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DEVELOPING A MULTI-DISCIPLINARY UNDERSTANDING OF THE DIFFUSION OF ECO-INNOVATIONS

Houda El Mustapha

DEVELOPING A MULTI-DISCIPLINARY UNDERSTANDING OF THE DIFFUSION OF ECO-INNOVATIONS

LESSONS FROM BEHAVIOURAL, BUSINESS AND TRANSITION STUDIES'
PERSPECTIVES FOR THE ADOPTION OF SOLAR ENERGY TECHNOLOGY IN
LEBANON

DISSERTATION

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List of Acronyms

CEDRO Project	Country Energy Efficiency and Renewable Energy Demonstration
DoI	Diffusion of Innovation
DREG Project	Small Decentralized Renewable Energy Power Generation
EDL	Electricité du Liban
EU	European Union
GEF	Global Environment Facility
GHG	Greenhouse Gases

GSWH	Global Solar Water Heating Program
LCEC	Lebanese Center for Energy Conservation
MENA	Middle East North Africa
MED-DESIRE	Mediterranean Development of Support schemes for solar Initiatives and Renewable Energies
MLP	Multi-Level Perspective
NEEAP	National Energy Efficiency Action Plan
NEEREA	National Energy Efficiency and Renewable Energy Action
NGO	Non-Governmental Organization
PV	Photovoltaics
SNM	Strategic Niche Management
SHAAMS	Strategic Hub for the Analysis and Acceleration of the Mediterranean Solar Sector
SWH	Solar Water Heating System
TPB	Theory of Planned Behaviour (TPB)
TRA	Theory of Reasoned Action (TRA)
UN	United Nations
UNDP	United Nations Development Program
UTAUT	Unified Theory of Acceptance and Use of Technology (UTAUT)

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“The self is an ocean without a shore. Gazing upon it has no beginning or end, in this world and the next” ~Ibn al' Arabi

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Chapter 1: Introduction

1.1. Background

In the past decades, concern has risen throughout the world about economic and human development. The way humans live is very much related to their behaviour, which has the propensity to influence negatively both our society and environment (Edenhofer et al., 2014). Energy consumption (in the form of electricity or heating) is among these behaviours which result in environmental damage if used negatively. Energy access is essential to almost all aspects of welfare. However, consumption of conventional electricity which releases enormous amount of carbon dioxide emissions when generated, is one of the greatest contributors to global warming (Stamm et al., 2000). Renewable energy technologies provide a feasible solution to decrease carbon emissions. Yet, for the world to accomplish progress in human welfare and prosperity, challenges facing sustainable development should be dealt with. However, these challenges are complex in nature because they entail various aspects such as economic, social, and technology factors and might lead to enormous future costs as is the case with environmental degradation. Access to modern and reliable energy services is a crucial condition for development and poverty reduction, especially in developing countries (GNEP (2007); Modi *et al.* (2004)). To ensure access to reliable energy supply in developing countries, a balance has to be made between economic, social, and environmental reforms, which entails great challenges. It has been estimated that global energy needs will increase 40% by 2030, with a large share of the new demand coming from developing countries, whose carbon emissions are expected to rise from 39% of total current GHG emissions to 52% by 2030 (WBCSD, 2009).

There is robust scientific evidence that climate change results from human activity, specifically through the production and consumption of energy (IPCC, 2014). The main cause of climate change is human induced carbon emissions from fossil fuel combustion. The shocking impact of climate change along with the depletion of natural resources (such as fossil fuels) stress the importance of transformative change towards using renewable energy sources. This adds an enormous amount of pressure to the energy challenge and makes it necessary to limit the environmental impact of increased

energy production. This can be done by adopting more low carbon energy technologies. Technological developments are critical to accelerate this process.

Governments and other market actors undertake various initiatives and market support mechanisms to increase consumers' uptake of sustainable energy technologies. However, consumers are still reluctant to change when it comes to energy usage (Steg, 2008). Adoption of technologies is multi-dimensional in nature, thus it incorporates aspects that might be of importance to consumers (Eseonu and Egbue, 2014). From this sense, for national commitments to become better attainable, interventions also need to take into account psychological, social, cultural, and organizational factors that influence energy choices. In other words, engaging the social and behavioural aspects of consumers is needed to identify opportunities and achieve long term sustainability targets (Stern et al., 2016).

Although sustainable energy technologies are beneficial to the society, their rewards from adoption usually takes time to occur thus creating difficulties for consumers to understand the benefits behind the technology (Toft, 2014). This is normally envisaged in the high investment costs and long payback periods of renewable energy technologies.

This dissertation focuses on the term “diffusion” which lies at the core of respectively all analyses. Diffusion is the process by which an innovation is disseminated amongst potential adopters being members of the social system (Rogers, 2003). Related to the diffusion of eco- innovations, there is the sustainability transitions research stream. This stream focuses on long-term and multi-dimensional transformation processes through which socio-technical systems shift to more sustainable modes of production and consumption (Markard *et al.*, 2012). This is reflected by the Strategic Niche Management (SNM) approach to sustainable transitions, in which the role of protected socio-technical niches can enhance the transformation and adoption of technologies. For example, Geels (2011) argued that sustainability transitions are about interactions between technology, policy, economics, culture and public opinion, and thus, provides insights to the diffusion process of eco-innovations. This thesis draws inspiration from the fact that dimensions from multiple scopes shape the diffusion of renewables. Specifically related to the consumer dimensions (such as behavioural, social, and

cultural) and the market in which the uptake and development of these technologies takes place.

There are several sources of renewable energy which are expected to pave the way for this transition towards sustainable energy consumption. In this thesis the focus is on solar energy technologies (being solar thermal and solar photovoltaics which will be discussed in details later in this chapter). This dissertation is focused on a developing country context through the study of diffusion of solar energy technologies in Lebanon. This selection was based on the idea that diffusion of technologies is influenced by the context it belongs to since there are many differences in conditions between developed and developing nations. Developing countries might encounter different opportunities and barriers. To find alternative development pathways one needs to understand certain specific technological, economic, social, cultural, and behavioural aspects that are related to the diffusion of innovation framework. Although developing countries face more acute problems than the environmental component of sustainability such as corruption, debt, security, education and other, innovations can still help in improving quality of life for the people of these countries.

Lebanon has a unique context that influences consumers' adoption decision-making. The country has witnessed various national initiatives to develop renewable energy markets, in particular solar energy. Lebanon suffers from unreliable electricity supply services provided by the national utility provider results in severe daily blackouts across the country (Harajli *et al.*, 2015). This has led me in this thesis to present the consumers' barriers, preferences, and point of view concerning the adoption of solar energy technologies. Then reflecting on the market development point of view, thus aiming to overcome ongoing market challenges and increase the uptake of renewable energy technologies in the country.

1.2. Overview of diffusion of renewables in MENA countries

Mediterranean countries are rich with solar resources, and the South Mediterranean countries in the Middle East North African (MENA) region are found to have higher degrees of direct solar irradiance than North Mediterranean countries (i.e. Southern Europe).

The Lebanese context

Access to renewable energy is still a fundamental challenge to many developing countries. In 2005, developed countries committed themselves to reduce greenhouse gases emissions during the Kyoto protocol period through integrating renewable energy technologies into power production systems (Khoury et al., 2016). However, developing countries face various challenges to meet this commitment. These challenges might include geo-political, legal, financial and physical factors.

The MENA region has abundant solar potential, yet in the light of climate change the region is facing increasing heat extremes and energy transition challenges. It often requires external financial and educational support. However, the presence of international organizations may ease the way for renewable energy technologies to expand with the financial stability and support provided from international aid organizations to both the market and to the government (Karp, 2015). The aid of European countries and bilateral agencies (European Investment Bank, 2010) has enabled countries in the MENA region to adopt renewable energy plans and projects (Jablonski et al., 2012; Tsikalakis et al., 2011).

Technology diffusion in a certain community depends on technology attributes, rewards, and a number of social specific factors (Rogers, 2003). Since Lebanon suffers from political and economic problems and has limited resources to achieve the sustainable transition to renewable energy sources, it has witnessed various initiatives. These initiatives were supported by international funding agencies to develop renewable energy market. Moreover, the diffusion of renewable energy technologies faced various challenges in Lebanon, namely the absence of clear policies to promote the use of renewable energy sources from the government side, and the overall mentality and culture of the consumers (Kinab and Elkhoury, 2012).

Some of the challenges that developing countries face in terms of including renewable energy in the energy mix are the infrastructure and the technological capabilities (Thornton, 2016). Lebanon is suffering from problems in the electricity production since its civil war (1975-1990;(Khoury *et al.*, 2016)). Its energy production relies on oil (both petrol and diesel) and other imports. However, the country lacks fossil fuel resources of its own. Currently, the domestic power generation is no longer sufficient for the growing demand, thus leading to 4-14 hours of electricity blackouts on a daily basis in

all Lebanese regions. Like many developing countries, Lebanon suffers insufficient generation of energy, thus creating many environmental impacts. Moreover, Lebanon is lacking access to a reliable supply of electricity, while demand is much higher than supply. This has forced citizens to pay for expensive diesel backup generators to secure their electricity need. Users rely on private diesel generators during blackouts to provide their electrical needs, however, often these operation processes result in bad electrical current quality because generators are managed poorly by unprofessional individuals (Khoury *et al.*, 2016).

1.3.Solar energy technologies - opportunities and barriers for diffusion

Lebanon has abundant solar resources for a variety of solar energy technologies and applications due to the fact that the country benefits from 300 sunny days throughout the year on average. However, in the absence of regulations and serious plans, while facing extensive economic and (geo-)political challenges, and high initial cost of most renewable energy technologies, the integration of these systems in Lebanon has been rather slow thus far (Khoury *et al.*, 2016).

Looking at the Lebanese case, there is a big concern of how to decrease demand on the electricity grid and how to provide users with reliable electricity for the whole day, which might in many cases be considered more important than reducing greenhouse gasses' emissions (Khoury *et al.*, 2016). Consumers pay approximately 10.4% of their income on electricity. For this reason, they can arguably be considered fuel poor. Therefore, there is a thrive to use renewable energy sources to significantly reduce CO₂ emissions. According to Chedid and Chaaban (2003) it is essential to look at alternative sources of energy production, in particular those that can be used during blackouts, and in multiple economic sectors (i.e. residential, commercial, and industrial sectors). In this case, the diffusion of renewable energy technologies would have the potential to solve a great part of the important challenge to reduce negative environmental externalities, while improving the quality of energy service delivery, and ensuring the sustainable, reliable and productive use of energy.

In spite of the positive geographic and climatic conditions the country is not benefiting from the available renewable energy sources to solve its great shortage in energy production. According to Thornton (2016) solar technologies could form a market for

their development regardless of Lebanon's hostile environment to green innovations. This hostile environment largely results from the political and the economic instability of the country. Despite that the gap between demand and supply in the Lebanese electricity sector is increasing, wide diffusion of renewable technologies does not take place. One of the most important economic challenges concerns the existing electricity system. The electricity prices from the national utility grid are subsidized, which makes it hard for renewable energy sources to compete in terms of pricing. Since the money spent on electricity consumption from conventional sources is much less than that coming from renewable energy sources, consumers are less likely to shift to renewable energy technologies. Another challenge concerns the high upfront cost of solar technologies and the lengthy and complex bureaucratic procedures of obtaining funding for such systems.

Renewable energy and most importantly solar energy, with its particular national climatic advantage, could play a significant role as a cost-competitive alternative to conventional fossil fuels. In 2010, the Lebanese Council of Ministers issued a policy paper regarding the electricity sector which launched and supported all public, private and individual initiatives to adopt the use of renewable energies to achieve the target of 12% of electric and thermal supply (Mourtada *et al.*, 2015). Five years later, only little improvement was noted, however. This was most likely related to the complex political, economic and social situation in the country. Moreover, the renewable energy and energy efficiency targets were still far from being met, although some important achievements have been attained by offering incentive programs for clean energy technologies, yet this is still not sufficient to translate the renewable energy strategy into sustainable projects. Despite this fact solar technologies have established a small niche market regardless of the hostile environment for green innovations in Lebanon (Thornton, 2016). Since 2015 the market for solar power is growing, and its products are starting to become a popular alternative in the industrial and the residential sectors with the implementation of large scale projects such as DREG and CEDRO (Ibid.).

In fact, introducing change to the energy sector or to address climate change efforts faces several difficulties. UNDP (2013) showed a lack of political engagement. This entails a major difficulty. The four-year electoral cycle with possible change of ministries and senior officials has led to short unstable time frames in addition to the influence of

economic lobbies to protect their interests and the slow decision making process. Furthermore, overlapping responsibilities between government institutions, lack of law enforcement and of monitoring structure further decreased effectiveness.

1.3.1. Solar Thermal systems

Reducing CO₂ emissions in the residential sector comes with various challenges. This also holds for producing renewable energy in this sector. The uptake of solar water heating technology (SWH) is one of these challenges. In Lebanon, several efforts were made thus far to increase the uptake of this technology. This will be discussed in more detail throughout this section.

In Lebanon various national initiatives have been undertaken to develop a domestic SWH market. This was in large part due to a joint effort between the Ministries of Energy and Water, and the United Nations Development Program (UNDP) through funding by the Global Environment Facility (GEF). The objective of such initiatives is to facilitate the installation of 190,000 square meters of SWH in the period 2009-2014. However, only 50,000 square meters of SWH had been installed when the program ended in 2014. This only equals 26% of the pre-set target. The country is targeting 1,050,000 m² of total installed SWH capacity by 2020 (Hajj Shehadeh, 2014), divided between 700,000 m² of SWH and another 300,000 m² for collective SWH systems as an achievable potential. However, several barriers are delaying efforts to meet these estimations.

The residential sector is facing several problems while the residential apartments lack space on the rooftop, since the roofs will mostly have water tanks and antennas thus lowering the effective energy yield of SWHs and their installation. Regulations can have a significant role in boosting the adoption rate yet none are actually implemented.

An initiative by the National Energy Efficiency and Renewable Energy Action (NEEREA) was recognized by the Ministry of Energy and Water. It concerned a project that was implemented through commercial banks focused on offering technical and financial support for individuals who are willing to install SWH. The project allowed the private sector to get near 0% interest loans from commercial banks to cover extra costs of incorporating energy efficiency and renewable energy components in development projects, buildings and industries (LCEC, 2012) along with a \$200 subsidy per system

limited to the installation of 7,500 SWH units (World Bank, 2011). However, 70.8% of the total number of systems installed in 2011 in the residential sector concerned households that did not apply for the NEEREA loan and installed either through direct cash payments or private "dealer-to-consumer" loans or agreements. The process of the 0% interest loan was considered to be a lengthy one taking between 60 to 90 days. This was related to the quantity of applications and availability of information (LCEC, 2012). Reports from the Energy Conservation Center showed that 50% of the available SWH suppliers do not have qualified systems (LCEC, 2015). This deprives consumers from receiving a \$200 grant when applying for a loan.

In promoting the installation of SWH systems, the Lebanese state governments and NGOs offered support grants to stimulate the installation of SWH systems. For example, in 2009 a number of subsidy arrangements were made available at state, provincial and municipal level. This amounted to about \$200 subsidy per system in an initiative to reduce the perceived impact of long payback periods. However, applying for these grants required considerable administrative skill and effort. This reality demanded from consumers that they should have a broad set of knowledge about various qualified suppliers, because there were few installers that offer a guarantee on the efficiency of the system, while consumers were often not aware that they could claim such a guarantee. In addition, some installers only offered a guarantee against manufacturing defects, or an annual maintenance contract, and few of them succeeded in creating a distribution network (SHAAMS, 2012). All these factors affected the adoption of SWH, yet all national reports focused on suppliers and producers with limited attention to consumer experience and behaviour.

1.3.2. Solar Photovoltaic systems

Regardless of the major advantages (such as financial savings and frequent electric supply) that the PV systems bring to Lebanese consumers, the PV system shares similar challenges as the SWH system (Hajj Shehadeh, 2014). These challenges include high investment costs, lack of roof space, and frequent maintenance of the system. Thus, integrating renewable energy technologies in Lebanon requires financial and technical support from wealthier countries to develop the market and increase consumers' willingness to pay. For instance, international donors play a significant role in the promotion of renewable technologies due to their active role in the establishment

of specific roadmaps while funding various demonstration projects (Smith *et al.*, 2014). In Lebanon, international organizations coordinate with local agencies for the purpose of developing the renewable energy market. Thus, international organizations support local actors through providing necessary resources such as financial and technical expertise (Thornton, 2016).

In Lebanon the PV market was launched in 2007 with a number of demonstration projects for public utility buildings funded by the Spanish Government and managed by the UNDP. Yet, the key event that shaped the market was the launch of an action plan proposed by the energy conservation centre in the ministry. Several efforts were implemented by governmental institutions in order to promote PV systems in Lebanon, such as the financial mechanism which provides discounted loans at a 0.6% interest rate and repayment period up to 14 years (UNDP, 2014). The Lebanese Central Bank permitted commercial banks to make use of part of their deposited reserve funds to provide consumers with the low interest rate loans for funding green projects (including installations of renewable energy technologies (Banque Du Liban, 2010). This financial mechanism supported the uptake of renewable energy technologies by different sectors and energy consumer groups (Bassil, 2010). International funders such as the European Union (EU) offered 15 million euros as a grant to increase uptake of PV in market. This resulted in the funding of 350 projects by the end of 2015 mostly from the commercial sector (Amine and Rizk, 2016). The amount of installed PV systems is, however, still very low compared to the mass market for solar electricity solutions that exists in Europe (Khoury *et al.*, 2016), thus placing the Lebanese renewable energy market in the preliminary phase of development.

Meeting the global agreements and the national targets will require more understanding of the practices and the decision-making processes at the individual, household, and organizational level. Both policies and other institutional factors are important to enhance the adoption of solar energy technology in Lebanon. However, change can be initiated not only by governments but also requires commitment by individuals, households, communities, and other non-governmental actors (McKenzie-Mohr, 2013; Parag and Janda, 2014; Stern *et al.*, 2016).

In fact, consumers play a crucial role in the diffusion of renewable energy technologies, by actually deciding whether to adopt them or not (Rogers, 2003). They have the power

and will to purchase energy efficient technologies and actively partake in decentralized renewable energy production. With this power in their hands, consumers basically have the potential to start the energy transition themselves. However, consumers often require tailored solutions to achieve this. This doctoral thesis will use various aspects from behavioural, socio-technical, and business perspectives to improve the understanding on eco-innovations in particular.

1.4. Research scope

The geographical scope of this study is Lebanon. The research focus is in particular on two solar energy technologies. The selection of the scope was based on the potential to result in change of the current electricity shortage situation and the unique political and geo-political situation in the region as elaborated previously. The country is home to a large number of demonstration projects in solar energy technology. Among other MENA countries, Lebanon stands out not only because of its natural climate but also because of its unstable government. This doctoral thesis starts by addressing the stakeholders' views on the diffusion of solar energy technologies. An overview of the technological and socio-cultural dimensions that influenced the uptake of solar energy technologies will be presented in Chapter 3. Further steps in this research will be undertaken to foster understanding of the behavioural drivers and challenges that influence consumers' decision making on whether to adopt SWHs (see chapter 4). Although various efforts were made by national government to achieve diffusion of SWHs through monitoring and the provision of financial incentives, a number of challenges troubled the wider diffusion and development of this technology when encountering the Lebanese market conditions. In light of the policies and projects that have been implemented to increase the uptake of such technologies, SWH has been adopted to a reasonable extent in Lebanon; more than other renewable energy technologies. This serves the purpose of the research to reveal preferences and opinions for the adoption of SWHs from householders to understand what makes consumers purchase and use such systems. To compare the niche market development of the two solar energy technologies (SWH and PVs) the socio-technical approach will be introduced in chapter 5. As explained earlier, this thesis will primarily look into the adoption and market development of solar energy technologies. To accomplish a comprehensive mapping of the procedures to shift to renewable energy

technologies I seek to engage and understand the diffusion (of green innovations) process from multiple disciplinary perspectives (i.e. behavioural, socio-technical, and business perspectives). After getting further insights from different diffusion perspectives, a comparative case study will be conducted.

This doctoral thesis has two general aims. First, it seeks to explore and understand what factors influence the diffusion of solar energy technologies in the commercial and residential sectors. Second, it seeks to understand how solar energy innovations diffuse and what drivers influence this. By reflecting on the diffusion of green technologies from a consumer-oriented, a socio-technical and a business perspective, the research will present a comprehensive, multidisciplinary picture of the drivers, challenges, and opportunities that influence diffusion.

The research objectives are as follows:

1. To understand different theoretical factors influencing adoption of solar energy technologies in Lebanon.
2. To understand the drivers and barriers that consumers face when deciding whether to adopt solar energy technology.
3. To analyze different solar technology projects from a socio-technical perspective to contribute to further understanding of solar energy market development in Lebanon.
4. To integrate relevant insights from the business model literature with the transition studies literature using illustrative case studies.

The research will start with an overview of stakeholders' views on the adoption of solar energy technologies. Next, an empirical analysis of consumers' adoption of SWHs will be conducted. From the socio-technical perspective, another empirical study will be conducted to understand the diffusion and development of solar energy markets in Lebanon. To create a more sustainable transition for renewable energy technologies in Lebanon (as an illustrative case for developing countries), the business model perspective was added to the socio-technical perspective.

1.5. Research questions

This study aims to understand the diffusion of solar energy technology in Lebanon from multiple theoretical perspectives.

This research is guided by two general research questions:

Research question #1: What is the set of drivers that explain the adoption of solar energy technology among different Lebanese stakeholders?

1.1 What are the stakeholders' views, roles, and influence on the diffusion process of solar energy technologies?

1.2 What are the specific socio-cultural factors that influence adoption?

1.3 To what extent do selected theoretical drivers explain household adoption of solar water heaters in Lebanon?

Research question #2: To what extent can SNM and other relevant theoretical insights on business models contribute to further understanding of niche market development of solar energy technologies in developing country contexts, particularly Lebanon?

2.1 How have the solar thermal niche and the solar photovoltaic niche developed in Lebanon, and how do they compare?

2.2 In which ways does the Strategic Niche Management framework help to understand the development of solar energy niches in a developing country context?

2.3 What is the role of business models in the transition towards decentralized energy systems using renewable energy sources?

2.4 What are the promising opportunities for business models utilizing solar energy in a developing country context?

In order to answer these questions, my theoretical approach to this doctoral study is sub-divided into two tracks. The first track assesses socio-cultural and contextual factors influencing the solar energy market diffusion using theory from sociology (innovation-diffusion; socio-cultural factors), and (environmental) psychology. The focus in this track is on consumers, assuming that they are a key stakeholder in the solar energy market. The second track evaluates the transition of solar energy technologies twofold, (1) by comparing the solar thermal energy niche with the solar PV niche using the Strategic Niche Management framework, and (2) by integrating insights from business models and synthesizing these with relevant transition studies literature. The next sections describe the two tracks. Figure 1.1 presents an overview of the structure of the thesis showing the chapters and their respective tracks.

Figure 1.1 Structure of the thesis

First track

The theoretical underpinning of this track concerns the innovation diffusion framework (Rogers, 2003). The aim of this track is to explore and describe ongoing factors shaping the uptake of solar energy technologies. This track has two stages; they concern the stakeholders' perspective and the consumers' perspective. The first stage has the purpose of understanding solar energy technologies' diffusion and mapping stakeholders with their respective views and influences. In this stage, socio-cultural concepts are integrated with the diffusion of innovation framework. Notions from the Lebanese context are integrated with frameworks from innovation diffusion on the individual and organization levels. The second stage combines innovation diffusion with notions from environmental psychology to provide a comprehensive overview of consumer adoption decision making in order to improve the explanatory power of the research model. The results of this track are presented in chapters 3 and 4. Figure 1.2 presents the chapters with the research questions that each of them answers.

