trained people within the energy sector is also among the most significant issues faced by the sector. The lack of support from electric utilities can be seen as the government's inability to enforce the national policy of increasing the use of RETs through electric utilities, and also the differences in the approach of government and electric utilities to generating electricity.

Table 6.1: Mean Score of the Barriers and Their Rankings

Code	Barriers	Barrier Category	Extremely significant		Very significant		Moderately significant		Slightly significant		Not at all significant		Mean Score	Ranking
	Likert scale		1		2		3		4		5			
	Number / Percentage		n	%	n	%	n	%	n	%	n	%		
B13	High initial investment costs required for RETs	E	31	63%	8	16%	5	10%	3	6%	2	4%	1.71	1
B10	Lack of regulatory obligation to increase the diffusion of RETs	P	24	49%	17	35%	6	12%	1	2%	1	2%	1.73	2
B16	Lack of government support schemes to promote the diffusion of RETs (grants, credit, and financial facilities)	E	25	51%	11	22%	7	14%	3	6%	3	6%	1.94	3
B8	Lack of trained people to implement renewable electricity projects	T	22	45%	14	29%	8	16%	3	6%	2	4%	1.96	4
B12	Lack of support from existing electricity providers to increase the use of renewable electricity	P	20	41%	16	33%	6	12%	6	12%	1	2%	2.02	5
B9	Lack of government plans to improve the diffusion of RETs	P	18	36%	20	40%	6	12%	4	8%	2	4%	2.04	6
B11	Administrative delays in issuing permits to start renewable electricity projects	P	21	43%	14	29%	7	14%	4	8%	3	6%	2.06	7
B18	Lack of space to install RETs	T	19	39%	13	27%	11	22%	1	2%	5	10%	2.18	8
B1	Difficulty for private businesses to enter the renewable electricity market	P	11	22%	20	41%	15	31%	2	4%	1	2%	2.22	9
B19	Limited grid capacity and infrastructure to connect RETs	T	15	31%	16	33%	10	20%	7	14%	1	2%	2.24	10
B20	Lack of recognition from businesses of the benefits of using RETs	S	10	20%	23	47%	10	20%	3	6%	3	6%	2.31	11
B5	Lack of international aid to support RETs	E	11	23%	16	33%	11	23%	7	15%	3	6%	2.48	12
B4	Lack of renewable electricity projects	E	7	14%	19	39%	16	33%	3	6%	4	8%	2.55	13
B7	Lack of information about RETs	S	14	29%	13	27%	8	16%	9	18%	5	10%	2.55	13
B2	Lack of interest by private businesses to use renewable electricity	S	5	10%	21	43%	14	29%	8	16%	1	2%	2.57	15
B6	Lack of interaction of local businesses with international manufacturers and suppliers of RETs	E	7	14%	19	39%	15	31%	4	8%	4	8%	2.57	15
B17	Government subsidies for fossil fuel based generation	P	17	35%	6	12%	12	24%	8	16%	6	12%	2.59	17
B15	Lack of local suppliers of RETs	E	10	20%	12	24%	13	27%	6	12%	8	16%	2.80	18
B14	High maintenance costs required for RETs	E	8	16%	10	20%	12	24%	11	22%	8	16%	3.02	19
B3	Perceived unreliability of RETs	S	3	6%	7	14%	12	24%	20	40%	8	16%	3.46	20

Note: Barrier category is represented by E = Economic; P = Political; S = Social; and T = Technical.

The rankings by the respondents of the bottom three positions in Table 6.1 show the respondents' perceptions of the least significant barriers to the diffusion of RETs in the Maldives. These are: perceived unreliability of RETs (B3); high maintenance cost of RETs (B14); and lack of local suppliers of RETs (B15). These show that technical considerations such as the reliability of technologies, and the operational cost of technologies, are not regarded as being problematic issues when it comes to evaluating the technologies. At the same time, the availability of suppliers to provide RETs is also not a remarkable barrier to increasing the use of RETs. There are a few suppliers and local businesses already in the market, and interviewees indicated that it is easy to procure solar PV from overseas.

In Table 6.1, the list of barriers is also identified according to the broad barrier category that they belong to (political, economic, technical, and social). The analysis of barrier categories based on the mean score ranking shows that barriers related to political factors are the most significant, and it is followed by technical and economic factors. The analysis shows that barriers associated with social factors are the least significant in inhibiting the diffusion of RETs in the Maldives. This analysis also indicates the significance of the political factors in inhibiting the diffusion of RETs in the Maldives.

Ranking of Barriers by Actors

The ranking of barriers by actor groupings, government (n=9), electric utilities (n=19), and businesses (n=14), is analysed in relation to the overall ranking of barriers in order to understand the differences in the perception of barriers by important actors (see Figure 6.1). Only these three actors are analysed separately because there were not sufficient respondents from other actors. In this analysis, the respondents from the tourist resorts are included in businesses.

Note: For each actor grouping, the barriers with the same mean score have the same ranking number.

Figure 6.1: Ranking of Barriers by Actors

The respondents from government and businesses noted issues related to the electric utilities as significant barriers for limiting the diffusion of RETs. Lack of support from existing electric utilities to increase the use of RETs (B12) is considered the most significant barrier by the respondents from the government, and the third most significant by respondents from businesses. Government respondents also noted administrative delays in issuing permits to start RET projects (B11) as the fourth most significant factor. The electric utilities give approvals to implement projects in inhabited islands. The respondents from government have emphasised the delays and inhibitions of electric utilities in respect of supporting RETs. These differences among the two actors are important in understanding the issues in policy implementation since electric utilities are also owned by the government. The differences imply misalignment of the policies across different agencies.

The respondents from electric utilities have identified the lack of information about RETs (B7) among the top barriers (4th), while it is ranked as less important in the overall list of barriers (13th) and by the other actors (government – 17th; and businesses – 19th). This high ranking by electric utilities of the lack of information about RETs might reflect their low interest in investing in large-scale RET projects.

The respondents from businesses have listed lack of government plans (B9) as the most important barrier, while it is 6th in the overall ranking and is listed fairly low by the two other actors (government – 10th; and electric utilities – 13th). The lack of government plans has a bigger impact on the role and scope of businesses in the sector, and this may explain the importance placed by businesses on this issue.

Common Barriers

The barriers identified by all the actors and the three actors are analysed separately to identify the common barriers. The top three barriers identified in the overall ranking and by the three actors are presented in Table 6.2.

Table 6.2: Three Most Significant Barriers by Actors

Actors / Positions	1	2	3
Overall	High investment cost (B13)	Lack of regulatory obligation (B10)	Lack of government support schemes (B16)
Government	Lack of support from electric utilities (B12)		Lack of space to install RETs (B18)
	High investment cost (13)		
Electric Utilities	Lack of trained people (B8)	High investment cost (B13)	Administrative delay (B11)
Business	Lack of government plans (B9)	Lack of regulatory obligation (B10)	Lack of support from electric utilities (B12)

Analysis of the most significant barriers identified by the stakeholders in the survey questionnaire shows government policy (B12, B9, B10 and B16), financial factors (B13), and the capacity of organisations (B11) and people (B8) are the most significant barriers to the diffusion of RETs in the Maldives.

The analysis also demonstrates that to some degree actors appear to be blaming each other for the slow diffusion of RETs in the Maldives. Respondents from the government have identified the lack of support from electric utilities as the most significant barrier for the diffusion of RETs in the Maldives. Respondents from the electric utilities have not acknowledged the lack of support from electric utilities among the most significant factors but identified the lack of trained people, high investment cost and administrative delays as the most significant factor. At the same time, respondents from the business sector identified factors associated with the government (lack of government plans, and lack of regulatory obligations), and electric utilities (lack of support from electric utilities) are the most significant barriers contributing to the slow diffusion of RETs in the Maldives.

6.3 Policy Measures

The literature review in section 3.4.2 identified a range of policies that can drive the diffusion of RETs and these include: targets and obligations; investment incentives; market facilitation activities; and discouraging measures. In this study, 14 policy measures or drivers were listed in the survey questionnaire. Additionally, an open-ended question was also included to better understand other drivers from the perspective of the survey respondents. Only one respondent identified an additional policy measure in the open-ended question. The respondent proposed to facilitate research opportunities in the Maldives for international researchers, in order to increase local capacity. The responses from the survey questionnaire were analysed to determine stakeholder perception of most important policy drivers that can support the diffusion of RETs.

The responses to the survey questionnaire on the different policy measures that are most important for the diffusion of RETs were ranked according to their order of importance. The ranking of the drivers was calculated in a similar way to the ranking of the barriers. The respondents marked the degree of importance of different drivers on the basis of a scale from 1 to 5, where 1 was the most important, and 5 was the least important. The mean score of the policy measures was ranked from the lowest to the highest score. In order to identify the most important policy measures from the list in the survey questionnaire, the three most important groups of policy measures are marked in a dotted oval in Table 6.3.

The most important drivers identified by the respondents to increase the diffusion of RETs in the Maldives are training people (P11) and improving the availability of loans for RET projects (P2). The next set of policy measures included the availability of tariff incentives (P8), tax incentives for renewable energy projects (P5), and instituting national targets (P1). These drivers, such as the availability of loans, and tariff and tax incentives, indicate the importance that many have been placed in government support schemes to reduce the investment burden and to make RETs more economically attractive. The respondents also gave prominence to the importance of market facilitation activities such as training people. The third set of policy measures identified by respondents included: access to the electricity grid (P13), tariff incentives such as a feed-in tariff (FIT) (P7), information about RETs (P14), and obligating electricity service providers to generate a designated level of electricity using RETs (P9).

Table 6.3: Mean Score of the Policy Measures and Their Rankings

Code	Policy Measures	Extremely significant		Very significant		Moderately significant		Slightly significant		Not at all significant		Mean Score	Ranking
	Likert scale	1		2		3		4		5			
	Number / Percentage	n	%	n	%	n	%	n	%	n	%		
P11	Training people to provide the necessary skills for renewable electricity projects	34	68%	12	24%	3	6%	0	0%	1	2%	1.44	1
P2	Availability of public loans for renewable electricity projects	36	72%	8	16%	4	8%	1	2%	1	2%	1.46	2
P8	Availability of a tariff incentive such as net metering.	34	68%	9	18%	4	8%	2	4%	1	2%	1.54	3
P5	Tax incentives for renewable electricity projects	25	50%	23	46%	1	2%	0	0%	1	2%	1.58	4
P1	Instituting national targets to generate electricity from renewable sources	31	62%	11	22%	5	10%	2	4%	1	2%	1.62	5
P13	Allowing private electricity producers easy access to electricity grid	28	56%	13	26%	5	10%	3	6%	1	2%	1.72	6
P7	Availability of a tariff incentive such as feed-in-tariff	31	62%	9	18%	5	10%	2	4%	3	6%	1.74	7
P14	Providing information about renewable electricity technologies	27	54%	12	24%	7	14%	4	8%	0	0%	1.76	8
P9	Government obligations on electricity service providers to generate a designated level of electricity from renewable sources	27	54%	11	22%	9	18%	1	2%	2	4%	1.80	9
P10	Educating the public about the impact of fossil fuels on the climate	24	49%	12	24%	11	22%	0	0%	2	4%	1.86	10
P3	Availability of grants for renewable electricity projects	29	58%	9	18%	4	8%	4	8%	4	8%	1.90	11
P6	Eliminating subsidies for fossil fuel based electricity generation	27	54%	7	14%	9	18%	5	10%	2	4%	1.96	12
P12	Improving interaction between local businesses and international manufacturers and suppliers of RETs	17	34%	21	42%	9	18%	0	0%	3	6%	2.02	13
P4	Government subsidies for renewable electricity projects	21	42%	14	28%	8	16%	4	8%	3	6%	2.08	14

The least important policy measures in order of their mean score are government subsidies for RET projects (P4), and improving interaction between local and international businesses (P12). The respondents marked incentives as important drivers, but subsidies and grants were not seen as most crucial to support the diffusion of RETs. Instead of direct subsidies for projects, low-cost financing schemes were ranked as more important in reducing the investment burden of RETs. Most of the interviewees also acknowledged that there is a sufficient level of interaction between local and international manufacturers and the survey respondents also placed less importance on this issue.

Ranking of Policy Measures by Actors

In order to understand the differences in the perceptions of policy measures among important actors, the ranking of the policy measures by the respondents from the three actors are analysed along with the overall ranking (see Figure 6.2). The analysis of policy measures by actors is confined to three actors as other actors did not have a sufficient number of respondents; and the number of respondents within the groups are the same as those noted above in the section on ranking of barriers by actors. The most remarkable observations from the analysis are presented below.

Figure 6.2: Ranking of Policy Measures by Actors

Comparison of the most important drivers overall and for government respondents shows agreement about the importance of investment, tax, and tariff incentives. The availability of loans (P2), and tariff incentives such as net-metering (P8), were ranked the second most important drivers by respondents from the government. It is also important to note that a market facilitation activity, training people (P11), was the overall top most important factor, while it was ranked sixth among the respondents from government. The respondents from electric utilities also emphasised the requirement of training and placed it as the most important factor in their ranking of the drivers. This relatively low recognition of the importance of this factor by government respondents may raise the question of the level of importance the officials within the government place on training. This low recognition of the importance of training may also explain the limited opportunities available within the country to train people in the electricity sector.

Respondents from government recognised the importance of targets and obligations and ranked government obligations such as a renewable portfolio standard (RPS) (P9) as the most important factor for driving the diffusion of RETs. RPS is an important factor that can be addressed at the policy level.

The respondents from electric utilities have listed government obligations such as RPS (P9) very low in order of importance. Incidentally, electric utilities are the most important actors that would have a direct impact on such an obligation. The lower importance placed on obligations imposed by government suggests the electric utilities are to be obliged to incorporate a higher proportion of RETs. The respondents from electric utilities placed most importance on training people (P11) and then on providing information about RETs (P14). The respondents from electric utilities generally ranked policy measures that could impact them directly as having low importance; for instance, the issue of government obligations, and implementing tariff incentives such as net-metering (P8), were ranked relatively low compared to their ranking by other actors. The low importance placed by the respondents from the electric utilities on matters that directly affect them can be interpreted as general avoidance of responsibility for taking action to address the slow diffusion of RETs, and an attempt to “passing the buck”.

The respondents from the business sector identified investment, tax, and tariff incentives among the most important policy measures. Business respondents marked tariff incentives such as net-metering (P8) as the most important driver, and they ranked government subsidies for RET projects (P4) seventh compared to the low importance other actors gave to government subsidies. Some market facilitation activities were also ranked relatively low by business actors compared to their ranking by other actors. For example, training people (P11) was ranked 10th, while improving interaction between local and international businesses (P12) was marked as the least important driver.

Common Drivers

The ranking of the drivers by different actors is analysed to understand the common drivers among different actors. The top three most important drivers identified by the actors (overall ranking, and the three different actors – government, electric utilities, and businesses) are shown in Table 6.4.

Table 6.4: Three Most Important Drivers by Actors

Actors / Position	1	2	3
Overall	Training people (P11)	Availability of loans (P2)	Tariff incentives such as net-metering (P8)
Government	Government obligations such as RPS (P9)	Instituting national targets (P1) Availability of loans (P2) Tariff incentives such as net-metering (P8)	
Electric Utilities	Training people (P11)	Providing information about RETs (P14)	Availability of loans (P2) Tax incentives for RE projects (P5)
Businesses	Tariff incentives such as net-metering (P8)	Availability of loans (P2) Tariff incentives such as FIT (P7)	

The analysis of the respondents' perceptions of policy measures shows human capacity (P11); financing (P8, P2, P7, P5); and establishing policy obligations and targets (P9, P1) were the most important policy measures to drive the diffusion of RETs in the Maldives.

6.4 Important Actors

There are a number of important stakeholders within the energy sector in the Maldives that are instrumental in affecting the diffusion of RETs. In order to understand the role of these actors and to assess the significance of these actors, in semi-structured interviews the interviewees were asked to identify which stakeholders they thought could be the most influential in increasing the diffusion of RETs in the Maldives. This was one of the first questions asked in the interview, and then interviewees were also asked their opinion on the role of those actors. The responses to the two questions provided a detailed list of actors and their roles in the Maldives energy sector. Based on interviewees' responses, the study identifies seven categories of actors who play an important role in the diffusion of RETs in the Maldives. This information is shown in Table 6.5. These actors are also briefly overviewed below.

Table 6.5: Important Actors and Related Organisations

Actors	Organizations
International Development Partners	Multilateral Agencies (e.g. Asian Development Bank (ADB), the World Bank) Bilateral cooperation (e.g. JICA)
Government	Ministry of Environment and Energy (MEE) Maldives Energy Authority (MEA) (Electricity Regulator) Ministry of Finance and Treasury (MoFT) Ministry of Tourism
Organizations	Financial Institutes (e.g. Bank of Maldives Plc. (BML)) Maldives National University Maldives Polytechnic Private institutions providing technical training
Electric Utilities	State Electric Company Ltd. (STELCO) FENAKA Corporation Ltd. (FENAKA) Independent Power Producers
Tourist Resorts	All tourist resort islands
Businesses	Private Businesses selling, installing and maintaining RETs (e.g. Renewable Energy Maldives Pvt. Ltd., Avi Technology Pvt. Ltd., and LinkServe Pvt. Ltd.) Diesel import and distribution: State Trading Organisation Plc Ltd. (STO), Fuel Supply Maldives (FSM)
Residential Consumers	Commercial and Domestic consumers

The Maldives has received assistance from international agencies and friendly countries to introduce RETs in the Maldives. Some of the assistance for RET projects is a result of bilateral relations the Maldives has with donor countries (e.g. Japan, Germany, and Australia). Additionally, some multilateral agencies such as the World Bank (WB), Asian Development Bank (ADB), and the United Nations Industrial Development Organization (UNIDO) have also supported RET projects.

The government ministries, electricity regulator, and local government agencies are important arms of the government in formulating and implementing government policies. Many of the important factors that are affecting the other actors in the diffusion of RETs are related to the policies and roles of the government.

Financial and educational organisations were not among the most prominent actors in terms of their current role within the sector, but the interviewees identified them as important organizations within the electricity sector to support the diffusion of RETs in the Maldives.

The government-owned electric utilities, STELCO and FENAKA, provide electricity service to most of the inhabited islands in the Maldives, as explained in section 2.4.2. The electric utilities generate and distribute electricity directly to the consumers; there is no wholesale and retail market. Electric utilities hold a monopoly in providing electricity to inhabited islands and own the electricity grid in the inhabited island. STELCO provides electricity services to the capital, Malé, and nearby islands, and FENAKA provides electricity services to the other outer islands. There are a few independent power producers (IPPs) that provide electricity services to five inhabited islands and a few industrial islands.

Tourist resorts generate around half of the electricity generated in the country, and in 2016 there were 126 tourist resorts in the Maldives (MoFT, 2017, p. 21). Tourist resorts in the Maldives are operated in a unique way, where each tourist resort island has just one hotel, and all the facilities on the island are designed to serve the tourists. All the facilities on the island, including electricity, water and sewerage, and waste disposal, are managed by the hotel operator. Tourist resorts are developed from uninhabited islands. The resort owners design and build the infrastructure and tourist facilities on the island according to the limited guidelines from the Ministry of Tourism. Tourist resorts were originally leased for a maximum period of 50 years, but the seventh amendment to the Maldives Tourism Act 1999 brought in 2015 allows for leasing the resort islands for up to 99 years.

Businesses that provide RETs and supporting businesses that serve the energy sector are also important actors for the diffusion of RETs. There are a very few businesses in the Maldives that import, install, and maintain solar PV systems for electric utilities, tourist resorts, and residential consumers. Some of these businesses have completed projects for electric utilities. The major businesses serving the electricity sector are the fuel suppliers.

Residential consumers are the end users of electricity and include commercial and domestic users. For electricity tariff purposes commercial users are businesses that use electricity for business operations such as shops, café, restaurants, and offices. Domestic consumers use it for residential purposes. Electricity tariffs are based on the type of end user. In addition to a commercial and domestic user category, there is a separate tariff for electricity usage at government properties.

The institutional framework of the actors is depicted in Figure 6.3, which shows the roles of the seven categories of actors. The role of these actors and factors related to the actors are discussed in the following sections.

Figure 6.3: Institutional Framework of Important Actors in the Maldives
Electricity Framework

6.5 Factors Affecting Important Actors

In this section, the significance of the important actors and the role they perform in supporting the diffusion of RETs are analysed. The study shows the dominant role of the government in shaping the sector and the positive impact of international development partners in initiating the diffusion of RETs. The study also shows the role of financial and educational institutions is weak, and that there is weak financial and training support to the sector. The tourist resorts are independent in their operation, and there is very little interaction with the other actors. Businesses and residential consumers are dependent on electric utilities since they own the electricity grid and as state-owned enterprises are supported by the government. These five aspects of the actors are further explained in the following subsections.

6.5.1 Dominant Role of the Government

The responses to the interviews show that there is recognition amongst the stakeholders that the government is the most important stakeholder driving the diffusion of RETs. The overarching influence of the government on different actors through policies and regulations (formulated by different government ministries), and its direct influence on the electricity regulator (Maldives Energy Authority, MEA), electric utilities (STELCO and FENAKA), and diesel importer State Trading Organisation Plc Ltd. (STO) allows the government to hold a dominant role in shaping the strategic direction of the sector.

The analysis of factors affecting the role of the government and its position in the electricity sector is based on thematic analysis of the interview responses. Some of the important codes marked on factors related to the government include: “Policies Not Appropriately Adopted”; “Lack of Political Will”; “Focus on Short-term Gains”; “Lack of Policy Direction”; “Initial Resistance”; “Administrative Hurdles”; and “The capacity of the Regulator”. The marking of these codes supported the formulation of the themes for the role of the government. Three important issues emerge when the role of the government is analysed: overarching influence on the actors; policies are not implemented; and lack of capacity. These issues are explained below.

6.5.1.1. Overarching Influence on the Actors

The government plays a dominant role in making energy policies. Government’s role is also instrumental in determining the scope and space allowed for other stakeholders in policy formulation and implementation. An interviewee (GOV 3) explains as follows: “The government could play a more significant role. Particularly through the regulator requiring electricity service providers to install a percentage of their generation from RETs”.

Additionally, the government could use supporting agencies to facilitate private sector engagement and to disseminate information about renewable resource availability. As an example, a government official (GOV 2) noted: “Maldives Meteorological Service could also engage more actively in collecting resource data for technologies using wind as a resource; if not project specific data has to be collected”. Such practices could reduce the cost of research and data collection for potential businesses.

6.5.1.2. Policies are not Implemented

The analysis of the role of government reveals that government policies are not implemented because of policy problems such as lack of focus on policy direction, lack of political support, short-termism, and that the subsidised tariff rate contributes to policy problems. These issues are further explained below.