Second track

In this track innovation diffusion will be addressed from a socio-technical perspective. The aim of this track is to investigate the market formation of solar energy technologies from both a societal and business model perspective. The first stage aims to compare and discuss different market formation situations regarding solar thermal energy technology and solar PV energy technology. Building on this and on the views of stakeholders in track 1, the business model perspective is used to map the challenges, drivers, and opportunities for diffusion of these solar energy technologies. The results of this track are presented in chapters 5 and 6. Figure 1.2 presents the chapters with the research questions each of them answers.

Figure 1.2: Research questions and their relation to chapters in this doctoral thesis.

1.6. Research framework

The ultimate purpose of this doctoral thesis, including all sub-studies, is to create a knowledge basis for developing guidelines for introducing renewable energy technologies in developing countries. This is will not be achieved without understanding the phenomenon of diffusion of solar energy technology from multiple disciplinary perspectives, thus with understanding of behaviour towards sustainable technologies, and possible actions and practices towards the diffusion, uptake and (niche) development of a specific solar energy technology. The study involves both quantitative and qualitative research. The introduction of research into the phenomenon is qualitative, and is later accompanied with a quantitative survey. With the inclusion of a quantitative hypotheses testing study along with qualitative explorative studies, a rich and comprehensive insight in the phenomenon of interest will be achieved. This multidisciplinary and multi-methodical approach has been incorporated to adequately meet the complex aspects of this study that require mixed method research.

The thesis begins by providing a theoretical basis for the empirical chapters that follows. Chapter 2 describes the theoretical frameworks applied in each empirical chapter.

The first empirical study (presented in chapter 3) starts by providing an overview of stakeholders' views and influence that contribute to the development of solar energy markets. This chapter contributes to the diffusion of innovation body of research through integrating socio-cultural insights. Thereafter the encountered barriers and potentials are introduced to be tested among adopters and potential adopters at the individual level. By doing so, the behavioural perspective of the end users is introduced for the aim of addressing individuals' perceptions. This presents one direction of the thesis, whereas the other direction basically addresses another perspective, that of diffusion studies from the socio-technical perspective. By combining these perspectives, a comprehensive overview is created which will result in more comprehensive insights into successful diffusion of solar energy technologies with the support of the business model perspective. By doing so, I strive to pave the way to present a guideline for diffusion of renewable energy technologies in a developing economy context.

1.7. Structure of the dissertation

The thesis is divided into four parts: an introduction (Chapter 1), a theoretical background (Chapter 2), an empirical research part (Chapters 3 to 5), a conceptual research part (Chapter 6) and a concluding part (Chapter 7). These chapters are structured as follows:

Chapter 1 introduces the study area and background for the dissertation. This chapter (the current chapter) also addresses the general research problem and the research questions which constitute the four empirical chapters. Furthermore, the methodological approach pursued in this study is presented briefly and later followed by a research framework representing the structure of this study. In the end, an outline of the thesis structure is explained.

Chapter 2 presents a review of the relevant conceptual and empirical literature. Different studies on renewable energy technologies' adoption, with a special focus on SWHs and solar PVs, will be discussed in this chapter. It outlines the overall theoretical process of diffusion of renewable energy technology and other clean technologies by integrating socio-cultural and behavioural perspectives to enrich the diffusion of innovation framework (Rogers, 2003). The second subsection, then, starts with a review of the conceptual diffusion-of-innovations literature, and more specifically on niche development of renewable energy technologies. Different theoretical angles will be explored to understand the uptake of sustainable technologies. The diffusion of innovation theory is selected due to its success in explaining diffusion. The thesis critically assesses the gaps that have been identified in earlier studies and possible complementary research areas are identified and used to complement this theory on one hand and to provide a comprehensive overview of diffusion from alternative perspectives. An integrated perspective from sociological studies and behavioural studies is then discussed, which will serve as a basis for the quantitative study of consumer behaviours in Chapter 4. By this, the first theoretical track, explaining diffusion at the individual level will be completed and the thesis moves to the second track, that is on the diffusion at a larger societal market level. Literature from the transition studies discipline is introduced briefly, as well as discussion of new insights.

Chapter 3 addresses an empirical study on the views of stakeholders on the uptake of solar energy technologies in the Lebanese market. This study presents an overview of the stakeholders' views, roles with a particular focus on socio-cultural factors that influence the diffusion process of solar technologies. The main aim of this chapter is to map the influence of different stakeholders. This study mixes grounded and critical theoretical approaches with a case study allowing a semi-inductive process of building on or complementing new insights into the existing literature. The analysis shows that contextual factors specifically related to the social, cultural, geographic, and market dimensions play a crucial role in shaping the market development and explaining the uptake of solar energy systems by different energy consumer groups. This study further reveals the importance of integrating certain socio-cultural dimensions into the adoption literature of renewable energy technologies from stakeholders' perspectives.

Chapter 4 presents the results of an empirical study that investigates the consumers' perceptions towards SWHs adoption. In this chapter, the behavioural perspective is combined with the diffusion-of-innovation studies to strengthen the explanatory power of this approach to address consumers' adoption decisions. The study represents a survey of 200 households divided into adopters and non-adopters to understand the influence of a selected set of theoretical predictors on the adoption-decision-making of households. This study emphasizes the householders' perceptions who are one of the main stakeholders in the market and are the ones that can result in system change.

Chapter 5 is an empirical comparative study of the solar thermal and solar PV market niche development. This chapter discusses the differences in niche development between the two technologies and the possible framework which can explain the steps taken to result in change. The results show the contextual differences for applying SNM in a developing country context, and by doing so, contributes to the transition literature. It further reveals the critical role of the international donors in niche market development and their influence on shaping niche internal processes.

Chapter 6 is further reflecting on the previous chapter (chapter 5) and integrating insights from a business model perspective to the transition studies perspective to lead to a sustainable transition of renewables in Lebanon. These strategies are expected to contribute to fostering sustainable, long term results regarding the diffusion of renewable energy technology. This chapter addresses the similarities between the

SNM framework and the business model perspective, and then describes the aim of the latter in satisfying consumer needs and addressing the challenges they encounter. The results show the development of business models in Lebanon and provide suggestions for innovative business models that contribute to niche development, overcoming market challenges, and increasing consumer adoption of renewable energy technologies, in particular solar energy technology.

Chapter 7 sums up the results from the empirical studies, discusses them on their academic merit, and draws on insights developed from using the transition studies framework, while discussing how solar energy niche development can influence the energy market regime in Lebanon. This chapter ends by answering the overall research questions. It also presents prospects for future research.

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Chapter 2: Diffusion of renewable energy technologies; behavioural, socio-technical and business model perspectives

This chapter starts with an overview of studies on adoption of renewable energy technologies. They use different conceptual frameworks.

The essence of this chapter is to create a broad understanding of theoretical concepts that are related the very uptake of renewable energy technologies. Furthermore, it addresses a set of theoretical frameworks that form the conceptual basis of research conducted in this doctoral study.

2.1. Diffusion of innovations and consumer adoption

Theories dealing with understanding diffusion of innovations go back to the period between 1920s and 1930s. The most well-known work in this field is Everett Rogers', Diffusion of Innovations (DoI) theory. According to Mowen (1988) consumer purchasing behaviour falls into three perspectives; decision making (which DoI encounters), experiential, and behavioural influence. In the decision making perspective consumers get through problem solving responses such as searching and evaluating products that will create a sense of satisfaction after the purchase. Even though DoI theory is presented as a single theory, it is basically a set of interrelated sub theories developed by studying diffusion and adoption from different perspectives, and in a variety of contexts (Rogers, 2003).

According to Rogers (2003) consumer innovation adoption behaviour is the degree to which individuals adopts a new product or innovation relatively earlier than the other members in a given social system. Five stages shape the innovation-decision process ranging from initial knowledge of the innovation. They are: persuasion (attitude formation), decision, implementation (use of the innovation), and finally, confirmation of the innovation decision. The first two stages of the innovation decision process are responsible for attitude formation, and are thus essential to the entire process. Personal traits (e.g., tendencies to seek for new experiences) are considered to be responsible for attitude formation of the potential adopter and on how the characteristics of the innovation are perceived (Parthasarathy *et al.*, 1995; Peter *et al.*, 2005). Due to the key role that consumer adoption plays in triggering innovation diffusion in a given market,

consumer behavioural aspects of DoI have received considerable attention (e.g., Im *et al.*, 2003). By understanding consumers' new product adoption behaviour, organizations and companies are more capable to identify the markets they target, position products and design communication strategies.

Therefore, consumer adoption can be seen as the micro-perspective of the diffusion of innovations, where the latter is viewed as the macro-perspective. In the DoI framework an innovation is defined as an idea, practice, or object that is perceived as new by an individual or other unit of adoption (Rogers, 2003: 134). The focus here is not only on the innovation itself, but also on how it is perceived by potential adopters. In fact, several adoption researchers focused on common characteristics of adopters have (such as personality traits and socio-demographic characteristics), and consumers' perception in relation to time of adoption (Wang. Adoption time is an aspect that classifies adopters. Another aspect would be how different adopter groups perceive different innovation characteristics. The latter would serve as a means of understanding how innovations can be introduced and communicated.

Although DoI is an intensively studied research domain there are still areas that need to be addressed. For example, the need to focus on values and general attitudes influencing adoption decision still receives limited scholarly attention (Wang *et al.*, 2008). In addition, there are only few studies that address eco-innovations using the DOI framework to explain for adoption. Other studies foremost deal with diffusion at the macro-level (Schwarz and Ernst, 2009). And relatively few studies focus on the adoption of eco-innovations from an organizational perspective (Janssen and Jager, 2002).

2.1.1. Adopter categories and innovativeness

The DoI framework categorizes adopters in relation to the time they take to adopt an innovation, thus categorizing individuals sharing similar characteristics. These are called adopter categories ranging from the groups most likely to adopt to the least groups least likely to adopt a given innovation: innovators (2.5%), early adopters (13.5%), early adopters (34%), late majority (34%), and laggards (16%) (Rogers, 2003)

The conceptualization of innovativeness; as discussed in previous section. has been criticized of being too much focused on the operational level (Midgley and Dowling,

1978). The conceptualization of innovativeness deals with whether all early adopters are innovative, and vice versa, and whether individuals with high innovativeness were always the ones most early to adopt. Therefore, the innovativeness construct has been understood more recently to be a psychological personality feature with higher generalizability across product categories (Roehrich, 2004). Tellis et al. (2009: 1) define innovativeness as, “a consumer’s propensity to adopt new products”, such as seeking information about new things and trying new types of behaviours. Regardless of innovativeness’ importance in classifying adopters into categories, it is not the only discriminating factor. By considering innovativeness as a personality trait instead of dependent on time of adoption, it reveals that innovators do not necessarily always exhibit high levels of innovativeness. Therefore, other more important factors might also contribute to how adopter groups can be characterized.

2.1.2. Innovators and early adopters

Rogers (1995) describes innovators as pioneers. Innovators have common communication patterns and friendships, and tend to have high income and education (Im *et al.*, 2003). They also have the ability to understand complex technical knowledge and to address uncertainty about innovations. Innovators play a crucial promotional role in the diffusion process (Phau and Lo, 2004). This role has been described by Rogers (2003) as that of launching a new idea into the system by importing the innovation from outside the system’s boundaries. In this perspective innovators and early adopters are considered to be an important source of information to later adopters. And early adopters are seen essential to a product’s ultimate success (Burns, 2007).

According to Rogers (2003) early adopters have the greatest degree of opinion leadership (the degree to which an individual is able to influence other individuals’ attitudes) in most systems, and potential adopters look to them for advice and information about the innovation. In other words, they are generally sought by change agents (such as marketers) to serve as local promoters for speeding up the innovation-diffusion process because early adopters are characterized as being a more integrated part of a local social system than innovators. Since early adopters are not too far ahead of the average individual in innovativeness, they serve as role models for many other members of the social system they belong to (Dickerson and Gentry, 1983;

Hirschman, 1980; 2003). That is why Rogers (2003) describes the early adopter as the ‘heart of the diffusion process’; they play a role in decreasing uncertainty about a new idea by adopting, presenting a subjective evaluation of the innovation to their peers.

2.1.3. Determinants of consumer innovation adoption

Rogers (2003) discerned the determinants of adoption into sociodemographic and personality variables (i.e., knowledge, openness for change, empathy, and coping with risk) and communication behaviour (i.e., exposure to media and social participation). Another set of important characteristics, is consumer perception of the innovation’s attributes.

Perceived attributes

According to Rogers (2003) these attributes influence adoption decision-makings. They are: (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability.

Relative advantage refers to “the degree to which an innovation is perceived as being better than the idea it supersedes” (Rogers, 2003). It is considered an important determinant of adoption. Relative advantage can be of any nature (such as economic, social, or personal aspects). In empirical studies perceived relative advantage was found to have a positive influence on the adoption of several environmental innovations, particularly solar energy systems (Guagnano et al., 1986; Labay and Kinnear, 1981), alternative fuel vehicles (Jansson, 2011), and on the intention to adopt electronic devices providing feedback on in-home energy use (Völlink et al., 2002). The main drivers for adopting micro-generation technologies are (perceived energy savings and lowering of fuel bills Caird et al., 2008; Caird and Roy, 2010). On the other hand, negative effects of investment costs (Mahapatra and Gustavsson, 2008), energy costs, and maintenance costs (Willis et al., 2011), and costs of SWH piping from roof to apartment (Mills and Schleich, 2009) proved important barriers to adoption of micro generation technology.

Compatibility is the degree to which an innovation is consistent to existing values, experiences, and needs (Rogers, 2003). Some researchers, such as Guagnano et al. (1986); and Völlink et al. (2002) addressed compatibility in a narrower context than Rogers and explained it as being consistent with values. The more compatible an

innovation is the less change in behaviour it presents and the faster it is adopted by individuals (Jansson, 2011; Ozaki and Sevastyanova, 2011).

Complexity is defined as the extent to which an innovation is difficult to understand and use (Rogers, 2003). Complexity may not be as important as relative advantage or compatibility for some innovations, but for other innovations complexity is considered an important barrier to adoption. For instance, Labay and Kinnear (1981) compared perception of consumers to solar energy systems and found that adopters consider these innovations as less complex than non-adopters. Hence, perceived complexity was found to negatively influence innovation adoption.

Trialability is the degree to which an innovation can be tested on a limited scale (Rogers, 1995). Janssen and Jager (2002), Labay and Kinnear (1981) and Völlink et al. (2002) found that trialability did not relate to adoption of energy conservation intervention technology, nor to adoption of solar energy systems. In fact, the nature of the technology was found to predetermine its characteristics, such as solar energy technology often being a one-time investment, and trialability of the system is not a feasible option without actually investing and installing the system.

Observability is the degree by which the results of an innovation are visible to others (Rogers, 2003). By their very nature, standing on rooftops, SWHs have on average a high degree of observability. Several researchers found that observability has a positive influence on adoption of clean energy technologies (Guagnano *et al.*, 1986; Jager, 2006; Jansson, 2011). However, Labay and Kinnear (1981) argue that the more familiar a consumer gets with innovations, the less observable they become.

2.1.4. Strengths and weaknesses of diffusion of innovation theory

DoI theory has made a valuable contribution to the academic literature increasing understanding of consumer innovation adoption. It has provided a clear understanding of how innovations diffuse and how these innovations end up being adopted by individuals and organizations through addressing the set of factors influencing such a decision. Although DoI deals with most of the critical aspects of diffusion, it fails to address certain problems. One of the shortcomings of this framework is the knowledge gap on cultural characteristics. Therefore, it is urgent to explore when and how socio-cultural factors influence the innovation-diffusion process. This can be explained more

by the differences between regions in socio-economic and socio-cultural dimensions that shape decision making. Another major gap is that DoI lacks research into fundamental value sets which determine adoption of a certain technology. More critically, pro-environmental values related to eco-innovation need more research and attention, such as the innovativeness concept, which is a crucial component in DoI theory (Rogers, 2003).

Knowledge is addressed by Rogers (1995) to be one of the most critical variables in the consumer innovation decision process. In this context, Keirstead (2007) argues that for consumers to adopt micro-generated electricity in their home, it is essential to be aware and to understand the technology itself. However, this point along with utilizing technology characterization were not empirically verified in eco-innovation adoption studies. As an example, Guagnano et al. (1986) and Labay and Kinnear (1981) conducted a study on solar energy systems, but did not focus specifically on the environmental aspects of these systems and did not include any specific measure of environmentally related values. Therefore, by addressing a broad perspective of perceived innovation characteristics next to other sets of factors would be a valuable contribution to existing understanding of eco-innovation.

To elaborate this, DoI will serve as a theoretical framework used in the empirical studies that will be presented in Chapters 4 and 5 of this doctoral thesis. These chapters will show that consumer innovation adoption is a function of socio-demographics, innovativeness, knowledge, values, and perceived innovation characteristics. The DoI framework is known for its focus on technological innovations and their associated determinants without focusing on eco-innovations and their respective determinants. Therefore, using the framework on its own is insufficient.

2.2. Consumer behaviour and its determinants

The use of an interdisciplinary approach is needed to understand and influence situations where behaviour and choice are closely linked to structural forces exerted by the prevailing socio-technical environment, and where coordinated change in choices, behaviours and socio-technical structural factors is deemed socially desirable.

Consumer behaviour can be researched from different disciplinary perspectives; each discipline using particular assumptions of its own. For instance, Olander and

Thøgersen (1995) criticized the economic disciplinary approach which states that all consumers are assumed to be rational decision makers. That is the economic incentives is the primary factor that matters vis-à-vis influencing consumer behaviour to become more pro-environmental (Frey and Stutzer, 2008). On the other hand, it is common in consumer psychology, sociology, and marketing perspectives, that consumers' decisions are less dependent on financial or rational factors, and are more commonly influenced by other decision-criteria such as social norms (Griskevicius, Cialdini and Goldstein, 2008). Therefore, one of the ways to understand consumer behaviour is to approach it from a behavioural and socio-cultural perspective.

The socio-cultural dimension

Consumer behaviour is often socially dependent since the decisions they make today will impact the future on both the individual and collective level. Therefore, the more people act pro-environmentally today, the better the long term benefit for society at large is likely to be (Jansson, 2009).

This shows that merely focusing on financial incentives to encourage pro-environmental behaviour is not enough and even neglects the significant role of environmental morals and motivations (Frey and Stutzer, 2008). Several scholars have shown the significance of values and norms in guiding consumer action (Olander and Thøgersen, 1995; Thøgersen, 2002).

Building on this, Daghighi, Petrof and Pons (1999) argue that to understand diffusion of innovations one should understand the crucial role value systems have on potential adopters. In turn, Ezeonu and Egbue (2014) argue that social and cultural factors play a significant role in the innovation diffusion research, yet it has often been neglected by researchers. The cultural dimension - although seen as a critical perspective – therefore, is added to other dimensions to successfully address innovation-diffusion challenges. For instance, Urmea (2016) holds that differences in adopting certain technologies between regions of different socio-economic status and cultural dimensions, and that the latter can strongly influence the way in which a particular technology is adopted. In addition, Disli et al. (2016) suggest that culture might act as a helpful dimension for policy makers to further understand (and contribute to problem definition within policy making processes) and trigger renewable energy technology adoption, which, in turn, can support lowering of carbon emissions.

Reflecting on the importance of the socio-cultural dimension Eseonu and Egbue (2014) support the idea of the cultural dimension having a strong influence on fostering innovation- diffusion and support considering this aspect in future studies. Different factors play a role in technology diffusion, yet integrating the social, cultural dimension along with DoI, technology and policy dimensions will present a rich and comprehensive contribution to explain innovation-diffusion to a more systemic approach. Therefore, when the cultural dimension is better understood and combined with other contextual aspects and system's characteristics leading to system change, various risks and challenges facing consumers' decision making might be better understood (Shortall and Kharrazi, 2017).

2.3. Frameworks on consumer behaviour determinants

By understanding consumer innovation adoption determinants and consumer behaviour from innovation, personal, and socio-cultural perspectives contribute to a comprehensive understanding of innovation adoption. For this reason, in this doctoral study determinants of eco-innovation adoption from innovation theory and pro-environmental behaviour will be integrated. According to Stern (2000) there is a set of factors that influence pro-environmental behaviour. They are: personal capabilities, contextual forces, attitudinal factors, and habits or routines. In turn, Steg and Vlek (2009) argue that it is very important to consider contextual factors, such as physical infrastructure, product characteristics, and technical facilities, next to intra-personal factors, such as attitudes, norms and habits in order to engage people in pro-environmental behaviour. Due to the focus of this thesis on consumers' adoption of solar energy technologies, the contextual factors will be integrated with attitudinal and innovation relevant factors to increase the explanatory power of the model.

2.3.1. Personal capabilities

Personal capabilities refer to skills and knowledge required to perform specific behaviour, general capabilities and resources such as time to act, money, and social status (Stern, 2000). Socio-demographic factors such as age, education level, and income are regarded as indicators that resemble personal capabilities (Jansson, 2009). Empirical studies have revealed that income has a positive influence on installing or adopting solar energy technologies (Jager, 2006; Mahapatra and Gustavsson, 2008;

Sidiras and Koukios, 2004; Wang et al, 2008). Sidiras and Koukios (2004) argue that rent of residential space, and low family income, are major barriers to diffusion of SWH collectors among householders. An explanation for this phenomenon would be that households of higher income have a greater financial ability to afford new products. In addition, they usually have a high level of education. And therefore they are more likely to be aware and have a relatively open mind-set to adopt new more expensive products (Wang et al., 2008). Similarly, Claudy et al. (2010) found that the more highly educated people are the more likely they are to adopt micro-generation technologies, due to their 'high-involvement' with this particular technology. In a study assessing twenty five issues related to decision-making Kastner and Stern (2015) revealed that education and energy-related investment decisions were found to statistically correlate positively and significantly with household energy investments.

Despite their assumed influence on adoption of clean energy technologies among householders, socio-demographics were found to have relatively little explanatory power (Cottrell, 2003; Ostlund, 1974; Rogers, 2003). Furthermore, these factors alone do not highly explain pro-environmental behaviour (Stern *et al.*, 1999) and are often merely used as control variables.

2.3.2. Contextual factors

Contextual factors include external factors such as political, economic, societal, and technological drivers and barriers that influence pro-environmental behaviour (Stern, 2000). These factors include rules and regulations in society, social norms, financial costs and benefits, physical and political barriers (Jansson, 2009). From a consumer behavioural perspective, the way contextual factors are perceived influences actual behaviour of consumers, i.e., the perception of contextual factors might be more important than the object of measurement itself. For instance, financial incentives are often used in government policy as a means to persuade householders to invest in renewable energy technology. According to Caird et al. (2008), Caird and Roy (2010) and Sidiras and Koukios (2004) governmental grant schemes are important drivers for homeowners to adopt SWHs. Steg and Vlek (2009) argue that for policy interventions to create change in the consumer decisions, it is effective to promote pro-environmental behaviour through shaping contextual factors rather than informational strategies targeting awareness raising and knowledge provision among target group members.

2.3.3. Personal and social norms

Stern *et al.* (1999) developed the norm activation model to a pro-environmental consumer behaviour (the VBN model), which conceptualizes attitudinal factors (values-beliefs-norms). This model has been used to explain a variety of low involvement consumer behaviours (which entails routine response behaviour or low problem solving), which includes acceptability of energy policies (Steg *et al.*, 2005), energy conservation behaviour (such as power conservation, ecologically aware consumer behaviour, garbage inhibition, and ecological automobile use) (Kaiser *et al.*, 2005), and willingness to reduce car use (Nordlund and Garvill, 2003). Personal norms are a set of internalized feelings of a personal moral obligation to act in a certain way (Schwartz, 1977). According to Thøgersen (2006) environmental behaviour not only correlates with personal norms, but also with subjective social norms. According to (Schwartz, 1977), social norms are a reflection of perceived expectations of important reference persons in the local community they belong to. Therefore, the impact of social norms on consumer behaviour is often a result of social pressure. When consumers decide to follow their personal norms, their behaviour is linked to the fear of negative self-related feelings such as regret (Bamberg *et al.*, 2007; Schwartz, 1977). Personal norms are formed as a result of shared expectations in social interaction. They are usually reshaped based on the interaction history of each individual person (Schwartz, 1977). Studies showed that personal norms have an impact on pro-environmental behaviour. Biel and Thøgersen (2007), for example, showed that personal norms relate to different kinds of consumer behaviour such as waste handling (Hopper and Nielsen, 1991), consumer purchases of green products (Thøgersen, 1999), or political decision-making (Stern *et al.*, 1999).

Previous studies focused on studying green consumer behaviours for low cost and low involvement products (i.e., Diekmann and Preisendorfer, 1998). However, few researchers thus far paid attention to high cost, and high involvement products. As discussed above, personal norms seem to be well suited for recycling behaviour and purchasing of non-durable products, yet little attention is paid to influence of personal norms when purchasing high involvement products. Therefore, Hage, *et al.*, (2009), Kaiser *et al.*, (2005) and Thøgersen (1999) have called for more research on focusing on norms and green consumer behaviour in high involvement products. Due to the

connection between social and personal norms, the former has received considerable more attention in the literature. Furthermore, few studies on most contextual factors have been conducted. However, the influence of social norms has received considerable attention, which is likely due to the connection between personal and social norms (Jansson, 2009). For instance, Ajzen (1991) and Schwartz (1977) discussed this point by pointing out that people are social beings, and therefore they are in continuous search to comply with social norms and keep a positive image of themselves in front of others. This claim was verified in studies by Biel and Thøgersen (2007) and Thøgersen (2006) who found that social norms guide consumer behaviour in particular contexts. This shows that social norms work best on a group level that influences individuals. According to Jansson et al.(2017) personal norms had a strong positive influence on green purchasing behaviour of high involvement durables (the case of alternative fuel vehicles). Social norms were also found to have positive direct influence on energy conservation behaviour (Goldstein et al. 2008). Biel and Thøgersen (2007) addressed the significance of social norms in guiding consumer behaviour claiming that social norms are functional in influencing consumer behaviour because they do not involve much cognitive effort.

2.4. Managing the development of technologies: Strategic Niche Management

This section provides an overview of key literatures on socio-technical transitions. The study of socio-technical transitions focuses on the interplay between technology and society. Since technology is rooted in the society, the two aspects are studied simultaneously because they are interrelated and cannot be separated. A change in technologies might have great societal impact, and might lead to unpredictable change in rules and routines of technology users. Here, the main focus is not just on the development of knowledge but also on the diffusion and use of technology, impacts, and the institutional and societal transformations that are essential for technological change (Geels (2004).

According to Foxon (2007) socio-technical transitions can be defined as a multi-actor, radical, long term macroscopic processes of transformations in the prevailing set of routines used by the actors in a particular area of technology. Technological change is

a process described as a socio-technical transition where producers and users of the technology are both rooted in a broader social and economic context (Geels, 2004; Rip and Kemp, 2009). So, a socio-technical system consists of heterogeneous elements such as technology, policy, markets, consumer practices, infrastructure, cultural meaning and scientific knowledge. (Nykqvist and Whitmarsh, 2008; Xue et al., 2016).

The energy supply sector is one among other economic sectors which can be conceptualized as socio-technical systems. These systems consist of (networks of) actors (individuals, firms, and other organizations, collective actors) and institutions (societal and technical norms, regulations, standards of good practice), and material artifacts and knowledge (Markard et al., 2012). Socio-technical transition can be interpreted as a set of processes that lead to a fundamental shift in socio-technical systems (Kemp, 1994). Kemp (1994) reflected on the role of the government. It is crucial in the transition process as it can provide financial support for technological innovation or facilitate the innovation process through creating and enforcing specific policies and/or institutions.

Seeking to understand the complex dynamics of societal change, and building on concepts from social constructivism and evolutionary economics, the Multi-Level Perspective (MLP) framework on socio-technical transitions was developed (Geels, 2002; Geels and Schot, 2007). MLP conceptualizes how sustainability transitions take place through the interaction of process at three different levels, namely the socio-technical landscape, the socio-technical regime, and the niche level (Geels, 2002). Based on this, regime shifts occur due to the alignment of processes and to the interaction of the multiple levels which in turn are perceived as a nested hierarchy. At the macro-level, the socio-technical landscape denotes the external context of a socio-technical system which influences dynamics at the regime and niche level. A socio-technical landscape is related to material context of a certain society. It is denoted by factors on the macro level such as geopolitical events, international agreements, oil prices, environmental problems, and deeply rooted cultural values (Viétor et al., 2015). That is to say that, the landscape forms the surrounding of interaction between actors. At the meso-level, the socio-technical regime represents a stable set of configurations consisting of institutions, techniques and artefacts, as well as the dominant cognitive, regulative, and normative rules. This various set of rules make each regime somewhat

autonomous. Yet, rules are connecting between regimes as well as within them. System innovations occur through interaction between dynamics at multiple levels (Nykqvist and Whitmarsh, 2008). Changes in regimes mostly have an incremental nature, yet internal or external pressures can lead to modifications in the structure of how things are done. Deviations from the current regimes are provoked by landscape pressures, such as higher awareness levels of the need for sustainable energy (Geels, 2004). Regardless of the scope of pressures, due to the vested interests of regime actors' radical innovation originating from outside the regime (i.e. originating from pressures of the landscape level and the niche level) are most likely to occur. Innovation in the regime only occurs in the form of improving or adjusting technology incrementally. However, radical innovations challenging the current regime can only develop at the niche level (Geels, 2002). Niches play a crucial role in the MLP, in which niches form a necessary condition for transitions to occur (Hoogma, 2000), yet this condition alone is not sufficient to result in transitional change.

Renewable energy technologies can be viewed as radical innovations because they require different socio-technical configurations, visions, rules, norms, knowledge, actors, and infrastructures to develop and diffuse. Moreover, radical innovations differ from incumbent technologies as they have the potential to radically replace them in a socio-technical regime. These social and technological dynamics mutually interact, develop, and structure new practices through protected "spaces" referred to as niches. Kemp et al. (1998) and Schot et al. (1994) analyzed early market introduction of sustainable transport innovations and found that 'protection' of such 'societal experiments' – that is using experimentation as a concept representing the uncertainty and learning dimensions involved in such activities – is very critical since the 'socio-technical regimes' might reject those innovations and prevent them from becoming mature. Therefore, experimentation in technological niches was seen as an essential step in maturing innovations and regime shifts towards sustainability. Although socio-technical transitions and sustainable technologies gained more consideration in the social sciences in the past fifteen years, socio-technical transition is rooted in evolutionary economics, history and sociology of technology in the late 1970s and 1980s (Markard, Raven and Truffer, 2012).

The early work of in the transition studies field put a lot of scholarly attention on regime orientation and managing sustainability transitions (e.g., Kemp, 1994; Schot et al., 1994; Kemp et al., 1998). Another crucial concept of transition studies is the focus on the niche level which plays an important role in the nurturing of novel technologies.

Strategic Niche Management (SNM) is an analytical approach introduced and developed to enable the diffusion of new sustainable technologies through societal experiments (Caniëls and Romijn, 2008). The term SNM was introduced by (Schot et al., 1994) in the *"Strategies for Shifting Technological Systems: the Case of the Automobile System"* paper, which discussed previous efforts to foster adoption of electric vehicles. It reflected the interest in looking at the change at the society level rather than just at the technology in isolation. The authors argue that technology cannot be separated from society, and therefore should be studied simultaneously. As a result, their strategic considerations went beyond the technical aspects to include regulations, industrial capabilities, economic and political factors.

For instance, Raven (2005) holds that SNM posits societal experiments where actors can examine an innovation in a real-life context and learn about its desirability. This results in a technological niche by the increased number of experiments and actors involved. Once the iterative process of learning and sharing experiences from ongoing experiments and designing new experiments occurs, the technological niche will encounter more stability. Although, the concept of "proto-market" was introduced as a driver to jumpstart market niche developments, a critical component of SNM was not yet developed which is the wide socio-technical context (Schot and Geels, 2008). For instance, Raven (2005) explains that SNM posits societal experiments where actors can examine an innovation in a real-life context and learn about its desirability. This would result in a technological niche by the increased number of experiments and involved actors. Thornton (2016) claims that SNM is a framework that is part of socio-technical studies that allow the analysis of movements within the socio-technical niche. Although SNM mostly supports the creation of niches, it is also suggested to be a way to trigger regime shifts (Hoogma et al., 2002). That is to say that SNM does not only focus on manage technological innovations and facilitating the design of policies at the niche level, but also on the systematic breakdown of socio-technical regimes which will later allow the development of niche. Schot and Geels (2008) argue that most of the

literature on SNM concentrates on understanding the early adoption of new technologies that will in the end contribute to sustainable development. The SNM approach assumes that the sustainable path of an innovation could be enabled through the modulating of technological niches. However, Schot and Geels (2008) argue that many SNM scholars (such as Kemp and Hoogma) argue that for a sustainable development to be achieved interrelated technical and social changes are required.

SNM can be defined as, “the creation, development and controlled phase-out of protected spaces for the development and use of promising technologies by means of experimentation, with the aim of (1) learning about the desirability of the new technology and (2) enhancing the further development and the rate of application of the new technology” (Ibid, p.539). In other words, SNM assumes that successful sustainable innovations initiate or demonstration that niches should be created (Xue et al., 2016) from real-world experiments. SNM is assumedly aimed at making connections and at stimulating learning process for further development. When niches are successful they can facilitate the diffusion of innovative sociotechnical practices and systems, this influence can happen through replication of projects within the niche, making changes through many small initiatives, enabling constituent projects to grow in scale and attract more participants, and ultimately by the translation of a niche idea to mainstream.

Caniëls and Romijn (2008) argue that one of the important points that SNM makes is the emphasis on the networks of social actors and the significance of this network for successful niche experimenting and sustainable technologies development (Thornton, 2016).

Articulation of expectations

Articulation of expectations is often seen as the first of niche internal processes. Expectations are described as promises of new technologies and can either be problem oriented and deal with specifications of technology, function oriented, or scenario oriented with a broad spectrum (Mourik and Raven, 2006). When radical innovations have uncertain outcomes, expectations can play a crucial role in bringing in new actors (Xue et al., 2016), strengthen the niche by allowing actors to learn about technology in real life circumstances and develop a community with a shared agenda (Geels, 2011) or guide their activities (Schot and Geels, 2008). In a similar vein, Raven (2005) argues

that at the beginning of a technological trajectory expectations are viewed as broad, general and fragmented. Expectations need to be at a high level of stability for them to contribute successfully to the niche development. Kemp (1994) calls this as the coupling of expectations, a concept that was later elaborated by Raven (2005) and Hoogma (1996, 2000) to the concepts of the voicing and shaping of expectations. Adhering to the latter, expectations tend to be more powerful when they are; (1) accepted and shared by more actors, (2) clear and specific, and (3) supported by experiment results (Schot and Geels, 2008).

Network formation

A technology needs to be supported by a social network if it is to develop a successful niche. In general, different actors have certain perceptions which drive them to be part of a network for various reasons (Xue et al., 2016). Mourik and Raven (2006) argue that actor networks tend to create coordination and convergence of diverse expectations. Thus, for a social network to be effective, it has to include diverse actors with a high level of alignment between them (van der Laak et al., 2007).

For a social network to become effective it has to include diverse actors with high alignment in between them (van der Laak et al., 2007). Moreover, for networks to play a sustaining role in niche development this requires commitment of resources and support for platforms on which actors interact, exchange visions and lessons and develop emerging rules through alignment processes (Opazo, 2014). Given the fact that actors represent institutions with clear practices, arrangements between institutions can foster cooperation and provide resource commitments to sustain the network. Once resources are available, interactions are more likely to occur regularly either in formal or informal platforms.

Learning through multiple dimensions

Learning is seen as the last of the three internal niche processes, It aims at identifying opportunities or barriers for niche development (Mourik and Raven, 2006). The co-construction of technologies, markets, and regulations does not only involve experimentation, but also learning (Watanabe et al., 2009). Since experimentation is seen as the core of SNM, learning has a crucial role in leading actors to learn about the effectiveness of a certain technology to achieve a previously determined goal, or to

change the rules that influence achieving the goal. This shows the importance of learning in niche development towards improving the technology and its societal embedding (Raven, 2005)¹. This can add up to the learning trajectories and thus gradually contribute to changing the content of knowledge, ideas, and perceptions (Raven and Geels, 2010).

By learning about the technology by using it, actors will be enabled to provide feedback to their wider social network. Some scholars distinguished between first order learning and second order learning (see for example Raven, 2005, Schot and Geels, 2008, Byrne, 2011). The purpose of the first order learning is to gather facts and data from different aspects (technology, infrastructure, policy, and user practice) as referred to by Raven and Geels (2010) by the accumulation of data within cognitive frames. This learning can contribute to improvements in the technical and economic performance of a technology practice. In summary, first order learning goes from identifying potential side effects and social desirability to technological solutions and potential improvements that can lead to a working technological configuration. However, first order learning alone is not sufficient to explain how the articulation of experiences and knowledge can create new rules needed for a niche (Opazo, 2014). When actors are able to retain cognitive frames and maps of reality and then adapt second order learning occurs. Second order learning is more reflexive than first order learning and focuses on questioning the available norms and rules to reformulate the expectations, redesign the niche technology, and reconstruct the social network (Mourik and Raven, 2006). Byrne (2009) explained this by arguing that second order learning is more about societal functions than functionality. For effective niche creation to occur, learning processes have to be broad and reflexive (Raven, 2005, Schot et al., 1996, Schot and Geels, 2008).

2.4.1. Assessment of the gaps in the theoretical literature of socio-technical change

Although SNM has many advantages the framework also comes with limitations. Drawbacks concern that the framework was developed in advanced economic and

¹ The impact of project sequence on the technological path at the global level was previously presented by (Geels and Raven, 2006).

social contexts (i.e. the global West). SNM was developed based on specific cultural, market, policy and technological contexts in developed countries, through offering new paths of economic growth (Hoogma et al., 2002, p. 6). Opazo (2014) argues that various empirical studies helped develop this theoretical insight by focusing on energy, food, and transport technologies, all in developed economies. Although these empirical studies have contributed greatly to the socio-technical literature, it was mostly biased towards the development of sustainable technologies through research and development and prototype testing activities. They concern activities that can hardly be replicated in developing economies because the latter lack the technological capacities, the resources, and the adequate policy frameworks. Based on this, the SNM framework was expanded to involve the social embeddedness of technological change through adapting technologies into real life contexts. In this case diffusion of technologies would rather be reframed to match the needs of the markets in developing countries. Opazo (2014) addresses this issue by claiming that the social context is more important than the development of a technology, thus resulting in a new analytical point in developing countries. Developing countries share responsibility in committing to the global climate actions just as developed countries yet the urgency of improving access to basic needs in developing countries is considered more important than responding to climate change issues. This explains that lack of access to societal needs has a direct impact on the wealth level and thus on acquiring eco-innovations as an indicator to the economic development of a developing country (Ockwell et al., 2010).

2.5. Integrating the business model approach into the transition literature

From a business model perspective Charter et al. (2008) argue that to develop sustainable patterns of consumption and production radical innovations are required, starting from market niches all the way to mainstream markets (Tukker et al., 2008).

The business model concept

The business model is relatively new, but is increasingly recognized in research and in business firms (Baden-Fuller et al., 2010; Wirtz 2011). For the business model concept different definitions have been used. They vary with their context of use. Business models can be viewed as a strategy that acts as a reference point guiding ones decisions (Casadesus-Masanell and Ricart, 2010). Moreover, business models can also evaluate business strategies to fulfill its goals and create economic value.

(Osterwalder, 2004). Business models are referred to by some scholars as “mediating devices” that capture the value of an innovative idea through linking it to customers’ needs (Chesbrough and Rosenbloom, 2002; Teece, 2010). Teece (2010) defines a business model as “the design or architecture of the value creation, delivery and capture mechanisms.” Similarly, Bidmon and Knab (2014) argue that “a business model describes how a firm creates and captures value in a value network, which transcends the boundaries of the focal firm.” In a similar vein, Wells (2008) argues that, “the business model undoubtedly influences how consumers think about the product, and the normative rules that shape expectations” (p. 84).

Despite the fragmentation among definitions business models can generally be described as market devices that shape how an organization creates, delivers and captures value (Zott and Amit, 2010). However, there is certain agreement on the basic conceptual meaning of a business model that describes how firms create and capture value (Korhonen and Seager, 2008).

Business models not only deal with linear value creation of a firm from suppliers to customers, but also with complex transactions within value-networks concerning value creation to multiple parties in those networks (Zott and Amit, 2010). A business model consist of three core elements, i.e., (i) the value proposition, that is the value of the product or service provided; (ii) the value creation, that is the process by which the value is developed; and (iii) the value capture, which is related to the financial system of turning the value of a product into financial-economic profit (Chesbrough and Rosenbloom, 2002; Baden-Fuller and Morgan, 2010).

According to Okkonen and Suhonen (2010) business models can be defined as an architectural configuration that maps out a process and its sequence, ownership and responsibilities between stakeholders who work towards creating a business opportunity. That is to say that a business model is a set of user dependent and interrelated elements which include offering a value proposition in return for revenue or earnings. Thus, the value proposition represents the value that a given company promises to offer to its customers either through products or services. Through this value the company distinguishes itself from its competitors. The earnings described here refer to the profit or revenue streams that the business company receives in return for its offerings (Jaap and Akkermans, 2007).

In their overview of the emerging literature of business model and sustainability, Boons and Lüdeke-Freund (2013) argued that business model literature can provide significant insights on market introduction and revenue streams of sustainable technologies. Bolton and Hannon (2016) argue that the core commonality between business model and socio-technical perspective is that they inspect interactions and interdependencies between different components which in turn create an output. For instance, in the business model perspective the key output is the creation and capturing of value for a specified firm and its respective partners, whereas in the socio-technical approach often the focus on the role that technology and technological innovation play in fulfilling societal functions.

Bidmon and Knab (2014) proposed that the core function of a business model within a socio-technical system is to commercialize innovative technology developed at a niche level. The most significant consideration of this would be the value creation and value capture by which a business model embeds a technology into a value network. Hence, business models serve as a link between firm-level activities and market outcome (Baden-Fuller and Morgan, 2010; Zott et al., 2011) and thus play a crucial role in the adoption and diffusion of technology.

A business model will allow to articulate value creation and the value capture mechanism for a technology among actors. In addition, communication between different innovation network actors will not only support learning processes and social network formation, but also attract consumer attention, and investors (Doganova and Eyquem-Renault, 2009). According to Bidmon and Knab (2014) a viable business model might even be more important for a breakthrough than the technical superiority of an innovation. Since business models can arguably be seen as 'value creation devices' (Zott et al., 2011), they are more likely to create value for multiple parties in a value network (Zott and Amit, 2010). That is, business models will not only create competitive advantage for new technologies, but also for new actors in the network who succeed in commercializing new technologies in innovative ways (Wainstein and Bumpus, 2016).

Chesbrough and Rosenbloom (2002) discussed this by explaining that business models can be viewed as market devices for certain innovations to compete with other ones to become widely adopted. In other words, this means having innovative business

models in place focusing on alternative financing schemes to achieve wider diffusion of renewable energy technologies (Gelbmann and Hammerl, 2014; Tongur and Engwall, 2014).

Just as niche experimentations are designed in SNM to help the niche compete with conventional technologies in market, so is experimentation in the business model (Teece, 2010). This means that a business model can be regarded by itself as a lasting experiment which is open to learning and improvements (Morris et al., 2005; McGrath, 2010). Thus, without experimenting and learning about a business model, a lot of market opportunities are basically missed (Tolkamp, 2015). With this experimenting, one can articulate the value creation and capture of a technology in market. Thus shaping business models in an experimental way. For the purpose of defining a business model, Tolkamp (2015) argues that just like process taking place at the niche level, a learning process of trial and error takes place regarding business models. Since a business model takes the form of an experimental process, it can facilitate not only single loop learning, but also double-loop (second order) learning (Sosna et al, 2010), that is involved in the learning process at the niche level. This shows that an “appropriately designed business model can be viewed as an important opportunity to overcome some of the key barriers to the market diffusion of sustainable energy technologies” (p.76) (Wustenhagen and Boehnke, 2008).

2.6. A multi-disciplinary approach

The developed knowledge on consumer adoption and consumer behaviour respectively contribute to the understanding of adoption from different perspectives. This doctoral thesis conceptually builds on four disciplinary approaches; namely DoI (originating from sociology), environmental psychology (from a behavioural point of view), SNM (from transition studies), and business models (from business administration). This multi-disciplinary approach of studying the diffusion of innovations from various point of views aims at improving understanding of the multiple dimensions that influence eco-innovation diffusion.

In this doctoral thesis different theoretical insights are combined to tackle the diffusion of renewable energy technologies from various angles. Further elaboration of the

theoretical aspects and their respective integration will be discussed in the respective chapters.

The approach applied in this thesis is multi-disciplinary due to the multi- and inter-disciplinary nature of diffusion of innovation. Innovation is a very broad term and can include anything which is perceived new by adopters. The diffusion research approach is applied across various fields, such as education, anthropology, marketing, geography, and sociology (Rogers, 2003). Thus reflecting on the multiple disciplines and different approaches are relevant to this phenomenon².

Why did I choose to use a multi-disciplinary approach? The diffusion of innovations is considered a complex phenomenon (see for example (Garcia and Jager, 2011)). Thus, it is important to study it from different perspectives in order to increase ones understanding of the multiple aspects influencing it. On the one hand, individuals (potential adopters) are at the core of the diffusion process, due to their choice in adopting a specific technology. As a result, understanding the various elements that influence their adoption decision is crucial in the diffusion process. On the other hand, policy makers or market actors might intervene in diffusion processes to disseminate a given technology in a market (Karakaya, 2015). Therefore, in order to understand the diffusion of solar energy technologies, one needs to consider multiple facets as well as the contribution of different theories to this particular phenomenon.

In order to increase the conceptual focus not only on technical and market factors but also on behavioural, social and cultural factors and their importance to the diffusion of energy technologies, I believe that by addressing a certain phenomenon from multiple disciplinary lenses we will present a comprehensive picture of critical concepts from various disciplines. Furthermore, we will also shed light on the similar concepts which create a room for integration and thus contribute to the literature of innovation diffusion. Thus reflecting on the diffusion phenomenon from multiple disciplinary lenses. Such research is believed to contribute to reducing the gap between social research and behavioural research on one hand, and between behavioural studies, transition studies and business model literature, and therefore building a solid ground for

² The different innovations that are analyzed in the literature go back to the early scholars of diffusion. For instance Ryan & Gross (1943) who analyzed the acceptance and diffusion of hybrid seed corn on farm operators in two different corn belt communities.

implementations of upcoming technologies. Figure 2.1 illustrates the interrelationships between multiple theoretical concepts.

Figure 2.1: Overview of multi-disciplinary approaches in this doctoral study.

2.6.1. Conclusion

This sub-section summarizes the key theoretical frameworks and concepts that will be used in this doctoral study, and discuss the conceptual similarities.

In the field of novel technology adoption, Rogers' DoI describes the importance of opinion leaders and change agents in influencing the diffusion of technologies within communities through their social network. In addition, this theory (Rogers, 2003) explains that when innovations are presented to the public, the public will experience various technology attributes that will impact its decisions whether to adopt or not. DoI highlights the significant role of the social environment on consumers' adoption decision-making. In researching the implementation of renewable energy technologies it is essential to systematically evaluate and compare cases in different regions or countries while taking into consideration the economic and cultural influences (Shortall and Kharrazi, 2017). That is to say that consumer decisions are socially embedded and

strongly influenced by cultural, personal and institutional constraints (DeCanio, 1998). It highlights the critical role value systems have on individual decision-making. This is also related to the level of complexity associated with adopting a specific technology, which differs between communities based on certain socio-economic and cultural dimensions (Urme, 2016). The socio-cultural dimension bridge the gap in the innovation diffusion literature in addressing cultural characteristics (Daghfous et al., 1999; Eseonu and Egbue, 2014). By doing so, culture can be viewed as a helpful dimension for policy makers to contribute to problem definition within policy making processes, while triggering renewable energy technology adoption. Being aware of the importance of the socio-cultural dimension in relation to other social and technology-related and behavioural concepts, enriches the innovation diffusion literature and improves the understanding of adoption decision making across communities.