Lack of Focus on Policy Direction

There have been a lot of talk but few practical steps towards supporting the diffusion of RETs. In 2009, the government formulated an ambitious target of achieving carbon neutrality by 2020. The Maldives also played an important role in raising awareness in the international arena, calling on the international community to do more to address climate change. However, when the government changed abruptly in 2012, the subsequent governments revised this target and then proposed less ambitious national targets to incorporate RETs. Opponents of the previous policy claim the carbon neutrality goal was unrealistic and not well thought out. Nevertheless, many environmental advocates suggest that the current national goals are weak and do not reflect the prominent role of the country in AOSIS, and in the international arena, in raising concerns about climate change.

The utility companies are dependent on the government for policy direction, but there is a lack of clear policy direction. A senior official from an electric utility complains about this lack of clear policies and guidelines pointing out the situation of the introduction of Net Metering Regulation 2015. The official says: “In implementing something new; there should be an appropriate policy direction so that it can be effectively implemented. At the moment, many things are at the policy level, and the implementation is ad hoc and minimal” (UTI 7). The policy direction from the government is instrumental in utility companies’ investment decisions, but the perspectives of these two actors, government and the electric utilities, are not effectively aligned in their approach to the transition to RETs.

The government has formulated a plan to install solar PV for electricity generation in inhabited islands through the Scaling Up Renewable Energy Program (SREP). The project aims to install solar PV to meet up to 30% of peak demand. These installations are fed into the islands' grids and then will be managed by electric utilities. However, the utilities have few initiatives of their own to install additional generating capacity from RETs. A senior official from a utility (UTI 7) company noted that they still consider diesel generators as a better option, and that utilities are placing a greater emphasis on catching up with the increasing demand for electricity by installing diesel generators.

Lack of Political Support

A number of interviewees identified the lack of political support for achieving the broad policy goal of increasing the level of RETs. This argument is based on the lack of a government budget to invest in RETs, and lack of efforts to support the role of the private sector within the energy sector.

The government plans in their development plans to incorporate more RETs and reduce the dependence on imported fossil fuel, however interviewees from the government and electric utilities noted there is little allocation of budget to phase out the diesel generation facilities and to increase RETs. An interviewee from an electric utility (UTI 1) proposed that if the government could not allocate funds from the budget, then other sources such as revenues collected as green tax should be allocated for the purpose.

Many interviewees considered that the lack of government schemes to support the private sector equated to a failure to encourage the involvement of the private sector in the provision of electricity from RETs. There are a few initiatives underway that target the private sector, such as the Accelerating Sustainable Private Investments in Renewable Energy (ASPIRE) project administered by the World Bank. These efforts are seen as minimal and not effective in overcoming the challenges for greater engagement of the private sector. Many interviewees from the private sector (e.g. BUS 9) argue that the government's approach to increasing the use of RETs is through electric utilities, rather than encouraging private sector investment through PPA, FIT, net-metering, or other financing mechanisms.

Interviewees from the private sector particularly noted that some of the rules and regulations obstruct the role of businesses. As an example, the net-metering regulation was often mentioned, noting that there are a number of restrictions to installing solar PV on customers' rooftops and feeding the excess to the electricity grid. When questioned if there are sufficient rules and regulations to support private sector involvement in the sector, a senior official from an electric utility (UTI 11) stated: "No. I do not think there are sufficient rules and regulations. Concerning the net-metering regulations, I think we have announced the regulations too early and without finalising the relevant processes. It's only now we are starting the process". Some of the regulations are also seen as unnecessary and should be removed to make the process simpler.

Most of the interviewees acknowledged the introduction of import duty exemption for renewable energy products as a positive step to support RETs, and some (e.g. BUS 2) credited that the procedure of getting approval was not as complicated as it was in other similar processes. A government official (GOV 4), critical of the process, noted that such administrative processes should be eliminated and that, if renewable energy products are to be exempted, this should be facilitated through Customs:

As for customs duty, why should we have to apply in writing to exempt duty for renewable energy products, rather why not decide to exempt duty for renewable energy products at the border. If it is to be done sincerely, it should be made a zero tax item. So it will also help to reduce the administration and costs involved in processing tax exemptions.

These arguments call to simplify the processes and increase the political supports towards achieving the long term objectives of high usage of RETs.

Short-Termism

The current investment decisions to increase generation capacity are primarily based on achieving short-term gains, and meeting the growing demand for electricity. Many interviewees argue (e.g. UTI 10) that diesel-based generation is most suitable to meet the immediate requirements since the use of RETs such as solar PV will require a high initial investment.

An easier choice has been to simply install diesel generators which can produce electricity throughout the day even though the operational cost is much higher. A politically influential respondent from the utility sector (UTI 4) noted:

As policymakers, we usually look for short-term gains, and diesel-based generators provide short-term achievements in meeting electricity demand. Whereas for solar it is more expensive to install so it may be not on top of our list, even though it would be a good investment in the long term.

The policymakers struggle to make investment decisions on generation capacity; on the one hand having to meet the immediate demand and to provide uninterrupted service, and on the other hand in their effort to support the transition to RETs. The interviewee responses demonstrate that short-term goals take precedence, and most investment decisions are based on meeting demand within the existing generation technology.

Subsidised Tariff Rates

Electricity tariffs play an important role in changing electricity consumers' behaviour towards RETs. Higher tariff rates make it more economical to invest in a solar PV system for home installation. A senior official from an electric utility (UTI 3) noted that the hike in the electricity tariff in Addu City has contributed to the sudden increase in public interest towards solar PV as a means to reduce the electricity bill.

Electricity tariffs in the Maldives are based on the island, user type, and level of usage (see Table 6.6). The rates in the greater Malé region are cheaper than they are in other islands because of the scale of generation. The rationale for this is that the cost of diesel and generation is cheaper in Malé region compared to the cost in outer islands. The rates are also different depending on the consumer category (domestic, government and institutes, and commercial). Tariff rates for domestic users are the lowest, and they are highest for commercial users. In other islands besides greater Malé region, all the users except the domestic users are charged the same rate. The relatively low tariff rates for domestic users aim to reduce electricity bills for residential consumers and are cross-subsidised from the high tariffs for commercial consumers. The tariff rate is based on a usage band, rather than a flat rate tariff. The relatively low tariff for small usage aims to reduce electricity bills for low-income users.

Table 6.6: STELCO's Electricity Tariff Rate

(in MVR, from 1st June 2016)

#	Band (30 Days)	Greater Malé Region			Other Island Powerhouses	
		Domestic	Government & Institutes	Commercial	Domestic	Government & Institutes, Commercial
1	Units 0 - 100	1.50	3.30	3.30	2.20	4.50
2	Units 101 - 200	1.70	3.35	3.35	2.75	5.75
3	Units 201 - 300	2.15	3.35	3.35	3.40	6.50
4	Units 301 - 400	2.50	3.65	3.65	3.50	7.50
5	Units 401 - 500	2.95	3.65	3.65	4.00	7.50
6	Units 501 - 600	3.55	4.00	4.00	4.50	7.50
7	Units 601 - 3,000	4.25	4.35	4.35	5.50	7.50
8	Units 3,001 - 10,000	4.25	4.35	5.75	5.50	7.50
9	Units > 10,001	4.25	4.35	6.65	5.50	7.50

Note: US\$1 = Approximately MVR15.42

Source: (STELCO, 2018b)

In addition to the tariff rate, a fuel surcharge is also levied when the price of diesel is higher than a designated base rate. When the diesel price is higher than the base rate, MVR0.03 is charged for each unit (kWh), for each increase of MVR0.10 per diesel litre. The fuel surcharge was introduced in 2009 to minimise the loss incurred by the electric utility when the price of diesel increased. Politically it is difficult to revise tariff rates even when there are increases in international fuel price. The increase in electricity prices also has an impact on the cost of most other economic activities.

The tariff structure makes it economically sensible for high usage consumers to install solar PV to help reduce the overall electricity bill. So, commercial consumers will gain a higher economic return by installing solar PV for their electricity usage. An interviewee from the business sector (BUS 7) notes this economic reasoning:

Considering the electricity tariff in the Maldives, solar PV can be used for cost saving. It is not an environmental thing; it is an economic issue. Because of the high electricity tariff, it is worthwhile to install solar PV at consumer's buildings even without a subsidy.

At present, the electricity tariff for domestic users in most of the usage bands is below the cost of generation. An interviewee (BUS 1) emphasized that electric utilities should support electricity consumers, particularly domestic users, to install solar PV rather than obstructing it, stating: “Even if electric utilities distribute solar panels to domestic users, it may be a benefit to the electric utility, since it can reduce the units sold at a loss to domestic users”. However, electric utilities are concerned about the loss of revenue from higher usage bands where the cost of electricity is covered by the tariff.

6.5.1.3. Lack of Capacity

The analysis of interview responses reveals that there is a lack of organisational capacity in government agencies, lack of trained people within financial and educational institutions, and lack of knowledge amongst policymakers about RETs. These issues are explained below.

Lack of organisational capacity

Lack of organisational capacity in government agencies creates problems in policy formulation and implementation. An interviewee (GOV 1) for the study noted that, because of the lack of capacity, some of the projects initiated by the government have still not been implemented although there are funds available for these projects through donors.

The electricity regulator has an important role in directing the technologies used for electricity generation. Most of the stakeholders note that MEA is weak in formulating regulations and in their implementation because of structural and resource constraints. The mandate of the authority states: “Maldives Energy Authority (MEA) is an independent regulatory body affiliated to the Ministry of Energy and Environment [MEE] and operates under the guidance of a Governing Board appointed by the President” (MEA, 2018b). However, functionally the authority is seen as part of MEE and is reliant on government direction as it falls under the mandate of the ministry.

MEA is also less resourceful than the electric utilities, and is often dependent on electric utilities to implement the regulations pertaining to the utilities. The regulator has difficulty in enforcing the existing regulations. In some instances, it is seen that electric utilities have the upper hand over the regulator in the system. As an example, an interviewee (UTI 8) marked the inability to implement net-metering and FIT regulations, since the electric utilities only welcome these arrangements unwillingly, and there are challenges in getting access to the electricity grid.

There is also debate on the extent to which the regulator can extend its authority in shaping the electricity sector. The existing laws and regulations provide limited authority to the regulator in enforcing some of the instrumental changes to the sector.

The regulator believes the existing regulations are sufficient for current needs, while that is not the opinion of many stakeholders in the sector. A government official (GOV 8) noted that the existing regulations allow MEA to mandate electricity service providers to generate a designated percentage of their electricity from RETs. The official also notes two challenges in enforcing these regulations. Firstly, the regulation is not comprehensive enough to penalise the provider for failing to abide by the regulation. The current regulation only allows for fining the service provider up to a maximum of MVR50,000 (about US\$3,243), and this is not a significant value for an electricity service provider. Secondly, the other alternative for MEA would be to cancel the provider's license to generate electricity, and this is also a difficult decision since it would stop a basic service for the residents on the island. These issues indicate the limited capacity and role of the regulator in supporting the diffusion of RETs.

Lack of trained people

There are limited training opportunities in the country to develop skilled people for the sector, and there are only weak efforts to provide such training. A senior official from an electric utility (UTI 8) notes, "Technically the sector is very weak, and there are not sufficient trained people in the sector to make an informed decision about technical issues". The country's national university does not have any programmes on RETs. The government's vocational institute had only a few attempts at such training, and there is no consistent approach to train and build the skills.

The lack of trained people in the sector is a significant hurdle to increasing the use of RETs and also to increasing confidence in the technology. An interviewee from an electric utility (UTI 1) commented that the absence of trained people in outer islands creates an issue for them to install technically different technology to the currently used diesel-based generation system. This lack of availability of skilled people in RETs seems to be creating a vicious cycle. The lack of trained people in RETs affects the interest in carrying out projects using solar PV systems, and the lack of RET projects then reduces the need to train people for the sector.

Lack of knowledge

In addition to the skill development required for the sector, there is a need to educate policymakers about RETs. A government official (GOV 3) observed the importance of creating this awareness and proposes to “Educate the people at the policy level and explain to them about the evolving technologies in the sector”. The official argues this function is not present at the moment. The economics and technological capability and efficiency of RETs have improved over the years, but many policymakers are still not informed of these developments.

6.5.2 Positive Impact of International Development Partners

International development partners, including friendly countries and development organisations, have supported the Maldives in introducing RETs, particularly solar PV. Some of the assistance for RET projects is as a result of bilateral relations the Maldives has with the donor countries (e.g. Japan, Germany, and Australia). The Japanese aid programme, Project for Clean Energy Promotion in Malé, provided initial exposure to large-scale use of solar PV. Additionally, some of the multilateral agencies such as the World Bank (WB), Asian Development Bank (ADB), and the United Nations Industrial Development Organization (UNIDO) have also supported RET projects.

The projects also provided a platform to see and experience the technologies and gave an opportunity to evaluate the performance of the systems. An official from an electric utility (UTI 7) explained the significant role of international development partners in the introduction of RETs in the Maldives, “Most of the projects or the largest amount of RETs installed in the country are from donor assisted projects. There are only a few commercial projects”. The role of international development partners has been instrumental in introducing RETs to the Maldives, and they have made a positive impact in creating awareness and demonstrating the technology.

The important codes identified from the interviews related to the role of international development partners include: “Seeing is Believing”; “Projects Through Donor Assistance”; “Quality of the Projects”; and “Not Able to Complete the Projects on Time”. These codes helped in highlighting the themes related to the role of international development partners. Two important factors related to their role have emerged: demonstrating RETs, and dependence on donors. These factors are explained below.

6.5.2.1. Demonstrating RETs

There is an initial reluctance to move to incorporate RETs at utility scale, because of the lack of information, lack of skills and expertise, and high initial investment cost. An interviewee from the business sector (BUS 11) notes diesel is the easy option, and the tendency for electric utilities to invest in a familiar technology, diesel generators, that have been reliable in providing the solution required. A top official from an electric utility emphasised the importance of showing and demonstrating an alternative technology that works and meets the requirement of the utility operators, and quipped, “Seeing is believing”. The absence of a fully functioning RETs-based utility-scaled operation raises uncertainty at the decision-making level about attempting such a transition.

Solar PV system projects installed with the assistance of international agencies have helped in breaking the status quo by demonstrating the complementary role of RETs. These projects provided exposure to RETs for local experts conversant with diesel generation and have helped to improve their confidence and experience with solar PV applications. An engineer (BUS 2) marked the significant role of these demonstrative projects, particularly the role of Japanese funded projects in the Maldives.

The role of the Japanese government has been very important in bringing confidence and increasing awareness for the renewable energy sector. They have installed solar PV systems in the Maldives, provided training to the locals, and built confidence in the systems. As for studies, they have also done in-depth studies on solar PV for the Maldives.

These outside inputs have also been crucial in improving stakeholder's confidence in the technologies. Installation of a solar PV on a rooftop in a residential house also creates interest and awareness among the people on the island. An interviewee from the business sector (BUS 5) noted: "When people see another person install a solar PV system on the island, then other people also follow it, and that increases demand for solar PV systems". The presence of functional systems within the islands also gives assurance to financial institutions considering lending for projects in the sector. The interviewees marked the significant role the international agencies have played in introducing the technologies and in implementing demonstrative projects. The exposure and experience these projects have triggered have been important in breaking the status quo in electricity generation and demonstrating the potential of RETs.

6.5.2.2. Dependence on Donors

There is dependence on international aid to support RET projects. Meanwhile, additional generation capacity for island powerhouses is still met with diesel generators. A senior official (UTI 7) from an electric utility noted that "The government is largely dependent on international donor assistance to finance renewable energy projects", and some respondents within the private sector also raised the concern that RETs are seen as something to be done through donor assisted projects.

There is little resistance from the government for donor-supported projects since it comes as aid, and little financial input is required from the government, although this is not always the case since co-funding is often required for project implementation. An interviewee from the business sector (BUS 3) noted that there is difficulty in spending for RETs from the government budget because of the constraints within the government budget due to the financial capacity of the country. A few others, such as an engineer from an electric utility (UTI 10), argued that RETs have yet to achieve confidence as an alternative means to replace diesel-based generation systems.

Many within the government acknowledge the availability of overseas funding, while others still argue that there is lack of funding to meet the sector requirements, “The limited funding from overseas donors is one reason for the limited improvement in increasing the capacity of RETs installation” (GOV 3).

An interviewee from the private sector (BUS 9) argues the government’s reliance on donor-funded projects and reluctance to engage the private sector in the electrification of inhabited islands has contributed to diminishing the role of the private sector in the industry. Even though some of the interviewees from the private sector are critical about the reliance on donors to support RETs, many acknowledge the significance of international development partners in introducing the technologies and providing exposure to solar PV in the Maldives.

6.5.3 Weak Financial and Training Support

The role of financial and training institutions has been weak in supporting the diffusion of RETs. There are limited financial options to support RET projects. The recurring issue that many interviewees identified as a barrier to the diffusion of RETs is the initial investment cost. An engineer from an electric utility noted that “Electricity service providers are a business entity so they will generate electricity using the most economical method. So far, the investment for solar PV has been high, so the utilities favour a cheap solution” (UTI 8). Hence, the initial investment cost requires financial support to incentivise the sector.

An interview with a senior official from the higher education sector confirmed that The National University of the Maldives and the Maldives Polytechnic are not able to provide sufficient training programmes to meet the market requirement. The scope of training from the educational institutes is mostly limited, and there are only a few opportunities for technical and engineering training.

The important codes related to the factors affecting the role of the two actors include: “Initial Investment Cost”; “Lack of Financing Options”; “Lack of Incentives”; “Economically Unattractive”; “Lack of Trained People”; and “Lack of Research”. These codes helped develop the themes related to the role of the actors. The two major findings related to these actors are that there is a lack of low-cost finance and there is lack of training for RETs. These two factors are discussed below.

6.5.3.1. Lack of Low-Cost Finance

Many interviewees have identified the lack of low-cost finance as a fundamental challenge to investment in RETs. A senior official from an electric utility (UTI 1) notes, “If there is an attractive financial scheme that allows individuals to buy solar PV, then many people will probably buy it and have a solar PV installation on their rooftop”. It is difficult for individual customers to seek a commercial loan for RETs, since property has to be used as collateral for the loan, and many are uncomfortable in using their properties for the purpose. The interest rate for the loans is also high, above two digits, and makes it a less attractive financing option for solar PV systems.

There are eight commercial banks in the Maldives, but the only financing scheme from a local bank that supports investment in environmentally friendly technologies is the Green Loan from the Bank of Maldives (BML). The BML Green Loan targets the three broad sectors in the market. Firstly, individuals who wish to install solar PV on their rooftop, or want to buy an energy efficient vehicle. Secondly, small to medium-sized businesses that import and install RE products. Thirdly, large businesses and institutions, such as tourist resorts and colleges. An interviewee from BML also claims the loan gives the best terms and interest among their products and explained the terms and conditions of the loan:

Our interest rate for this loan is 10%. Our interest rate for business loans is 11.75%. So 10% is a good rate compared to the other loans. The repayment period is 20 years, and that is the maximum repayment we have for any loan with the bank. As for equity requirement, we usually have 20 – 30%, but for the Green Loan, we have set it to 15%, the lowest for any loan with the bank. Additionally, collateral is required. As per the bank’s policy, a property should be the primary collateral, and if the value is not adequate from the property, then additional security can be added. It may be possible to include the value of the things that will be purchased.

However, interviewees for this study note that the interest on the loan and the collateral requirement make it less attractive to individuals and businesses. A bank official informed of the range of issues that they look into in approving a loan and suggested that to address the issue of collateral a government guarantee could reduce the requirement:

As for commercial banks, we cannot offer other incentives by compromising these things: purpose, why the loan is taken; payment, if payment capacity can be met; equity, if they can raise sufficient equity for the loan; and collateral. So none of the banks will compromise any of these four aspects, especially when it is given at a lower interest. However, the government can play a role in expanding the corporate guarantee scheme to advance the projects that they have an interest in.

The BML already manages a fund from the Ministry of Economic Development and provides loans to support individuals and small businesses in different development projects. The terms and conditions of the loans from these funds are much more attractive to customers. Private sector respondents underscore that such a scheme should target the expansion of RETs and address the financing costs of the sector.

6.5.3.2. Lack of Training

Skill shortage is an issue in many sectors, but there are particular challenges in engineering fields. There are few training opportunities within the country to train people in engineering fields, including RETs. A senior official (INS 1) from an institute pointed out the lack of trained professionals in the energy sector:

We need to train people for the energy sector, including diesel and solar PV based generation. Many people who are already working on the diesel-based system are working with the knowledge obtained through experience.

Experts pointed out that the engineers already working on the diesel-based system can be easily trained to implement solar PV systems. The solar PV system is described as requiring “very simple connections” (INS 1). An experienced engineer (BUS 1) working in the business sector also explained that solar PV systems are easy to install, but the necessary training should be included in the curriculum of electricians’ training:

Very basic training is required for the implementation of a solar PV system. What we need is people to design the system, implement it, and repair them. Solar PV installation is nothing complicated. Most electricians can do this work, and we just need to include the solar PV installation in the electrician training curriculum.

The experts in the energy sector underscore the importance of training people in electrical and electronic engineering, fault finding, maintenance, control engineering and power management to support solar PV systems. The long-term use of the diesel-based system has engendered familiarity with diesel-based generation: “As for the diesel engineering side, we have more trained people since it has a long history, but we need to increase the number of skilled people” (BUS 2). There is also recognition of the value of obtaining overseas experience about RETs:

We have only recently started to install solar PV systems. So we should seek experience from other places where they have had the system for a longer period, and find the issues that may arise 10 to 15 years after installation (INS 1).

The experts in the energy sector agree about the lack of trained professionals in the renewable energy sector. An engineer (UTI 10) pointed out that this lack of technical people is because of the incentives available for engineers compared to some other professions:

The income people receive working in the technical sector is less compared to people working in an office environment. People working in the engineering field may have to work sometimes in very warm, noisy, or even risky environments. So it makes it less attractive for people to choose the engineering profession.

Some other engineers also point out the lack of interest in engineering fields. An engineer (BUS 6) from the business sector explained that the most competent students often do not choose the engineering field as a career choice and it is regarded as a second choice career:

There are relatively few students who are interested in the engineering field, and many do not believe the engineering sector is a good means of earning income. Very often we train people to become mechanics and to work on machines and other related engineering fields when they are not successful in other fields. So it is sometimes seen as a second choice career, and there is little attention given to training people in engineering fields.

The lack of training opportunities in the country and the low importance placed on training people in engineering fields create problems in developing skilled people. The training institutes in the country do not provide sufficient training to meet the requirements of the energy sector.

There are two universities in the Maldives, both established by the government. The first university, The Maldives National University (MNU) was established in 2011. While there is a Faculty of Engineering, Science and Technology at MNU, there are no courses and training on renewable energy or RETs. The second university provides religious education, Maldives Islamic University (MIU), and was established in 2015. There are about ten private colleges in the Maldives but most of these colleges are focused on management, accounting, and education training courses, and there is little focus on science and engineering programmes. Maldives Polytechnic, a government training institute, is the main institute that offers technical and vocational training, but they have limited engineering training programmes.