As already mentioned, the social influence plays a significant role in technology adoption (Rogers, 2003). Thus, confirming that consumers engage in activities in which they start to use norms that are considered important in (social) groups to which they belong (Ozaki, 2011). This shows that consumer's decision to adopt an innovation is related not only to external influences of the technology but also to the way in which it reflects their identity, values, and norms. That is increasing the understanding of innovation adoption by adding more variables to the contextual model, such as physical infrastructure, product characteristics, and technical facilities, next to intra-personal factors, such as attitudes, norms and habits create higher engagement of consumers in environmental behaviour, and thus adoption (Steg and Vlek, 2009). As a result of expanding the set of explanatory factors, understanding of consumer behaviour will be broadened. Hence, by giving more attention to the consumers' role in the diffusion process, more clarity of users' perspectives will be formed as a starting point for technical developments and marketing strategies. Moreover, having more understanding of the consumer's perspective will benefit upcoming initiatives on market level to have innovative approaches in fostering the diffusion of renewable energy technologies.

For diffusion of low carbon systems to occur, it does not only require understanding and changing consumer practices and behaviour, but also change of government policy, market incentives and technological approaches. Therefore, a socio-technical

approach to transitions was used in chapter 5. This has to do with its focus on technology and technological innovation in fulfilling societal functions.

Niche formation processes are often influenced by certain contextual, institutional, economic, and cultural factors (Lachman, 2013). SNM was applied in this dissertation to reflect on contextual factors from a developing country context. In that sense, reflecting on the use of this framework in a country that readily differs from typical western, developed countries, in which SNM has been typically applied in scholarly work. Chapter 5 presents the insights from using SNM to a developing country context, shedding light on certain contextual and social settings and their influence on eco-innovation adoption decision-making.

The relationship between factors from multiple disciplines is somehow interrelated. This is manifested in the overlap between specific concepts representing information from two different perspectives. So, to reflect on the role consumers have, business models contribute to diffusion of niche technologies by creating value through finding a solution for a current problem in their lives (Tolkamp, 2015). Business models are also said to play a crucial role in bringing sustainable innovation to the market and promote dissemination (OECD, 2012). Thus, the importance of business models lies in their ability to commercialize technology and in implicit rules that apply among actors (Doganova and Eyquem-Renault, 2009; Baden-Fuller and Haefliger, 2013). In this way business models structure certain activities in the niche, and allow for value creation of a technology (Doganova and Eyquem-Renault, 2009). Just as demonstration and experimentation occur at the niche level, business models are also shaped in experimental ways to address market and consumer needs. This shows that business models play a significant role in facilitating various activities in internal niche processes within the wider SNM framework. As such, contextual factors need to be taken into consideration to understand their influence on the business model and thus increase customer participation (Provance et al., 2011) This leads me to explore the role of corporate firms' business models in socio-technical transitions. By doing so a wider understanding of the latter is likely to occur. The business model approach has various similarities with niche internal processes of SNM; they help to (1) shape visions and expectations; (2) form network; and (3) support learning conditions. This is explained in more detail in chapter 6. Expanding this and on consumer needs and behavioural

challenges that influence market development and technology uptake, different types of business models applied in Lebanon are presented in chapter 6.

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Chapter 3: Understanding stakeholders' views and the influence of the socio-cultural dimension on the adoption of solar energy technology in Lebanon³

3.1. Abstract

In light of climate change and global commitments, a great amount of programs and policies have been implemented by governments targeting the diffusion of renewable energy technologies. Successful diffusion relies on the understanding, persuasion and acceptance by consumers and other stakeholders. This article investigates the views, roles and influence of stakeholders on the adoption of solar energy technology in Lebanon. The main research questions are: What are the stakeholders' views, roles and influence on the diffusion process of solar energy technologies? And are specific socio-cultural factors therein that influenced adoption? The influence of different stakeholders (end users, public representatives, banking sector, suppliers, consultants and NGOs) was assessed via qualitative data analysis, in particular semi-structured interviews. Our research perspective combines grounded and critical theoretical approaches with a case study research design allowing for a semi-inductive process to elaborate and complement new insights to the current body of literature on adoption of clean technology innovation, with a particular focus on the socio-cultural dimension. The results show that contextual factors, specifically related to the social, cultural, geographic and market dimensions, played a crucial role in shaping market development, especially in relation to the uptake of solar energy technology by different consumer groups. Based on the results of this study we argue that more scholarly attention should be awarded to the influence of the socio-cultural dimension and stakeholders' perspectives on adoption of renewable energy technology.

³This chapter is based on paper (paper 1) which has the same title. The paper is authored by Houda Elmustapha (the main writer of the paper and author of this dissertation), Professor Hans Bressers based at the University of Twente and Dr. Thomas Hoppe based at the Delft University of Technology. The paper has been published in *Sustainability*, Vol 10 No. 2, January 2018, pp. 364, doi:10.3390/su10020364.

3.2. Introduction

The rapid growth in global energy demand, alongside the decrease in gas and oil reserves and the problem of the global warming, has led many countries to formulate policies to promote the uptake of renewable energy technologies. Developing countries, however, face many problems to do so. They often suffer from a lack of resources, a dearth of political will and challenging national priorities that prevent the establishment of facilitative action (Urmee, 2016).

This article presents a case study on innovation adoption of solar energy technologies (i.e. solar thermal systems and solar photovoltaics in this study) by households and business firms in the developing Middle Eastern country of Lebanon. This choice reflects the fact that solar energy technologies have a large potential in the country, given its rich solar resources. Although national government and donor initiatives contribute to the diffusion of renewable energy technology in developing countries such as Lebanon, consumers play a crucial role in the process by actual deciding whether to adopt or not (Rogers, 2003).

In August 2010, the Lebanese government became the first Arab country to develop an action plan for energy efficiency and renewable energy of its own (Khoury et al., 2011)—entitled NEEAP. It aimed to achieve a goal of 12% renewable energy by 2020 through various initiatives and actions by the national level. Support for solar water heaters (SWHs) and solar photovoltaics (PVs) were among the initiatives launched by national government and supported by the United Nations to support establishing projects. The latter were generally funded by international parties.

At the national level, solar energy technologies received subsidies to become more attractive to end users. For instance, SWH entailed one of the most mature renewable energy markets in Lebanon (Nassab, 2013) and was said to lower the total electricity bill for a typical Lebanese household by up to 25% (LCEC, 2012). Globally, SWH is seen as one of the most popular solar thermal systems. It accounts for 80% of the solar thermal market world-wide (Wang et al., 2014). Due to the unique conditions of Lebanon, solar PVs are also increasing in importance as an option for citizens to overcome the shortfalls of power supply from the utility grid and without having to revert to costly local diesel generators (Harajli et al., 2016).

We argue that socio-cultural factors are of great importance in understanding the innovation diffusion process of clean technologies like SWH and PV. We believe that by understanding socio-cultural aspects in a regional context, a stronger and richer understanding will be developed of the dynamics shaping the policies and transformation strategies to foster solar energy technology adoption (Shortall and Kharrazi, 2017). Previous studies have much ignored the importance of the end users' needs and socio-cultural perspectives (Elmustapha et al., 2018a). Due to the multidimensional nature of technology adoption, a difference in rates of adoption of technology can occur as a result of, not only economic and technological factors but also of socio-cultural factors (Eseonu and Egbue, 2014). For instance, Qian and Yin (2017) argued that instrumental attributes may not be the most crucial factors for adoption of sustainable innovations (Qian and Yin, 2017). Instead, other environmental, symbolic, or innovative aspects may be more important to consumers (Noppers et al., 2014). This means that technology adoption may reflect various dimensions, including socio-cultural and situational differences.

The purpose of this study is to explore the role of socio-cultural aspects next to other technical and economic aspects in the adoption of solar energy technologies. Therefore, we will explore the views, roles and influence of various stakeholders' groups in the solar energy market in Lebanon and reflect on adoption from a contextual and socio-cultural point of view. This article addresses two main research questions: (1) What are the stakeholders' views, roles and influence on the diffusion process of solar energy technologies in Lebanon? And (2), what are the specific socio-cultural factors therein that influence adoption? To answer these questions, this study combines grounded and critical theoretical approaches with a case study research design allowing for a semi-inductive process to elaborate and complement new insights to the current body of literature on adoption of clean technology innovation, with a particular focus on the socio-cultural dimension. In doing so two types of end users are addressed: (i) individual households (in the residential sector), and (ii) business firms owning buildings to which solar energy technologies can be applied.

This article is structured as follows. Section 3.3 presents key conceptual insights on innovation-adoption of renewable energy technologies, and the role of socio-cultural factors therein. Section 3.4 presents the research design and methodology of this

study. In Section 3.5, the results of the case study are presented. Next, in Section 3.6, the results of the empirical study positioned against the theoretical claims introduced in Section 3.3. The article ends with a concluding section (Section 3.7), that includes recommendations for future research.

3.3. Theoretical background on the diffusion of renewable energy technology

In this section, we present the “Diffusion of Innovation” (DoI) (Rogers, 2003) as a main theory to understand diffusion of clean energy innovations. We address its benefits and shortcomings, and pay special attention to specific technology related and socio-cultural dimensions.

3.3.1. Diffusion of Innovation

DoI (Rogers, New York, United States of America, 1962) is considered an academic milestone in the field of novel technology adoption diffusion. Rogers (2003) argues that opinion leaders and change agents play an influential role in diffusing innovation within communities through their social network. In addition, this theory Rogers (2003) explained that when innovations are presented to the public, the public will experience uncertainty when deciding whether to adopt or not. As a result of this uncertainty, potential adopters will engage in information seeking behaviour to assess the necessary factors (innovation characteristics or social factors) before adopting. This is contested by scholars who argue that sharing information alone is not sufficient to initiate behaviour change in communities (Viardot, 2013).

Limitations of the Diffusion of Innovation Theory

In various studies DoI was used as an analytical framework focusing on innovation-diffusion of energy efficient systems in residential sector communities (e.g. (Labay and Kinnear, 1981; Mallett, 2007; Mahapatra and Gustavsson, 2008)) and in the industry and built environment (e.g. (Dieperink et al., 2004; Vermeulen and Hovens, 2006)). Although widely used, the DoI theory is not without limitations. An important limitation is when major socio-cultural factors in the value system of end users and technology specific constraints are not considered.

Given the fact that renewable energy innovations are perceived by many stakeholders as “new” (Sovacool, 2009), it is likely that some uncertainty surrounds this topic. To capture this, several empirical studies provided insights on how stakeholders view the renewable energy initiatives and what aspects of the innovations may still need to be addressed to influence consumers to adopt renewable energy technologies. For instance, Urmee (2016) mentioned that the level of complexity associated with adopting a specific technology varies between countries in the developed world and those in the developing world. This was primarily based on the different level of understanding of a certain technology, individuals’ socio-economic status and a set of cultural dimensions. Since the value system of potential adopters is critical to understanding innovation-diffusion and there appears to be a knowledge gap in the innovation-diffusion literature in addressing cultural characteristics (Daghfous et al., 1999; Eseonu and Egbue, 2014), it is urgent to explore when and how socio-cultural factors influence the innovation-diffusion process.

Several studies have discussed stakeholders’ influence on innovation diffusion of clean technologies in a qualitative manner. Berardi (2013), however, argues that only little attention has been given to stakeholders’ influence on the adoption of energy-saving technologies. Others argue that strong support from engaged stakeholders, on some occasions, seems to stimulate this (Andrews and Krogmann, 2009; Lee and Yao, 2013).

In the following sub-sections, we discuss the factors found in empirical studies that explain for adoption of renewable energy innovations.

Technology Attributes

People are more likely to adopt an innovation when it has a *relative advantage* over alternatives; i.e. that it is found superior or better than the idea that it supersedes (Rogers, 2003; Silk et al., 2014). Caird et al. (2008) and Caird and Roy (2010) found that the main drivers for adopting micro generation technologies were (perceived) energy savings and lowering of fuel bills. The main barriers were uncertainty about reliability of the technology and performance, long payback periods, high system costs and limited roof space in multi-story buildings.

Silk et al. (2014) deduced that if stakeholders did not value renewable energy then adoption would be less likely to occur. *Compatibility* of innovations, such as solar energy technologies, with personal values (Labay and Kinnear, 1981) and needs, existing practices (operational/practical) (Tornatzky and Klein, 1982) or infrastructure (Claudy et al., 2011) were also considered important to innovation-diffusion.

Another important predictor to innovation-diffusion would be *complexity*, which concerns the extent to which an innovation was difficult to understand and use (Rogers, 2003). Thus, if a technology is viewed by stakeholders as complex, it becomes less likely to be adopted by them (Silk et al., 2014).

Trialability is the degree to which an innovation can be tested on a limited scale (Rogers, 2003). Regarding this predictor, Silk et al. (Silk et al., 2014) assumed that the absence of the opportunity to test an innovation might decrease the likelihood of adoption. However, at the individual level, trialability was difficult to implement based on the financial costs associated with the renewable energy systems (Labay and Kinnear, 1981).

Finally, *observability* concerns the degree by which the results of an innovation are visible to potential adopters (Rogers, 2003). Observation by friends, neighbours and family was considered a key motivational factor. Silk et al. (2014) explained that if stakeholders were able to observe a renewable energy innovation that was used elsewhere, they might be more comfortable with the idea of adopting the innovation themselves.

3.3.2. Market and financing incentives

In their research, Pinkse and Dommisse (2009) and Comodi et al. (2012) found that the local government was seen as powerful enough to influence the adoption of energy-saving technologies through implementing tight norms to create the conditions in which adoption was encouraged. For instance, Murphy (2012) stated that when regulations were missing, then the uncertainty of a specific situation increases, leading to barriers to the adoption of energy-saving technologies. The motives for adopting a clean energy technology not only depended on the technology performance or regulations but also on other factors relative to end users, such as social and socio-economic ones.

In addressing the factors behind the diffusion of solar energy use for hot water systems, several authors (Sidiras and Koukios, 2004; Caird et al., 2008; Caird and Roy, 2010) found that financial incentives are important drivers for households to adopt SWH systems. Although financial incentives are often favoured in policy to promote the use of renewable energy technologies, they are certainly not the only important influential driver (Stern et al., 2016). Non-financial aspects are also of great importance. Moreover, the non-financial aspect of policy implementation is associated with marketing strategies and consumer trust in sponsoring incentive programmes.

3.3.3. Socio-cultural factors

Several behavioural researchers found that non-financial factors influence household renewable energy adoption and use. For instance, values and environmental self-identity strengthen awareness of energy issues and lead to consequences in households' action and create a feeling of moral obligation to energy problems (Stern et al., 1999; Steg et al., 2015). Face-to-face interactions, users' feedbacks and community approach strategies have proven themselves to be effective models to achieve desired actions (Steg, Dreijerink and Abrahamse, 2005; Abrahamse and Steg, 2013).

Mulugetta et al. (2000) found that sustainable energy development programmes required multi-faceted intervention that was well-coordinated beyond the donor commitment period. Once technologies were installed, their operation and maintenance became the responsibility of the community or users, who could or may not always want to pay for it (Murni et al., 2014). Poor or inappropriate communication with users can also form an important social barrier in the innovation-diffusion of solar heating systems (Lilefors and Sahlin, 2014). According to DeCanio (1998) diffusion failure often happens for the reason that decisions are always socially embedded and strongly influenced by cultural, personal and institutional constraints that oppose adoption.

In researching the implementation setting of renewable energy technologies a major methodological problem is to systematically evaluate and compare cases in different regions, while taking into consideration levels of technology, economic conditions and cultural influences (Shortall and Kharrazi, 2017). Thus mentioning that the relationship

between socio-cultural characteristics and renewable energy technology adoption remains under-researched (Urmee, 2016).

Contribution of Socio-Cultural Factors

Different factors play a role in renewable energy technology diffusion, yet integrating the social, cultural dimension along with DoI, technology and policy dimensions will present a rich and comprehensive contribution to explain innovation-diffusion to a larger extent. Shortall and Kharrazi (2017) addressed this by saying that through understanding the cultural dimensions of a region, policy makers will be able to better address the risks and challenges with on-going stakeholder engagement in decision-making processes. The cultural dimension—although seen as a critical perspective—therefore, needs to be combined with other dimensions to successfully address innovation-diffusion challenges. For instance, Disli et al.(2016) and Eseonu and Egbue (2014) supported the idea that culture might act as a helpful dimension for policy makers to further understand (and contribute to problem definition within policy making processes) and trigger renewable energy technology adoption, which, in turn, can support lowering carbon emissions.

3.4. Methods

This section presents information on case selection, data collection and data analysis for the case study of the solar energy market in Lebanon. Lebanon presents a unique case study given its geographic location, abundant solar resources and deficiency of conventional energy resources. Despite its positive geographic and climatic conditions, Lebanon has a hostile environment to green innovations associated with its political and the economic instability (Thornton, 2016). The national initiatives implemented in the country demonstrate stakeholders' involvement and interests in the initiatives implemented and their influence on market development.

In this study, special attention is paid to the views and influence of relevant stakeholders. The perspective taken mixes grounded and critical theoretical approaches with a case study allowing a semi-inductive process to build on and complement new insights in the existing literature. This approach allows us to explore comprehensive issues, phenomena and insights that emerge from analysing a rich set of qualitative data, collected among a large number of stakeholders. It allows us to

learn and understand the phenomenon of solar energy technologies adoption through the views and experiences of stakeholders. The study of solar energy technologies diffusion starts from a particular theoretical point of view (Rogers' traditional model) and builds on it to enhance the theoretical frameworks from empirical research and to address important situational factors.

The case study was conducted in a stepwise manner. First, an analysis of multiple information sources was conducted, looking into study reports, memos and documentation. Second, a preliminary list of different stakeholders' groups was identified. Based on this, stakeholder representatives were contacted by telephone to check for availability and, if so, follow-up e-mails were sent to address the focus and relevance of the interview. Once stakeholder availability had been confirmed, face-to-face meetings with interviewees were arranged. All stakeholders' views and perspectives were discussed. Third, the influence of stakeholders and other socio-cultural factors on solar energy technologies adoption was also addressed. For this purpose, a case study approach was adopted to investigate a contemporary phenomenon in its real life context and derive meaningful insights from it (Yin, 2014).

3.4.1. Stakeholder analysis

Stakeholder analysis has been used as a management and strategic tool for identifying the best strategies for managing other stakeholders, identifying current and future opportunities and challenges and how to handle them (Blair and Fottler, 1990). During the diffusion process many stakeholders of different backgrounds interact and influence the adoption decision-making process (Cooke et al., 2007). De Blois et al. (de Blois et al., 2011) highlighted how the contrasting priorities among stakeholders were viewed as the most common barrier to the adoption of energy-saving technologies.

3.4.2. Data collection and analysis

A stakeholder analysis was conducted to generate knowledge about stakeholders involved in the market initiatives so as "to understand their behaviours, intentions, inter-relations and interests and for assessing the influence and resources they bring to bear on decision making or the implementation process" (Varvasovszky and Brugha, 2000) (p. 338). The stakeholder analysis consisted of the identification of the stakeholders' views, interests, their influence on the adoption of solar energy technologies and other experienced barriers. Data collection involved participatory research and in-depth

interviews with 30 informants across eleven different groups of stakeholders (see Table 3.1); namely national government institutes, NGOs, banks, contractors, consultants, the public sector and end users. Semi-structured questionnaires were used for in-depth interviewing to provide rich insights for understanding different viewpoints. To enrich our understanding for the solar energy market development, different interviewees belonging to the same stakeholder group were approached. This was based on the experience of each stakeholder in respective projects, either addressing SWHs, or PVs, or both. During the interviews, stakeholders were asked about the factors that triggered the Lebanese solar market, the barriers they experienced, strategies and other stakeholders' influence on the diffusion of solar technologies in the Lebanese market.

Table 3.1: Stakeholders' roles and views on the solar energy market.

Stakeholders	Roles	Experienced Challenges and Drivers
International Cooperation Agency (project managers of projects)	Supports the government in achieving sustainable goals. Initiates and shapes the market based on the needs of the country.	Observes highly bureaucratic procedures when dealing with government institutions; limited flexibility in changing grid regulations when dealing with the national utility provider; highly interested and conscious private sector end users; uncertainty from end users, shifting in the areas of the future funds providers.
Consultancy/advisory agent	Provides advice on the solar energy systems and proposes areas for project development.	Lack of coordination between sequential projects; need for policies to overcome technical installation barriers; competitive electricity prices.
Private incubation firm	Creates awareness and develops market competencies.	Loss of resources due to repetition of similar target projects across the country; low coordination with actors from geographical remote areas; technical barriers in connecting to the national grid; need for continuous awareness of the public.
Providers of solar energy technologies	Manufacture/import and sell solar energy systems to the market.	High competition between actors to take part in internationally funded projects; consumer uncertainty and financial commitments; changing end users views and attitudes takes too long.
NGOs	Create awareness and collaborate with the public needs to tackle challenges in renewable energy markets.	Need for financing methods for poor end users; low technical knowledge of end users.
Research institute	Calls for regulations and policies that serve market development.	Lack of availability of continuous stable funding.
Consumers (e.g. households, corporate)	Purchase and use solar energy systems.	High investment costs of solar PV systems; reduction of energy costs; existing conventional means for energy and water heating options.

National consultancy agency	Monitor and maintains a well-developed market through coordinating between major market actors and the government while implementing regulation.	A well-developed market with large numbers of technology suppliers and supportive financing schemes.
Public sector institutes (ministry, research centres, technical institute)	Develop action plans and plan for policies to support the diffusion of renewable energy technologies.	Lack of policy focus; country prioritized plans; low coordination between institutions.
Financing institutes	Provide loans for end users to install and operate their own solar energy systems.	Demand fluctuates across regions depending on the client profile, lengthy loan procedures and difficulty in pushing green technologies in market, constructive support from the national consultancy agency.
Educational units	Provide knowledge and technical expertise to the public.	Lack of available resources for research and development; bureaucratic procedures for developing education material; availability of young local talents who are technically knowledgeable about solar energy systems.

Interviews were conducted face-to-face. Interviews were recorded and transcribed into text files, which were later used for data treatment and analysis using CAQDAS (Atlas.ti). This data treatment used a coding scheme consisting of codes resembling the theoretical concepts presented in Section 3.3 and codes emerging from insights derived from the available data itself. This permitted a more in-depth representation of the situational dimensions from the case study without being limited to specific theoretical notions.

This was followed by a qualitative research approach to look for emerging themes. In a few cases, this led to the desire to contact more experts. Hence, a “snowball method” was applied to retrieve additional informants who could serve as interviewees and provide additional documents for the analysis. In addition, the primary researcher of this study (first author of this article) also participated in meetings for one of the solar energy acceleration projects (SHAAMS). The main topic of this was about the challenges facing solar energy, finding possible solutions to address them and organizing activities (shared between local and foreign actors) to overcome such challenges. Data collection was conducted in two stages, from March to April 2015 and from February to July 2017 (with the same group of stakeholders; yet with different representatives). The selection of experts was based on their involvement in specific solar energy projects. By doing so, the study addressed the evolution of major stakeholders’ views, how their interests could be identified and how any changes occurring in the market could be addressed. This would provide a rich understanding

of the situation and the socio-cultural and other factors influencing adoption decision-making.

3.5. Results

Table 3.1 presents an overview of the stakeholders' roles and their views regarding the adoption of solar energy technologies. Since this study focuses on exploring the role that socio-cultural, technical and economic aspects have in the adoption of solar energy technologies, in the next section, barriers experienced by stakeholders relevant to each of these aspects will be discussed in more detail.