6.5.4 Independence of Tourist Resorts

The tourist resorts are self-sustaining businesses and operate independent powerhouses in the resort islands. Tourist resorts have very minimal interaction with other service providers, but they should also meet the national standards set by MEA. Most of the policies and projects initiated by the government regarding RETs are focused on inhabited islands and focused on electric utilities. This approach leaves the tourist resorts independent from many policies and programmes aimed to improve the diffusion of RETs in the Maldives.

Many within the business sector suggest that the tourist resorts should be required to generate electricity using RETs up to a designated level. However, a government official (GOV 1) noted that it is difficult to put forward such a regulation targeted at the tourism sector, and officials from the tourism sector advocated not to propose regulations that only target them. The tourism sector constitutes the most important industry of the economy and has a strong political voice and strong support. Many in the tourism sector are comfortable with the low engagement approach of the government, but welcome additional financial support targeted towards RETs.

The study finds two major issues related to tourist resorts: the cookie cutter approach to providing electricity service, and the concerns and issues related to roof space and aesthetics in using RETs. These two issues are further explained below.

6.5.4.1. The Cookie Cutter Approach

Tourist resorts follow the same electrification process as the inhabited islands and use diesel generators for electricity generation but with extra backup capacity. There was no consideration given in the design stage to installing and to incorporating RETs. As in inhabited islands, the absence of these design considerations creates a number of challenges to adding RETs, such as a solar PV system, to the generation system. A chief engineer from a tourist resort explained how tourist resorts follow the same pattern for electricity generation as in inhabited islands:

I can say they [resorts] like to go with the trend. The common trend here is to use diesel driven alternators to produce electricity. 99.99% of the resorts follow the same process. What we do is we take the load factor and try to configure generators to that load factor keeping around 25% allowance for expansion. The same process is applied to the water plant.

Diesel based generation is considered a reliable means of generation in the Maldives. Large-scale use of diesel generation systems in the Maldives has created advantages in respect of the availability of expertise and spare parts to service the machines so that it is easy to attend problems at times of breakdown.

The interviewees from the resort sector expressed their interest in installing RETs, such as solar PV for electricity generation, but they were uncertain over the economics and wanted to see a fully functioning installation in other resorts before they committed to it. An engineer from a tourist resort stated, “Actions speak louder than words. Make the products affordable and demonstrate that they work then there will be scope for the technology”. The resorts are more comfortable to mimic the advantages achieved by an early adopter:

If there is evidence that can be shown that the renewable technologies will work in the tourist resorts with the figures, then tourist resorts will invest. We have a small community in the Maldives, so if the people who have installed solar PV systems can demonstrate that it is feasible and working reliably, then others will follow suit.
(BUS 10)

There have been a few initiatives recently to install utility scale solar PV for electricity generation. In late 2014, Gasfinolhu island resort installed solar PV with a battery backup to completely switch its generation to RETs. It was reported that the project is expected to payback within seven to eight years (Hotelier Maldives, 2014). However, the success of this project is not known, and some experts in the field question the viability of such projects:

The issue is nobody is willing to take the first step. The person who invested in the first resort probably had enough collateral to start a project, but everybody is not like that. But if this property came out and explained that their investment was this, this is the impact, and this is what made the difference, then they [resort operators] will obviously take it into consideration. Obviously, everyone will welcome energy saving if it makes a profit. (BUS 10)

The unknown fate of such projects creates doubts about the success and the applicability of large-scale installation of RETs for electricity generation in other islands.

6.5.4.2. Roof Space and Aesthetics

As in inhabited islands, solar PV is the RET that is mostly considered as an alternative means of electricity generation in tourist resorts. A large-scale installation of solar PV requires a large area, and this is a challenge in small islands. An engineer from a tourist resort explained how this issue had stopped them from initiating a RET project:

[The resort operator] did a feasibility study on this island as well, and the biggest obstacle is that, since the island is only 23,000m², even to accommodate 25% of the total load, the roof capacity to install solar panels is very much insufficient. Unfortunately, because of that, the project came to a standstill.

There is also a restriction on the built-up area in tourist resorts, and it should be less than 30% of the land area of the island. The same engineer from the resort argues that the existing roof area in most resorts would not provide sufficient space to meet the total requirement of electricity needed for the island. However, if the existing structures were fully utilised, then it could provide space to contribute to the electricity requirement of the island.

Roof space is also a significant challenge in installing solar PV in Malé and the other inhabited islands. In Malé, almost all the houses are multistorey buildings (see Figure 6.4), and the roof space available in the buildings is not sufficient to install a solar PV system to meet the electricity requirements of the building. In outer islands, there are few buildings and structures, and this also limits available spaces to install solar PV systems. However, there is more space available in the islands compared to Malé for solar PV installation, while the shade from trees is an issue in many areas, and the islands also have constraints for utility scale installation.

Figure 6.4: Aerial view of Malé

Photo credit: Shahee Ilyas

A senior official from an electric utility (UTI 11) explained the challenges in formulating solar PV projects in the islands because of the difficulty in obtaining sufficient roof space for solar PV installation:

Even recently a Norwegian company expressed interest in investing in a solar PV project in the islands through a PPA, but it was stopped because of the difficulty in finding roof space. We told them that they have to find the roof space on their own, from that point the company was also reluctant to move forward. Most of the businesses interested in installing solar PV are interested in roof space in government buildings since they have relatively large buildings, but such roof spaces are also limited.

The government-owned properties, such as buildings housing government offices and schools, are usually most suitable for solar PV installation because of the structure of the buildings and the available roof space. Most of the solar PV's are currently installed in government-owned buildings. However, some of the government offices are reluctant to allow the utility companies to use their roof space to install solar PV. There are no incentives for the offices that own the buildings, and in some instances the installation of solar PV can damage the roof. An official from STELCO explained the challenges that they have in obtaining space for solar PV installation:

Two years ago, STELCO signed a contract with a Chinese company to install 1.5MW of solar PV in Malé region, but the implementation has not started yet, and it is almost at a standstill because the government is also not able to find roof space for the installation.

If we consider floating solar then again we do not have sufficient space around Malé because the lagoon is used for other purposes. The difficulties about floating solar maybe less in some of the outer islands but the space constraint is an issue in the Maldives. The highest demand for electricity is in Malé, and installing solar PV can make the most impact in terms of increasing the installed capacity.

Some of the buildings in which solar PV are installed in Malé are in fact requesting to remove them since they are not able to use the roof for other purposes and we are not able to give them any incentives.

The resorts are also particular about the aesthetic appeal and design of the building structures on the island. The buildings in the resorts, including tourist rooms and bungalows, were not designed with a plan to install solar panels on the roofs. Some structures may support the installation of solar PVs, but it is of concern that they may not be aesthetically appealing. A chief engineer for a resort chain mentioned that, if the installation of solar PV was profitable, then the owners would be willing to go back to the architects and request modifications to the buildings to install solar panels on the island:

The biggest issue I see is the space factor. Even if the island is large, there is a big role that aesthetics play. The guests will not like to see commercial things on top of the roofs; as long as it is at the back of the house it is fine. For some, if they see anything visual, it is a problem. That is also a major factor.

Interviewees from the resort sector also explained that resorts are less willing to install wind turbines, both onshore and offshore, as they are seen as spoiling the scenery of the islands.

6.5.5 Businesses and Residential Consumers Dependent on Electric Utilities

Businesses and electricity consumers are dependent on electric utilities. An interviewee from the business sector (BUS 5) noted that local businesses involved in RETs are increasingly focused on inhabited islands because of the difficulty in penetrating the tourism sector. At the same time, interviewees from the business sector also noted the challenges in connecting privately installed RETs to the electricity grid since electric utilities own them.

On the basis of the analysis, two major issues were identified: the electric utilities have not found a good business model to provide the service by incorporating the private sector, and there is lack of information about RETs. These two issues will be further explained below.

6.5.5.1. The Absence of a Good Business Model

Electric utilities are concerned that if a large proportion of the electricity generation requirement is produced by privately owned RETs, then it can erode the revenue of electric utilities. An engineer (UTI 8) from an electric utility explained below the perception of electric utilities towards private sector involvement:

There is a perception that if the private sector feeds a high volume of renewable energy into the grid, then it will be at a loss to the electric utility. So, even though there are FIT and net-metering regulations, the use of renewable energy has not increased because the utilities are not willing to implement them and give space to the private sector. As long as we have this perception, then there will be less room for the private sector. (UTI 8)

There is a lack of information about the outcome of previous projects using alternative technologies, and they are not often celebrated to inform others about the economic benefit of those projects. Surprisingly, the benefit of some of the projects is not even assessed. An engineer from an electric utility (UTI 6) noted that they were not able to assess and evaluate the benefit of a large solar PV installation after the project was done citing lack of time and unavailability of people.

Many private sector officials argue that it is not in the interest of electric utilities to allow the private sector to access the grid since they currently own the distribution network. Hence, some of the interviewees noted that electric utilities have not been able to find a good business model that can incorporate private businesses:

The utility companies have not found an innovative way to use renewable energy and to survive in their business. If they can figure this out, then it will be an important step to increasing the use of renewable energy. (BUS 7)

Even though there are regulations such as FIT and net-metering, the absence of such a good business model contributes to the reluctance of electric utilities to allow the private sector to feed electricity into the grid. At the same time, electric utilities and government officials (e.g. interviewee GOV 1) emphasised that electric utilities are mandated to provide a continuous supply of electricity to the public, and have made a huge investment in the infrastructure. Hence, they argue the sustainability of electric utilities is paramount.

The study also found that there are three additional arguments for the reluctance of electric utilities to allow the private sector to feed RETs into the electricity grid: ensuring a continuous supply of electricity; maintaining the stability of the electricity grid; and retaining control of electricity generation.

Firstly, diesel generators are still needed to ensure a continuous supply of electricity, unless additional investment is made on energy storage. Hence, RETs are considered as a secondary means of electricity generation because of the intermittent nature of solar PV. An interviewee (GOV 7) also noted that there is an accusation that the current practices of purchasing and distributing diesel to the outer islands provide undue benefits to the operators, and thus encourage them to want to maintain the current practices. However, the significance of these accusations is difficult to establish.

Secondly, electric utilities raise concerns about managing a large amount of electricity from intermittent sources and maintaining system stability. Some engineers, particularly from the electric utilities (e.g. UTI 10), have expressed concern regarding system stability, stating that installing RETs on a large scale could disrupt the power supply in the grid, particularly in small islands. In order to address the issue of possible interruption, a cap on what can be fed into the grid through intermittent sources is already in place under net-

metering regulations. An interviewee from the government (GOV 1) acknowledged that the use of battery backup and control management of the generator systems are also possible ways to address the issue.

Thirdly, electricity security has also been cited as a reason for the electric utilities to hold control of generation capacity. An engineer from an electric utility (UTI 10) noted that there is concern that dependence on the private sector to generate electricity to the grid could give them control of electricity service, which should be maintained within government control for security purposes.

6.5.5.2. Lack of Information

Lack of information and awareness among different actors about RETs were often cited by many interviewees as a challenge to increasing the use of RET. In comparison to diesel-based generation, there is a lack of technical knowledge and experience and understanding of the economics of using solar PV and RETs. The lack of guidance and information from government authorities and electric utilities contributes to this information asymmetry. A senior official from an electric utility (UTI 11) also acknowledged the absence of information and shifted the responsibility of providing the information to the regulator and the government:

The regulator or the Ministry of Environment and Energy are not very prepared for the private sector installing RETs. Even now, for example, I have been approached by a person who has tried to find a way forward to make a solar PV installation on their rooftop. So, the process of installing solar PV on your rooftop is not clear. Appropriate information is not available from the ministry or MEA. I think MEA is not very firm in the process or it is not very clear to them.

An interviewee from the business sector explained their role in educating and informing the public about the potential of solar PV systems, emphasising that when people see an operational system it helps to spread the message about the benefit of the system:

Awareness is not raised necessarily by bringing everyone together and explaining the benefits of using RETs. When we install a solar PV in a house on an island the people in the community see that the cost of the electricity bill is reduced. So, through their family and friends, the information spreads slowly. (BUS 8)

Nevertheless, some interviewees from the private sector also noted the absence of information dissemination about the performance of RET projects already implemented in the country; and also the absence of dissemination of information gathered by government officials from their exposure overseas. The real contribution from locally implemented projects is not widely understood by the stakeholders, and there is a difference in opinion on the level of savings and benefits from these projects.

6.6 Discussion

The survey respondents for this study perceived political and economic factors as the main contributor to the slow diffusion of RETs, rather than technical issues. This is also similar to the findings from the interview data.

Table 6.7 shows a summary of the findings on the role of important actors and the factors affecting them. The interviewees for this study have also highlighted the significant role of the government and their policy direction, and the importance of financing mechanisms to support the sector.

Table 6.7: Factors Affecting the Role of Important Actors

Role of the Actors	Factors Affecting the Role of the Actors		
Dominant Role of the Government	Overarching influence on the actors	Lack of Political Support	Lack of Capacity
Dependence on International Development Partners	Impact of Donors	Significance of Demonstrating RETs	
Weak Financial and Training Support	Lack of Low-Cost Finance	Lack of Training	
Tourist Resorts are Waiting for Successful Projects	Cookie Cutter Approach	Roof Space and Aesthetics	
Businesses and Residential Consumers Dependent on Electric Utilities	The Absence of a Good Business Model	Difficulty in Accessing the Grid	Lack of Information

The early studies on the barriers to the diffusion of RETs in SIDS have emphasised the role of technical failures such as inappropriate design, use of unreliable components, and improper installations and poor maintenance (Jafar, 2000, p. 308), while others have emphasised the absence of a science and technology base in these island countries (Singh, 2012, p. 255). The greater emphasis on other challenges in this study besides technical

considerations indicates the diminished significance of such factors. The technological performance of RETs has improved over the years and the understanding of the application of the technologies has also improved. Nevertheless, the technical capacity of the available workforce continues to be highlighted as a significant barrier. Dornan (2015, p. 491) noted the significance of limited technical skills; UNEP also (2014, p. 29) mentioned lack of technical capacity; and Weisser (2004b, pp. 128–129) identified lack of awareness and knowledge of existing RET options as significant barriers to the diffusion of RETs in SIDS. Similarly, this study has also identified the importance of training and information dissemination.

Studies on the diffusion of RETs in the Maldives have highlighted issues around economic feasibility, appropriate composition of RETs, availability of space to install solar PV, and scope for private sector participation as important challenges (see section 3.6). Recent studies on the diffusion of RETs in the Maldives have particularly identified the lack of understanding of the cost-effectiveness of RETs as an important factor affecting investment decisions (Jung et al., 2018).

The lack of information about the economic feasibility is also evident in earlier studies which highlighted this lack of information as a significant barrier (IRENA, 2012a, pp. 14–16; van Alphen, Hekkert, et al., 2008), and the same can be observed in this study. There are very different understandings of the investment returns from RET projects as highlighted in the discussion on the tourism sector, and some have stated very long periods for investment return. On the other hand, a recent study on an island in the Maldives which is using a hybrid system with solar PV shows the payback period is within only 4 to 5 years (Ali et al., 2018, p. 31). Additionally, the absence of a good business model to incorporate the private sector into service provision by electric utilities, as identified in this study, can be argued to be a related issue because it also shows a lack of understanding of the economics of RETs.

The survey respondents of this study perceived that policy measures associated with human capacity building; financing; and establishing policy obligations and targets were the most important drivers that could potentially improve the diffusion of RETs in the Maldives.

The studies on policy measures to improve the diffusion of RETs in SIDS have highlighted a range of relevant issues, as discussed in section 3.5.2. These studies highlight the importance of policy frameworks to support the sector (UNEP, 2014, p. 29; Weisser, 2004b, pp. 128–129), but there is not enough recognition of the significance of the role of the state and the implications of prioritising policy objectives that incorporate a higher level of RETs. An important insight from this study is the recognition of the sector experts on the significance of the role of the government, and that state has the primary role in supporting the diffusion of RETs, but the responsibility should be shared with other stakeholders. The second important insight on the factors affecting the actors is the significance of implementing the diffusion of RETs as a policy priority. It is not only sufficient to set out a policy framework to achieve a higher level of RETs, but these policy goals need to be a national priority, so that achieving these policy objectives is given consideration in resource allocation.

6.7 Summary

The findings from this chapter attempted to answer the research sub-questions. The study found that the three most significant barriers to the diffusion of RETs in the Maldives according to the respondents' perceptions were: government policy; financial factors; and the capacity of organisations and people. Accordingly, the policy measures that they perceived to be most important in driving the diffusion were: building human capacity; financing; and establishing policy obligations and targets. The findings reaffirm that the slow diffusion of RETs is contributed to by political and economic factors rather than technical considerations. This study also concurs with the findings of recent studies that the lack of information about the economic feasibility of RETs is a continuing challenge to driving the diffusion of RETs in the Maldives.

The analysis of interview data shows that the role of government and international development partners are the most important factors in driving the diffusion of RETs in the Maldives. The study also found that there is weak financial and training support for RETs, tourist resorts operate independently, and businesses and residential consumers are dependent on electric utilities to incorporate RETs into the electricity grid. These findings emphasise the potential role of development partners and their ability to make meaningful

impact in supporting the diffusion of RETs. Similarly, the findings also highlight the overarching influence of the government on the other local actors and that the state has the primary role in supporting the diffusion of RETs. The study asserts that it is not sufficient to have a RET policy framework, but that the policies should be prioritised in order to drive the diffusion of RETs.

The study has aimed to understand the significant barriers that are hampering the diffusion of RETs, and policy measures that can support to drive the diffusion of RETs. In order to answer why the diffusion is slow, this research has also attempted to understand the process of diffusion and apply the adapted TIS to examine its applicability as an assessment tool to understand the diffusion of RETs in the context of SIDS. The adapted TIS framework will be applied in the following chapter.

CHAPTER 7: UNDERSTANDING THE DIFFUSION OF RETs USING TIS

7.1. Introduction

In this chapter, the data are analysed using an adapted TIS framework to address the main research question, ‘Why is the diffusion of RETs slow in SIDS such as the Maldives?’, and to obtain additional insight into answer the research sub-questions. The TIS framework allows analysing the development and diffusion of energy-related technologies. In analysing the diffusion of RETs using the TIS framework, the actors, networks, institutions, and relevant functional activities supporting the innovation system are assessed to map and guide innovation processes and to derive policy advice. The analysis of the framework also allows identifying the drivers and barriers hampering the energy transformation. The TIS framework is adapted to SIDS conditions as explained in the analytical framework chapter (section 4.3). The analysis is presented sequentially using the six-step TIS analysis approach explained in section 4.3.2.

7.2. Landscape

Landscape is defined as a broad set of external factors that can impact overall performance of the system. Three such broad factors are the natural resource endowment, economic and social development, and the external developments that can influence the diffusion of RETs. These three factors are explained below.

7.2.1. Natural Resource Endowment

As an archipelago, the Maldives has an abundant source of ocean energy. However, the lack of commercial technologies available to utilise wave and tidal energy means the potential value of ocean energy in the Maldives has not been fully explored (Robert Gordon University, 2011). The Maldives is also a flat country; there are no waterfalls and flowing rivers, and there is no hydropower potential. Other renewables such as geothermal are also not existent in the Maldives.

A wind resource study conducted by the National Renewable Energy Laboratory (NREL), which used a computerised wind mapping system to assess wind power density at 50m above ground, showed that wind resource is only moderate and adequate only for small scale application in a large region of the Maldives (Elliott et al., 2003, pp. v–vi). Wind energy is largely seen not to be feasible in the Maldives because of low wind speed. An interviewee (GOV 4) noted that the failure of a previous project based on a wind-diesel hybrid system in Haa Alif Uligam island has also contributed to this impression. An interviewee from the government (GOV 2) pointed out that ground assessments need to be done to verify the wind speeds and noted that there are ongoing works to measure ground level wind speed.

There is not enough information about the potential of biogas, and biomass resources in the Maldives (MEE, 2012, pp. 42–44). An interviewee from the government (GOV 3) said that there is an ongoing study to explore the potential of using biomass for renewable electricity generation, but a project has yet to be formulated:

We are exploring how waste can be used to generate electricity, particularly in areas where there is a large population. Use of waste can be a big advantage since managing waste is also a big problem. So, using it for electricity production can be a solution to manage waste (GOV 3).

Studies show solar energy is abundantly available in the Maldives for most of the year and virtually in all locations (Renné, George, Marion, Heimiller, & Gueymard, 2003, p. 16). There is relatively more information about solar resource availability (MEE, 2017b) than there is about other renewable resources, and it is also the most widely tested and used RET in the Maldives. Solar PV is often referred to as *the* RET in the Maldives because of the dominant role that solar PV has been playing in comparison to the other RETs.

There was a general consensus among research participants on the applicability of solar energy in the Maldives, and none of the interviewees disputed its potential role as a RET in the Maldives, but a few argued that other RETs should also be explored. Some of the quotes from the interviewees are included below to show the general approval of solar PV technology:

The studies show very clearly that solar is the most applicable renewable energy source to the Maldives, and there is no debate about it. It might be because of the sunshine, and the geographical location of the country since we are located on the equator. We can easily generate 4.5kW a day from a 1kW of the solar PV system. When solar efficiency improves, the space required for roof space will also decrease. So from a small footprint, you get more energy. (BUS 2)

Solar energy is most applicable to the Maldives even in comparison to the wind. It is much simpler to install and operate. The technology is also something that can be managed by individuals and small companies. It is difficult to find the space to install a wind turbine for an individual, but they can install solar PV on their rooftop. In the Maldives, now people do not consider other renewable energy technologies. (GOV 4)

Solar PV has a number of other advantages over other RETs currently available. It requires low maintenance and businesses are more comfortable with the technology because it requires less visits to the sites. A business providing RETs explained that the low maintenance feature had been an important consideration in its decision to sell solar PV systems:

We considered all the technologies when we started the business, but solar PV seems to be most applicable now. The dispersed nature of the islands is also one reason for choosing solar since solar PV requires low maintenance, and we can meet the requirements of the islands much easier (BUS 9).

At the same time, solar resources have the fundamental disadvantage of being unavailable at night, during rainy days, and when there is cloud cover. The electricity generated from solar PV is intermittent, and there are challenges in obtaining a steady flow of electricity without resorting to a battery backup, which increases the cost of investment and the payback period.

Increased focus on the use of solar PV is also seen as a hurdle for exploring the potential of other renewable resources. All the government projects on RETs are based on solar PV. An interviewee from the business sector (BUS 9) was critical about the focus on solar PV and claims: “The government is only trying to implement projects using solar PV, even though we know some companies are interested in using technologies such as OTEC [ocean thermal energy conversion], but there is no such interest from the government in exploring the technology”.

Some of the interviewees advocated that diesel hybrid systems would be most applicable in the Maldives to meet the electricity demand: “I think a hybrid system using diesel-based generation is most applicable for the Maldives. This would minimise the cost of diesel and enable getting the best from free resources (UTI 11)”. The researcher observed the availability of a limited range of renewable resources, particularly sources that could provide baseload generation. This is a factor creating reliance on diesel-based generators for electricity generation.

7.2.2. Economic and Social Development

Until recently, many people in the Maldives were reliant on renewable energy sources to meet their daily needs, ranging from the use of wood for cooking, to using sailboats for transport within islands. The outer islands initially received electricity at a slower pace. However, when all islands started to receive 24-hour electricity service, the lifestyle of the people changed. An interviewee (GOV 5) noted, “In the last 10 years the lifestyle of Maldivians has changed tremendously, and people have moved into the house”, compared to earlier when many spent most of the day outside the house. The GDP growth rate in the Maldives between 2010 and 2016 is on average 5.9% (MoFT, 2017, pp. 34–35). The change in lifestyle due to development has increased the usage of electronic devices and the demand for electricity.

The inability to obtain finance for investing in RET projects and the lack of personal funds reduce domestic capacity to invest in large-scale RETs. The government's ability to deploy resources to support the diffusion of RETs is limited because of budget constraints. There is over-reliance on international assistance for investment and development of RETs. Most of these issues are related to the level of development of the country. A respondent critical of the government's role in supporting the energy sector asserts that even if the government wanted to there is very little that they can deploy to the sector since "They are struggling to pay even monthly salaries to government staff (BUS 3)". Nevertheless, there is scope for prioritising government projects and allocating the budget by priorities.

7.2.3. External Developments

The interviewees in this study were asked their opinion of the most significant external developments that could improve the penetration and diffusion of RETs in the Maldives. The most important issues identified by the interviewees were: international aid supporting RETs; increase in international fuel prices, and reduction in the price of RETs in the international market; and improvement in efficiency and reliability of RETs. These issues are discussed below.

International Aid for RET Projects

Many SIDS are dependent on international assistance for the development of infrastructure, including the provision of electricity services. The analysis of the factors affecting the important actors in the Maldives in section 6.5.2 also identified the positive impact of international development partners in the diffusion of RETs in the Maldives.

External initiatives undertaken to address climate change and efforts to mitigate the emission of GHG also support the use of RETs. The establishment of the Green Climate Fund (GCF), and international prioritisation of the provision of sustainable energy in Sustainable Development Goal 7 (ensure access to affordable, reliable, sustainable, and modern energy for all), are identified as important external developments in the sector. Many interviewees noted that these renewed efforts supporting RETs, and assistance from international development partners towards RETs, had been instrumental factors in diffusing RETs in the Maldives.

Increase in International Fuel Prices

International fuel prices affect the cost of electricity production in fuel importing countries. According to data obtained from electric utilities, the cost of diesel accounts for over 70% of the cost of production in a diesel-based generation system. Increase in fuel prices incentivizes the search for RETs and makes these technologies economically more attractive. However, very often this increase in fuel price is absorbed by government subsidies, in the form of subsidised tariff rates that aim to reduce the economic impact on individual consumers. An interviewee (BUS 7) observed that, when the electricity subsidy was removed in 2015, it increased the electricity bill for residential consumers and contributed to the increase in residential consumers' initiatives to install solar PV in the Maldives.

Reduction in the Cost of RETs

The cost of RETs has been decreasing over the years, and this has contributed to making the technologies more competitive with existing technologies (see Figure 2.3). The interviewees often cited the cost of investment as a barrier to using RETs, but the reduction in the cost of the technologies is making it more competitive. Advancement in technologies and the increase in global production is contributing to this reduction in prices. The reduction in the cost of RETs is a positive development which can further contribute to increasing the use of RETs.

Improvement in Efficiency and Reliability of RETs

There are still some concerns about the efficiency and reliability of solar PV for electricity generation. An interviewee from the government (GOV 4) with an engineering background explained that this uncertainty poses a challenge for investing in RETs:

For some people, it is not certain that renewable energy technologies are a reliable technology that they can rely on and sustain. For example, if a Yanmar engine is brought to an island, everyone knows that the engine will work appropriately and it can be serviced relatively easily. The same is not true for renewable energy technologies. So the uncertainty of technology is the main reason for the lack of acceptance of the technology. People do not want to make a big investment when they are not certain about what will happen the next day. So the fear is still there for renewable technologies. The fear should be managed to persuade the private sector and the resort sector to switch to renewable energy technologies.

The efficiency and reliability of RETs have improved over the years. An interviewee (BUS 2) also explained that this improvement in efficiency now allows higher output from a smaller size of solar PV panels. Many interviewees with engineering backgrounds also explained that solar PV is simple to install, unlike diesel-based generation systems.

7.3. Structure

Structural components form the basis of the TIS framework and consist of actors (public bodies, commercial organisations, influential interest organisations), networks (formal networks such as public-private partnerships and informal networks such as buyer-seller relationships), and institutions (laws, regulations and culture). In this section, the role of these components is analysed to understand the diffusion of RETs in the Maldives.

7.3.1. Actors

The role of the actors and the factors affecting them were discussed in section 6.5, and these highlighted the following: the government has a dominant role in sector; international development partners have made a positive impact in supporting the diffusion of RETs; the role of financial and training organisations has been weak; tourist resorts operate independently; and business and residential consumers are dependent on electric utilities to use RETs. The role of these actors will not be elaborated on again in this chapter, but the interaction of the actors is discussed in the following section.

7.3.2. Networks

The interaction of the actors within the system can provide an important impetus to facilitate engagement and strengthen the performance of the system. The role of networks in a system such as the RET sector is important since networks can facilitate interaction among the stakeholders and improve the exchange of information and knowledge among the actors. These interactions can be instrumental in shaping policy direction and regulations in the sector.

There are a few actors in the Maldives electricity sector, particularly from the private sector, but there is a lack of interaction between the players. An electric utility official (UTI 7) affirmed this limited interaction and noted, “The Maldives is a small country and many people in the sector know each other, but there are no managed interactions, and there is no proper system to support interaction among the players within the sector”. Analysis of the role of the networks in the sector indicates that the actors are dominated by the government, and there is an expectation that a government initiative will support interaction between the actors. Additionally, based on interviewee responses from prominent business officials, it can be argued that improving co-operation among the private sector participants is not among the priorities of the private sector.

Government Initiatives

There is an expectation among many actors within the electricity sector that the government should initiate interaction among the stakeholders. This expectation could be a result of the government’s dominant role within the sector, and the resources available to them to facilitate such a formal interaction. However, many interviewees note that there have been very few exchanges initiated by the government to bring together the stakeholders in the sector. An interviewee (BUS 1) also argues:

There is no interaction between the players. For one thing, there is no organisation representing all the organisations in the sectors. Everyone is dependent on the government, and the government is doing it without the private sector. The private sector does not have the access to understand what the government is doing, but the government is doing most of the RET projects. (BUS 1)

A government official (GOV 3) also noted the need to improve interaction among the stakeholders:

I think the interaction between the stakeholders should be strengthened. At the moment what we see is that the government is implementing projects without much participation from the private sector. Additionally, the public should also be informed more about the technology and improve their know-how.

The lack of initiatives from the government to support such interaction is an important reason for the lack of any formal interaction or association among the stakeholder. A government official (GOV 1) noted the importance of such interaction to spread information about RET projects and resources available within the sector to the public. The official also suggested licenced engineers in the sector could be used to spread information about RETs.

There are also issues of interactions among government agencies, such as MEE, the electricity regulator, and electric utility companies. A senior official from an electric utility (UTI 11) argues, “Concerning the net-metering regulations, I think we have announced the regulations too early and without finalising the relevant processes”; implying MEA did not properly consult with electric utilities before announcing net-metering regulations. A government official (GOV 2) also raised concerns about the change of staff within the ministry with many important positions filled on a contract basis:

There are issues of continuity within administrations. There are issues of staffing since for most of the projects we hire contract staff, and when the project is done they are no longer with the Ministry. So, permanent staff for these organisations are also important. (GOV 2)

The changes in staff within government agencies, particularly senior staff hired for renewable energy projects, are also seen as a disruption to the exchange of information across agencies and in establishing proper contacts.

Co-operation is not a priority

Improving co-operation among its participants is not among the priorities of the private sector. Cooperation is not listed among the significant barriers by respondents from electric utilities and businesses, and it is also not identified among important policy measures by respondents from the government, electric utilities and businesses. Some private businesses believe it is too challenging to form private sector association, while others within the sector recognise the importance of an association to raise a common voice to protect the interests of private businesses. An owner of a private business (BUS 2) noted that there are only a few businesses in the sector, and that they compete fiercely with each other for the limited projects in the market:

There are only a few companies in the sector who compete with each other for projects. So it will be difficult to work to form an association since there are reservations on sharing any knowledge with the other parties. The businesses are competing to sustain their businesses, so it makes it difficult to form an association among the few players in the sector. (BUS 2)

As a result, there is some level of uneasiness in opening up with others as they value their business secrets much more highly. However, one of the respondents (BUS 1) argued, “Even though there are only a few parties in the private sector they could form an association and collectively lobby the government on different issues”. The respondent highlighted the merits of working together to raise common concerns and build strength as a team to advocate for private business interests to the government.

This analysis of the networks within the electricity sector shows that there is weak interaction among the actors, and this is contributed to by the reliance on government to initiate interaction and the lack of such an initiative from the government. Additionally, the private sector has not collectively prioritised interaction among private sector actors as an important initiative.

7.3.3. Institutions

The actors and the networks contribute to the institutions in the sector. The institutions in this study are defined as the laws, rules and regulations that shape the functioning of the sector. In addition to the written rules and regulations, the unwritten rules, customs, cultures, and attitudes towards RETs are analysed to have a deeper understanding of the role of institutions.

Laws and Enforcement

The study found by examining the available laws and regulations and from interviewee responses that there is a lack of laws, including written regulations, and that there are problems in the implementation and enforcement of the existing regulations in the energy sector. The existing laws and regulations are not sufficient to address many of the emerging issues in relation to RETs. The current practices followed by the regulator and electric utilities are also not appropriately documented and are not readily available for inspection by potential investors. An interviewee (GOV 7) explained this problem:

I was approached by a foreign company interested in investing in the renewable energy sector in the Maldives, and they wanted to have formal documents about the existing regulations in the sector. I noticed there were not sufficient regulations about the sector and the existing ones were not comprehensive or convincing for the investors. The problem is we do not have such regulations even in Dhivehi. If we had them, maybe we could translate them into English.

Table 7.1 lists the laws and regulations of the energy sector of the Maldives. These laws, regulations, and draft regulations are available on MEA's website⁵. There is no specific energy Act in the Maldives. The regulations related to the energy sector are developed within the mandate given by Law 4/96 (Provision of Utility Services). Currently, there are two published regulations – the Net Metering Regulation 2015 and the Generation, Distribution and Supply License Regulation 2015. The Net Metering Regulation 2015 sets the maximum capacity of solar PV that a customer can install for their use and connect to the electricity grid. The regulator defends that this limitation is important to maintain grid stability, and to balance the financial sustainability of the utility to address their revenue loss. Many practices currently followed by the regulator are still based on draft regulations.

Table 7.1: Laws and Regulations of the Energy Sector of the Maldives

Laws: <ul style="list-style-type: none"> • Law 4/96 (Provision of Utility Services)
Regulations: <ul style="list-style-type: none"> • Net Metering Regulation 2015 (Regulation No.: 2015/R-231) • Generation, Distribution and Supply License Regulation 2015 (Regulation No.: 2015/R-143)
Draft Regulations: <ul style="list-style-type: none"> • Service Provider's Code • Engineering Licensing Regulation • Guideline for Power Systems Approval • Installation Standards Regulations • Guideline for Approval of Standby Power Generation • Metering Scheme Regulation • Utility Investment Approval Regulation

Source: (MEA, 2018a)

⁵ MEA's FIT regulations are not listed on its website.

The interviewees have highlighted the weakness of the regulatory framework and institutional capacity. An interviewee (UTI 7) from a utility noted that a previous attempt to promote FIT has now been silenced, and there is not much discussion about it:

Concerning the sales of renewable energy, two regulations have been set forward; for net-metering and feed-in tariffs. However, the feed-in tariff is now paralysed in the Maldives, and there are no more opportunities for feed-in tariffs with the introduction of net-metering.

Many interviewees have noted that the regulator is slow in introducing regulations that could address the present problems in the sector. For instance, net-metering regulations came a few years after consumers started to install a home-based solar PV system. An interviewee (UTI 5) noted when the new regulations were introduced the previously installed installations were disconnected by the electric utilities, and this caused a problem for many people who had invested in solar PV systems.

There are potential regulations that can be introduced to the energy sector, and additionally to the construction and building sector, to support energy efficiency and the use of RETs. However, the pace of introducing the regulations has been slow.

Investor Confidence

There are issues affecting investor confidence in the Maldives. An interviewee (GOV 3) noted, “I think there is not sufficient investor confidence to invest in this sector. It is particularly because of the regulations, and also related to the availability of local funding for the projects”. An interviewee (BUS 2) also pointed out “The protection that is required for any long-term business will be applicable and required for this sector as well”. Interviewees from the business sector particularly pointed out that investor confidence in the RET sector is not only based on regulations in the sector, but it is also related to the whole business environment and confidence in doing business in the country:

For investor confidence, it is not limited to the regulations of the sector. It also involves regulations that allow making a PPA with a building owner so a business can use their roof to install solar PV. (BUS 9)

Investor confidence is related to the enforcement of rules and regulations. Foreign-based companies have higher risks compared to local companies especially for projects that are contracted for a long period. The life of the solar panels can be 25 to 30 years, and it will be difficult to get assurance from any party for the products and on their security for such a long period.

Private business also views many of the regulations in the sector as being designed to protect the interest of electric utilities. A senior government official among the interviewees explained that they had planned to charge a fee for solar PVs connected to the electricity grid in inhabited islands as a “capacity charge”. However, the plan was scrapped after public outcry. The proposed fee for connecting solar PV to the grid was coined as “tax on renewable energy”. Abrupt changes in regulations is also an issue with potential investors and with the consumers.

Cultural Challenges

There are no significant cultural issues affecting the use of RETs. However, the failure of an early wind farm project gave a negative perception of RETs. The required user intervention for the home-based solar system is also a problem for some consumers, but it is a lesser issue for utility scale installation. An interviewee (UTI 7) also noted that Maldivians are generally fond of new technologies:

There are no such behavioural factors that reject the use of RETs. Maldivians are often very fond of new technologies and easily adopt them. As for cultural factors, there may be some aspect of resistance in moving towards new means of generation since we have been generating electricity using diesel generators for many years now. (UTI 7)

The phenomenon of Not In My Back Yard (NIMBY) is also not significant because solar PV is currently used as a RET and it is mostly installed on the rooftop of buildings and creates almost no problem for the residents of the building.

This analysis of the institutions related to the electricity sector in the Maldives shows that there is a lack of Acts, regulations, and enforcement, and that there are few cultural challenges that are affecting the diffusion of RETs.

7.4. Functions

7.4.1. F1: Entrepreneurial Activities

Studies on the diffusion of RETs highlight the importance of the involvement of the private sector. Private sector participants include the private businesses involved in the sale, installation, and maintenance of RETs (businesses), and residential consumers (commercial and domestic consumers). In previous studies (UNDP, 2007; van Alphen, Kunz, et al., 2008), the lack of opportunities for private sector participation and entry to the market are also highlighted as problems for the diffusion of RETs. This study offers an opportunity to understand if the circumstances have changed over the years, and to explore entrepreneurial activities in the electricity sector in the Maldives.

The study found based on interviewee responses that the scope for private sector involvement is limited because of policy and regulatory restrictions, difficulty in accessing finance, and restrictions on participating in ongoing government initiated RET projects.

Many interviewees identified the restrictions for private sector participation in the electricity sector in the Maldives. An interviewee from the private sector (BUS 9) argued, “The role of the private sector is very small within the Maldives”, and claimed the cap of 30% of peak time use of electricity that can be installed to the grid under the Net Metering Regulations 2015 as a significant restriction. There are challenges in entry into the electricity sector, particularly in the provision of RETs. Only a few players are actively involved in the sector. The government and electricity utility officials are starting to recognise the potential role of the private sector in the provision of electricity services:

The government and the state-owned enterprises alone cannot make the necessary investment in installing solar PVs. Opportunities should be given to the private sector. The sector should be commercialised so that there is business potential and investor interest in the sector. (UTI 7)

Net metering and FIT were introduced to support RETs and had the potential to increase the scope and role of private sector participation in the sector. However, the Net Metering Regulation 2015 restricts the capacity of RETs installed through the scheme to the annual average consumption of the consumer and is aimed at individual consumers (not for large-

scale businesses). FIT has not been functional, and only STELCO's "Six Island Project" used PPA to purchase electricity through the private sector.

Interviewees from the private sector have identified several shortfalls with the current Net Metering Regulation 2015. For example, it is difficult for a third party to own or rent solar PV installed on the rooftop of other buildings. The Net Metering Regulation 2015 also does not allow payment to the owner, it just adjusts the electricity bill according to the electricity used and fed into the grid from the owner's system. Some of the interviewees stressed the importance of making payment for the sale of electricity through net metering rather than needing to manipulate the electricity bill depending on usage. These policies and regulations reduce the scope for private businesses.

Difficulty in accessing finance for RET projects is also a significant factor that affects the involvement of private sector and entrepreneurial activities. It is relatively difficult to raise finance for RETs, and some of the informants (UTI 7) highlighted the issue and pointed to the hurdles faced by the private sector:

We also should provide a financing mechanism for them to invest in the sector, and it should be easy to apply. It could provide mixed credit or soft loans that are more attractive than the existing commercial loans. There should be schemes targeted for home users to install solar PV systems on their rooftop. So that they could pay it back on a monthly basis and without requiring such a high initial investment. The red tape and administrative hurdles to connect to the system should also be removed. (UTI 7)

The government in collaboration with the World Bank is supporting a loan scheme for the private sector for investments in RETs (World Bank, 2014). An interviewee (UTI 6) noted that the project had been delayed because of the difficulty in obtaining roof space in Malé to install solar PV. The local businesses also find it difficult to secure internationally funded government projects to supply and install RETs. An interviewee from the private sector explained why they are not able to secure such projects:

The projects are awarded as bulk projects for the whole atolls, rather than for different islands. This makes it difficult for local companies to qualify for the projects because of the high financial requirements. So most of the projects are implemented by foreign contractors. (BUS 3)

These terms and requirements for the suppliers and service providers of the projects limit the scope for local businesses within the sector.

7.4.2. F2: Technology Transfer

SIDS are recipients of RETs developed in other industrial countries, therefore it is important to understand technology transfer. The study found that solar PV systems are easy to obtain, and that the businesses supplying solar PV systems cooperate with overseas suppliers to import the products.

Solar PV is widely considered as the RET of choice in the Maldives. Many interviewees observed that solar PV is readily available and easy to access for domestic, business, and utility scale installation. The increase in the international production of solar PV means there are several manufacturers and suppliers within Asia. An interviewee (BUS 7) noted that several suppliers are available in China and are willing to engage with local businesses on favourable terms by allowing them to start with purchasing a low quantity of products. Interviewees in this study observed the heightened ease of availability of solar PV systems:

It is not difficult to obtain the technology from overseas. Some of the largest suppliers of solar PV and wind turbines are in China, and it is easy to trade with them since they are willing to supply even a small quantity. So many solar PV products are imported from China. (BUS 7)

Solar PV products are readily available on the Internet, and you can find the suppliers easily with a Google search. However, if you use established local businesses, it is also easy to find sales and maintenance services. (UTI 1)

There are a few RET suppliers and service providers in the Maldives, but many of them have already established ties with overseas manufacturers and suppliers of solar PV products. Maldivian businesses have also started to attend international trade fairs on RETs:

Now it is easy to obtain the technologies. Many are reliant on Chinese companies. We meet with the suppliers at both Dubai and German trade fairs. Maldivian businesses in this sector also attend these fairs. We obtain the contacts through the Internet or by visiting the trade fairs. (BUS 5)

The local businesses are also able to obtain warranties for the products. At least one business in the sector has formal co-operation with an international manufacturer of solar PV and has implemented solar PV projects in the country.

Local businesses acknowledged that access to the technology is not a major concern, but it is difficult to buy them in the outer islands. An interviewee argues, “Renewable energy technologies need to be available from different locations within the country, and not only within the capital, Malé. At the moment, all the businesses are based in the capital (GOV 3)”. Market size limits the location of suppliers, but another interviewee (GOV 4) within the government also identified the importance of expanding the reach of RET service providers:

There need to be more distribution centres for solar PV systems. So people can easily purchase them and install them on their rooftop the next day. That mechanism should be provided by the government or the utility companies or by private businesses.

There are also challenges in obtaining the most recent technologies introduced to the market. An interviewee from the business sector (BUS 5) shared the challenges in obtaining the most recent technologies that are introduced to the market:

There is a range of technologies available in the international market. We may be using some of the old technologies now, but we need groundbreaking new technologies that enter the market such as Tesla’s battery backup. However, we do not know when these technologies will be available in the Maldives. (BUS 5)

Many products are relatively easily available from the international market, but some of the engineers emphasised the importance of ensuring the quality of those products. Since solar PV systems are bought for long-term use, the quality and performance of the system may not be evident within a few years. So, it may take more time before many of the local customers are certain about the quality of these products, particularly when the products are not purchased from well-established sellers.

7.4.3. F3: Knowledge Exchange

The analysis of knowledge exchange is important in understanding the activities that are present to support the exchange of information about the technology. Knowledge exchange is not only about creating awareness of the technology among the public and with other stakeholders but also about improving understanding of the technology and its potential.

The study found that there is a lack of exchange of information about RETs and dissemination of information about rules and regulations and opportunities in the sector. The limited avenues in the form of workshops, seminars, or product fairs promoting RETs, and the lack of local research supporting RETs, contribute to the lack of knowledge exchange. These issues are further explained below.

The lack of exchange of information is limiting dissemination of information across the actors. For instance, there are different opinions on the level of savings from RET installation for an electric utility. An engineer (UTI 10) argued that theoretical savings are not achieved in practice, citing that generators must be still operated and they are not able to increase the efficiency of the generators. These doubts are further instilled in the sector because of the absence of sufficient data to demonstrate the level of savings from existing installations.

An electric utility official (UTI 6) explained that they do not have the time and resources to analyse the savings from their existing installations and to evaluate the benefits. There is not much of a sense of urgency or sense of a need to obtain the data and evaluate it in order to understand the cost and financial benefit of solar PV projects.

Formal interactions in the forms of workshops, seminars or product fairs play an important role in exchanging information. These gatherings and avenues provide an opportunity to exchange information in multiple directions. In this study, many interviewees emphasised the importance of creating awareness and the lack of information about RETs in the sector. However, there is little effort to improve the exchange of knowledge among stakeholders. Some of the important stakeholders are not clear about the regulations on connecting RETs, and about the Net Metering Regulations 2015.