3.5.1. Technology attributes and investment

When discussing the relative advantages of solar energy systems over non-renewable sources, the end users (i.e. households and decision makers in business companies) mainly focused on the economic benefits of these systems. For instance, this was illustrated by a hotel owner who stated, "end users experience high uncertainty in the country due to unstable economic and safety issues." In this case, end users view investments with high payback periods as particularly risky. This uncertainty makes potential users cautious to engage in long-term investment, since they are more concerned with short-term issues, which appears to be related to unstable lifestyles in the country. The unreliable utility grid and the absence of formal feed-in-tariff schemes also influence the high investment cost of the PV systems. A project manager in an internationally funded project (and technology supplier) illustrates this in the following quote:

We developed a report to show in numbers how much investors are saving their growth rate and size of investments. We use this report to market the benefits of solar PV. It gives people numbers to trust, because there is a lot of scepticism on this in Lebanon...many of the industries we are working with wouldn't have invested if it were not for the financial incentive (low interest loan) provided to them.

While discussing the compatibility of energy technologies, stakeholders often reflected on how congruent the solar energy technologies are with end users' lifestyles. Banks and technology suppliers are acting as energy advisors for consumers to persuade them to adopt by identifying what types of technologies are required to satisfy the needs

and what complementary energy efficient actions are required to lower their energy consumption.

However, the advice was not always taken into consideration by end users, especially in the long run. The main reason for this was that end users might prioritize other investments that they deem more important to their lifestyle and commitments. The advice and close relations formed between suppliers and the end users influenced the latter's satisfaction with the service provided by the former and the commitment to spread via positive word-of-mouth communication. Thus, when end users became better informed about the pros and cons of a solar system and about possible technical designs that fit their circumstances, the likelihood would increase that they embrace the uncertainty they have when making investment decisions.

Due to the nature of the solar systems (visible on rooftops), end users (on both the household and corporate firm level) reported on the importance of observability of solar panels. For instance, end users coming from suburban or rural areas (such as villages in the Koura area) indicated that social interaction next to observability could be seen as an important factor influencing adoption decision-making. Through social interaction, potential consumers established a strong desire to obtain feedback on the performance of the solar energy system before making the decision to adopt. This relates to potential consumers basing their decisions on the trialability of solar systems by others and concerned services offered by the same technology supplier. This was based on (positive) experiences they had (i.e. financially and on technical performance).

Although trialability did not have a major impact on the uptake of the technologies, technology suppliers were offering the option of installing trial solar PV panels in order to handle the uncertainties end users have with certain functions of solar energy systems. Thus, customers would not only have the opportunity to try and use the solar energy system but also to form commitment and build trust toward the technology supplier. A technology supplier commented:

We always try to prioritize what the client wants. We offer advice and we offer a trial system for a short time to check its efficiency and if performance lives up to the expectations.

Interviewees also mentioned that the mentality and behaviour of end users was hard to change. This can be observed by the following quotes made by an energy consultant:

While interacting with various households, I often notice that most of them have the habit of turning on the conventional water boiler while the electricity is provided from private generators—using fixed monthly fees—based as a supplement of the national utility grid (due to frequent shut down of the latter). So, they have the attitude of making optimal use of the subscribed amperes they are entitled to use following the energy contract they have. This means that they have no motivation to install SWHs.

In this case, it became competitive to convince end users to switch to a solar energy technology at the time that they are making use of an available option (conventional electricity). Technology suppliers suggested that it is easier to convince organized community groups initiatives when promoting the technology. Interacting with one representative from a village who has the relations and power to find a funder and reach out for end users can do this. Although householders consider the option of purchasing a solar energy system, the prioritization of other financial commitments often delays the decision. The financial concern of middle-income households fluctuates based on other crucial life commitments. A technology supplier exemplifies this:

I interact with a large number of clients and through contact with them I often hear comments that they delay the purchase of a SWH for a certain time when they have less (other) financial commitments. For instance, our sales decrease when schools' curricula start and holiday periods commence. However, they increase in summer.

This example sheds light on the impact of age and family life cycle on decision-making by householders. Similarly, education and educational specialization (i.e. engineering, environmental specialization) also influence the propensity of end users to adopt technologies, especially that of innovativeness. One of the commercial end users commented on this as follows:

I have an engineering background and I am interested in renewable energy technologies. I even considered installing a wind turbine for my factory but settled for a collective PV system.

To tackle problems regarding investment, available roof space and other barriers, a few interviewees mentioned the importance of establishing trust among the community and embracing the individualistic culture among citizens. As suggested by one of the project managers of an international funded project:

In the future solar PV development should be brought to a new level; for instance, by making collective investments among citizens in local communities.

Another interviewee (a project manager) mentioned the future plans of paving the way for community initiatives through working on a community net metering project locally and striving to scale it country-wide.

3.5.2. Market performance

Due to the relatively high cost of solar energy systems, stakeholders mentioned the importance of financial incentives in the market, which promote change and influence actions among households and commercial end users of solar systems. However, the efficiency of the incentives depended on how the funding programme was implemented. According to the interviewees, it was important that the financing scheme also took into consideration the needs, lifestyles and living conditions of the consumers. The end users' opinion on the financing scheme varied based on the ways they approached it, the perception of the funding institution, the level of the cognitive effort to the incentive received, trust in the technology provider, and trust in the performance of the solar energy systems supplied. As a result, end users preferred to substitute financing incentives (i.e. a one-on-one procedure with a technology supplier), as they perceived that the government-financing scheme would not be worth the effort, especially in relation to small-sized systems.

Furthermore, the implementation of the financing mechanism exposed some flaws. For instance, it did not take different social (user) groups into consideration, as it was designed to fit individuals of certain employment status and income level. An NGO representative exemplified this:

If we didn't contribute ourselves with our own money to guarantee these un-bankable end users, they could have never received the loan.

Interviewees mentioned that the demonstration projects were found to have created awareness and improved technical talents and created jobs in the renewable energy market. For instance, the technology suppliers were interested in having a role in the demonstration projects to acquire technical knowledge, to achieve higher market status and to interact with potential funders; all these being considered useful to acquire future projects. In addition, technology suppliers formed alliances with foreign importers. This is illustrated by the following quote from a technology supplier:

The UNDP managed projects are seen as good references for us. They were very helpful to provide knowledge; especially in the sense that they provide training sessions and information on the design of the projects which we submit to them. In other words, it is a bidirectional learning process. We are a new company and we lack knowledge in certain areas. So UNDP managed to realize projects and acted as consultants to us.

All interviewed suppliers and project managers mentioned the term ‘foreign’ when they wanted to show a higher quality of workshops and training sessions on offer. For instance, several corporate stakeholders (such as technology suppliers and project managers) stated that the quality of knowledge shared in training sessions and workshops can be increased via relationships with foreign technical experts and partnerships with foreign technology suppliers. Importing products from certain Western countries that are seen as leaders in solar energy markets (i.e. Germany and Italy) were perceived to give a certain advantage. This also holds for technology suppliers who seek to acquire a certain market status through marketing their products in specific countries that are considered leaders in solar energy technology. This is illustrated by a quote from a solar PV supplier:

We work with European technology suppliers and interact with the German market for monitoring systems and inverters, since most of our clients have the opinion that by acquiring European products they get guaranteed high quality.

3.5.3. Socio-cultural factors

Diffusion is best achieved when a set of different factors are combined. For instance, sometimes the driver to adopt a new technology might not only be technical or economic in nature but also social and cultural (Sharma and Gadenne, 2014).

Most stakeholders mentioned the importance of participation, information sharing and transparency as important factors triggering change and having a positive impact on end users' engagement in renewable energy technologies.

Few stakeholders observed the individualistic nature of the citizens, which, to some extent, created a social challenge for integrating the collective solar PV system concept (e.g., a large group of end users sharing one large scale solar PV system) into the market. This explains why individuals prefer to have autonomous control and take care of their own needs. The householders experienced a lack of trust in other citizens (for instance, between neighbours who are mutually dependent when constructing a collective solar PV system to a residential building) and a collaborative spirit hardly existed. This occurred, in particular, in urban areas where busy lifestyles go along with low rates of social interaction between residents. Therefore, a possible solution to this challenge could be by introducing community initiatives and collective concepts in villages deemed to have a good chance of becoming successful.

This is exemplified by the following quote by a technology supplier in a Lebanese suburban area:

Here in the village people influence each other especially when someone installed a SWH and is satisfied; they immediately spread positive words-of-mouth.

The reasons behind this are strong social ties and a sense of belonging to a large social group. Therefore, in this case, the social influence strategies, which target non-financial factors, resulted, to a certain extent, in higher adoption rates. Strategies, such as face-to-face interactions, that included community approaches and a commitment to strategies of actions were considered particularly effective.

Another dimension that was viewed by stakeholders to define and trigger the solar energy market concerned public investment actions. This is, to a certain extent, embedded in the social norms of Lebanese society. When the key stakeholders (i.e., the national consultancy agency, the international agency, or ministries) in the renewable energy market launched the first SWH initiative, massive investments were made. Although this entrepreneurial growth contributed to economic development, it faced various challenges that led to negative views spread by word-of-mouth about the

SWH systems. The challenges were classified as the absence of quality control schemes, which resulted in low quality products with poor installation. In a later stage, the financing schemes indirectly improved quality of products in the market through grant provision for end users, based on specific qualified solar energy systems.

A noticeable factor among all interviewees was the transnational influence of acquiring expertise and knowledge from specific developed countries that served as role models. This could be explained by the culture in which citizens live and in which they accept a high degree of hierarchy. Every person in the Lebanese society has a particular role and status in the society. This also applies to inter-actor behaviour of actors in the solar energy market.

Interestingly, end users (i.e. households and companies) were using a similar approach to create a certain public image. Some of them only requested solar energy systems from specific countries to reflect their social identity and preferences regarding high quality assurance of the product, especially those having long life spans. This, in turn, reflected the importance that social status has at the household level and also on the corporate level, especially among decision makers who are in continuous contact with other stakeholders in the society.

Several stakeholders mentioned the geographical dimension, which includes social, cultural and economic dimensions. Based on the empirical evidence from the solar energy market in Lebanon, various differences between the cities located in North Lebanon and cities Central Lebanon were discussed. The stakeholders mentioned that end users Central Lebanon have a relatively higher income level and, to some extent, higher living standards influenced their lifestyles. Approaching end users in rural areas mainly took place via social interaction and word-of-mouth. However, approaching end users living in the more urbanized (often hectic and densely populated) cities required different marketing approaches. In these circumstances, technology suppliers are investing to create a certain market identity through involvement in funded projects and connecting with prospective funders. Consumer mentality, lifestyle and openness differ across regions. Openness and income level influence uptake levels as exemplified in a quote made by an energy consultant and a project manager of an international funded project:

Poor communities are still in need for supportive programs to tackle the renewable energy technologies uptake obstacles.

This is also true for the networking activities between stakeholders. Most of the workshops and activities were centralized and mainly took place in the country's capital and cities in its close proximity. This affected the integration of stakeholders from relatively far regions in the activities and the amount of information shared. Actors from these more distant regions often felt isolated. They felt a need to make a lot of effort to keep continuous interaction with active solar market stakeholders and efforts in the capital.

Geographic area was said to influence interaction with potential consumers. This was exemplified in the following quote made by a technology supplier:

The interaction between us and the clients differ across regions. For instance, in a centralized region (i.e. in Beirut and its suburbs) people have a busier lifestyle and therefore often do not have the time available to visit technology suppliers and have face-to-face communication with them. Most the interactions are either by phone or by email. Yet, here in Tripoli (a large city in North Lebanon) clients prefer to make a visit to our company and check the available systems.

3.6. Discussion

The analysis of stakeholders' views revealed that there is more innovation diffusion than that expected in the DoI theory.

According to Rogers (2003), end users tend to look at the immediacy of the reward in relation to relative advantage; while the reward of certain innovations is not expected to occur immediately. The interesting advantage that was discussed by most interviewees (covering most of the stakeholders' variation) was the idea that the long-term benefits of solar energy systems outweigh the short-term costs. The national financing scheme proved to be successful in increasing the adoption rates across multiple economic sectors. However, we agree with Reddy and Painuly (2004) that the policy makers have to choose the right type of financing schemes, while also taking into consideration the local needs and traditions of citizens in society. This means, for instance, coping with the demand for specific renewable technologies that need to

comply with the available challenges (e.g., PV systems with batteries, collective available funds to tackle challenges, or funds for poor households with limited financial-economic capabilities).

Therefore, in the case of solar PVs and collective solar energy systems, the long payback period associated with the high uncertainty embedded in the country creates a challenge for their uptake. We agree with Silk et al. (Silk et al., 2014) that introducing the perception that the good of society outweighs the needs of the individual can overcome on-going uptake challenges and lead to social and economic benefits. However, due to the individualistic nature of many citizens, such a concept is challenging. We argue that the results of our study contribute to the results of a study by Shortall and Kharrazi (2017) and Urmee (2016) who came across a knowledge gap in diffusion of innovation research regarding social and cultural factors. Our result show that the individualistic nature of the end users in society is challenging the innovative solutions around issues such as handling roof space availability and making high upfront investment costs. Furthermore, the perception of acquiring a 'foreign' product is strongly linked to the mind-set of the potential users, who are typically considered as having high social status in their identity among other end users. This is mainly characterized by the propensity of the individuals to 'show off' in their social environment, where acquiring eye catching radical innovations is considered one of the ways to do so.

Uncertainty, compatibility, complexity and perceived benefits appear interrelated when it comes to the uptake of solar energy technologies. The complexity associated with the installation of solar systems on the limited roof spaces available, the requirement for long pipelines for high story buildings (in the case of SWH) and the lengthy process of receiving loans, all affect the perception of the solar energy system. These factors had an overarching impact on attitudes and perceived norms (Silk et al., 2014).

The demonstration projects that took place in the country positively influenced the development of the market. The benefits were not only limited to increasing awareness among the public and building trust in the technologies while removing risk and uncertainties but also created technical knowledge and improved the technical expertise among the local workers. These projects were viewed as trials for the end users from selected industries; such as factories. This helped technology suppliers to

improve their expertise and learn from demonstration projects, which, in turn, improved their market status.

We agree with several authors (Janssen and Jager, 2002; Schelly, 2010; Sopha et al., 2010; Palm and Tengvard, 2011) on the importance of social influence, particularly the influence of recommendations from friends and neighbours on households' decisions as to whether to adopt solar systems. The interest of end users and stakeholders in reflecting a specific social identity appeared to be of significance in influencing the adoption process (Janssen and Jager, 2002). The individualistic culture among households appeared to create a challenge for the collective concept (launching large scale systems for large groups of end users), which is ideal to solve, both the roof space problem and the high investment cost. We also agree that education appears to be linked to the adoption of renewable energy systems. In particular, the type of education specialization; for example, when potential adopters had engineering or environmental backgrounds, this led individuals to be more likely to adopt renewable energy systems than those having other educational backgrounds (Karytsas and Theodoropoulou, 2014; García-Maroto *et al.*, 2015).

When addressing the role of technology suppliers, a key element is the customer-value proposition (Kaplan and Norton, 2001). This defines how organizations can differentiate themselves as competitors and attract and deepen the relationships with the targeted customer groups to build a higher market share. In line with this, we agree that the technology suppliers were engaging with the consumers on the social and personal level to build trust and guarantee strong social benefits. This close relation varies between regions; yet, the satisfaction of the end users results from positive word-of-mouth and low-cost marketing of the adopted technologies.

This study showed the significant role that socio-cultural, technical and economic aspects have in the adoption of solar energy technologies. The results show that the on-going challenges are mainly culturally and economically embedded and require creative solutions that are tailored to the end users' needs and situational circumstances. To result in broad changes in societal discourses challenges in values, behaviours, habits alongside infrastructural, institutional and organizational challenges, need to be addressed. This stresses the need for new policy approaches to address a

clear connection to the on-going contextual and situational circumstances, along with the social structures and relevant preferences of local actors.

3.7. Conclusions and implications

There were two main research questions in this article: (1) What are the stakeholders' views, roles and influence on the diffusion process of solar energy technologies in Lebanon? And (2) what are the main specific socio-cultural factors that influence adoption?

The implementation of demonstration projects in the solar energy field contributed to the market on various levels. It created higher observability and improved the technical experience of installers in the market. Furthermore, it raised awareness among stakeholders and increased trust in the technologies.

As technology-related attributes, such as relative financial advantage, observability and compatibility with values, play a role in shaping the uptake of solar energy technologies, so do social ties between end users and their wider community of friends, family and neighbours, whilst recognising the variations between rural and urban areas. More than this, end user characteristics play a role in adoption of technologies along with their interest in acquiring certain social identity. For instance, the educational level and specialization play a role in promoting the uptake of solar energy technologies at both the household and corporate level.

Regarding the second research question, we provided the following differentiation between households and corporate end users:

1. At the household level—the main findings can be grouped into three categories. First, end user characteristics are important to understand when considering adoption decision-making. The most important are: the income level and how these guarantee access to capital; education; and, to some extent, how family lifecycle settings influence householders' financial commitments and priorities and thus drive the propensity to invest in renewable energy solutions. Second, the costs and benefits of investing in a solar energy system are divided between monetary (the investment cost and savings) and non-monetary aspects (such as comfort and compatibility, which depend on the physical context and cultural expectations of the households). This category deals with the attributes of the technology and also

involves the real and perceived risks and uncertainties that play a crucial role in the Lebanese context. Third, a factor that has received less attention concerns the particular geographic influence on the end users. This factor is broad enough not to be limited to just the physical classification of rural and urban areas across different regions. It also includes the intensity of social ties and interaction between end users and other stakeholders (such as technology suppliers), thus reflecting the importance of local and regional networks. Furthermore, the individual openness and mentality of the people tend to vary between different Lebanese regions, shaping the means of interaction between them and the other stakeholders, thus reflecting the rather uneven diffusion patterns.

2. At the corporate firm level—several similarities appear comparable with individuals at the household level, while others remain specific to the corporate level. First, the individual characteristics of the decision maker are important to acknowledge. One concerns how education specialization affects the propensity to adopt when considering renewable energy solutions. Second, the costs and benefits of investing in a renewable energy solution are considered important. This relates to the awareness level of the decision-maker to assess renewable energy solutions so as to reduce the cost of consumed energy and also undertake the appropriate networking and research to find the most convenient investment decision. The third factor concerns the competitive advantage and the market image that a company or organization will acquire in the market. For instance, the adopter will enhance the market image of the corporation through their environmental involvement and responding to a leading attribute in considering innovative solutions. Thus, these will also result in increasing customer attraction to organization values. Furthermore, the social status and public image were found to be important to firms. Various decision makers at the corporate level were concerned about the social identity of their firms and preferred specific foreign high quality products to convey this identity. It revealed the importance given to the socio-cultural dimension in marketing strategy in particular, and the adoption process at large.

Due to the autonomous control of consumers over their energy use and the continuous decline in the prices of renewable energy technologies (Banks, 2015), there is a need to shift to performance-based approaches. These approaches will promote the shift

from cost of service to the value of service and eventually provide an opportunity for consumers and service providers to meet their goals. This means that consumers will receive rewards based on their energy savings, which motivates their involvement in energy efficient practices and results in lower energy demand on the utility providers.

Looking to future research opportunities, this would be a great opportunity for integrating the socio-cultural dimension with other social and technology-related aspects. In this arena, it is crucial to compare the wide range of dimensions with and between countries when they have different cultures, yet relatively similar economies. By doing so, research into a rich set of independent variables, rather than the DoI, as it is typically applied and psychological variables will be conducted vis-à-vis adoption decision-making of renewable energy technologies.

The results of this study provide a context for understanding the views of various stakeholder groups regarding renewable energy initiatives. Although these data may not be generalized yet, they can be used to guide and inform future qualitative and quantitative research about the adoption of solar energy technologies. Further research tackling behavioural, social, cultural and economic aspects, in relation to the uptake of renewable energy technologies from developing economies, can be applied. Future research should also examine the influence that cultural, social norms and values have on a person's likelihood to adopt a renewable energy innovation.

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Chapter 4: Consumer renewable energy technology adoption decision-making; comparing models on perceived attributes and attitudinal constructs in the case of solar water heaters in Lebanon⁴

4.1. Abstract

Climate change and environmental problems are of major concern to governments, organisations, and consumers. This stresses the need for a transition towards clean renewable energy systems. To enable the diffusion of cleaner energy technology it is not enough to just have supportive policies in place. The challenge is to ensure that consumers adopt them. This paper integrates insights from different research traditions into a research model to analyse consumers' adoption decision-making behaviour. We use the innovation-diffusion model by Rogers and add hypotheses from environmental psychological models to ours. A survey was conducted among householders to assess the adoption of solar heating systems in the Metn neighbourhood in Lebanon (N = 200). The results revealed that adopters and non-adopters differ significantly according to socio-demographic factors, such as income and household size.

The study confirmed the significance of typical variables of the diffusion of innovation model, such as relative advantage, observability, independent judgment-making, and novelty-seeking; even when testing integrative analytical models. Furthermore, the results indicate that, by integrating hypotheses from environmental psychology models to the diffusion of innovation model, a reasonable fit was achieved which is higher than the value of each model tested separately. The results can be of use to policy makers. The paper ends with suggestions for future research.

4.2. Introduction

In the light of climate change, the Paris agreement in December 2015 set strict goals and urging all countries to formulate action plans to decrease energy use (Paris, 2015).

⁴ This chapter is based on paper (paper 2) which has the same title. The paper is authored by Houda Elmustapha (the main writer of the paper and author of this dissertation), Professor Hans Bressers based at the University of Twente and Dr. Thomas Hoppe based at Delft University of Technology. The paper has been published in *Journal of Cleaner Production*, Vol 172, January 2018, pp. 347-357 doi.org/10.1016/j.jclepro.2017.10.131.

Green innovations, such as solar panels, have a potential to help reduce carbon emissions, lower fossil fuel dependency and stabilise energy costs (Claudy et al, 2010). However, introducing renewable energy technologies in developing countries requires a lot of financial and educational support (Karp, 2015). Policy interventions are very important to promote the uptake of renewable energy technologies. However, on their own, they are not enough unless consumers take action themselves to adopt these technologies. Therefore, consumers play an important role and it is important to stimulate behavioural change (Bressers and Ligteringen, 2001).

Stern (2000) acknowledged research traditions that study the influence of moral concerns on consumer purchasing decisions, and addressed their importance in understanding environmental consumer behaviour. In doing so, he called for more research on consumers adopting environmental products. In this paper, we will investigate drivers and barriers to adoption and non-adoption of environmental innovations by integrating two research streams rooted in two research traditions: (i) innovation diffusion, and (ii) environmental psychology.

Our research deals with householders adopting renewable energy technology in Lebanon. Lebanon is a country that has witnessed various initiatives supported by international funding agencies to develop the renewable energy market; especially solar energy thermal systems. As an example, a Global Environment Facility (GEF) funded initiative aimed to promote solar water heater (SWH) installations in the residential sector to achieve a target of 1.05 m² by 2020 (LCEC, 2016). This initiative was accompanied by a policy paper which sought to increase renewable and energy efficient technologies penetration by a financing mechanism and the removal of taxes on imported renewable energy technologies (Bassil, 2010). As a result, the solar market (including suppliers of SWH) grew from 10% to 50% (LCEC, 2016). The residential sector accounts for the highest amount of installed SWHs across sectors (74% of installed systems), showing that the total of installed capacity until 2014 was approximately 550,000 m². However, the diffusion of renewable energy technologies faced various challenges, namely the absence of clear policies to promote the use of renewable energy sources from the government side, and the overall mentality and culture of the consumers on the other (Kinab and Elkhoury, 2012).

Lebanon has a unique context that influences consumers' adoption decision. For instance, unreliable electricity supply services provided by the national utility provider results in severe daily blackouts across the country (Harajli et al., 2015). This has led consumers to rely heavily on expensive substitute sources of electricity supply, such as private backup diesel generators (Dagher and Ruble, 2010). Harajli et al.(2015) found that Lebanese households spend a significant amount of their income to secure the electricity and hot water (given that water is mostly heated through electric boilers) needs. They found that consumers pay approximately 10.4% of their income on electricity (this includes the utility and the backup generator bill). For this reason, they can arguably be considered 'fuel poor'⁵.