There have been few events showcasing RETs and promoting renewable energy. RETs are not on display nor targeted in local trade fairs. An informant (BUS 10) from the tourism sector noted the omission of RETs in tourism trade fairs:

There are some resort sector exhibitions in the Maldives to introduce different products, but there is no emphasis on the electricity sector. There is also a trade fair and boat building fair every year, but renewable energy technologies are not showcased in these fairs.

The absence of these products in trade exhibitions for the tourism sector is partly because of the limited interest from the resort sector. The lack of activities to support knowledge exchange suggests that the sector is in an early stage of development, where the number of players and the interaction among the players is limited.

There is a lack of local research supporting RETs and of involvement of academic institutions in the electricity sector. It is easy to access solar PV technologies, but there are not sufficient attempts to explore other potential technologies. There is no active search to understand the optimal renewable energy resources within the country and how these can be utilised more extensively. The local research institutes are at an infant stage and are not tied to the electricity sector and are not exploring means to support the sector. It should also be noted that there is a lack of research in other industries. The lack of research could be attributed to the lack of trained people and the absence of policy priority.

7.4.4. F4: Guidance of the Search

Analysis of the guidance of the search function provides an understanding of how the government direction in respect of RETs has been formulated and communicated to the stakeholders. The government's targets and policies with respect to the sector give signals to other stakeholders including private businesses to formulate their business targets and to allocate resources accordingly.

Formulating targets and policies specific to the sector and communicating those targets to the stakeholders is one of the important aspects of this function. Government plans, foresight studies, government targets for the industry, estimates of future growth of RETs, and regulatory pressures applied on service providers are important sources of information to determine the guidance of the search function.

The analysis of the guidance of the search function found that there is an absence of strong policies to support RETs and that RETs are considered a supplementary means to provide electricity services.

The Absence of Strong Policies to Support RETs

The national development plans continue to mention the ambition to reduce dependency on fossil fuel, but these have not been followed up with appropriate strategic action plans and sufficient resources. Energy transition to renewable energy has not been made a national policy priority and there has been a lack of strong policies to support RETs.

In 2009, at the UN General Assembly, the first democratically elected president of the Maldives announced his intention to become carbon neutral within 10 years (MHE, 2010). The government also formulated a national energy policy and strategy, reaffirming its policy to achieve carbon neutrality in the energy sector by the year 2020, and developed a policy to promote renewable energy technologies (MHE, 2010). The ambitious goal helped to create urgency and prioritised the transition to RETs. It also interrupted some of the ongoing diesel-based generation projects, but the subsequent governments have changed the goals and reduced the targets.

The carbon neutrality goal was changed to a less ambitious goal to reduce unconditionally 10% of the GHG by the year 2030 and to increase it up to 24% in a conditional manner (MEE, 2015). In addition to downgrading the more ambitious renewable energy targets, there are no policies to introduce RPS, nor to mandate electricity service providers to incorporate a designated amount of RETs in their generation. The policy change had an overall impact on the service providers' impression of their obligations. An interviewee from the government unofficially stated that the previous target was unrealistic, and the renewed ones are achievable. The subsequent administrations maintained that there had not been a change in the commitment of government towards incorporating more RETs.

Nevertheless, the current government's initiative to explore the availability of fossil fuels in the Maldives is seen as an effort that reduces the priority given to renewable energy goals. The government defends the initiative to explore for oil as an economic development effort. Even though there has been a study on the availability of fossil fuels, there is not sufficient information about the availability and the economics of extracting it yet.

The absence of electric utilities' policies and strategies for incorporating RETs is also affecting the scope and potential for other important actors within the energy sector. An informant (BUS 9) from the business sector emphasised the need to clarify the position of electric utilities in adopting RETs:

When there is a new technology that affects the status of the existing players, then the role of the players should be defined, and they should be able to see their role in the new context, otherwise there will be resistance from the existing service providers.

Electric utilities are seen to be hesitantly welcoming the installation of solar PV systems to the electricity grid. The utility companies are struggling to balance their interest in promoting RETs and the loss of revenue from the private sector if there is a large installation of RETs by the private sector.

The Net Metering Regulation 2015 was introduced to support the installation of RETs and increase their usage. However, many domestic consumers and renewable energy businesses claim that it is creating the opposite result. The regulation came into effect in 2015, at a time when a government-initiated solar PV project targeted to install solar PV systems in all the inhabited islands was underway. The project was designed to install solar PV to meet up to 30% of daytime peak for each island. The Net Metering Regulation 2015 also allows only up to 30% of daytime peak capacity of the intermittent source to be fed into the electricity grid. As a result, in many islands, there is no additional capacity available for residential consumers to install solar PV systems. An interviewee (BUS 9) from the business sector involved in providing RETs argues that the regulation has slowed down their business:

We are approached by individual customers and business customers who are interested in installing solar PV in different islands, including Addu City, but the barrier now is connecting those systems to the grid. So, we are not able to go ahead with the projects.

The introduction of the Net Metering Regulations 2015 has also resulted in disconnection of some of the solar PV systems that were connected to the grid. An interviewee from an electric utility (UTI 2) explained that those systems were disconnected because they were not registered or approved by the utility in the first place. The domestic users were instructed to follow the new regulations to connect their solar PV system to the electricity grid.

RETs Considered as Supplementary

The electric utilities prefer to invest in diesel-based generation systems to meet the growing demand and to increase generation capacity. RETs, such as solar PV systems, are mainly considered as a supplementary system to existing generation because an additional source is required for continuous supply of electricity. Some of the officials from electric utilities suggest that it may not be possible to deploy 100% RETs in the Maldives since the main RET available in the Maldives is solar PV which is an intermittent source of electricity. Additionally, when there is no sunshine, or at night, an alternative source, ideally diesel generators, are still needed. Hence, solar PV needs to be installed as a hybrid system or along with energy storage.

The electric utilities argue that they already struggle to raise capital for diesel-based generation systems. Hence, seeking additional investment for a solar PV system is difficult. However, these additional investments in solar PV help to reduce electric utilities' operational costs, and increase the time required for additional investment on diesel generators. This is because solar PV can contribute to supporting the day's peak demand. Electric utilities often increase generation capacity to meet the day's peak demand, which often falls at midday, when solar PV output is at its best. Interviews with officials from electric utilities indicate that the cost-benefit calculation of incorporating battery backup for a solar PV system is not often undertaken, in order to understand the viability of operations at utility scale.

7.4.5. F5: Market Formation

This analysis of the market formation function attempts to understand the activities that reduce the cost of investment in RETs and their maintenance, and activities that increase ease of access to the market. Access to finance and schemes providing financial assistance can reduce the cost of investments and operations. Improving access to the electricity grid can improve access to the electricity market. This study found the electricity market is centred on electric utilities, and that there are limited initiatives to reduce the cost of investment in RETs and to improve access to the market.

There are two broad segments of the market for RETs in the Maldives: installation in buildings by residential consumers to reduce their electricity bill (through net metering), and installation for electric utilities and tourist resorts as a commercial activity to contribute to their generation capacity (through FIT or PPA). Businesses (the local RETs service providers) that sell, install, and maintain RETs play an important role in supporting the two types of consumers. The challenges with net metering, FIT/PPA, and the monopoly on the market held by electric utilities limit the market for businesses.

There are a few initiatives to reduce the cost of investment of RETs. However, the government's decision to remove import duty on items related to RETs has been welcomed by businesses even though individual requests have to be submitted for duty exemptions. The policy change has helped to reduce the cost of RETs. In the financial sector, only the Bank of Maldives provides a loan scheme (the Green Loan) targeted at renewable energy. However, the loan scheme has been of limited success because of the high interest rate and borrowing requirements.

The electricity market in the inhabited islands is monopolised by electric utilities. The regulations introduced to support the use of RETs, such as net metering and FIT/PPA, give the electric utilities significant authority in allowing private sector entry to the market. Electricity service provision in tourist resorts is managed by the resort operator, and there is very little scope for additional businesses. The resort operators have shown little interest in involving a second party in the provision of electricity service within the islands. The government's efforts in promoting the use of RETs is also focused on the inhabited islands.

The Net Metering Regulations 2015 were expected to improve the use of RETs and improve private sector participation in the sector. However, the regulations have had limited success so far in expanding the RETs market because of the limitations of the regulations. The two fundamental problems identified by business and electricity consumers are: the maximum cap of RETs that can be installed in each island and for any given electricity consumer; and restrictions on monetising from RETs connected to the electricity grid.

The Net Metering Regulations 2015 set a maximum amount of renewable energy from an intermittent source that can be fed into the system, which is 30% of the peak load. The cap aims to avoid disruption to the electricity grid. However, there are differences in opinion among engineers about the percentage it is set at. An interviewee (BUS 1) with an engineering background argues that 30% represents a conservative value. They argue that the amount of electricity fed into the grid could be increased, particularly by improving the distribution and system stability with an automatic synchronism system.

Engineers and businesses critical about the maximum cap argue that the conservative figure of the cap is to protect the interests of electric utilities. Informants from the government have also expressed the importance of protecting the financial interests of electric utilities on the grounds that the electric utilities have already made investments in diesel-based generators to meet the electricity demand of the islands and will need to make an additional investment to meet the growing demand. The service provider will also have to supply electricity when the customers cannot meet their energy demand such as at night or when the weather is not good. A senior official from an electric utility (UTI 10) also argued that, for security purposes, it is important that the government utility maintain the majority of the generation capacity, and that it is not transferred to the private sector.

In financial terms, solar PV installation by a large number of customers is likely to affect the revenue of the service provider. An interviewee (GOV 2) from the government explained the purpose of the Net Metering Regulation 2015 which was to create a means to reduce customer's electricity bills and not to create a mechanism to monetise from the installations:

There is a limit on the capacity of the solar PV system that individual consumers can install. It aims to avoid payment for the excess amount fed into the grid. The scheme does not allow for oversized installation and making payment for the excess amount.

The excess electricity fed into the grid is deducted from consumers' electricity bills, and the electric utility charges the consumer for the difference consumed. By limiting the capacity of consumers' installations, the consumer will be using more electricity from the electric utility than they can feed into the electricity grid.

The utilities have yet to find a mechanism to balance their interest in promoting RETs by engaging the private sector and maintaining their financial interest. When a senior official from an electric utility (UTI 1) was asked how to overcome the challenge, he acknowledged that they do not have a strategy to address the issue but proposed the utility service providers incorporate RETs on their own:

I don't know how to overcome the issue. If the service provider opens up installation, it will result in a sharp fall in revenue for electric utilities. However, if the electric utility installs solar PV on their own, then it may not be a problem.

Businesses argue that the upper hand held by the electric utilities reduces their scope of engagement and business in the sector. Additionally, there are administrative barriers that limit the process of installing solar PV systems within the current Net Metering Regulation 2015. The current process is described as unclear and cumbersome:

After sending the line diagrams, sometimes we need to call them and explain these. The utility companies provide little assistance in completing the forms. They simply say the forms are incomplete, and it is difficult to find help, but they are also the approving agent. The process to connect an installation to the grid is also difficult, and unclear. After getting approval from one place then we must take it to another place. There is no agreement on how the connections to the grid should be made. (BUS 9)

Some of the interviewees from the businesses sector argue that the monopoly status of the electric utilities and their ownership of the electricity grid is giving electric utilities an undue advantage, and some have even called to unbundle the services. However, interviewees from the government have not indicated that there are any plans for such a structural change.

7.4.6. F6: Resource Mobilization

Analysis of the resource mobilisation function improves understanding of the physical, human, and financial resources available to support the use of RETs. The resources may be in the form of: infrastructure development to support the transition of existing generation facilities to RETs; human resources development to develop the necessary skills for the sector; or financial resources to incentivise investment and entry to the RETs sector.

This study found that there are insufficient incentives to transition to RETs and to enter the RETs market. It also found that skill development is weak and does not enable development of the necessary skills for the sector.

Insufficient Incentives

Access to finance and availability of finance is one of the most significant challenges in increasing the use of RETs. There are a few competitive financial schemes within the country that are willing to lend for investments in RETs. Bank of Maldives is the only bank in the Maldives that has a scheme targeted to support renewable energy:

It is very difficult to obtain funding for renewable energy projects. The only scheme we know of is the one offered by the Bank of the Maldives, the Green Loan scheme. However, the scheme is also not so attractive because of the loan interest rate, even though it is lower than the commercial rate. In addition to that, the borrower has to mortgage their properties and has to demonstrate that they have a certain percentage of the capital. So, there are not many opportunities for raising finance for projects.
(GOV 3)

An informant (UTI 7) argues that the stringent terms and conditions attached to the loan make it almost the same as obtaining another commercial loan. Many interviewees argue that the government should initiate schemes and programmes to make it easier and less costly to access funds to invest in the sector.

Interviewees from the business sector indicate that electricity consumers would be willing to install a solar PV system in their buildings if it could be paid on instalment basis. However, the businesses explain that they do not have the financial capacity that would enable them to support individual customers. An interviewee (INS 2) from an NGO explained that instalment payment schemes have already worked in the islands where the

government wants to promote a certain product. The interviewee provided an example where the government distributed large water tanks to households who were willing to pay for them on an instalment basis. The project was a success with a large uptake of the water tanks. An interviewee (UTI 11) from an electric utility also acknowledged that an easy payment plan would interest electricity consumers in installing a solar PV system as this had worked in other countries, and said electric utilities could initiate a potential scheme:

We could start a scheme to install solar PV systems on consumer buildings, and electricity consumers could pay the utility back on a monthly basis by deducting the payment from what is being fed into the grid. For example, in Sri Lanka, to promote energy saving, they distributed energy saving bulbs and charged the customers the cost on an instalment basis through their electricity bills. So that is an arrangement we could do for solar PV.

Nevertheless, the interviewee noted that they do not have a plan at the moment to introduce such a scheme. Many interviewees noted that the electric utilities are struggling to accommodate solar PV systems through the Net Metering Regulation 2015 as well. An interviewee (UTI 8) within the electric utilities, who advocated for higher participation of the private sector, also proposed to introduce a two-metered system instead of net metering:

I think there should be two rates for the purchase and sale of electricity from diesel and renewable energy. If we want to increase public interest in the sector, the sales rate for renewable energy should be higher than that from diesel.

In net metering, the customer's electricity meter can measure the flow of electricity in two directions. It can read how much electricity comes from the electricity company, and how much unused renewable electricity the customer, who generates their electricity from RETs, feeds back to the grid. The electric utilities bill the consumer for the excess amount consumed. The home-based solar PV system would be more economically attractive if electricity generated from solar PV could be sold at a higher rate than the rate sold by the electric utility. However, such a change could increase the cost of electricity provided by electricity service providers.

As well as insufficient incentives, there is also a lack of regulatory pressure and drive to push electricity service providers to incorporate more RETs in their generation. An engineer (BUS 2) from the private sector argues that the easiest way to increase the diffusion of RETs is for the government to provide regulations that the resort sector generate a designated amount of their electricity from RETs. However, there are challenges in introducing such regulations in the tourism sector, especially when they are not applied to the electric utilities.

Skills Development is Weak

Education and training institutes within the country are not focused on developing technical skills and on training engineers. The training institutions do not have the formal ties with electric utilities and the electricity sector that would enable them to identify the sector requirements and train people to meet the market need.

The unavailability of trained people, especially in the outer islands, affects the speed at which some of the technical issues can be resolved within the islands. Most of the engineers and technical people are based in Malé, and sometimes they must travel to the outer islands to resolve simple issues. A senior official from FENAKA explained the challenges that they have because of skill shortage within the sector:

We operate powerhouses in 153 islands, and the biggest challenge for us is the unavailability of technical people within the islands. Solar or diesel-based generators are based on the islands, and we have technical people in our head office in Malé. So, we need trained people stationed on the islands.

The lack of trained engineers has increased demand for engineers particularly at tourist resorts, and the electric utilities struggle to offer the same benefits to staff and maintain the trained people. The same interviewee from FENAKA also explained the challenges they have in keeping the trained people within the islands:

Trained people also move workplaces, so we need to replace them with skilled people. Some of our staff move to work in the resorts as they can offer a better pay than we can. This is a common issue for people trained in all the sectors, including those trained for the sewerage system or water desalination.

In addition to the lack of training opportunities within the country, some engineers argue that the benefits offered to technical people are not attractive enough to encourage more people to join the sector and to obtain training.

7.4.7. F7: Creation of Legitimacy

The creation of legitimacy function analyses the attitude towards RETs, and their acceptance within the energy sector. Legitimacy is affected by international developments as well as local developments that affect the policies, level of international support, cost, technological performance, and awareness with respect to RETs. The role of the actors supporting RETs and their collective action is also an important aspect of improving the legitimacy of the technologies.

This study found the acceptance of RETs, particularly of solar PV, has improved in the Maldives. The interviewees for this study discussed a range of issues that they believe have contributed to the recent increase in generation capacity of RETs in the Maldives. The following five factors have contributed to the improvement in legitimacy and acceptance of solar PVs: the improvements in government policy; donor assistance; solar PV economics; confidence in solar PV; and improvements in awareness about the technology. However, the renewable energy sector is still at an early stage of development, and there is minimal collective action within the electricity sector in general. The above-mentioned five factors and the issue of collective action are further discussed below.

Government policies have been the most instrumental in achieving the current level of generation capacity of RETs. The first democratically elected government in 2008 showed renewed interest in renewable energy and announced a bold policy to transition the country to carbon neutrality by the year 2020. The policy was followed by a strategic action plan to increase the use of RETs. Subsequent governments did not maintain the carbon neutrality policy; however they maintained the efforts initiated by the previous government and supported renewable energy initiatives.

Support from development partners in installing solar PV systems as demonstrative projects was also an important step. Some of the interviewees argue that this may have been the most important input to the sector: “International assistance is the main factor that has contributed to the current level of achievement in installing renewable energy in the Maldives” (GOV 4). International support is also associated with the increase in global action to address climate change and the increase in financing for environmental mitigation: “I think the role of climate change and the international effort to address the problem has contributed to the renewable energy projects that are now implemented in the country” (GOV 3). International donor support has initiated RET projects, but there is reliance on donors to support additional RET projects.

Improving solar PV economics is making it an economically attractive option to install it on consumers’ buildings to reduce their electricity bill. It has also started to generate electricity at a competitive rate compared to diesel-based generation (see Figure 2.3). An informant (BUS 9) from the business sector providing RETs explained that the cost of solar PV has reduced over the years and it is becoming economically more attractive:

Until the last 5 or 3 years, the cost has been a factor for solar PV because it was expensive. The high initial investment must have affected people’s interest in the technology. However, now the investment cost or the installation cost is not so high.

Our customers who have installed solar PV systems are starting to see the benefit of the technology. The installations are helping to reduce their electricity bill. When we started the business, the payback was 5 to 6 years, but considering the current prices and the electricity rates now its easily one and a half years to 3 years.

The increase in fuel prices and electricity tariffs has also helped to make solar PV systems economically more attractive. The high electricity bills forced many people to explore other means to reduce their electricity costs. However, the high initial investment still acts as a deterrent.

The confidence in RETs was affected by the failure of the wind turbine project in Haa Alif Uligamu island. The project created a negative impact on the perception of RETs in the Maldives. Many participants in this study have cited this project as an example of the reliability issues of the technology. An interviewee (GOV 4) with knowledge of the project explained that the issues in this project did not only pertain to RETs, and that the acceptance of solar PV has improved, unlike acceptance of wind turbines:

As for now, we do not see anything wrong with solar PV systems. An initial renewable energy project using wind turbines implemented by the State Trading Organisation in Haa Alif Uligam failed because of problems with the battery system and the controls. The project created a false impression about renewable energy because many do not consider the reasons why it failed. However, solar PV systems are different, and they are good. (GOV 4)

The confidence in RETs is improving, even though diesel-based generation is still considered more reliable for uninterrupted electricity. An interviewee (GOV 4) argues, “Solar PV systems are not complex at all”, and they are easy to install. Even though the reliability of solar PV is high, it also requires user intervention from time to time, and this is problematic for some residential consumers in home-based installations:

When consumers use electricity from the utility, they do not have to think about the generation and optimisation of usage, and it is readily available. However, when you install solar PV and use power from the system, even though it requires low maintenance, it is not a zero-maintenance system, and you must intervene from time to time to manage the system. It can be like managing a child and you will have to take ownership of it. For some, this may not be possible and not a desirable thing. (GOV 4)

The grid-connected systems generally require much less user intervention than distributed generation systems. Consumers installing solar PV systems connected to the electricity grid through the net metering scheme can use electricity from the utility when the solar PV system is not operating.

Many interviewees argue that the increase in consumer interest in a rooftop solar PV system is related to the slow increase in awareness (e.g. BUS 5 and BUS 8) and to improvements in the economics of solar PV systems (e.g. BUS 9). There is still a lack of understanding about the financial benefit of a solar PV system and its investment returns. Many interviewees in the electricity sector provided a range of figures for the investment and return on investment. A top official from a utility company shared his experience of how an understanding of the benefits of solar PV systems is influencing others to install such systems in their houses:

I know of a family who is trying to install solar PV in Malé. They have a relationship with a family living in Sri Lanka who has benefited from the installation of solar PV in Sri Lanka. And that's why they are interested in installing solar PV on their rooftop in Malé (UTI 11).

As explained in section 7.3.2 (networks), there is minimal collective action from the actors within the electricity sector, and there is limited interaction among the government agencies, among government and other stakeholders, and among other stakeholders. No active effort is underway now to form an association and to represent the interests of the sector. Some of the informants from the private sector suggest that there are too few actors from the private sector to form an association. The lack of these efforts may be because the sector is at such an early stage.

7.5. Phase of Development

The development phase of the functional activities (whether they are at the formative phase, growth phase, or maturity phase) impacts the overall performance of TIS. It is easier to assess the performance of the system by analysing the development of individual functional activities rather than trying to assess the system based on a single measure. Assessment of the performance of individual functions also provides better insight into the operation of the system, and the interrelations between the landscape, structural activities, and functional activities.

In this section, the fourth step of the TIS analysis, the performance of the functions is analysed based on the development phase of the functional activities, and then on the dynamics of the functions.

7.5.1. Development Phase of the Functions

Two different aspects of the functions are assessed. First, the phase of development of the functional activities is assessed based on the analysis of section 7.4. Secondly, the perceived significance of barriers to functions, based on survey respondents' assessment of different barriers associated with the functions, is assessed.

The phase of the development of the functions informs how well the functional activities are performing to support the overall system performance. The development phase of the functions are not inferred based on a quantitative measure, but it is a judgement based on the interviewee responses related to the performance of the functional activities. Table 7.2 shows factors inducing and blocking the performance of the functions based on the analysis presented in section 7.4.

Table 7.2: Factors Inducing and Blocking the Performance of the Functions

Inducing Factors	Blocking Factors
F1: Entrepreneurial Activities	
	Policy and regulatory restrictions Difficulty in accessing finance Restrictions on local business to obtain government initiated RET projects
F2: Technology Transfer	
Solar PV systems are easy to obtain Local businesses have sufficient cooperation with overseas suppliers	Challenges in obtaining most recent technologies
F3: Knowledge Exchange	
	Limited avenues to promote RETs Lack of local research supporting RETs
F4: Guidance of the Search	
Policy initiatives supporting RETs	There is the absence of strong policies to support RETs are considered a supplementary means to provide electricity service.
F5: Market Formation	
	The electricity market is centred on electric utilities Limited initiatives to reduce the cost of investment in RETs and to improve access to the market
F6: Resource Mobilization	
	Insufficient incentives to transition to RETs and to enter the RETs market Skill development is weak to develop the necessary skills for the sector
F7: Creation of Legitimacy	
Improvements in government policy Donor assistance Solar PV economics and confidence in solar PV Improvement in awareness about RETs	There is minimal collective action within the electricity sector

The assessment of the inducement factors shows many factors are supporting the functional performance of function F2, F7, and F4. Meanwhile, all the functional activities have a number of blocking factors that are hindering the performances of the functions. On the basis of these inducement factors and the performance of the functions, the researcher observes that three functions (F2, F7, and F4) have started to show some progress in their development, while all the remaining functions are still at their formative phase. The function at the most advanced stage of development is F2 (technology transfer), followed by F7 (creation of legitimacy). The function F4 (guidance of the search) has started to show improvements even though it is at the formative stage of development just like the remaining functions.

The analysis of functions on the basis of different barriers can provide additional information about respondents' perceptions of the development phase of different functions. In order to understand how respondents perceived the barriers to the performance of the functions, the list of barriers used in the survey questionnaire is categorised into seven functions (see Table 5.8). The significance of the barriers to different functions was assessed by examining the mean score of the barriers. Table 7.3 shows the listing of the barriers under different functions, along with the mean score of the barriers and the ranking of the seven functions based on the perceived significance of the different barriers.

The analysis of the barriers to the different functions demonstrates that the barriers associated with F4 (guidance of the search) are viewed as being the most significant barriers to the diffusion of RETs. F4 is followed by F3 (knowledge diffusion) and F6 (resource mobilisation). The analysis of the functions based on the interviews in section 7.4 also demonstrates the significance of the three functions. The analysis of F4 in 7.4.4 reaffirms the significant role of the policy direction in the diffusion of RETs. There have been some initiatives within the government to improve the use of RETs with the formulation of a policy plan and investment plan for the sector. However, the performance of the function is not sufficient to support other related functions and to overcome associated barriers within the function. The three functions (F4, F3, and F6) are at a formative stage of development, while F4 has started to make progress with recent efforts from the government and is heading towards the developing phase.

Table 7.3: Ranking of Functions Based on Significance of Barriers

Function	Code	Short Description	N (No. of Respondents)	Mean Score	Mean Score	Rank
F4		Guidance of the Search			1.96	1
	B09	Lack of government plans	50	2.04		
	B10	Lack of regulatory obligation	49	1.73		
	B11	Administrative delay	49	2.06		
	B12	Lack of support from electric utilities	49	2.02		
F3		Knowledge Exchange			2.26	2
	B07	Lack of information by RETs	49	2.55		
	B08	Lack of trained people	49	1.96		
F6		Resource Mobilization			2.34	3
	B05	Lack of international aid to support RET projects	48	2.48		
	B16	Lack of government support schemes	49	1.94		
	B17	Government subsidies for fossil fuel based generation	49	2.59		
F1		Entrepreneurial Activities			2.40	4
	B01	Difficulty for the private sector to enter the market	49	2.22		
	B02	Lack of interest by private businesses to use RET	49	2.57		
F5		Market Formation			2.43	5
	B04	Lack of RET projects	49	2.55		
	B13	High Investment	49	1.71		
	B14	High maintenance cost required for RETS	49	3.02		
F7		Creation of Legitimacy			2.55	6
	B03	Perceived unreliability of RETs	50	3.46		
	B18	Lack of space to install RETs	49	2.18		
	B19	Lack of grid capacity and infrastructure	49	2.24		
	B20	Lack of recognition from business about the potential benefits	49	2.31		
F2		Technology Transfer			2.69	7
	B06	Lack of interaction between local businesses and international manufactures	49	2.57		
	B15	Lack of local suppliers of RETs	49	2.80		

The survey respondents for this study found the barriers associated with F2 (technology transfer) to be the least significant barriers for the diffusion of RETs, and F2 is followed by F7 (creation of legitimacy). The lesser degree of significance given to the barriers associated with F7 demonstrates that positive steps have taken place over the years in building confidence over RETs. Interviewees for this study also explained that there is relatively easy access to RETs, proving the barriers associated with F2 are less significant for the diffusion of RETs (as explained in section 7.4.2). The fulfillment of F2 compared to the other functions places it at the most advanced stage of development. There is increasing acceptance of solar PV for electricity generation because of its use over the years and because of the technological development of the technology. The technology has achieved increased legitimacy (F7) and is in the developing phase.

The survey respondents also identified the barriers associated with F1 (entrepreneurial activities) and F5 (market formation) as significant barriers, although not the most or least significant barriers. The difference of the mean score for the two functions (F1 and F5) are minimal. The two functions are among the least developed functions in the system. In order to fulfill these two functional activities, other functional activities that are perceived to be the most significant barriers should be fulfilled. Hence, it can be understood that the survey respondents have identified barriers associated with F1 and F5 as less significant compared to barriers associated with the more significant functional activities F4, F3, and F6. Those three functions are also important to activate and drive F1 and F5.

On the basis of the analysis, Figure 7.1 shows the phase of development and the perceived significance of the barriers to all the functions. The perceived significance of the barriers is ordered sequentially on the basis of respondents' perceptions of the barriers associated with different functions. The barriers to the bottom-ranked functions (F2 and F7) are perceived as having low significance, while the barriers to the top-ranked functions (F4, F3, and F6) are on the high end of the scale.

Figure 7.1: Phase of Development and Significance of the Barriers to the Functions

The development of the functions (movement from the formative stage to the maturity stage) and the interaction among the functions are important for the development of subsequent functions and the performance of the system.

7.5.2. Dynamics of the functions

Interaction of the functions and fulfilment of each function is important for the development and diffusion of technology. The positive development of the functions can result in self-reinforcing virtuous cycles supporting the functioning of the system, whereas self-reinforcing vicious cycles can hinder the functioning of the system. Examining the dynamics of the functions can explain the path to the current status of the system and illuminate a potential path to activate the remaining functions.

Based on the research data, the study has been able to identify the role of different functions that have led to the current achievements. The study also explored the potential path to activate and improve the performance of the remaining functions of the system. The current performance of the functions in the Maldives shows that the system is still at the formative phase. In order to move to the maturity phase, where there is active performance of the private sector, the performance of a number of functions should be accelerated and pass through a growth phase by incentivising the market. In addition to different stages of development of the functions in the system, the analysis also demonstrates the interaction between the functions. This is important in order to understand the sequence of actions that are taking place within the system, and the course of actions that could be taken to activate a particular function or to overcome the barriers to the development of a function.

The seven functions and their interaction at present are shown in Figure 7.2. The active functions in the current phase are determined based on the development phase of the functions (see section 7.5.1). The interactions of these functions are inferred from interview data and researcher's judgement of the current activities in the electricity sector. The active functions are represented by the shaded circle. The active interaction of the functions is denoted by a solid black arrow, while the dashed arrow depicts the weak interaction of the functions.

Figure 7.2: Functional Patterns at the Formative Phase

The TIS of RETs in the Maldives is currently at the formative stage. The analysis of the perceived significance of the barriers to the functions demonstrates that the role of government (F4) is instrumental in activating the functional patterns of the system. In the case of the Maldives, the external factors, as explained in section 7.2.3, have contributed to activating the role of F4. External developments have been instrumental in activating the government's policy direction (F4). The government's policy initiatives supporting the use of RET's, and national targets to achieve RETs, had an important impact on improving the legitimacy of RETs (F7). There are other potential factors that are not related to the functional activities that might have contributed to the improvement in the legitimacy of RETs, such as general development and international trends. Figure 7.2 shows only the interaction of the functional activities, but the potential impact of external factors is not depicted in this figure.

The development of F7 (creation of legitimacy) can also be attributed to external developments, and the support received from development partners in demonstrating RETs and initiating pilot projects. The acceptance of solar PV systems (F7), and also particular external developments, have allowed improving technology transfer (F2). The particular external developments were a decrease in the cost of the technology, and improvements in the performance and availability of the technology in the international market. These three functions (F4 – guidance of the search, F7 – creation of legitimacy, and F2 – technology transfer) are directly influenced by external developments, and the three functions are also crucial to kick-off and activate the remaining functions. The use of landscape in this study has helped in understanding the influence of the external factors on the established functions used in TIS studies.

The analysis of the functional activities indicate, development of the three functions (F4, F7 and F2) has helped to start interactions of the functions with some of the other functions, even though they are weak (F4 – guidance of the search to F5 – market formation, and as a result, F5 – market formation to F1 – entrepreneurial activities, and F2 – technology transfer to F3 – knowledge exchange). This process can activate the remaining functional activities and advance the development of TIS.

The government's energy policy, national RET targets, and the introduction of net metering and FIT have to some extent initiated the market mechanism (F5). However, the interaction has been weak as represented with by the dashed lines in Figure 7.2, and the policies and the regulatory mechanisms are not effective and have only been partially implemented. Hence, the performance of F5 has not increased, and the interaction between F4 and F5 is denoted by a dashed arrow in Figure 7.2. Small improvements in the market mechanism have helped to initiate entrepreneurial activities (F1), but the level of activities and the significance of these activities is also weak. The improvements in technology transfer have contributed to exchange of information about the technology (F3), however the process is slow and not significant. This weak interaction of F2 and F3 is represented as being in the formative stage by a dashed arrow in Figure 7.2.

The potential path and functional patterns at different phases of the development of TIS in the Maldives are depicted in Figure 7.3. As in Figure 7.2 the active interactions of the functions is denoted by a solid black arrow, the dashed arrow depicts the weak interaction of the functions. The long dash dot double line arrows show the ongoing interactions from the previous phase. The activation of the functions and the interaction of different functions at the next two stages of development are inferred from interview data on efforts required to develop the sector and the researcher's insight to the functioning and interaction of different functions.

Figure 7.3: Potential Path and Functional Patterns at Different Phases

The market should be incentivised (and pass through growth phase) to progress from the existing formative phase to full-scale functioning of the remaining functions of the system and to improve private sector participation (reach maturity phase). The system functions have not been performing sufficiently to incentivise the market, and the system is limited due to the poor performance of market formation (F5), resource mobilisation (F6), and knowledge exchange (F3). Government efforts to support the market have not been sufficient (F5), there are limited means of obtaining finance for the sector (F6), and there is still lack of information about the performance of the technologies and a lack of human resources to support the sector (F3). In the growth phase, these three functions (F5 – market formation, F6 – resource mobilization, and F3 – knowledge exchange) should be improved while maintaining the achievements of the formative phase. Hence, the weak interactions in the previous phase (F4 – guidance of the search to F5 – market formation, F5 – market formation to F1 – entrepreneurial activities, and F2 – technology transfer to F3 – knowledge exchange) should be strengthened.

The role of policy direction and policy priority (F4) is important at this phase to activate the allocation of resources (F6) to activate the market. In addition to favourable regulations supporting the entry of RETs into the market (F4), financial incentives are important to activate the market mechanism (F5). These actions can be initiated with government initiatives.

Some of the interactions work in both directions to reinforce the development of the functions (e.g. F2 – technology transfer and F3 – knowledge exchange, and F3 – knowledge exchange and F4 – guidance of the search). Availability and the use of technologies (F2), and the government initiatives supporting the interaction of the stakeholders and efforts in building capacity within the sector, can improve knowledge exchange (F3), and these exchanges can feed back to the two functions. As the understanding of the technologies improves, and information about the availability of the technology increases, technology transfer (F2) improves. Improving knowledge exchange (F3) can also improve policy makers' understanding of the potential of the technologies and their applicability to generating electricity, and this can create an impact on the policy direction (F4). These improvements in knowledge exchange (F3) again contribute to improving the acceptance and legitimacy of the technology (F7).

Improving the role of entrepreneurial activities (F2) is important to increase private sector participation, and to reach the maturity phase of the TIS. Previous studies on renewable energy in the Maldives have also identified the lack of private sector participation in the energy sector. The role of private sector involvement is dependent on the fulfilment of a number of functions. The absence of those functions and their weak performance have slowed the progress of entrepreneurial activities. To reach the maturity phase, the achievements from the previous two phases (formative and growth) should be maintained. The direct interactions from all the functions towards F2 (technology transfer) are also important for the growth of the system. The ease of access to technologies (F2), the acceptance of the technologies (F7), and the interaction of the two functions, also feeds back to the progress of entrepreneurial activities (F1).

This analysis of the path of the functions and their interactions demonstrates a sequence of actions taking place in activating the functions. To achieve the full performance of the system, the role of the entrepreneurial activities should be achieved but this is dependent upon the progress and fulfilment of the remaining functions. The innovation system occurs over time, and the fulfilment of the functions is cumulative.

7.6. System Failures

This analysis of system failures will improve understanding of the causes of the poor performance of the functions. In order to improve understanding of the poor performances, the inducement and blocking mechanisms of the TIS need to be examined. There are forces that support and block the performance of the functions. These forces can be the result of an impact from the landscape or structural factors. Analysing the impact of the landscape and structural factors on different functions demonstrates the system failures within TIS.

In this section, the fifth step of the TIS analysis, first the inducement and blocking mechanisms on the functional activities are examined, and then the impact of landscape and structure on separate functions are analysed to understand the system failures within TIS.

7.6.1. Inducement and Blocking Mechanisms

The analysis of the functions in step 3 (section 7.4) explained the different factors associated with the functional activities of the TIS. The current performance of the TIS in the Maldives encounters several barriers in achieving the performance of functions. These challenges can be described as blocking mechanisms that obstruct achievement of optimal performance of the functions. There are a few drivers that are trying to overcome those barriers and to achieve the performance of the system. These drivers are described as inducement mechanisms that attempt to overcome the blocking mechanisms associated with different functions. Figure 7.4 shows inducement and blocking mechanisms for RETs in the Maldives.

Figure 7.4: Inducement and Blocking Mechanisms for RETs in the Maldives

The performance of the functions is blocked by a range of factors as identified in the analysis of the functions (see Table 7.2). On the basis of the performance of the three functions (F2, F7, and F4), and the factors associated with them as summarised in Table 7.2, the inducement mechanisms have been identified as external developments, policy initiatives, and improved acceptance of RETs. External developments contribute to the development of the three functions (F2, F7, and F4), while improved acceptance of RETs is also contributing to F2 in addition to F7. However, these functions also have several factors blocking their potential performances as seen in Figure 7.3. These blocking mechanisms are stronger than the current drivers that are pushing the system forward (the inducement mechanisms).

The inducement and the blocking mechanisms that impact the performance of the functions are also associated with the landscape and the structural elements of the TIS system. In this study, the availability of data on solar PV showed prominence of factors related to solar, but these might be relevant beyond solar energy. An analysis of those factors will provide better insight into the structural failures within the system.

7.6.2. Impact of Landscape and Structure on Functions

Landscape and structural components of the system have an impact on different functional activities. These factors are respectively analysed below to understand their impact on different functional activities.

Table 7.4 summarises the impact of the landscape on the structure and different functions within TIS. The table has only listed most of the significant functions that are associated with the factors related to landscape. The impact of the landscape may be indirect and interrelated with the other functions as well, and those relationships may not be simplified. Only the most evident functions are listed in Table 7.4.

As an overarching aspect of the TIS, the landscape has an impact on the structural elements of the TIS, particularly the economic and social development and the external development aspects of the system. As a developing country with limited financial and human resources available to support the sector, the government plays a significant role, and there is reliance on the government to initiate interaction among actors and to support the development of the sector. The institutions are not well developed to support the sector since they are at an early stage in their own development. There is also reliance on external assistance for funding, introducing technologies, and facilitating exchange of information.

Table 7.4: Impact of Landscape on Functions

Natural Resource Endowment	
F4	Policy directions are formulated in consideration of available (or explored) resources and are largely focused on solar PV.
F7	The natural climate has made it attractive to use solar PV and has contributed to the increase in usage of the technology.
Economic and Social Development	
F4	The lack of both financial and human resources limits the drive to raise the use of RETs among the most important policy issues.
F6	The lack of national funds and resources limits the government's capacity to allocate resources to the sector. The lack of skilled professionals in the sector limits the availability of support for policymaking. The lack of technical people also limits the support available for operation and maintenance of the technologies.
Actors	The government companies play an important role in the economy, and the government has a significant role in the sector.
Networks	The interaction of the actors is not developed because of the lack of initiatives from the government and the absence of a system to facilitate interaction.
Institutions	Institutions are not well developed to support the RET sector. The sectors rules and regulations are at an early stage.
External Development	
F2	Reduction in the cost of solar PV and the increase in manufacturers and suppliers of the technology has facilitated the availability of the technologies in the Maldives.
F4	The international focus on global climate change and the introduction of a funding mechanism to address mitigation has helped to increase the priority given to RETs in policy.
F7	The demonstrative and pilot projects initiated by international development partners have helped to improve the legitimacy and acceptance of the technologies.
Actors	There is dependence on international development partners for funding for RET projects.
Networks	Development partners have supported the government in knowledge exchange through seminars, workshops and site visits to countries where RET projects are implemented. These exchanges facilitate interaction with government officials and foreign counterparts.
Institutions	Development partners have contributed to the formulation and implementation of regulatory frameworks such net metering.

The natural resource endowment directly impacts the performance of the functions as well. The favourable climate and the availability of sunshine most of the year have contributed to the acceptance of solar PV in the Maldives (F7). However, unavailability of renewable sources to provide baseload for electricity generation without a battery backup has limited the range of renewable resources available for electricity generation (F7). Policy directions have been formulated in consideration of solar energy (F4), while other competing renewable resources have been less explored (F7).

The economic and social development level of the country limits the resources available for development projects including for projects investing in RETs (F6), and constrains prioritising development projects based on new technologies (F4). The lack of skilled professionals in the sector limits the availability of support for policy making and operation and maintenance of the technologies (F3).

External developments in the form of aid and support from donor and bilateral agencies have been important in providing demonstrative projects and exposure to new technologies (F7). Change in the cost of the technologies and the increase in the number of manufacturers and distributors have also contributed to making the technologies more available within the Maldives (F2). The international focus on global climate change and the introduction of a funding mechanism to address mitigation have helped to increase the priority given to use of RETs in policymaking (F4).

In addition to the impact of the landscape on the structural factors and the functions, the structural factors also have an impact on the functions. Analysing these forces aids understanding of where the system failures are with the performance of individual functions. Table 7.5 summarises the impact of structural components on functions within TIS.

Table 7.5: Impact of Structure on Functions

Actors	
F1	The role of the government is significant in the sector, and there is limited scope for private sector involvement.
F2	The private sector is supporting the transfer of technologies.
F3	There is dependence on the government to initiate and support the exchange of information because of the dominant role of the government in the sector.
F4	Ambitious policy around improving the diffusion of RETs it not yet a priority for government.
F5	The dominance of electric utilities reduces space for the private sector, and there are weak initiatives to facilitate market growth.
F6	Attaching a national budget to the sector in order to improve the diffusion of RETs is not yet a priority for government.
F7	The support of government and electric utilities in incorporating the initial RET projects have contributed to the increased acceptance of the technologies.
Networks	
F1	There are weak efforts to improve the interaction of actors.
F3	There is reliance on the government to support knowledge exchange because of the dominance of the government's role in the sector.
F7	The acceptance of solar PV for electricity generation has improved but the role of the actors in raising a collective voice to support the sector has been weak.
Institutions	
F1	The rules and regulations in the sector favour electric utilities and the scope of the private sector is limited.
F4, F5	There is a lack of rules and regulations facilitating market formation and entry of the private sector to the market
F6	There is not sufficient institutional support to raise funds to invest in RETs.

Functions

F1 (entrepreneurial activities), F2 (technology transfer), F3 (knowledge exchange)

F4 (guidance of the search), F5 (market formation), F6 (resource mobilization)

F7 (creation of legitimacy)

External developments have contributed to pushing the policy direction. However, local initiatives embracing ambitious renewable energy policy have contributed to the initial steps in this formative stage. The above analysis of system failures suggests that the blocking mechanisms in the system are currently overriding the inducement mechanisms that support the performance of the system.

In the next section, the policy instruments applicable to overcoming the system failures and to supporting the performance of the functions are analysed.

7.7. Policy Instruments

In the previous steps of the analysis, the diffusion of RETs was analysed using TIS to explore the development of functional activities and their dynamics and the inducement and blocking mechanisms for the performance of the system. The analysis provided an understanding of the problems that are inherent in the system in the Maldives. The analysis also provided an understanding of problems associated with the landscape and the structural elements of the TIS. The purpose of analysing the policy instruments is to understand the policy measures that are available to overcome the blocking mechanisms in the system and to propose specific policy instruments to drive the diffusion of RETs. Insights from the above analysis are important in the design of policy instruments.

In this section, first the policy measures applicable to overcoming the blocking mechanisms are evaluated. Next different policy instruments are analysed based on the survey respondents' perceptions of the most important measures needed to drive the diffusion of RETs in the Maldives.

7.7.1. Overcoming Blocking Mechanisms

Analysis of the inducement and blocking mechanisms with respect to the diffusion of RETs in the Maldives in section 7.6.1 and illustrated in Figure 7.4 shows that there are limited forces supporting the performance of the system. The inducement mechanisms are driven by three specific factors: external developments, policy initiatives started by the government, and the improved acceptance of RETs. However, these drivers are not sufficient to overcome the blocking mechanisms associated with all the functional activities.

In addition to maintaining the current driving factors, a specific policy driver is needed to overcome each of the barriers associated with the functional activities of the system. Figure 7.5 illustrates different policy drivers targeted to overcome each of the existing barriers associated with the functional activities and to improve the inducement mechanisms.

In order to overcome the blocking mechanisms associated with the seven functions, this study suggests five sets of important policy drivers, based on the analysis of system failures. The suggested policy drivers are: policy and regulatory support for private sector participation; policy support in facilitating the interaction of actors; policies and obligations requiring the use of RETs; budget support to the sector; and prioritising technical training and human resource development. These drivers (as depicted in Figure 7.5) are derived from the review of the literature. Those policy measures drive against the identified blocking mechanism associated with different functions.