In the light of the policies and projects that have been implemented to increase the uptake of such technologies, SWH was chosen as a case for analysis. An important reason for doing this is that this technology has been adopted to a reasonable extent in Lebanon; more than other renewable energy technologies. Instead of analysing the mere intention to adopt (Ozaki, 2011; Alam et al., 2014), we address actual adoption. We seek to reveal preferences and opinions for the adoption of SWHs from both adopters and non-adopters to understand what makes consumers purchase and use such systems. Technology diffusion in a community depends on a number of factors, including the type of technology, government policy, and a number of social and culture specific factors (Rogers, 2003). Of these, we assume that social characteristics influence diffusion-adoption processes in particular. To address this issue, next to applying the more general innovation-diffusion concepts, this study also pays attention to social norms SWH (non-)adopters have.

The main research question of this paper is: To what extent do selected theoretical drivers explain household adoption of SWHs in Lebanon? An integrated research model was used to analyse adoption decision-making using insights from both Rogers' famous 'Diffusion of Innovation' model (Rogers, 2003), together with other relevant models from the domain of environmental psychology (Jansson et al., , 2010; Steg, Dreijerink, and Abrahamse, 2005; Steg and Vlek, 2009; Stern et al., 1999). This integration was made to tackle the gaps of the diffusion of innovation model in

⁵ "a fuel poor household is defined as one which needs to spend more than 10% of its income on all fuel use and to heat its home to an adequate standard of warmth" (Energy UK, 2017)

addressing values and attitudes on the one hand and to apply factors from the VBN theory on high investment system (rather than on consumption and low investment choices) on the other hand.

To answer the research question, a survey was conducted to test hypotheses from an integrated research model on consumers' choices and preferences regarding adoption of SWHs. Based on the results of the empirical study, implications for policy makers (on how to approach target groups) became evident that are presented in this paper.

4.3. Consumer decision-making on the adoption of clean energy technology

The focus of our research is on consumers, without ignoring the fact that other actors can also play a crucial role in the process of environmental innovation adoption. In this section relevant theory and results from empirical studies are presented on the adoption of innovation and innovation diffusion in order to identify the factors that influence consumers' adoption decisions and to construct a conceptual framework for our empirical study.

Several studies have addressed the gaps in early research which focused either on non-consumption behaviour (such as energy savings) or on post-purchasing behaviour (such as waste recycling), (Follows and Jobber, 2000; Jansson, 2009; Joshi and Rahman, 2015). These neglected to study the pro-environmental behaviour in high involvement purchases (purchases which require extensive search for information and involve high expenditure (Asamoah, 2012)). This led to calls for more research on high involvement purchases with large environmental impact (Jansson et al., 2011; Lehman and Geller, 2004). Jansson *et al.* (2010), for instance, found that the Values-Beliefs-Norms (VBN) theory explained 41% of the variance on adoption of alternative fuel vehicles; leaving a considerable proportion unexplained. In their study, the explanatory power of the model would probably have been higher if contextual factors, such as external drivers and barriers, had been included in the model Stern (2000).

Thus, the “diffusion of innovation theory” (Rogers, 2003), in addition to theoretical literature on pro-environmental behaviour (e.g., Jansson et al. (2009), Jansson (2011), Nordlund and Garvill (2003), were applied to understand consumers' decisions to adopt a technology.

In the next sections we provide an overview of the literature on the theory of innovation diffusion regarding adoption of eco-innovations, such as clean energy innovations, and the theory regarding pro-environmental behaviour to provide a rich understanding of 'green' consumer behaviour and, therefore, 'green' innovation adoption decision-making.

4.3.1. Innovation diffusion

The diffusion of innovation theory draws upon ideas on organisational life from economics, sociology, and communication theory, and applies these to different types of innovations (Karakaya et al., 2014). Whereas cognitive behavioural theories focus on intentions as predictors of consumer behaviour, the adoption and diffusion of a technology, as viewed by Rogers (2003), is a social process whereby consumers form a general attitude towards an innovation based on their perception of its characteristics. According to Rogers (2003) several conditions influence individuals and occur before the process of innovation decision-making takes place: e.g. previous practices, existing needs, innovativeness, and norms of the social environment of the consumers. The adoption decision of potential adopters was found by some researchers to be highly influenced by their social environment on the one hand (Jager, 2006; Ozaki, 2011; Sidiras and Koukios, 2004), and interpersonal communication on the other (Mahapatra and Gustavsson, 2008). Therefore, it is assumed that social influence plays a significant role in technology adoption (Rogers, 2003; Young, 2009). Ozaki (2011) confirmed this by showing that consumers engage in activities in which they start to use norms that are considered important in (social) groups to which they belong.

4.3.2. Pro-environmental behaviour

A consumer's decision to adopt an innovation is related, not only to external influences (e.g. costs and functionality), but also to the way in which it reflects their identity, values, and norms (Ozaki, 2011). Environmental psychological research has focused on the attitudinal factors, due to their success in explaining 'green' consumer behaviour across different aspects (Jansson, 2011). In this field, studies have been conducted to test the relation between certain values and pro-environmental behaviour. As discussed previously, social influence is considered an important factor influencing consumer adoption decision-making. Norms are an important aspect of the social influence. These embrace personal and social norms (Jansson et al, 2017). The unique role of

social influence stems from several theories, such as the theory of reasoned action, the theory of planned behaviour, and the norm activation model (Schwartz (1977).

Stern et al. (1999) developed the norm activation model to a pro-environmental consumer behaviour (the VBN model), which conceptualizes attitudinal factors (values-beliefs-norms). This model has been used to explain a variety of low involvement consumer behaviours, which includes acceptability of energy policies (Steg et al, 2005), energy conservation behaviour (such as power conservation, ecologically aware consumer behaviour, garbage inhibition, and ecological automobile use) (Kaiser et al, 2005), and willingness to reduce car use (Nordlund and Garvill, 2003). According to Jansson et al. (2010) and (Jansson, Nordlund and Westin, 2017) personal norms had a strong positive influence on green purchasing behaviour of high involvement durables (the case of alternative fuel vehicles).

According to Thøgersen (2006) environmental behaviour not only correlates with personal norms, but also with subjective social norms. The correlations between social norms and behaviour become significantly weaker when personal norms are added to the research models. According to Steg and Vlek (2009), it is very important to consider contextual factors, such as physical infrastructure, product characteristics, and technical facilities, next to intra-personal factors, such as attitudes, norms and habits for engaging people in pro-environmental behaviour.

4.3.3. Innovativeness

Rogers (2003) defines *innovativeness* as the degree to which an individual has adopted an innovation earlier than others within the social environment of the consumers. However, innovativeness has been operationalized in several ways using different constructs. For instance, Midgley and Dowling (1978) define it as: “the degree to which an individual makes innovation decisions independently of the communicated experience of others”. This construct has been referred to as consumer independent judgment making. This reflects the reliance on others when making decisions. Another concept is consumer novelty seeking: “the desire to seek out the new and different” (Hirschman, 1980). According to Tellis et al, (2009) there has not been a clear census on the measurement of the innovativeness construct. Some researchers found that consumer novelty seeking influenced adoption of new products (Biswas and Roy, 2015; Im et al, 2003; Tanner and Kast, 2003) .

4.3.4. Perceived products characteristics

Closely related to innovativeness are the product attributes and the ways in which the consumers perceive them. According to Rogers (2003), these attributes influence adoption decision-makings. They concern: (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability.

Due to the intrinsic nature of renewable energy technologies, it is important to consider product characteristics when studying consumer behaviour and related adoption decision-making. For instance, several studies (Guagnano et al., 1986; Labay and Kinnear, 1981; Ostlund, 1974) show that perceived attributes are better predictors of consumer adoption than personal characteristics, such as particular socio-demographic factors.

Relative advantage refers to: “the degree to which an innovation is perceived as being better than the idea it supersedes” (Rogers, 2003). It is considered an important determinant of adoption. Relative advantage can be of any nature, either in economic, social, or personal terms). In several studies, perceived relative advantage was found to have a positive influence on the adoption of several environmental innovations; namely solar energy systems (Guagnano et al., 1986; Labay and Kinnear, 1981), alternative fuel vehicles (Jansson, 2011), and on the intention to adopt electronic indicator providing feedback on in-home energy use (Völlink et al, 2002). In studying the adoption of green power by households, Arkesteijn and Oerlemans (2005) did not find any factor correlating significantly with adoption. On the other hand, Caird et al (2008) and Caird and Roy (2010) found that the main drivers for adopting micro-generation technologies were (perceived) energy savings and lowering of fuel bills. Other studies revealed that investment costs (Mahapatra and Gustavsson, 2008), energy costs, and maintenance costs (Willis et al., 2011) are considered important barriers to adoption of micro-generation technology.

Compatibility is the degree to which an innovation is consistent with existing values, experiences and needs (Rogers, 2003). Some researchers, such as Guagnano et al. (1986); Völlink et al. (2002), dealt with compatibility in a different way to Rogers and explained it as being consistent with values. The more compatible an innovation is, the less change in the behaviour it requires and, thus, the faster it is likely to be adopted (Jansson, 2011; Ozaki and Sevastyanova, 2011)

Complexity is defined as the extent to which an innovation is considered difficult to understand and use (Rogers, 2003). Complexity may not be as important as relative advantage or compatibility for some innovations, but for others complexity is an important barrier to adoption. For instance, Mills and Schleich (2009) found that installation piping that is essential for any SWH installation can deter households adopting SWH systems. Labay and Kinnear (1981), compared perception of consumers to solar energy systems and found that adopters consider these innovations as less complex than non-adopters. Hence, perceived complexity was found to negatively influence innovation adoption.

Trialability is the degree to which an innovation can be tested on a limited scale (Rogers, 2003). Janssen and Jager (2002) and Labay and Kinnear (1981) and Völlink et al. (2002) in their studies found that trialability did not relate to adoption of energy conservation intervention technologies, nor to adoption of solar energy systems. In fact, the nature of the technology predetermines its characteristics.

Observability is the degree to which the results of an innovation are visible to others (Rogers, 2003). For instance, SWHs by their very nature are installed on rooftops and tend to have a high degree of observability. Several studies revealed that observability has a positive influence on adoption of clean energy technologies (Guagnano et al., 1986; Jager, 2006; Jansson, 2011) However, Labay and Kinnear (1981) argue that, the more familiar a consumer gets with the innovations, the less observable they become.

In addition to the five perceived attributes discussed by (Rogers, 2003), several researchers added *perceived risk* or uncertainty on innovations as a factor explaining innovation adoption (Kleijnen et al., 2009; Midgley and Dowling, 1978; Ostlund, 1974). Perceived risk addresses the fact that adopting a new technology bears a certain level of operational or financial risk to potential adopters. To varying degrees it influences adoption decision-making (Labay and Kinnear, 1981) and leads to a negative impact on purchasing green innovations, but also to changing behaviour (Claudy et al., 2011; Jansson, 2009; Ostlund, 1974).

4.3.5. Personal capabilities: socio-demographic characteristics

Empirical research reveals that income has a positive influence on installing or adopting solar energy technologies (Jager, 2006; Mahapatra and Gustavsson, 2008; Sidiras and

Koukios, 2004; Wang et al., 2008). Sidiras and Koukios (2004) argue that rent of residential space, and low family income, are major barriers to diffusion of solar hot water collectors among householders. An explanation for this phenomenon would be that households of higher income have a greater financial ability to afford new products. In addition, they usually have had higher levels of education. Thus, they are more likely to be aware and have a relatively open mind-set to adopt new more expensive products (Wang, Dou and Zhou, 2008). Similarly, Claudy et al (2010) found that the more highly educated people are more likely to adopt micro-generation technologies, due to their 'high-involvement' with this technology. Kastner and Stern (2015) found that, in a study assessing twenty five issues related to decision-making, education and energy-related investment decisions correlated with household energy investments.

Despite their assumed influence on adoption of clean energy technologies among householders, socio-demographics were found to have relatively little explanatory power (Cottrell, 2003; Ostlund, 1974; Rogers, 2003).

4.3.6. Contextual forces

Policy and monetary incentives

According to Rogers (2003) the rate of adoption becomes self-sustaining, once a 'critical mass' point of adopters is obtained. One of the major influences to create 'critical mass' among potential adopters is the use of financial incentives (Mahapatra and Gustavsson, 2008).

Financial incentives are often used in government policies as a means to persuade householders to invest in renewable energy technology. According to Caird et al. (2008), Caird and Roy (2010) and Sidiras and Koukios (2004), governmental grant schemes are important drivers for homeowners to adopt SWHs. Similarly, Zhai and Williams (2012) recognize the importance of the availability of financial programmes for customers purchasing solar energy systems. However, Steg and Vlek (2009) argue that structural strategies that target changing contextual factors are highly important. They are considered more effective in promoting pro-environmental behaviour than informational strategies targeting awareness raising and knowledge provision among target group members.

Our research integrates contextual factors from a number of existing perspectives (partly relying on Jansson (2011) and Ozaki (2011)). By purposefully integrating factors from diffusion of innovation, and pro-environmental behaviour, we will broaden our understanding of consumer behaviour and investigate the factors that influence adoption of eco-innovation. As such, we can draw implications for policy and explore how renewable energy technologies can be diffused more successfully. Due to the nature of SWHs, trialability is removed from analysis, since it is irrelevant to this technology and might disrupt the analysis.

Theories having a cognitive approach, such as Theory of Planned Behaviour (TPB) and the Theory of Reasoned Action (TRA) focus on intention as a predictor of the actual behaviour. Similarly, the Unified Theory of Acceptance and Use of Technology (UTAUT) developed by Venkatesh and Davis (2000) on the basis of eight theories, explains that one set of factors (performance expectancy, effort expectancy, and social influence) influence behavioural intentions, while these behavioural intentions and facilitating conditions determine the use of technology. Although these models and theories differ in their focus, they overlap in the factors that influence adoption (Ozaki, 2011). Since our focus is on the actual adoption of a technology, the diffusion of innovation theory was applied, given its usefulness as a systemic approach to study adoption and non-adoption (Al-Mamary et al., 2016). The theories taking a cognitive approach (i.e., TRA, TPB, and UTAUT) were considered in the preparation phase of this study. However, due to our research focus, the diffusion of innovation theory was selected, and constructs from Ozaki's (2011) survey were integrated.

4.4. Research model

4.4.1. Hypotheses

The overview of literature in section 4.3 identified several factors from empirical studies that help explain consumers' adoption decision. The theory and literature review of empirical studies helped select (independent) variables that covariate with adoption of innovation. The hypotheses that follow from the assumed inferences between the selected independent variables and environmental innovation adoption are clustered by issue: (i) norms and innovativeness; (ii) perceived attributes of the product; and (iii) policy incentives. They derive from both the "diffusion of innovation" research tradition, and from the environmental psychological research tradition. We believe that

combining insights lead to an integrated research model that has a higher explanatory power when compared to the current mono-disciplinary models.

Norms and innovativeness:

H₁: Pro-environmental personal norms have a significant and positive relationship on householder's decision to adopt a SWH.

H₂: Social influence and norms have a significant and positive relationship on householder's decision to adopt a SWH.

H₃: Adopters of SWHs have higher levels of novelty seeking than non-adopters.

H₄: Adopters of SWHs have higher levels of independent judgment-making than non-adopters.

Perceived attributes of the product:

H₅: Relative advantage has a significant and positive relationship to a householder's decision to adopt a SWH.

H₆: Compatibility has a significant and positive relationship to a householder's decision to adopt a SWH.

H₇: Complexity has a significant and negative relationship to a householder's decision to adopt a SWH.

H₈: Observability has a significant and positive relationship to a householder's decision to adopt a SWH.

H₉: Risk has a significant and negative relationship to a householder's decision to adopt a SWH.

Policy incentives:

H₁₀: Financial incentives have a significant and positive relationship on a householder's decision to adopt a SWH.

4.4.2. Research design and methodology

Measures and preparation

Items in the survey were based both on relevant literature (i.e., Jansson (2011); Ostlund (1974); Ozaki (2011); Steg et al. (2005)), and on the results of a pilot study that preceded the survey. Scale items and reliabilities are presented in Appendix A.

The study conducted a household survey using a questionnaire divided into five sections. The sections covered financial incentives, attitudinal factors and norms, demographic, and household specific details of respondents. A reliability test using Cronbach's alpha was used to measure the reliability of selected constructs (see Table 4.2).

The survey was conducted in 2015, and was managed in all its stages (pre-test, pilot test, and actual data collection) by the primary researcher (the first author of this paper) to ensure the validity of the research design and to evaluate the acceptability and clarity of the questionnaire. The questionnaire design was intended for those who make decisions at the household level.

Several challenges influenced data collection. The first challenge concerned a lack of official statistics and detailed local level information and socio-demographic details about SWH adopters and non-adopters. The second challenge concerned budget constraints and security reasons in a critical period of conflict in Lebanon. These influenced the response of potential respondents when approached by 'strangers', i.e., the researchers contacting them with the aim of having them completing questionnaires.

Sampling

A survey was conducted among a sample of households in the Metn district in Lebanon. The reason behind choosing this region was the high adoption rate that ensured that the data could be collected from both adopters and non-adopters. The adoption rates in each region were acquired by contacting the national energy conservation centre. This helped in locating the regions in which a high concentration of SWHs had been installed. As a second step, major suppliers in the selected region were contacted to identify the areas in which the highest concentration of SWHs had been installed. This helped to locate the survey targets to ensure availability of SWH adopters. The place of residence, type of dwelling, and ownership of SWH were also used to contact potential respondents.

Data collection

A total of 308 households were targeted. The distribution of respondents among socio-demographic statistical indicators is presented in Table 4.1. The nature of the surveyed region meant the respondents' employment status, education, and income were, to a certain extent, high as when compared to average households in Lebanon.

Data was collected by face-to-face interviews using closed-ended questionnaires. Data collection was conducted between December 2015 and January 2016 by a team of five university students and the study's primary researcher (first author of this paper). The average time used for completion of a questionnaire was between 10 and 15 minutes. In the end 213 respondents completed the questionnaires. This yielded valid responses from 200 households. From this sample, responses from 131 adopters and 69 non-adopters (a response rate of 69.15%) were analysed.

Data Analysis

Descriptive Statistics

Several analyses were conducted to assess the validity and reliability of the data. First, non-response bias was analysed by comparing early and late respondents, as recommended by Armstrong and Overton (1977), on relevant variables, such as dwelling characteristics, dwelling ownership, employment status, education, and age. No significant differences were found between the two groups, which indicated the absence of non-response bias. Then, the data were tested against common method bias. For this, Harman's single factor test was conducted (Harman, 1967; Kassinis and Soteriou, 2009). The factor analysis, using principal component analysis, revealed seven factors with Eigen values greater than 1.0. In total, they accounted for 61% of the total variance. Moreover, the first factor only accounted for 21% of the variance (which is less than the official 50% cut-off point). The results show that common method variance can be considered to be of little influence in this study.

To investigate factors driving and hindering adoption, several analyses were conducted. Socio-demographics were operationalized as segmentation variables (Rogers, 2003), both adopters and non-adopters were analysed on differences. The differences between the two groups were tested using a chi-square test for categorical variables and a t-test for continuous variables. Next, the mean, the standard deviation

(SD), significance values, and construct validities of the five independent measures were analysed. Further details can be found in Tables 4.1 and 4.2.

Logistic Regression

To analyse the influence of selected items of perceived attributes, and attitudinal and innovativeness factors on SWH adoption, a binary logistic regression with the backward stepwise likelihood ratio was used. All variables were entered in the first step, and in every step after that the variable with the smallest correlation with adoption was removed; Exp β coefficient being the odds ratio of the probability that an event will occur against that it will not occur (Arkesteijn and Oerlemans, 2005). To assess the model fit, model chi-square was used. A p-value less than 0.05 shows that the model with its variables fits the data better than when those variables are excluded. The second test was a Hosmer and Lemeshow goodness-of-fit. This test tests the statistical significant differences between the observed and the predicted probabilities in the model. One can deduce that the model fits the data when the value of this test is small and p-value is greater than 0.05. Nagelkerke R square was used to check the predictive values of the independent variables, in which 0 means no predictive value and 1 presenting a perfect prediction.

In order to test our hypotheses (formulated in Section 4.4), logistic regression was used to identify those predictors most strongly associated with adoption. Since the nature of the dependent variable is binary (adoption/non-adoption), binary logistic regression was performed. This was preferred to alternatives, such as structural equation modelling. The main reason is that we were mainly interested in testing theoretically predicted statistical relationships between multiple independent variables and one dependent variable (instead of between variables without a sound theoretical basis). Moreover, by selecting binary logistic regression, we adhere to methods commonly used by researchers studying household adoption of green energy innovations (e.g., Arkesteijn and Oerlemans, 2005; Claudy et al., 2010; Jansson et al., 2011, 2017; Walekhwa et al., 2009).

4.5. Results

To examine factors influencing the adoption of SWH systems, an analysis was carried out on different categories of variables: (1) to test the influence of perceived attributes,

attitudinal and innovativeness factors, and other influencers in explaining adoption; and (2) to test the differences on socio-demographic characteristics between adopters and non-adopters.

4.5.1. Socio-demographics

Among 200 surveyed households 65.5% were adopters of SWHs. The statistical mean of time since adoption was 3.9 years, the SD being 3.4 years. The statistical mean of age and household size was respectively 42.2 years, and 4.3 household members with standard deviations of 12.2 years and 1.3 household members respectively. 54% reported a monthly income between 900 and 1,799 US dollars. 42% of respondents lived in urban areas, 35% in suburban areas, and 22% in rural areas. 32% of the respondents live in an apartment in a building with more than 5 floors, 44% live in an apartment of less than 5 floors, and 24% live in a detached house.

4.5.2. Financing incentive and customer satisfaction

To gain a better insight about adopters and non-adopters and their responses regarding various factors, we provide further details about the adopters and their time of adoption and satisfaction level. Furthermore, we discuss the importance of financing incentives from the point of view of both groups.

Among the surveyed adopters 64.2% stated that they had purchased a SWH in the past 2 to 6 years. A possible (context-related) explanation for this could be that, in 2011, the Lebanese government introduced a subsidy scheme to promote the use of renewable energy (Abou Jaoudeh, 2015). To analyse the significance of this subsidy in households' decision to purchase a SWH, respondents were asked to indicate the importance they give to each item of the subsidy programme. The results show that the importance of subsidized loans had a mean of 3.97. This is slightly less than the mean of the importance given to cash grants (4.03). Mostly non-adopters agreed that financing incentives were important when purchasing SWHs. When testing for differences between adopters and non-adopters on financing incentive construct, no significant differences were found ($p=0.321$). Furthermore, the construct did not show significant correlation with adoption of SWH. Therefore, H_{10} can be rejected. It is important to note that, after the first year of implementing the incentive programme, conditions of applying for these subsidies became more difficult as stricter qualification rules were imposed on the installing companies to ensure high quality installations. In

this case, households faced the dilemma of a complex or time-consuming application process for grants. The chances were high that consumers become demotivated to apply, and could have either postponed their adoption decision or sought other financing options.

Differences between adopters and non-adopters

Table 4.1 shows no statistical differences were found between adopters and non-adopters on most of the socio-demographic data. Two significant statistical differences ($p < 0.05$) appeared between the two groups, (1) household size, and (2) income. Results show that adopters had a greater number of persons living in the house (Mean is 4.57), and that there was a higher number of adopters with higher incomes ($p < 0.05$). Although education and employment status did not have any statistical significance, they reflected important characteristics of the households. More than half of the householders (adopters 65.2% and non-adopters 52.7%) were employed and earning wages. Moreover, the majority of the householders had at least a university degree.

Table 4.2 presents the mean, standard deviation (SD), significance values and the construct validities of the five independent measures (relative advantage, observability, personal norms, social norms, and consumer novelty seeking) assessed by Cronbach's alpha values (ranging from 0.629 to .845).

Table 4.1: Differences between adopters and non-adopters.

Socio demographic variables	Adopters (%)	Non-Adopters (%)	Chi-square	p	T value
Gender			0.99	0.32	
Male	56.5	63.8			
Female	43.5	36.2			
Employment status			7.263	0.123	
employed for wage	52.7	65.2			
self employed	32.1	15.9			
Unemployed	3.1	1.4			
Housemaker	9.2	11.6			
Retired	3.1	5.8			
Income			17.567	0.007	
<\$500	0	3			
\$500-\$899	16.9	26.9			

\$900-\$1,199	22.3	34.3			
\$1,200-\$1,499	16.9	16.4			
\$1,500-\$1,799	13.8	6			
\$1,800-\$2,099	8.5	7.5			
>\$2,100	21.5	6 (contributing most)			
Education			6.951	0.073	
Primary or less	5.3	16.2			
High School	21.4	19.1			
University	45.0	44.1			
Graduate Studies	28.2	20.6			
Dwelling characteristics			0.511	0.775	
Apartment in building less than 5 floors	43.5	44.9			
Apartment in building more than 5 floors	33.6	29.0			
Detached house	22.9	26.0			
Region			2.751	0.253	
Urban	42	43.5			
Rural	19.1	27.5			
Suburban	38.9	29			
Dwelling ownership			2.796	0.094	
Owned	93.9	87			
Rented	6.1	13			
Age Mean (SD)	41.71 (10.466)	43.22 (15.059)		0.461	-0.826
Household size Mean (SD)	4.57 (1.228)	3.78 (1.316)		0.000	4.218

Regarding product perceived attributes, our results show that adopters perceive SWHs to be more advantageous, compatible with their values, and observable by others. The results show that adopters exhibit significantly higher levels of relative advantage, compatibility with values, and observability. This supports the hypotheses H₅ and H₆ and H₈. Moreover, SWHs were seen by adopters to be less complex to install and use properly; meaning that H₇ is supported. Functional risk was not statistically significant ($p>0.05$) different between the two groups, which means H₉ are rejected. Thus,

functional risk did not have an impact on purchasing decisions. Turning to attitudinal factors, adopters had significantly higher levels of social norms, independent judgment making, and novelty seeking, which supports H₂, H₃, and H₄. Conversely, environmental personal norms did not show any significant difference between adopters and non-adopters, which means that H₁ can be rejected.

Table 4.2: Independent constructs and differences between adopters and non-adopters using t-tests.

Independent variables		Adopters		Non-adopters		p
	Scale (items)	Mean	SD	Mean	SD	
Perceived attributes						
RA	0.657 (4)	4.13	0.58	3.89	0.666	0.014
COM_value		4.09	0.808	3.71	0.941	0.005
COMX_inst		2.31	1.068	2.67	0.934	0.021
OBV	0.67 (2)	4.09	0.725	3.69	0.858	0.001
RSK		3.09	1.048	2.97	0.874	0.389
Attitudinal factors						
PN	0.796 (2)	3.9	0.835	3.93	0.653	0.778
SN	0.644 (2)	3.94	0.757	3.54	0.721	0.000
IJM		2.08	0.982	1.7	0.88	0.008
CNS	0.629 (2)	3.89	0.761	3.51	0.817	0.001

Bivariate correlations

The analysis bivariate correlations show that some variables were measured with a combination of several items. Each item represented a specific concept (such as saving, investment cost, and convenience which fall under relative advantage). These items are listed in Table 4.3. The following analysis is on the level of these items. An analysis using Spearman nonparametric correlation was performed (see Table 4.3) between items of previously tested variables and adoption of SWH systems to provide primary clues for the next analysis step to support or reject hypotheses. Although the determination coefficient (R-square) had relatively low statistical power, the results reveal that the most significant positive impact on adoption was the perceived advantageous convenience of the SWH ($p < 0.001$, $r = 0.266$), followed by social norms

as approved by peers ($r=0.262$), and by people who consider, “I should change to environmental boiler” ($r=0.22$).

Respondents seemed unsure of SWHs’ reliability in the long run (with a mean of 3.05). Although this item was not significant, it does reveal that consumers might not be fully informed about the functionality and nature of the system they are purchasing. Thus, providing information for consumers about the pros and cons of the system can increase trust in the system’s functionality. In fact, this factor might influence adopters’ trust and motivation to buy other renewable energy technologies.

For the next analysis, items were selected based on higher significant values, correlation, and on the higher prediction ability that would be used in the next test (logistic regression goodness of fit).

Table 4.3: Correlation coefficient and means of items.

Item	R	Mean (SD)
Relative advantage		
RA_saving	0.085 (0.136)	4.1925 (0.7241)
RA_cost	0.114 (0.108)	3.64 (0.993)
RA_conv	0.266** (0.000)	4.16(0.853)
COM_value	0.212** (0.003)	3.96 (0.873)
COMX_inst	-0.187** (0.008)	2.44 (1.035)
Observability		
OBV_care	0.222** (0.002)	3.86 (1.003)
OBV_notice	0.215** (0.002)	4.05 (0.822)
RSK	0.073 (0.302)	3.05 (0.991)
Personal green norms		
PN_obl	-0.084 (0.235)	3.8 (0.891)
PN_help	0.099 (0.161)	4.03 (0.808))
Social influence/social norms		
SN_repl	0.22** (0.002)	3.7 (0.94)
SN_encr	0.262** (0.000)	3.91 (0.842)
IJM	0.208** (0.003)	1.95 (0.963)
Consumer novelty seeking		
CNS_inform	0.148* (0.037)	3.79 (0.878)
CNS_search	0.248** (0.000)	3.73 (0.992)

** $p<0.01$, * $p<0.05$

Backward stepwise logistic regression analysis

In this analysis, three models were constructed. In the first model, the influence of perceived attributes was tested; in the second model, the influence of attitudinal factors and innovativeness; in the third model, the influence of both factors combined was tested. All models regressed separately on the likelihood of adoption. As a result, the predictive power of each set of variables was analysed. The third model combined perceived attributes to attitudinal factors and innovativeness. The three regression models are presented in Table 4.4. The aim of this combination of models was to explore the predictive ability of different sets of variables to adoption.

The three models had a relatively sufficient degree of model fit; referring to model Chi-square and Hosmer and Lemeshow test. Model 3, which incorporated product perceived attributes with attitudinal factors and innovativeness, had a reasonable fit of Nagelkerke R^2 of 0.233, which is higher than that of each partial model.

The accuracy of each model in explaining correctly predicted cases varied between 69.5% of the model containing perceived attributes and attitudinal factors each separately and 72.5% of the model including all variables. This revealed a sound fit of the models.

Each model had a different set of predictive variables. Model 1 tested the influence of product perceived attributes on adoption/non-adoption. Significantly higher levels of convenience in relative advantage of SWHs, and higher levels of environmental observability are found to increase the likelihood of SWHs adoption.

In model 2, attitudinal factors and innovativeness were included in the logistic regression model. The model shows that social norms, independent judgment making (*friend's opinion*), and novelty seeking (*searching for new*) are highly significant and positively influenced adoption. However, social norms were excluded from the model (referring to model 3) when perceived attributes were combined with attitudinal factors. It seems that consumer decisions to adopt or not to adopt sustainable technologies mainly relies on technology-related attributes and personal characteristics, such as independent judgment making and novelty seeking.

Model 3 combined perceived attributes, attitudinal factors and innovativeness. It achieved a reasonable fit of Nagelkerke R^2 of (0.233), which is higher than the value of

the models 1 and 2. Four out of ten variables were statistically significant. Higher levels of observability, convenience, novelty seeking, and independent judgment-making all increased the likelihood of adoption. A possible explanation for that could be the innovativeness of consumers in making decisions on the one hand and the advantages one perceives of having convenience and high observability to neighbours on the other hand.

Table 4.4: Logistic regression model with adoption being the dependent variable.

Independent variables	Model 1	Model 2	Model 3
Perceived attributes			
RA_conv	1.708 (0.005)		1.574 (0.026)
COM_value	1.34 (0.119)		1.306 (0.186)
COMX_inst	0.782 (0.125)		0.802 (0.193)
OBV_care	1.413 (0.031)		1.473 (0.028)
RSK	1.224 (0.232)		1.215 (0.309)
Attitudinal Factors and innovativeness			
PN_obl		1.07 (0.741)	1.017 (0.945)
SN_repl		1.532 (0.023)	1.267 (0.261)
IJM		1.964 (0.001)	2.070 (0.001)
CNS_search		1.698 (0.003)	1.669 (0.006)
Constant	0.057 (0.01)	0.016 (0.000)	0.003 (0.000)
Model -2LL	239.621	228.112	220.757
Model chi-square	18.097 (0.000)	29.607 (0.000)	39.961(0.000)
Hosmer and Lemeshow test	7.773 (0.255)	7.637 (0.47)	10.268 (0.247)
Nagelkerke R square	0.119	0.19	0.233
% Correct Overall	66%	69.5%	72.5%
% Correct Adoption (accuracy rate of predicting)	89.3%	87%	89.3%
% Correct Non-Adoption	21.7%	36.2%	40.6%

4.6. Discussion and conclusion

Our main research question was: To what extent do selected theoretical drivers explain household adoption of SWHs in Lebanon? An integrated research model was used to

analyse this using insights from both Rogers' 'Diffusion of Innovation' model and related models from the domain of environmental psychology. A key strength was the use and integration of combined models. The integrated model was found to be more powerful than each of the models alone. It shows the importance of combining theoretical notions from different academic traditions. Another strength of the study was that actual adoption was analysed, instead of mere intention to adopt (Ozaki, 2011; Alam et al., 2014).

An important goal of this study was to analyse which factors best-explained consumers' decision to adopt SWHs. Our major contribution is that the research results support most of the hypotheses formulated and support the higher explanatory power of the more comprehensive model in this "high involvement" context. How adopters perceive certain characteristics of innovations was found to correlate significantly with adoption decision-making. This is in line with the diffusion of innovation model (Rogers, 2003).

Our results show that, not only does novelty seeking and independent judgment making influence adoption decision-making, but also that strong social norms have significance when people are able to show their social inclusiveness by engaging in activities that are regarded by the social group they belong to, as a social norm. As SWHs are often visible from the street, their adoption cannot only be viewed as an activity of high involvement, but can also be characterised by their high observability. It is important to understand consumers' views to be able to choose the right technique which can increase their knowledge about certain technologies.

Policy incentives were also found to correlate positively with adoption decision-making. The availability of funding programs (Zhai and Williams, 2012) and government support and policies (Luthra et al., 2016) were important in tackling barriers and driving adoption of technologies. Our results show that the grant incentive programme implemented in Lebanon to increase the uptake of SWHs did have a positive impact on adoption decision-making. This policy approach can therefore be seen as successful in the Lebanese market, yet it might likely fall far short of what is truly achievable if it continues to neglect the social and the behavioural insights of consumers and their energy use.

Taking into consideration the low statistical power of the model's fit, the results demonstrate that relative advantage, environmental observability, consumer novelty seeking, and independent judgement making were significant in all three models.

However, social norms were not significant when model 2 was combined with model 1. This result contradicts the results of Thøgersen's study (2006), since social norms had higher explanatory power when combined with pro-environmental personal norms. As socio-demographic indicators were used as control variables in this analysis, the results reveal that more than half of the surveyed households had higher education (Claudy et al., 2010; Kastner and Stern, 2015) and that most of the householders were employed (earning wages). This says much about the particular (high-end) social environment in which adopters of SWH systems live.

The results also revealed that, among perceived attributes, there were significant differences between adopters and non-adopters in their relative advantage, compatibility, complexity, and observability. This would imply that adoption might be related to particular social norms, independent judgment making, and consumer novelty seeking which are prevalent in a (given) social community to which a certain consumer is a member.

Our research has also revealed that relative advantage, compatibility, and observability increase the likelihood of adoption, whilst complexity was found to lower the likelihood of adoption. When SWHs are viewed as advantageous, more compatible, or less complex, it is more likely that they will be adopted. Our results are in line with Arkesteijn and Oerlemans (2005) and revealed that consumers do not adopt an innovation if they do not see the differences in the advantages when compared to conventional purchases.

The results of our analysis also show that adopters have a relatively high novelty seeking motivation. This indicates that there is a certain market segment that exhibits innovative traits. Although advertisements in the mass media are useful to create knowledge and influence earlier adopters, interpersonal sources were found to be more effective in influencing individuals' attitudes. This, in turn, was useful in the process of persuading householders to adopt SWHs.

In summary, our research provides evidence in support of claims for the influence of social norms on adoption decision-making (Jager, 2006; Mahapatra and Gustavsson, 2008; Sidiras and Koukios, 2004). However, they seem to contradict the claim by Thøgersen (2006) that personal norms are more important than social norms when it comes to adoption decision-making.

4.7. Limitations and suggestions for further research

There are limitations of our study. For instance, the surveyed respondents who had adopted SWHs could have formed their attitudes after adopting the innovation and not before. To avoid this from happening in future studies, we suggest conducting longitudinal studies to analyse specifically how attitudes change before and after adoption. Further studies also could test a wider set of factors from the pro-environment behaviour literature, such as consumption attitude. Another clear limitation was that only one type of renewable energy technology was tested to generalise findings to other higher involvement products, e.g. solar panels and other technologies available in the market. The low statistical power of R square and Nagelkerke R square, which leaves approximately 75% of the variance unexplained, is another clear limitation. Finally, our research focused on only one type of renewable energy technology. This made it difficult to generalise our findings to other high involvement products and renewable energy and other technologies more generally available in the market.

Looking to future research opportunities, giving more attention to the consumers' role in the diffusion process will provide more clarity of users' perspectives as a starting point for technical developments. We suggest that it would be of great importance to study the awareness of consumers of policy incentives, and to analyse to what extent householders accept, use, and benefit from those policy incentives. This could give clarity from a consumer's perspective on how they would benefit most from programmes and initiatives that primarily target engagement of consumers in sustainable energy markets and contribute to better living conditions.

Another issue concerns socio-cultural and aesthetic aspects. Although they were not examined in detail because of the specific focus of this study, we believe that they should receive more attention in future research. Going forward, we also believe that it is important to research community-based approaches in fostering innovation and adoption of renewable energy technology. Achieving remarkable diffusion rates will likely require the integration of various aspects from technological, economic, social and cultural aspects, policy and environmental perspectives.

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4.9. Appendix A

Survey items, constructs, and Cronbach's alpha coefficients

Cronbach's alpha of 0.5 and above where selected (Neuendorf, 2003)

GRNT: Financial Incentives ($\alpha=0.845$)

GRNT_In: The importance of interest free loans in the decision to buy SWHs

GRNT_sub: The importance of the financial subsidies in the decision to buy SWHs

RA: Relative Advantage ($\alpha=0.657$)

RA_dep: To use a SWH means that I depend less on electricity from private generators

RA_saving: To use a solar water heater would reduce my heating bill

RA_cost: To purchase a SWH is a low cost investment

RA_conv: To use a solar water heater means increase in the hot water comfort at home.

COM: Compatibility

COM_value: When I use SWH in my house, I reduce national dependency on foreign energy sources.

COMX: Complexity

COMX_inst: Installing a SWH would lead to high annoyance (because of piping).

OBV: Observability ($\alpha=0.670$)

OBV_care: By buying a SWH I show people living nearby that I care about the environment.

OBV_notice: By buying a SWH it would be noticed by people close to me.

RSK: Functional Risk

SWHs are risky since they often break (stop heating properly)

PN: Personal Norms ($\alpha=0.796$)

PN_obl: I feel a personal obligation to prevent climate change, no matter what other people do

PN_help: People like me should do everything they can to reduce their emissions and help prevent climate change

SN: Social Norms ($\alpha=0.644$)

SN_repl: People close to me think I should replace my water heater with an environmentally friendly water heater.

SN_encr: The people in your life whose opinion you value most would encourage you to install SWH on your house

IJM: Total Independent Judgment Making ($\alpha=0.537$)

When I am interested in buying a new product/service I usually trust/rely on opinions of friends or close acquaintances who have used this product/service (reverse coding)

CNS: Consumer Novelty Seeking ($\alpha=0.629$)

CNS_inform: I like newspapers and magazines that inform about new brands

CNS_search: I continuously look for new products and new brands

Chapter 5: Comparing two pathways of Strategic Niche Management in a developing economy; the cases of solar PV and solar thermal energy in Lebanon⁶

5.1. Abstract

There is abundant solar potential in the Middle East North Africa (MENA) region, yet access to sustainable energy is still a fundamental challenge in many MENA region countries. In this paper we seek to understand the success and failure of the development and the diffusion of solar energy technologies by analyzing Strategic Niche Management (SNM) to compare the niche development of solar thermal energy (i.e. solar water heaters; SWHs) and solar PV in Lebanon. This paper has two main questions: (1) *What challenges are the SWH and PV niches facing, and how have these niches developed in Lebanon*, and (2) *What are the structural differences in niche formation between the SWH niche and the solar PV niche in Lebanon and in which ways does the SNM framework help to understand the development of these niches from a developing country's context?* To answer these questions, a cross case analysis of SWH and PV was conducted. The main SNM propositions were grouped and compared per item (i.e. on voicing and shaping expectations, social networks, and learning). The results show that the SWH niche affected the solar PV niche to a large extent, especially concerning the learning and coordination processes, which gradually contributed to establishing a clear vision. However, both niches lacked a niche manager who was able to coordinate, manage and maintain the dynamics of the niche processes, and lacked horizontal collaboration between key actors involved (i.e. ministries). International donors were found to play a crucial role in initiating and shaping the market with certain constraints of prioritization in the region. The paper ends with conclusions and ideas for future research on solar energy niche development in the context of developing countries.

⁶ This chapter is based on paper (paper 3) which has the same title. The paper is authored by Houda Elmustapha (the main writer of the paper and author of this dissertation), Professor Hans Bressers based at the University of Twente and Dr. Thomas Hoppe based at Delft University of Technology. The paper has been published in *Journal of Cleaner Production*, Vol No., 2018, pp. doi: 10.1016/j.jclepro.2018.03.098

5.2. Introduction

Integrating renewable energy technologies in developing countries is a challenge and requires external financial and educational support. These challenges might include, geo-political, legal, financial and physical factors. However, the presence of international organizations may ease the way for renewable energy technologies to expand in complex phenomena with the financial stability and support provided from international organizations to the market and to the government (Karp, 2015). One of the challenges that developing countries face in terms of including renewable energy in the energy mix is the infrastructure and technological capabilities (Thornton, 2016). Kinab and Elkhoury (2012) came across a study from the United Nations discussing that the lack of energy supply will soon face third world countries due to (1) population growth, (2) load growth, (3) stable governments and political situation planning, (4) tangible resources.

The Middle East and North Africa (MENA) region has abundant solar potential which lead countries in this region to adopt solar renewable energy plans and projects (Jablonski et al., 2012; Tsikalakis et al., 2011) with the support of European countries and bilateral agencies (European Investment Bank, 2010). Lebanon is one of the Middle Eastern countries that suffers from great shortage in energy production. Although it does have potentially positive climatic and geographical conditions for renewable energy production, it does not benefit from these circumstances. This is related to the absence of clear policies to promote the use of renewable energy sources, and other challenges such as the relatively low awareness of the decision makers to the exponential benefits of renewable energy technologies (Kinab and Elkhoury, 2012).

Lebanon witnessed various national initiatives to develop renewable energy technology markets, in particular solar energy. The first of those technologies is that of Solar Water Heaters (SWHs): a device which is designed to convert sunlight into heat which is transmitted to water by heat transfer phenomena (Sellami et al., 2016). The second technology is Photovoltaics (PVs): a technology which produces electricity from solar energy through conversion of solar radiation into electricity.

5.2.1. Solar Water Heaters

The Lebanese SWH market witnessed various efforts supported by non-governmental organizations (NGOs) and international agencies or supported through grants from foreign governments (such as China, Spain, Turkey, and Greece). The turning point in the history of the market was launched by the United Nations Development Program (UNDP). In Lebanon this program was implemented by the Ministry of Energy and Water through funds by Global Environment Facility (GEF) which aimed at promoting SWH installations in the residential sector to reach a 190,000 m² surface of installed solar collectors by 2014 (LCEC, 2016). This initiative was followed by a policy paper which set out to increase SWH penetration and devise a financing mechanism to reach 1 million m² of installed capacity by 2020 (Bassil, 2010). As a result of this initiative the sales of the local SWH dealers increased by 40% (LCEC, 2016). However, the industrial sector is still lagging behind (representing only 4% of the installed SWHs). The residential sector is the leading sector, containing 74% of the installed SWH systems. The total surface of installed systems until 2014 is approximately 550,000 m² (LCEC, 2016).

5.2.2. Solar PV

Since 2007, a project managed by UNDP and funded by the Spanish government for the recovery of Lebanon after the 2006 invasion started demonstration of both SWH and PV in thirteen public buildings. The key event in shaping the market was the launch of an action plan proposed by the energy conservation center in the ministry. A financing mechanism was adopted to support new and existing renewable energy projects allowing different sectors to benefit from subsidized loans with low interest rates (Bassil, 2010). During the startup phase of the program, the European Union (EU) offered 15 million euros as a grant resulting in the funding of 350 projects by the end of 2015. The total installed capacity of PV until 2015 was 9.45 MWp. Most PV systems are installed by the commercial sector (22%). In the residential sector and agricultural sector this is 18%, and in the industrial sector this is 17% (Amine and Rizk, 2016).

This paper aims to understand the challenges facing the niche market development of two technologies; solar photo-voltaic (PV) and solar water heaters (SWH) and the differences in niche formation between those in a developing country's context. The research questions are: 1) *What challenges are the SWH and PV niches facing, and*

how have these niches developed in Lebanon, and (2) What are the structural differences in niche formation between the SWH niche and the solar PV niche in Lebanon and in which ways does the SNM framework help to understand the development of these niches in a developing country's context? To answer these questions, chronological narratives using the sequence of key events which were implemented on the national level will be presented followed by a discussion of ongoing challenges. After that a cross analysis of SWH and PV using internal niche processes will be presented and ending up with insights specific to niche development in developing economy.

5.3. Strategic Niche Management

To move towards low carbon systems, it requires a wide range of changes not just from the consumer practices and behaviour changes, but also change of government policies and incentives and technological approaches. The Strategic Niche Management (SNM) approach, firstly introduced by (Schot et al., 1994), advocates “the creation, development, and controlled breakdown of test beds (experiments, and demonstration projects) for promising technologies and concepts with the aim of learning about the desirability and enhancing the rate of diffusion of this new technology” (Weber et al., 1999). Similarly, Urban et al. (2016) mentioned that for diffusion of clean energy technologies to occur, a process of research and development, demonstration and deployment should take place. Beyond that, a wide environment of aspects evolves in the process including market creation, presence of adequate incentives, and specialized technicians. Therefore, a wide range of actors play a role in diffusion from public institutions to firms and research organizations. In other words, SNM is used to manage technological innovations and facilitate the design of policies and experiments at the niche level (Thornton, 2016). Successful innovations initiate from real-world experiments and protected spaces, and for this reason niches should be created to cover these aspects (Markard et al., 2012). SNM sees promising innovations develop in niches enabling experimenting the technology which if sustained over time will pave the way for the market niche creation of viable market niches (Romijn et al., 2010). For the experiments to achieve desired objectives, three internal processes are critical to take place: (i) voicing and shaping expectations; (ii) building social networks, and (iii) learning processes (Kemp et al., 1998). The three internal

niche processes have been used by many scholars to study social experimentation and niche market development of clean technology (e.g. Valdez 2015; van der Laak et al., 2007, and Xue et al., 2016).

However, the framework has also been criticized, for instance by Lachman (2013) who argues that it is heavily characterized by the context in which it was comprehended. And this is typically done in studies conducted in Western countries (predominantly in Western Europe), mostly neglecting large parts of the World, in particular the global South. In this part of the world, particular contextual, institutional, economic, and cultural factors might be of great importance in enabling or disabling niche formation processes in specific ways that are different from practices more commonly found in Western countries. Moreover, there is a call for using SNM to study niche processes in non-OECD and developing countries (e.g. Jain et al., 2016). The gap that the SNM approach is facing here is in shifting the growth path in developing countries. Due to the lack of technological capacities or adequate policy frameworks or resource constraints and narrow involvement of actors, promising technologies are hardly ever developed in these countries (Opazo, 2014). Sagar and Majumdar (2014) discussed the important role that the government can play in these countries by financially supporting technological innovations through creating specific policies or institutions or through initiating research and development (Sagar and Majumdar, 2014). In addition, Opazo (2014) states that social embedding of a novelty is more important than merely stimulating technology development. In developing countries, a lack of access to services that fulfill societal needs, such as access to reliable energy supply and other basic services might be considered of greater importance than, for instance, focusing on carbon emission reduction. Due to the limited capabilities of developing countries in getting access to and allocating resources for sustainable technology development, international collaborative programs have been set-up to support these countries.