Figure 7.5: Policy Drivers to Overcome the Existing Blocking Mechanisms

In order to overcome the blocking mechanisms associated with F1 (limited business scope), F5 (dominant role of electric utilities), and F7 (minimal collective action), the policy and regulatory support for private sector participation should be improved. The lack of policy and regulatory support has been identified as a fundamental factor limiting the role of the private sector, and market formation. The improved role of the private sector also allows private sector actors to play a greater role and can potentially improve collective action to raise their concerns.

The lack of exchange of information (F3) and the difficulty in accessing the latest technologies (F2) are associated with the lack of interaction between the actors. These blocking mechanisms can be addressed through policy support to facilitate the interaction of actors. Improving the interaction of the actors will facilitate the transfer of knowledge, and can also improve the understanding and ties with foreign actors supporting RETs.

The absence of strong policies to support RETs and the view that RETs provide only a supplementary means of electricity generation (F4) have contributed to the poor performance of F4 (guidance of the search). Implementing ambitious policies to support the use of RETs and laws requiring the use of RETs are needed to drive the guidance of the search (F4) function and to activate its associated functions.

The lack of financial and human resources (F6) have reduced the performance of the resource mobilisation function. The proposed two policy drivers, budget support to the sector and prioritising technical training and human resource development, are important to improve the performance of the functional activities.

The broad policy drivers identified above which aim to overcome the blocking mechanisms can be further examined by understanding specific policy instruments that will be most effective in addressing those barriers.

7.7.2. Policy Instruments by Policy Types

In order to understand the importance of different policy instruments to overcoming the blocking mechanisms and to driving the inducement mechanisms, policy instruments are analysed based on policy types. The survey questionnaire used in this study allowed us to obtain insight from sector experts on the different policy instruments that they perceived as most important to drive the diffusion of RETs.

In order to assess the importance of different policy types in the context of the Maldives, drivers were grouped into four categories in the survey questionnaire: targets and obligations, investment incentives, market facilitation activities, and discouraging measures. The importance of the policy types was calculated using the mean score of all the policy instruments under each policy type. The mean score was used to rank the policy types in order of the importance placed on them by the survey respondents. Table 7.6 shows the ranking of policy types based on the importance given to different policy instruments.

Table 7.6: Ranking of Policy Types Based on the Importance Given to Different Policy Instruments

Policy Type	Code	Short Description	Mean Score	Mean Score	Rank
Targets and Obligations	P1	Instituting national targets	1.62	1.71	1
	P9	Government obligations on electricity service providers	1.80		
Investment Incentives	P2	Availability of loans	1.46	1.72	2
	P3	Availability of grants for RET projects	1.90		
	P4	Government subsidies for RET projects	2.08		
	P5	Tax incentives for renewable energy projects	1.58		
	P7	Availability of tariff incentives such as FIT	1.74		
	P8	Availability of tariff incentives such as net metering	1.54		
Market Facilitation Activities				1.76	3
	P10	Educating the public about the impact of fossil fuels	1.86		
	P11	Training people	1.44		
	P12	Improving interaction between local and international businesses	2.02		
	P13	Private sector access to grid	1.72		
	P14	Providing information about RETs	1.76		
Discouraging Measures	P6	Eliminating subsidies for fossil fuels	1.96	1.96	4

The analysis of the policy instruments according to different policy types indicates that the respondents identified targets and obligations, and investment incentives, as almost equally important policy types in supporting the diffusion of RETs. These two policy types are followed by market facilitation activities, while discouraging measures was ranked as the least important among the policy instruments. This analysis bundled a range of policy measures that fit into the policy category, and the importance that some individual instruments were given by survey respondents is not reflected in their placement in Table 7.6. For instance, respondents marked training people (P11) as the most important policy instrument among the list of drivers in the survey questionnaire. However, grouping it with the other policy instruments in the market facilitation activities category caused it to be displayed among the third most important policy type to support the sector.

The importance placed by the survey respondents on the top two policy types also coincides with the two most significant barriers that the respondents identified to the diffusion of RETs: high investment cost, and lack of regulatory obligations. The analysis demonstrates the importance of establishing targets and obligations and providing investment incentives to support the diffusion of RETs.

The discouraging measure, eliminating subsidies for fossil fuels, was among the least important of the policy instruments. This may indicate that initiatives to drive RETs are perceived as more important than policy instruments that discourage the continuation of current practices. However, before the survey was conducted, the government stopped an earlier introduced fuel subsidy, and many considered that there was no longer a fossil fuel subsidy in the Maldives and that this was not an applicable driver anymore.

This analysis underscores the significance of policy direction, in the form of instituting national targets and by introducing obligations on electricity service providers to incorporate a designated amount of RETs. At the same time, facilitating investment incentives are instrumental in driving the diffusion of RETs.

The analysis of the policy priorities in chapter 6, and the analysis of policy mechanism in this chapter reaffirms that there are common pressing drivers to support the diffusion of RETs. The policy priorities identified in chapter 6 to support the diffusion of RETs are improving human capacity, financing, and establishing policy obligations and targets. Similarly, the policy mechanism identified in this chapter underscores the significance of instituting national targets and obligations such as RPS and facilitating investment incentives to support the diffusion of RETs.

7.8. Summary

This chapter addressed the research questions using an adapted TIS framework. The study found that the landscape, which consists of natural resource endowment, economic and social development, and external developments, includes important factors that affect diffusion. The reliance on solar PV as *the* RET, the lack of government funding to support the sector, and the reliance on international support explain the relevance of landscape aspects to understanding the diffusion of RETs.

The role of the actors within the structural elements of the TIS is analysed in chapter 6. The analysis highlighted the significant role of the government as an actor, as well as in facilitating the interaction of other actors in building networks. International development partners also had a significant impact on the diffusion of RETs through the demonstration

projects they supported. Institutional support for RETs is weak, and there is a lack of financing mechanisms and engagement by training institutes in the sector. There is little focus on driving the diffusion of RETs within tourist resorts, and businesses and electricity consumers are dependent on electric utilities to incorporate RETs into the electricity grid. The analysis of networks and institutions found that the rules and regulations pertaining to RETs are inadequate, and that the existing regulations are not enhancing the role of the private sector.

The analysis of the functional activities identified several factors that blocked their performance. The functional activities are at a formative phase, where technology transfer (F2), the creation of legitimacy (F7), and guidance of the search (F4) functions are performing, and the growth stage could be achieved by activating the performance of all the functions. The blocking mechanisms of the functions are causing a system failure. These blocking mechanisms are associated with the landscape and structural elements. Policy instruments encompassing RET targets and obligations, and investment incentives, are essential to drive the inducement mechanisms to overcome the barriers and to support the diffusion of RETs.

CHAPTER 8: CONCLUSIONS

8.1 Introduction

This chapter presents the conclusions of the study by summarising the findings, reflecting on them and how they relate to the literature, and their implications for the Maldives and the SIDS. The chapter concludes by noting the thesis' contribution to the literature and practice, acknowledging its limitations, and identifying scope for further research.

There are challenges in making energy transitions, and most countries are locked into the existing methods of electricity production which use non-renewable resources, albeit to different degrees. The situation in SIDS is no exception, and most SIDS, such as the Maldives, are highly dependent on imported oil for electricity production. The problems associated with dependency on fossil fuels include a high economic dependency on imported fossil fuel; high cost of electricity; low levels of access to electricity; concerns about energy security; and challenges in meeting decarbonisation goals in electricity production. In order to address these issues, there has been an increasing effort by governments and international agencies to transform the electricity sector in SIDS. However, the energy transition from the existing means of electricity production to a renewable energy-based system has been slow, although in many cases there are economic and social benefits of moving towards renewable electricity technologies.

The existing literature does not provide satisfactory explanations of the diffusion mechanism, nor sufficient theoretical approaches that can be applied within the context of SIDS. In order to address this research gap, this study attempted to understand why the diffusion of the RETs is slow in the Maldives, and thus improve our understanding of the factors that are hindering and supporting the diffusion of RETs.

The diffusion of RETs in the Maldives has been slow. The records from MEE show that the installed capacity of solar PV was only 74kWp in 2008, and in the past the growth has been minimal (see Figure 2.11). The installed capacity has started to grow since 2008, and there has been a particular increase in government projects using RETs. At the end of 2016, the installed capacity of solar PV was 6.7MWp, although the total installed capacity of diesel generators was 214MW in inhabited islands (MEE, 2017a, p. 12). This increase also coincides with a renewed political commitment to use RETs.

8.2 Main Research Findings

There are five key findings of this study. These are: (1) the distinct features of the Maldives impede its capacity for energy transformation; (2) the government and international development partners have been the most significant actors driving the diffusion of RETs in the Maldives; (3) it is political and economic factors, rather than technical constraints, that are primarily responsible for the slow diffusion of RETs in the Maldives; (4) the lack of information about the economic feasibility of RETs continues to be a barrier to diffusion in the Maldives; and (5) the study improved the understanding of the dynamics of TIS functions in the Maldives. These findings are explained below.

Firstly, the distinctive features of the Maldives impede their capacity for energy transformation. The analysis of the landscape element of the TIS framework in section 7.2 has highlighted many of these issues. The geographical dispersion of islands over a large area, and the limited space available to install some of the mature RETs, such as solar PV and onshore wind turbines are limiting factors. Additionally, the lack of a renewable resource base in the Maldives, also contributes to these challenges. The dispersed nature of the islands in the Maldives increases the cost of provision of services to the islands and reduces the ability to achieve economies of scale. For electricity provision, this requires investment in multiple power generation facilities and electricity grids. The lack of space within the islands also poses a significant challenge to installing solar PV in the Maldives. In terms of other SIDS, there is good potential for solar, but most of them have a limited base of some other renewable resources, especially sources which can be used as a baseload such as hydro, biomass, and geothermal (see Figure 2.4).

Secondly, government and international development partners are the most significant actors driving the diffusion of RETs in the Maldives. The analysis of the important actors in the electricity in the Maldives in section 6.5 indicated the significant role of these actors. The government plays a significant role in the provision of electricity in the Maldives. The government owns the electric utilities in inhabited islands and has control over the electricity regulator. So, unlike in many other competitive markets where the role of the private sector is much more significant, the government can take a significant role in transforming the electricity sector to increase the uptake of RETs. International development partners have also been instrumental in contributing to the current success in improving the installed capacity of RETs in the Maldives. The government is largely dependent on international development partners for funding RET projects. The role of the domestic financial and training institutions is weak. There is a weak regulatory and monitoring mechanism of the power sector in the tourist resorts, and the resorts operate independently. Businesses and electricity consumers are dependent on electric utilities to incorporate RETs for their electricity usage. They have only a limited capacity to act independently.

Thirdly, political and economic factors, rather than technical constraints, are the main contributors to the slow diffusion of RETs in the Maldives. The analysis of the survey questionnaire revealed that respondents perceived barriers related to government policy, financial factors, organisational capability, and human resources to be the most significant factors affecting diffusion of RETs in the Maldives (see section 6.2). This is consistent with the policy measures that respondents identified as being the most important to support the diffusion of RETs (see section 6.3). Political factors consist of policy issues such as the lack of support from electric utilities, lack of government plans, and lack of regulatory obligations. These are policy issues because they are shaped by the policy position of the government. The electric utilities are owned by the government, and they have control in determining the scope and role of electric utilities. Hence, the restrictions arising from electric utilities can be addressed by the government. The other policy issues such as the lack of government plans and regulatory obligations are commitments required by the government.

Fourthly, the lack of information about the economic feasibility of RETs continues to be a barrier to the diffusion of RETs in the Maldives. The study respondents noted a range of figures that they anticipate as requirements to invest in solar PV and on its return on investment. This implies that there is lack of understanding of the investment requirements and its payback period. An interviewee also noted the lack of availability of information about successful projects and its performance contributes to this issue. There is also lack of effort within electric utilities to collect data on RET projects and to demonstrate their economic performance. The lack of availability of a skilled labour force also contributes to the lack of awareness and information about the economic viability of RET projects. As discussed in section 6.6, this lack of information about the economic feasibility of RET projects has been highlighted in previous studies as well, and the issue remains an important challenge as confirmed by other recent studies (Jung et al., 2018).

Fifthly, this study improved the understanding of the dynamics of the TIS functions in the Maldives. The study used an adapted TIS framework to examine the diffusion of RETs in the Maldives. The analysis of the pathway and the interaction of the functions of TIS demonstrated that a sequence of actions takes place in activating the functions. In order to achieve the full performance of the system, the role of the entrepreneurial activities should be achieved, but this is dependent upon the progress and fulfilment of the other functions. The findings from applying the adapted TIS framework show the significant role of the landscape in determining the capacity of SIDS to transform the electricity sector. See Table 8.1 for a summary of the important findings based on the elements of the adapted TIS framework. The presence of indigenous renewable resources, particularly sources that can generate baseload electricity; the level of economic development; and the maturity of RETs and donor support in introducing the technologies have been instrumental in the diffusion of RETs in the Maldives.

Table 8.1: Summary of the Findings Based on the Elements of Adapted TIS Framework

TIS Element	Important Findings
Landscape	
<i>Natural Resource Endowment</i>	The availability of diverse indigenous renewable resources, especially sources that can generate baseload electricity, can improve the use of RETs.
<i>Economic and Social Development</i>	There is little allocation from national budget for projects on RETs. The level of economic development restricts the ability to invest in alternative sources.
<i>External Development</i>	External developments such as international fossil fuel prices, cost of RETs, and improvements in the efficiency and reliability of RETs have direct impact on the use of RETs in SIDS. The Maldives is also dependent on international aid for the diffusion of RETs.
Structures	
<i>Actors</i>	The government plays the dominant role within the electricity sector, while international development partners have made a positive impact on the sector.
<i>Networks</i>	There is reliance on the government to facilitate the interaction of the actors in the electricity sector.
<i>Institutions</i>	The laws and regulations are not conducive to supporting the diffusion of RETs.
Functions	
<i>F1: Entrepreneurial Activities</i>	The business scope for the private sector is limited because of the policy and the regulatory restrictions, difficulty in accessing finance, and restrictions on participating in ongoing government initiated RET projects.
<i>F2: Technology Transfer</i>	RETs are relatively easily available from the international market.
<i>F3: Knowledge Exchange</i>	There is lack of exchange of information about RETs and dissemination of information about the rules and regulations.
<i>F4: Guidance of the Search</i>	There is an increasing interest in RETs. However, RETs are considered as a supplementary means to provide electricity service.
<i>F5: Market Formation</i>	The electricity market is centred on electric utilities, and there are limited initiatives to reduce the cost of investment in RETs and to improve access to the market.
<i>F6: Resources Mobilization</i>	There are insufficient incentives to enter the RET market, and there are only weak efforts to develop the necessary skills in the sector.
<i>F7: Creation of Legitimacy</i>	The acceptance of RETs, particularly solar PV, has improved in the Maldives. Nevertheless, there is minimal collective action within the electricity sector

8.3 Reflection on the Findings

This section will draw together themes identified in the literature with research findings, the new insights obtained in applying the TIS for SIDS, and then will discuss the findings that are relevant to SIDS in general, and to other geographical contexts.

The literature review pointed out different types of lock-in (technological, organisational, industrial/system, societal, and institutional) in reference to Delrio and Unruh (2007, p. 1501). These lock-in mechanisms benefit the incumbent technology and firms and inhibit the entry of new technologies and firms into the market and delay energy transition. In assessing the relevance of these lock-in types, it shows while technological factors are important in deploying large scale RETs, the institutional lock-in is most significant in breaking the status quo. The analysis of the barriers associated with the diffusion of RETs in the Maldives found that in addition to the economic factors, the factors associated with policy and regulations are most significant compared to technical factors.

The study reviewed a range of literature to examine the barriers associated with the diffusion of RETs in general as well as within SIDS, and particularly to the Maldives. The literature review categorised these barriers into broad categories (political, economic, technical, and social) and subcategories, and listed different studies that identified these barriers (see Table 5.6). The findings from this study also identified relevant barriers associated with all the four broad categories of barriers and the subcategories within those barriers. Nevertheless, there are differences in the significance of the barriers associated with these categories.

This study found that the subcategories of barriers associated with political factors (policies, regulatory framework, and institutional capacity) are among the most significant barriers for the diffusion of RETs in the Maldives. Similarly, the barriers associated with economic factors (cost, financial, and market failure) are also significant barriers within the context of the Maldives. In this review, the technological constraints and infrastructure are listed as the two subcategories of barriers within technical barriers. The studies on technological barriers tend to list technological risks; those are factors associated with the performances of individual technologies and their reliabilities (Reddy and Painuly), as well as the lack of technology knowledge base (Dulal et al., 2013; IEA & OECD, 2001) as

technological constraints. Among these two issues, the low technical capabilities are addressed as human capacity issue in this study under the broad category of social barriers. In this study, the issues surrounding technological risks have not emerged among the most pressing issues. However, the human capacity and the lack of understanding of the economic feasibility of RETs is found as a significant barrier (Jung et al., 2018). These findings also reaffirm (Sovacool & Watts, 2009, p. 107) argument that transition to RETs is stalled not necessarily because of the lack of technology, but because of the lack of political and institutional support, and social awareness.

The issue related to the lack of support from electric utilities is a particularly striking barrier related to politics and policies. This may not be expected in the first place since the electric utilities are state-owned enterprises, and the government has started to announce targets to incorporate more RETs. However, there are not sufficient strategic plans to implement those broad targets. The electric utilities are reliant on existing means of electricity generation, and there are few initiatives from electric utilities to install additional RETs. The private businesses and electricity customers wishing to install solar PV for their own usage and sell the excess to the electricity grid through net metering arrangements raises concerns about the difficulty to access the electricity grid.

Assessing the findings of the barriers from this study with (Wilkins, 2002, p. 123) seven types of barriers related to national policies and programmes shows that there are many similar challenges in the Maldives. These barriers include lack of government strategic and implantation plans, fiscal policies and support mechanisms, and access to the electricity grid. However, the study did not find the issue of the lack of focus on the ownership of renewable energy development as a significant factor.

Based on the work of (Wilkins, 2002) and (Singh, 2012), six factors (policies, financial capacity, institutional capacity, human capacity, business environment, and technology) have been identified as the broad barriers to the diffusion of RETs in developing countries (see Table 3.4). The studies also highlight that the lack of knowledge and understanding about the economics of RETs is a significant factor in other developing countries as well. However, in the case of the Maldives, findings of this study show that the availability of technologies and the investment risk are not among the significant barriers to the diffusion of RETs in the Maldives.

The literature review has identified a range of policies that are applicable to support the diffusion of RETs, and it includes price-driven and quantity-driven policies (Groba & Breitschopf, 2013, p. 19). The policy measures identified in the review are categorised into four types: targets and obligations; investment incentives; market facilitation activities; and discouraging measures (see Table 3.6). The findings from this study support that most of these categories of policy measures are applicable to drive the diffusion of RETs in the Maldives. However, policies associated with discouraging measures are not seen as a significant driver.

The application of the adapted TIS in this study provided new insight to improve the understanding of the interrelationship of different functional activities and its significance in unlocking the existing market setup. The analysis also helped to improve the understanding of the structural elements (actors, networks and institutions) and its impact on the functional activities and their significance in driving the diffusion of RETs. The inclusion of contextual factor as the landscape and examining the ease of technology availability as a functional activity instead of knowledge development improved the applicability of the framework as a means to analyse the diffusion of RETs. These additional factors and changes allowed to consider contextual factors in detail and improves the broader understanding of the energy sector and its boundaries.

The study identified five main findings, and these findings can apply to other relevant SIDS. As one of the main findings, the study found that the distinctive features of the Maldives impede their capacity for energy transformation. These distinct features include the geographical dispersion of islands, the limited space available to install solar PV and onshore wind turbines, and the lack of a renewable resource base. Many SIDS share similar characteristics, and the finding from this study can apply to another similar geographic context. The role of the government and the development partners are also significant in the energy sector in many SIDS, and this study reaffirms the findings to the Maldives. This also implies the potential role that these actors can play in contributing to improving the diffusion of RETs. As another important finding, this study also found the lack of information about the economic feasibility of RETs in the Maldives and this may be a potential factor in many SIDS in perpetuating the status quo and inhibiting the diffusion of RETs.

8.4 Contribution to Literature

This study makes two specific contributions to the literature. Firstly, there is a theoretical contribution that derives from adaptation of the TIS framework, and secondly, this study can be used as a template for looking at the diffusion in other SIDS. These contributions are explained below.

Firstly, this study modified the TIS framework to make it more applicable to the context of SIDS such as the Maldives. In this regard, three changes were incorporated into the TIS framework: an additional landscape element; a change to a functional activity (F2) of the TIS; and a strengthening of analysis of the creation of legitimacy function (F7). These changes were designed to make the framework more applicable to SIDS. In addition to the structural elements and the functions of the existing TIS framework, this analysis incorporated the landscape elements. These changes provided important insights into the status quo, and improved the analytical capability of the framework to understand the diffusion of RETs (or lack thereof).

Secondly, the Maldives case study provides an opportunity to assess the analytical capability of the TIS framework and understand the diffusion of RETs in SIDS. Most of the theoretical frameworks on the diffusion of technologies, including the TIS approach, are Westernised constructs and are not often applied outside of the European context.

The TIS approach has been applied extensively in understanding the innovation of technologies, but the focus of this study is the diffusion of new technology, RET. Recent studies have started to apply the TIS framework to understand the diffusion of RETs. The study has identified some of the limitations in applying the TIS approach directly to analyse the diffusion of RETs in SIDS. The study particularly stresses the omission of the contextual feature as a significant limitation in the application of the approach. The TIS with the suggested improvement to the framework has been a useful analytical tool to understand the diffusion of RETs in SIDS.

8.5 Contribution to Practice

This study contributes to public policy by informing policymakers, international development partners, and other stakeholders interested in SIDS about important factors that are crucial for accelerating the diffusion of RETs in the Maldives. In this regard, this study makes three specific contributions: (1) identifying barriers inhibiting the use of RETs; (2) demonstrating significant drivers that are supporting the diffusion of RETs; and (3) identifying potential policies to support the diffusion of RETs.

The assessment based on the functional activities of the TIS framework demonstrated that the respondents in this study perceived barriers associated with F4 (guidance of the search), F3 (knowledge exchange), and F6 (resource mobilisation) to be the most significant barriers to the diffusion of RETs in SIDS. The three functions are also at an infant stage of development. Hence, the barriers associated with the three functions are significant in limiting the progress of the diffusion of RETs. The specific barriers that the study identified as the most significant were the high initial investment cost (B13), a lack of regulatory obligations (B10), a lack of government support schemes (B16), a lack of trained people (B8), and a lack of support from electric utilities (B12). The respondents in this study perceived policy measures such as building human capacity, financing, and establishing policy obligations and targets were the most important policy measures to facilitate the diffusion of RETs in the Maldives.

The study identified specific barriers to the diffusion of RETs within the context of the Maldives and also the driving factors that have contributed to the current level of RET installation. The identified policy drivers can serve as a policy guideline for policymakers to drive the diffusion of RETs in the Maldives. Table 8.2 shows a summary of potential policies that can address the main barriers affecting the diffusion of RETs in the Maldives.