The need of support for developing countries to achieve climate mitigation goals was discussed by Mdivani and Hoppe (2016) and Sagar and Majumdar (2014), who mentioned that most of the collaborative programs in these countries are top-down in nature, specifically targeting market creation and diffusion, while focusing on sharing knowledge rather than being involved in research and development. Moreover, they might conflict with on-going projects that have been initiated at the regional or local

level. Another important aspect influencing niche development in developing countries concerns support provided by international donors (Hansen and Nygaard, 2013; Jolly et al., 2012; Romijn et al., 2010). In developing countries donor interventions denoted by the development programs and projects funded by multilateral organizations such as the GEF and agencies of the United Nations or other bilateral donor agencies distributing aid between countries play a critical role in shaping the market. Regardless of their contribution to technology market development, donor interventions have their own complexities. For instance, leading fund seekers to shape the market concepts to meet donor concerns in order to receive funding and ending up in continual search for funding (Nygaard, 2010). At the niche level, donor intervention takes the form of supporting technological experimentation through providing financial support to these experiments such as demonstrating the technology (Hansen and Nygaard, 2013). As such, donors directly or indirectly play an important role in shaping niches through programs supporting experiments and related niche formation requirements (Jain et al., 2016). For instance, Byrne (2009) found that donor interventions help develop the market through standing the initial investment risk for private-sector project developers thus creating a protected niche where experimentation and actor network formation occur (Smith and Raven, 2012). In developing countries, this can be regarded as an essential step since at the start of the market there is limited or no experience in renewable energy projects making it difficult for investors to finance their projects. Therefore, donors promote renewable energy technologies in developing countries and support institutions in order to prompt change in institutions at the regime level (Hansen and Nygaard, 2013).

5.3.1. Expectations

In niche internal processes, expectations are described as promises of new technologies and can be “problem oriented and deal with specifications of technology”, “function oriented”, or “scenario oriented with a broad spectrum” (Mourik and Raven, 2006). When radical innovations have uncertain outcomes, expectations can play a crucial role in bringing in new actors (Xue et al., 2016), strengthen the niche by allowing actors to learn about technology in real life circumstances and develop a community with a shared agenda (Geels, 2011), and by guiding their activities (Schot and Geels, 2008). In a similar vein, Raven (2005) stated that at the beginning of a technological trajectory expectations are viewed broad, general and fragmented. Taking this into

account, early expectations need to be at a high level of stability for them to contribute successfully to the niche. Kemp (1994) refers to this as the coupling of expectations, which was then elaborated by Raven (2005) on the concepts of the voicing and shaping of expectations. Therefore, expectations tend to be more powerful when they are; (i) accepted and shared by more actors; (ii) clear and specific; and (iii) supported by experimentation results (Schot and Geels, 2008).

5.3.2. Actor networks

For a technological innovation to develop it has to be supported by a social network. In general, different actors have certain perceptions which drive them to be part of a network for various reasons (Xue et al., 2016). Mourik and Raven (2006) view that actor networks tend to create coordination and convergence of diverse expectations, therefore for a social network to be effective it has to include diverse actors with higher alignment in between them (van der Laak, Raven and Verbong, 2007). Moreover, for networks to play a sustaining role in niche development, commitment of resources and support for platforms on which actors interact, exchange visions and lessons and develop emerging rules through alignment processes are required (Opazo, 2014). Given the fact that actors represent institutions with clear practices, then arrangements between institutions can foster cooperation and provide resource commitments to sustain the network. Once resources are available, interactions will occur regularly either via formal or informal platforms.

5.3.3. Learning

The co-construction of technologies, markets, and regulations does not only involve experimentation, but also learning (Watanabe et al., 2009). Since experimentation is the core of SNM, learning has a crucial role in leading actors to adjust either the niche's central technology or the social environment in which the technology is embedded (Raven, 2005). Therefore, learning in SNM is not only about learning from series of technical experimentation but also about social experimentation with a novel technology; i.e. in a new social setting. A series of social experimentation learning aims at revealing critical opportunities that support niche development or barriers that hinder it (Mourik and Raven, 2006). Experimentation sequences can add up to the learning trajectories, and gradually change the content of knowledge, ideas, and perceptions surrounding a given novelty in a niche environment (Raven and Geels, 2010).

By learning about the technology by using it, actors engaged will be able to provide feedback to the wider niche network. Some scholars distinguish between first order learning and second order learning amongst others (Byrne, 2009; Raven, 2005; Schot and Geels, 2008). According to Schot and Geels (2008) the purpose of the first order learning is to gather facts and data from different aspects (technology, infrastructure, policy, and user practice) as referred to by Raven and Geels (2010) by accumulation of data within cognitive frames. This type of learning can contribute to improvements in the technical and economic performance of a technology practice. Not only this, but first order learning goes from identifying potential side effects and social desirability to leading to technological solutions and potential improvements that can lead to a working technological configuration. However, first order learning alone is not sufficient to explain how the articulation of experiences and knowledge can create new rules needed for a niche (Opazo, 2014). When actors are able to retain cognitive frames and maps of reality and adapt them then second order learning occurs. Second order learning is more reflexive and will focus on questioning the available norms and rules to reformulate the expectations, redesign the technology, and reconstruct the network (Mourik and Raven, 2006). Byrne (2009) explained this by reflecting that second order learning is about societal functions rather than functionality. For an effective niche creation to occur, learning processes have to be broad and reflexive (Raven, 2005, Schot et al., 1996, Schot and Geels, 2008).

5.3.4. Interaction between niche processes

To understand the process of niche formation, the niche processes mentioned previously should not be studied in isolation of each other for the reason of their dynamic interaction. Kemp and Rip (2001) discussed this aspect by mentioning that the outcomes from an activity at niche level should be viewed as a modulation of ongoing dynamics. Actors carry certain visions and expectations, and develop relationships within networks as a result of this alignment within the network. Expectations consequently influence how experiments are organized. Then, these experiments will offer results to be interpreted by actors and therefore influence engagement in additional experiments. Outcomes of the learning processes might lead to changes in expectations and may have an impact on the extent to which visions change. However, there are also other external factors that can influence how learning is interpreted (Opazo, 2014). Geels and Raven (2006) differentiate between local

experiments from which lessons can be learnt and experiences which lead to learning and coordination at a higher level of aggregation (i.e. the global level). In turn, technological developments are said to occur at the local level. Cognitive rules and practices are shared at higher levels of abstraction though (Raven and Geels, 2010). In sum, the sequence of concrete local projects gradually adds up to a technological path at the global level (Raven and Geels, 2010). This explains that a sequence of local projects might enable socio-cognitive cycles and elaboration of cognitive rules.

Figure 5.1: Technical path of sequential local projects; adapted from Raven and Geels, 2010.

Because SNM research focuses on internal niche processes it is criticized for giving little attention to the roles of actors in local projects, showing a lack of consideration of agency and the role of power reflecting on the important role of decision making in determining niche construction and niche-regime interaction (Geels, 2010). By stating this, decision making can, in fact, be viewed as a central element in technological change (Opazo, 2014).

5.4. Research design and methodology

The research design used in this study concerns a cross case design. The two cases are solar PV niche development and SWH niche development in Lebanon, and concern historical cases. Comparative-historical methods are useful to understanding both the dynamics and processes underpinning social change and technology development (Lange, 2013).

The design of this study entails tracing the events, processes and dynamics of technological change and the diffusion of solar energy technologies in accordance with

the SNM framework embraced. According to Opazo (2014), the SNM framework often relies on case-study approaches since it links events, that happened historically with real life events that define trajectories of change.

Using a case study approach will allow to elaborate on existing theory and building on complementary new insights with an explanatory aim. The study of niche development of solar energy technologies in Lebanon starts from the theoretical strands of the SNM framework to provide insights on diffusion phenomena from a wide perspective taking into account actors and projects which took place on national level. Lebanon presents a unique case study due to its geographic location, abundant solar resources and deficiency of conventional energy resources. Despite its positive geographic and climatic conditions, the country still relies on imported fossil fuel for energy production. Lebanon shows a hostile environment to green innovations, and this hostile environment is due to the political and the economic instability (Thornton, 2016). Based on that, Lebanon is selected to present the complexity of market development and to serve as an example case for other developing countries of similar geo-political and socio-economic dimensions.

The analytical aim of this research is threefold: (i) to understand and map the challenges facing diffusion of renewable energy technologies; (ii) to gain more insights in the complex phenomena of SNM in a developing country context; and (iii) to reflect to SNM on the basis of empirical research from comparative cases in a developing country context. Through the methodological approach adopted, this study uses existing theoretical building blocks of the SNM approach by including the role of actors in socio-technical diffusion processes. The formation of solar energy niches is investigated from a reflective-analytical perspective by understanding niches' formation and challenges encountered. For this purpose, a case study approach was adopted and case studies of two solar energy technologies in the Lebanese market were selected. Case studies can be viewed as "an empirical inquiry that investigates a contemporary phenomenon within its real life context; especially when the boundaries between the phenomenon and context are not clearly evident" (Yin, 2014:13).

This section presents information on the data collection and data analysis of the selected case. To generate knowledge about the market initiatives and the involvement of the stakeholders in the past and the ongoing projects, various stakeholders were

contacted. The primary researcher discussed the projects which were implemented in the country regarding SWHs and PVs with addressed actors in the renewable energy market. Further information about project details, key actors and institutions, sources of funding, delivery and implemented models were collected. Afterwards a project data base was constructed, desk research was used to retrieve and analyze possible information from documents, interview transcripts were made, and transcripts from previous interviews and studies conducted in these projects were made.

Projects within each of the two case studies were identified through a detailed review of program documentation available from CEDRO, UNDP project newsletters and publications, UNDP documents, GEF projects' documents (such as the ones published by the LCEC) and other archival records obtained from project databases and from experts. Additional information about the project details (such as implementation), key actors and institutions, and management models) were also compiled. Using a snowballing method to get access to additional information sources, additional key informants were identified and contacted with the aim of expanding the original list of projects. For the purpose of triangulation, direct observation from the field complemented the evidence obtained from interviews and those sources were compared to seek confirmatory evidence. This field observation enhanced the understanding of technology at work and how projects are implemented and developed. The list of actors was triangulated with the ones used by UNDP and LCEC to assess the relevance of other actors.

Data collection concerned 15 face to face in-depth interviews with different stakeholder groups relevant to the solar energy market. Field visits were made during interviews with end users of implemented projects. In Appendix III, an overview of the interviewees who were contacted for this study is presented. The interviews were conducted between February and March 2017, and took between 45 to 60 minutes each. Interviews took place at interviewees' work environment. Field visits were organized with the staff involved in the selected implemented project.

To be able to analyze the development of the SWH and PV niches, an interview protocol was designed. Conceptual elements of SNM were used when formulating the questions. The interview questions were adjusted to the role and area of expertise of each actor. Semi structured interviews were conducted using a mix of open ended and

focused questions, hence giving informants flexibility in sharing their opinions about the projects and gaining insights into the interviewees' opinions regarding events.

The interview questions were designed to examine the following research areas:

1. The general context of SWH and PV niche formation, challenges encountered during niche formation, and general project development;
2. Internal niche processes and their role in niche formation (i.e. the social network, learning processes and experimentation);
3. Niche dynamics (e.g. actor's roles and rules) influencing the socio-technical regime for each of the two solar energy technologies of interest.

See for more details of the interview questionnaire Appendix III.

Data collected from interviews and other information were coded in a data extraction template (using ATLAS.ti software) which reflected the concepts used in SNM. By using the theoretical propositions reflected in the framework, the data were analyzed relying on how relevant the literature is to the renewable energy projects implemented in Lebanon and to the formation of new insights from the developing country context. The results were interpreted based on the use of concepts from the SNM framework of niche development with attention to: (1) experimentation and relevant government protection, (2) learning processed, and (3) social network formation with regards to visions and expectations.

Based on the results of each of the two case studies (SWH and PV) a cross case analysis was conducted. Common and differentiating determinants of SNM and other new determinants influencing niche development were constructed. For the single case studies, chronological narratives were constructed by identifying the sequence of key events, which influenced niche development processes and their dynamics. Finally, an analysis on similarities and dissimilarities between the two cases was conducted to analyze niche development processes and dynamics in key niche development characteristics.

5.5. Results

The results of this study are presented in 3 subsections. Section 5.5.1 and section 5.5.2 give a general overview of the SWH and solar PV market development respectively.

Then, the SNM niche internal processes of the two case studies are compared and presented in section 4.3.

5.5.1. Overview of SWH market development

The initiatives in the SWH market started in 1999 with early demonstrations of the technology funded by a French agency. The initiative was implemented in cooperation with a local agency and with the Ministry of the Environment to shed light on the importance of energy efficiency and the role that SWHs have in reducing energy bills (Houri, 2006). With this effort, the role of the implementing agency was to promote for sustainable methods for energy management and to call for sustainable policies. However, the SWH market was still facing huge obstacles preventing its development and risks in sustaining a steady growth. Therefore, there was a need for more technical and financial support. Figure 5.2 presents a timeline of key implemented projects for SWH in Lebanon.

Figure 5.2: Timeline of key SWH projects.

Accompanying the Kyoto protocol in 2006, the Ministry of the Environment was the first to start supporting a scheme which calls for investments in sustainable projects. Yet, due to the low interest from other ministries, it did not achieve its targets. After the

invasion of Lebanon in 2006, UNDP projects, CEDRO 1, CEDRO 2, and CEDRO 3, were launched through the recovery of Lebanon under a fund from Spanish Government between 2007 and 2013. This fund was launched to support the country after the damage of major infrastructure utilities in 2006. The projects implemented concerned both the installation of SWHs and PVs on public buildings. The main role of the projects was to assist in the market readiness from an economic, social, and environmental perspective, which reflects the UNDP role in supporting the government with the environment targets and sustainable development. This explains the key role that international aid agencies play in supporting stakeholders, like ministries, the private sector, and financial institutions and in shaping the market direction.

After the 2009 Copenhagen Summit, the cooperation between the ministries (of the Environment, Energy, and Finance) started to develop, yet with slow progress. As a consequence, and for the purpose of opening up the market and increasing trust in the technology, an initiative called the GSWH was launched under the direct management of the Ministry of Energy and the UNDP with funds from GEF (an international organization providing funding for developing economies to help in meeting environmental international targets). This fund captured the attention of the Ministry of Energy to get involved in renewable energy initiatives and affiliate a team implementing the project as an energy conservation center linked directly to it. The initiative focused on policy, financing, quality control, and capacity building. The team implementing the project succeeded in drafting a financing scheme to support the SWH market, which was later adopted by the government. The Ministry of Energy assumed a role of planning policies and guidance through drafting an action plan, and allocating funding either internally or through international funders to accomplish targets. To sustain market growth efforts of stakeholders the GSWH brought together different actors; the ministry of energy and its energy conservation center, the ministry of education, the central bank, international agencies, research institutes, NGOs, and private renewable energy technologies dealers. Achievements of the GSWH initiative can be seen as a result of interrelated initiatives which involved awareness raising, market demand creation through financial facilitation, large scale installations from foreign donations and other funded projects, quality control, standardization, and certification (Abou Jaoudeh, 2015).

Figure 5.3: Timeline of key PV projects.

5.5.2. Overview of PV market development

Although many initiatives which targeted the adoption of SWHs were also relevant to niche development of solar PV technology, the solar PV market was less mature than that of SWH, and was in need of more support. Some of the initiatives concerned: the clean development mechanism managed by the Ministry of the Environment in 2006, the CEDRO 1, CEDRO 2, and CEDRO 3 programs. Figure 5.3 presents a timeline of key projects implemented to support solar PV niche development at the national level.

In 2012, a EU co-funded project called Strategic Hubs for the Analysis and Acceleration of the Mediterranean Solar Sector (SHAAMS) started, targeting policy development, entrepreneurial and research engagement, and social awareness in the solar sector. This project was managed by three stakeholders from the business sector (project developers). At the national level, projects with similar targets were implemented. For instance, a project managed by the energy conservation center and funded by the EU, (MED-DESIRE), aimed at removing barriers related to the legal, regulatory, economic and organizational framework relevant to solar energy technologies. Another EU funded project, CEDRO 4, which shifted attention in 2014 to the commercial and

industrial sectors to work on more large-scale projects with a different financing scheme through a fund from the European Union. This project delivered support to factories and private companies by bidding for contractors, conducting feasibility studies, and launching the project on the ground. The project administered several demonstration projects across the country as its main objective was to help establish the solar electricity market through facilitating work between donors and beneficiaries. In parallel, another UNDP project, entitled DREG (targeting small decentralized renewable energy power generation) started under the fund from the GEF, focusing on pre-feasibility studies and data monitoring with the aim of documenting existing solar electricity performances and carrying out cost benefit analysis of solar electricity generation technologies. Table 5.1 gives an overview of the key projects with their objectives and relevant funders.

As mentioned previously, bilateral agencies (such as UN organizations) were triggering and supporting the government to meet its global commitments and the international funding bodies are providing the resources to ensure implementation of work. Furthermore, the agenda and objectives were pre-determined by the funding agencies giving limited flexibility to the project managers to reshape the objectives and relevant activities themselves.

Table 5.1: Overview of analyzed SWH and solar PV projects

Project Name	Objective	Current Stage (Spring 2017)	Funder
Project 1: GSWH-Global Solar Water Heating Market Transformation and Strengthening Initiative	To accelerate market development of SWHs	Completed	Financed by the Global Environment Facility (GEF) and managed by UNDP
Project 2: CEDRO 1, 2, and 3 country energy efficiency and renewable energy demonstration project for the development of Lebanon	To improve end user energy efficiency and stimulate adoption of renewable energy technologies in public buildings (SWH and small scale PV)	Completed	The Lebanon Recovery Fund through a donation by the government of Spain
Project 3: CEDRO 4 country energy efficiency and renewable energy demonstration project for the development of Lebanon-private sector	To improve the use of renewable energy and energy efficiency systems and measures in economic sectors (commercial, industrial, and utility-scale, and a village scale)-large scale PV	Implementation stage	Financed by the European Union and co-financed by beneficiaries (from industrial and commercial sectors)
Project 4: SHAAMS-Strategic Hub for the Analysis and Acceleration of Mediterranean Solar Plan	The effective deployment of the solar MED plan through policy development, entrepreneurial and research engagement, social awareness	Completed	Financed by the European Union, and implemented under the ENPI-CBCMED (cross border corporation in the Mediterranean)
Project 5: DREG-Small Decentralized Renewable Energy Power Generation	Reducing greenhouse gas emissions through the removal of barriers to widespread application of decentralized renewable energy based power-private owned grids.	Implementation stage	Financed by the Global Environment Facility (GEF). Executed by the Ministry of Energy and Water of the Government of Lebanon and implemented by UNDP

5.5.3. Challenges

The SWH market is arguably in a mature stage yet there are efforts which still need to be made. This would include improving lab testing facilities, putting a building code into action, and open the market for new developments in the technology (in particular to tackle the roof space problem), and to increase promotion for collective system type for different sectors. With regard to solar PV, the national electricity operator has a

shortage of open-minded thinking of qualified staff, which makes it end up not being supportive of integrating alternative energy sources. Grid connected PV systems face the challenge of connecting to the national grid. This is due to the technical restrictions such as the inability of the national grid to supply electricity 24 hours a day. Another problem concerns net metering, which is encountering challenges. This requires installed small scale PVs to use batteries which increases the price of the system and makes it unable to compete with the subsidized electricity coming from the national grid (CEDRO, 2013). Yet, there is still an unclear option available for medium sized installations. Support for these technologies can take any of these forms: (1) direct capital grants, interest rate subsidies, and tax concessions or premium feed in tariffs supported by the state budget; (2) spreading the costs of premium feed in tariffs for RE across the overall energy production costs (i.e. through minimum RE purchase obligations by utilities); and (3) by creating additional revenue streams for investors. One obstacle facing the financing scheme is the lengthy assessment procedures which are drawing investors away.

For the purpose of boosting decentralized renewable energy markets in Lebanon, the GEF financing as a primary outcome was used as a complementary grant co-financing scheme to leverage financing mechanisms. For instance, CEDRO 3 was an EU funded project which was entirely financing renewable energy take up in the Lebanese public sector. The programs of Med Solar and CEDRO 4 are supposed to facilitate a move from entirely grant financed projects to a more (financially) sustainable model which involves the private sector to finance the investments. It is expected that moving away from pure grant funding for investments in renewable energy towards more sustainable business models will be sufficiently accelerated by the GEF project to open up new market opportunities.

Although the financial support programs stimulated a large market growth, this measure cannot be seen as sustainable. There is a need for more sustainable measures such rigid regulations which can ensure long term sustainable market growth. Therefore, it is important to point out that the current advertising campaigns are launched by private companies who promote their products by referring to the subsidy provided by the ministry of energy as a quality and trust mark.

For these reasons the solar sector presents an interesting study of the dynamics of diffusion. The two technologies differ in technological, economic and social characteristics and dynamics. For instance, PVs are still considered rather expensive and unlike SWHs they require integration with the electricity grid which is still considered by main stakeholders in market to be a major bottleneck, mainly because of its institutional and political nature.

5.5.4. Internal niche processes

Voicing and shaping of expectations

At the start of the SWH since the early 2000s, there were no government policies to stimulate social experimentation nor adoption. Encouraged by the achievements of the GEF funded program (project 1 in Table 5.1), PV projects benefitted from the experience actors gained through implementation of SWH and received support from government institutes at an earlier stage due to the role the international donors (who handled expectations from different perspectives) played in including government institutes at the planning and implementation stage. The expectations shaped in the renewable energy market were triggered by the international bodies and then adopted by central government represented by the Ministry of Energy. The SWH niche formation set a higher quality level of expectations for solar PV from the start.

Attaining energy targets and reducing emission was an important expectation shared by government institutions. A common vision for implemented demonstration projects entailed creating market readiness and increase market demand through lowering market prices was set by UNDP projects and shared by other actors such as the energy conservation center and other financing institutes. Hence, afterwards the expectations shifted to include enhancing potential users' knowledge about available solutions and international demonstration projects.

Actors promoting the first SWH and solar PV projects were foremost international agencies, NGOs, and ministries (of the Environment, and Energy). Although positive attitudes surrounded the early efforts of SWH promotion, projects hardly linked up and were not much more than promises in terms of technological performance.

Substantial support was given through the energy conservation center followed by emerging strategies of a private electrification program. The potential of complementing the national grid deficiency and covering a part of deficiency in the national grid cut hours was seen as the only solution in the short term to solve the problem of conflicting interests between the parties involved; for instance, between personal and national priorities, and in vision between different public institutes.

Most projects, and particularly those that were done at the beginning of the experimentation phase targeted public and community buildings, yet by using the GEF and EU funded programs. However, the solar PV niche projects rather targeted the private and industrial sectors which require high energy demand, and comprised of certain actors who had the willingness to invest in this particular technology (such as end users, private sector). The policy rationale behind the financing mechanism aspect resulted in widening diversifying domains of application for renewable energy. In the SWH case, norms and guidelines for quality control were developed, yet in the solar PV case project guidelines for grid connections paved the way for future investments. Based on this, the Ministry of Energy and other agencies could call for an expression of interest to the private sector to start producing PV-generated electricity. Due to the technical differences between SWH and solar PV, the latter is currently getting more attention regarding adjustment of regulations that hinder diffusion.

Higher expectations were set for solar PV based on results from successful projects and mechanisms for SWHs. For example, during the implementation of some of the SWH projects the Energy Conservation Institution started setting standards in collaboration with other government agencies. However, in the case of solar PV, projects were initiated without any definition of the standards, and the financing applications were granted based on lengthy assessment procedures. For instance, the national electricity company (EDL) had unclear plans about net metering. Moreover, this institute did not have a clear role in key decision-making processes