Table 8.2: Summary of Potential Policies and the Barriers

Potential Policies	Barriers
Improving financing options and economic incentives	High initial investment cost
Instituting national targets and improving institutional capacity	Lack of regulatory obligations
Obligating electricity service providers to incorporate a designated amount of RETs	Lack of support from electric utilities
Building human capacity, and improving awareness and information about the economic viability of RET projects	Lack of trained people

The assessment of the survey questionnaires in this study indicated that the most significant barriers to the diffusion of RETs in the Maldives are the high initial investment cost (including a lack of government support schemes), a lack of regulatory obligations, a lack of trained people, and a lack of support from electric utilities. These pressing issues are listed as barriers in Table 8.2.

The study has provided empirical evidence based on the analysis of factors inducing and blocking the performance of the functions that three significant drivers that are supporting the diffusion of RETs: external developments; government policy initiatives; and the improved public acceptance of RETs. However, these drivers are not sufficient to overcome the blocking mechanisms associated with all the functional activities. Additional policies, such as those noted earlier, are needed to overcome the barriers.

The analysis of the drivers currently supporting the diffusion of RETs showed that three significant drivers have contributed to the current level of installation of RETs in the Maldives. These factors are external developments; government policy initiatives; and the improved public acceptance of RETs. However, these three factors are not sufficient enough to speed up the diffusion of RETs, and the inhibiting factors should be addressed. Table 8.2 also lists a summary of potential policies based on the study to address the barriers affecting the diffusion of RETs in the Maldives. The analysis of the drivers to support the diffusion of RETs in the Maldives showed that instituting national targets, providing investment incentives, and obligating electricity service providers to incorporate a designated amount of RETs are important drivers to the diffusion of RETs in the Maldives. The study also highlights, as one of the five main findings from this study, that the lack of

information about the economic feasibility of RETs is a significant barrier. As a policy initiative, the government should also address to build human capacity, and improving awareness and information about the economic viability of RET projects.

Different policy types (targets and obligations, investment incentives, market facilitation measures, and discouraging measures) were assessed regarding their perceived applicability in the context of the Maldives. The study demonstrated the significance of policy direction in driving the diffusion of RETs. In particular, instituting national targets and obligating electricity service providers to incorporate a designated amount of RETs, and investment incentives. The existing regulatory policies include weakly implemented FIT and net metering. The findings on the perception of respondents on the importance of different policy measures support the case for implementing an obligatory renewable standard such as RPS for electricity service providers. At the moment, only one country among UNCTAD's unofficial list of SIDS has implemented electricity quota obligations (see Table 2.7). This can be an important take away for policymakers in SIDS in order to accelerate the diffusion of RETs.

8.6 Limitations and Scope for Further Research

There are limitations in all research, and it may not always be possible to avoid them. I have attempted to minimise those limitations in this study. The two main limitations of this study are data collection methods and their biases, and the use of a single case study and the issue this creates around generalisability of findings to other contexts.

The first potential limitation highlighted here is around data collection. The primary data used in this study are based largely on interviews. There is a potential bias in interview data because of the bias on the part of interviewees, but the study also used a mixed methods approach and employed a survey questionnaire to generate quantitative data and to capture some of the common aspects covered in interviews. In addition to the interviewee bias, the researcher is also aware of the potential bias of the researcher, particularly when the researcher is closely involved in the case. The researcher used a structured mechanism for the analysis of the data to limit the significance of such a bias. In fact, the researcher's familiarity with the context has also helped to obtain data and to facilitate easy access to important interviewees.

Research inevitably poses new questions for further research, and additional research may also address some of the limitations identified in the study and possible measures that could be taken to address the methodological challenges faced in the research. The findings from this study also indicate there is scope for further research around issues in SIDS, particularly examining the economic feasibility of RETs, examining the potential of RET diffusion with electricity sector reform, and assessing investors' perspective on the diffusion of RETs.

This study explored the diffusion of RETs in the Maldives in order to understand why the process has been rather slow. This exploration was based on a detailed case study. However, a comparative study using multiple countries within SIDS and comparing them with other developing countries would provide additional insight into the process of the diffusion of RETs. Such a study would require additional time and resources that are not easily available for a PhD project and were beyond the scope of this study.

Such additional resources may also address some of the logistical challenges and minimise the methodological limitations identified above in collecting the data. Using research teams and multiple researchers can facilitate collaborative research. Collaborative research would improve the verification of data by cross-examining the findings among the research members and by minimising researcher bias in qualitative data.

The second potential limitation for this study is a single case study and generalizability of its findings to other contexts. I acknowledge the limitations of this study due to the use of a single case study and the issue this creates around generalising the findings to other contexts. The issue has been also explained in section 5.3.2. This study used the Maldives as a case study to inform the understanding of the diffusion of RETs in other similar SIDS. SIDS also differ from one another in multiple ways, including economic, political, and social aspects. Hence, a single case study based on the Maldives may be difficult to generalise to other SIDS.

Additionally, there is a focus in the study on solar PV as the RET, because solar PV happens to be the only source of RET in use in the Maldives. Thus, many respondents experience with the use of RETs are also tied with the use of solar. Therefore, the generalizability of the findings to other SIDS with high wind resources and not similar to the Maldives may not be as high. However, the study might apply to SIDS that share common features with the Maldives, and that may include the geographic, economic, and social factors. These common features can be such as small islands dispersed over a large area, abundant supply of solar as a renewable resource but limited win resource, a growing economy, and a small population with a slow diffusion of RETs.

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APPENDICES

A. Semi-structured Interview Questions

Actors

- 1) Who do you think are the most influential stakeholders that can contribute to increasing the diffusion of renewable electricity technologies in the Maldives?
- 2) In your opinion, how significant is the role of international development partners in supporting the diffusion of renewable electricity technologies in the Maldives?

Networks

- 3) What needs to be done to improve the interaction of stakeholders in the renewable electricity technologies sector in the Maldives?

Institutions

- 4) Do you believe that there are sufficient rules and regulations in place to have investor confidence in the renewable electricity technologies sector?
- 5) Do you think there are any cultural factors affecting the diffusion of renewable electricity technologies in the Maldives?

F1: Entrepreneurial activities

- 6) In your opinion, currently what is the role of entrepreneurs in the renewable electricity technologies sector in the Maldives?

F2: Technology Transfer

- 7) How easy is it to obtain renewable electricity technologies from overseas?
- 8) Are you aware of any cooperation between local businesses and overseas manufacturers or suppliers of renewable electricity technologies?

F3: Knowledge Diffusion

- 9) Do you think enough is being done to promote renewable electricity technologies in the Maldives, and what more needs to be done?

F4: Guidance of the search

- 10) Why do you think that there has been very little increase in the use of renewable electricity technologies in the Maldives in the past decade despite a lot of talk about renewable energy targets and ambitions?
- 11) What do you think are the most important incentives to increase the diffusion of renewable electricity technologies in the Maldives?

F5: Market Formation

- 12) What do you think are the main barriers for connecting renewable electricity technologies to the electricity grid? (and what do you think should be done to overcome those barriers?).
- 13) In your opinion, what energy policies and regulations that are implemented in other countries to support renewable electricity technologies should be applied here in the Maldives?

F6: Resource Mobilisation

- 14) What are the funding sources available from the finance sector in the Maldives for renewable electricity technologies projects?
- 15) What are the types of trained people that will be required to enable the renewable electricity technologies sector to expand?

F7: Legitimisation of the technology

- 16) What are the important developments that have taken place in the past that contributed to the current level of generation of renewable electricity in the Maldives?
- 17) Do you think there is enough private sector presence within the renewable electricity technologies sectors to form an industry association in the Maldives?
- 18) In your opinion, how well do renewable electricity technologies perform compared to diesel-based generation in terms of their (1) relative advantage, (2) compatibility with expectations, and (3) complexity?

Landscape

- 19) In your opinion, what are the most applicable renewable energy sources to generate electricity in the Maldives? And why?
- 20) What international developments could increase the diffusion of renewable electricity technologies in the Maldives?
- 21) What significant local developments could increase the diffusion of renewable electricity technologies?
- 22) Do you have any other comments on the electricity sector, and efforts to expand the renewable electricity sector?

B. Information Sheet for Interview Participants

Diffusion of Renewable Electricity Technologies in Small Island Developing States: The Case of the Maldives

INFORMATION SHEET FOR INTERVIEW PARTICIPANTS

Thank you for your interest in this project. Please read this information before deciding whether or not to take part. If you decide to participate, thank you. If you decide not to take part, thank you for considering my request.

Who am I?

My name is Ali Azwar, and I am a Doctoral student in Public Policy at Victoria University of Wellington in New Zealand. This survey forms part of my research towards my PhD thesis.

What is the aim of the project?

This project aims to understand why the diffusion of renewable electricity technologies (RET) is low in most small island developing states (SIDS), such as the Maldives, and to identify factors that are contributing to the slow diffusion of RET. The study is using a mixed-methods approach and will collect quantitative and qualitative data. The quantitative data will be collected by using a self-administered survey questionnaire, and the qualitative data will be based on semi-structured interviews. The study aims to make a significant contribution to the literature on the diffusion of RET with particular reference to the Maldives, as well as generating knowledge that is transferable to SIDS with similar contexts.

This research has been approved by the Victoria University of Wellington Human Ethics Committee (reference 0000023650).

How can you help?

If you agree to take part, I will interview you in your workplace, or in an agreeable location. I will ask you questions about the use of renewable electricity technologies in the Maldives. The interview will take about one and half hours. I will record the interview and write it up later. You can stop the interview at any time, without giving a reason. You can withdraw from the study by contacting me up to three weeks after the interview. If you withdraw, the information you provided will be destroyed.

What will happen to the information you give?

This research is confidential. This means that my two supervisors, the transcriber, and I will be aware of your identity, but the research data will be aggregated, and your identity will not

be disclosed in any reports, presentations, or public documentation. However, you should be aware that in small projects your identity might be obvious to others in your community.

Only my supervisors, transcriber and I will read the notes or transcript of the interview. The interview transcripts, summaries, and any recordings will be kept securely and destroyed 5 years after the research ends.

What will the project produce?

The information from my research will be used in my PhD dissertation, and a summary of the results may be used in academic reports and/or presented at conferences. Your name will not be used in reports, nor will any information that would identify you.

If you accept this invitation, what are your rights as a research participant?

You do not have to accept this invitation if you don't want to. If you do decide to participate, you have the right to:

- choose not to answer any question;
- ask for the recorder to be turned off at any time during the interview;
- withdraw from the study up to three weeks after your interview;
- ask any questions about the study at any time;
- read over and comment on a written summary of your interview;
- agree on another name for me to use rather than your real name;
- be able to read any reports of this research by emailing the researcher to request a copy.

If you have any questions or problems, who can you contact?

If you have any questions, either now or in the future, please feel free to contact either:

Student:

Name: Ali Azwar

Email: ali.azwar@vuw.ac.nz

Supervisor:

Name: Prof. Jonathan Boston

Role: Supervisor

School: School of Government

Phone: +64 4 463 5456

Email: jonathan.boston@vuw.ac.nz

Human Ethics Committee information

If you have any concerns about the ethical conduct of the research you may contact the Victoria University HEC Convener: Associate Professor Susan Corbett. Email susan.corbett@vuw.ac.nz or telephone +64-4-463 5480.

C. Consent to Interview

Diffusion of Renewable Electricity Technologies in Small Island Developing States: The Case of the Maldives

CONSENT TO INTERVIEW

This consent form will be held for 5 years.

Researcher: Ali Azwar, School of Government, Victoria University of Wellington

I have read the Information Sheet, and the project has been explained to me. My questions have been answered to my satisfaction. I understand that I can ask further questions at any time.

I agree to take part in a video/audio recorded interview.

understand that:

I may withdraw from this study up to three weeks after the interview, without giving any reason, and any information that I have provided will be destroyed.

The information I have provided will be destroyed five years after the research is finished.

Any information I provide will be kept confidential to the researcher, the transcriber, and the supervisors. I understand that the results will be used for a PhD report and a summary of the results may be used in academic reports and/or presented at conferences.

My name will not be used in reports, nor will any information that would identify me. However, the reports may use pseudonyms, and they will refer to the role.

- I would like a summary of my interview: Yes ☐ No ☐
- I would like to receive a summary of the completed study emailed to me within four months of the completion of the doctoral programme, and have added my email address below. Yes ☐ No ☐

Signature of participant: _____

Name of participant: _____

Date: _____

Contact details: _____

D. Self-administered Survey Questionnaire

Survey Questionnaire

Barriers

- How significantly does each of the listed barriers below hinder the uptake of renewable electricity technologies (based on energy from solar, wind or biomass) in the Maldives? Please rate the significance of each barrier on a scale of 1 – 5: (1) extremely significant, (2) very significant, (3) moderately significant, (4) slightly significant, and (5) not at all significant.

Barrier Code	Barriers	Please rate the significance of each barrier on a scale of 1 – 5				
		1	2	3	4	5
B1	Difficulty for private businesses to enter the renewable electricity market					
B2	Lack of interest by private businesses to use renewable electricity					
B3	Perceived unreliability of renewable electricity technologies					
B4	Lack of renewable electricity projects					
B5	Lack of international aid to support renewable electricity technologies					
B6	Lack of interaction between local businesses with international manufacturers and suppliers of renewable electricity technologies					
B7	Lack of information about renewable electricity technologies					
B8	Lack of trained people to implement renewable electricity projects					
B9	Lack of government plans to improve the diffusion of renewable electricity technologies					
B10	Lack of regulatory obligation to increase the diffusion of renewable electricity technologies					
B11	Administrative delays in issuing permits to start renewable electricity projects					
B12	Lack of support from existing electricity providers to increase the use of renewable electricity					
B13	High initial investment costs required for renewable electricity technologies					
B14	High maintenance costs required for renewable electricity technologies					
B15	Lack of local suppliers of renewable electricity technologies					
B16	Lack of government support schemes to promote the diffusion of renewable electricity technologies (grants, credit, and financial facilities)					
B17	Government subsidies for fossil fuel based generation					
B18	Lack of space to install renewable electricity technologies					
B19	Limited grid capacity and infrastructure to connect renewable electricity technologies					
B20	Lack of recognition from businesses of the benefits of using renewable electricity technologies					
B21	Others (please state)					

Drivers

2. How important are each of the listed policies below to support the uptake of renewable electricity technologies in the Maldives? Please rate the importance of each policy on a scale of 1 – 5:

(1) extremely important, (2) very important, (3) moderately important, (4) slightly important, and (5) not at all important.

Policy Code	Policy Measures	Please rate the significance of each policy on a scale of 1 – 5				
		1	2	3	4	5
P1	Instituting national targets to generate electricity from renewable sources					
P2	Availability of public loans for renewable electricity projects					
P3	Availability of grants for renewable electricity projects					
P4	Government subsidies for renewable electricity projects					
P5	Tax incentives for renewable electricity projects					
P6	Eliminating subsidies for fossil fuel based electricity generation					
P7	Availability of a tariff incentive such as feed-in-tariff, where it allows private producers to sell the renewable electricity they generate back to the electricity grid					
P8	Availability of a tariff incentive such as net metering. In net metering, the customer's electricity meter can measure the flow of electricity in two directions: how much electricity comes from the electricity company, and the renewable electricity from the customer who generates their electricity from renewable electricity technologies to feed electricity they do not use back to the grid.					
P9	Government obligations on electricity service providers to generate a designated level of electricity from renewable sources					
P10	Educating the public about the impact of fossil fuels on the climate					
P11	Training people to provide the necessary skills for renewable electricity projects					
P12	Improving interaction between local businesses and international manufacturers and suppliers of renewable electricity technologies					
P13	Allowing private electricity producers easy access to electricity grid					
P14	Providing information about renewable electricity technologies					
P15	Others (please state)					

Respondent's Demographics

3. Which of the following categories best describe the type of organisation you primarily work in?

i. Government	vi. Renewable electricity technology supplier	ix. Multilateral organizations
ii. Local government agency	vii. Academic institution	x. Non-governmental organisation
iii. Independent institution	viii. Financial institution	xi. Tourist resort
iv. Electricity regulator		xii. Private business
v. Electricity service provider		xiii. Other (please state)

4. Which of the following best describes your role in the organisation?

i. Upper Management	iv. Administrative Staff	viii. Consultant
ii. Middle Management	v. Support Staff	ix. Self-employed
iii. Junior Management	vi. Trained Professional	x. Other (please state)
	vii. Skilled Labourer	

E. Information Sheet for Survey Participants

Diffusion of Renewable Electricity Technologies in Small Island Developing States: The Case of the Maldives

INFORMATION SHEET FOR SURVEY PARTICIPANTS

Thank you for your interest in this project. Please read this information before deciding whether or not to take part. If you decide to participate, thank you. If you decide not to take part, thank you for considering my request.

Who am I?

My name is Ali Azwar, and I am a Doctoral student in Public Policy at Victoria University of Wellington in New Zealand. This survey forms part of my research towards my PhD thesis.

What is the aim of the project?

This project aims to understand why the diffusion of renewable electricity technologies (RET) is low in most small island developing states (SIDS), such as the Maldives, and to identify factors that are contributing to the slow diffusion of RET. The study is using a mixed-methods approach and will collect quantitative and qualitative data. The quantitative data will be collected by using a self-administered survey questionnaire, and the qualitative data will be based on semi-structured interviews. The study aims to make a significant contribution to the literature on the diffusion of RET with particular reference to the Maldives, as well as generating knowledge that is transferable to SIDS with similar contexts.

This research has been approved by the Victoria University of Wellington Human Ethics Committee (reference 0000023650).

How can you help?

Participation in this survey is voluntary. If you agree to take part, I request that you complete the attached survey questionnaire. The questionnaire will ask you questions about the use of renewable electricity technologies in the Maldives. It may take about half an hour to complete the questionnaire. For the analysis of data, I will compile the data provided on the survey questionnaire. You can stop completion of this survey at any time, without giving a reason. You can withdraw from the study before submitting the completed survey form to me.

What will happen to the information you give?

This research is confidential. This means that my two supervisors and I will be aware of your identity, but the research data will be aggregated, and your identity will not be disclosed in any reports, presentations, or public documentation.

Only my supervisors and I will read the completed survey forms. The completed survey questionnaires will be kept securely and destroyed 5 years after the research ends.

What will the project produce?

The information from my research will be used in my PhD dissertation, and a summary of the results may be used in academic reports and/or presented at conferences. Your name will not be used in reports, nor will any information that would identify you.

If you accept this invitation, what are your rights as a research participant?

You do not have to accept this invitation if you don't want to. If you do decide to participate, you have the right to:

- choose not to answer any question;
- withdraw from the study before submitting the completed survey questionnaire;

If you have any questions or problems, who can you contact?

If you have any questions, either now or in the future, please feel free to contact either:

Student:

Name: Ali Azwar

Email: ali.azwar@vuw.ac.nz

Supervisor:

Name: Prof. Jonathan Boston

Role: Supervisor

School: School of Government

Phone: +64 4 463 5456

Email: jonathan.boston@vuw.ac.nz

Human Ethics Committee information

If you have any concerns about the ethical conduct of the research you may contact the Victoria University HEC Convener: Associate Professor Susan Corbett. Email susan.corbett@vuw.ac.nz or telephone +64-4-463 5480.

F. Consent to Survey Questionnaire

Diffusion of Renewable Electricity Technologies in Small Island Developing States: The Case of the Maldives

CONSENT TO SURVEY QUESTIONNAIRE

This consent form will be held for 5 years.

Researcher: Ali Azwar, School of Government, Victoria University of Wellington

I have read the Information Sheet, and the project has been explained to me. My questions have been answered to my satisfaction. I understand that I can ask further questions at any time.

I agree to complete survey questionnaire for this study.

understand that:

I may withdraw from this study before submitting the completed survey form, without giving any reason.

The information I have provided will be destroyed five years after the research is finished.

Any information I provide will be kept confidential to the researcher, and the supervisors. I understand that the results will be used for a PhD report and a summary of the results may be used in academic reports and/or presented at conferences.

My name will not be used in reports, nor will any information that would identify me.

Signature of participant: _____

Name of participant: _____

Date: _____

Contact details: _____

G. Provisional List of Codes

Component of the Framework	Category	Sub-category
Landscape	Applicable RE Source	Solar
		Wind
		Biomass
		Marine
		Waste-to-heat
	Others	
	International Development in the Sector	Technology
Funding		
Policies		
Local Initiatives Crucial for RET		
Relationship with Other Functions		
Actors	Most Influential Actors	
	Important Actors	Roles
	Development Partners/Donors	Dependency
		Success/Failures (Impact)
Networks	Level of interactions	
	Causes for Weak Interactions	
	Supporting Networks	
Institutions	Rules & Regulation	Existing
		Required
		Effectiveness
	Investor Confidence	
	Cultural factors	Perception of RETs
	Environmental Concerns	
	Behavioral factors	
Entrepreneurial activities (F1)	Role of Private Businesses	Factors affecting
	List (Types) of Activities	Implications
	Contributing to Entrepreneurial Activities	
Technology transfer (F2)	Availability of RET	Factors Affecting Availability
		Relationship Between Other Functions
		List (Types) of Activities
Knowledge exchange (F3)	Level of Knowledge Diffusion	
	List (Types) of Activities	
	Relationship with Other Functions	Pre-requisite/Driver for Diffusion
Guidance of the search (F4)	Reasons for Slow Diffusion	Important Incentives
		Challenging Barriers
	Role of Policy Goals	Consistency with Goals
	If Policy Goals Communicated	
	Relationship with Other Functions	
Market formation (F5)	Barriers to Connect to the Grid	Technological
		Policy
		Measures to Address Barriers
	Support for Market Entry	
	Learning from Other Countries	
	Relationship with Other Functions	
Resources mobilization (F6)	Funding Sources	
	Financial Support	
	Economics of RET	
	Availability of Trained People	Required Areas of Expertise
		Efforts on Training
	Relationship Between Other Functions	
Creation of Legitimacy (F7)	Important Developments	
	Positive Forces	
	Scope for Association	
	Acceptance of Technology	Relative Advantage
		Compatibility with Expectations
	Complexity	
	Relationship with Other Functions	

H. Transcribing Confidentiality Agreement

Transcribing Confidentiality Agreement

Project Title: Diffusion of Renewable Electricity Technologies in Small Island
Developing States: The Case of the Maldives

Principal Investigator: Ali Azwar

I,, agree to ensure that the
audiotapes I transcribe will remain confidential to Ali Azwar and myself.

I agree to take the following precautions:

1. I will ensure that no person, other than Ali Azwar, hears the recording.
2. I will ensure that no other person has access to my PC.
3. I will delete the files from my PC once the transcription has been completed.
4. I will not discuss any aspect of the recording with anyone except Ali Azwar

Signature:

Date: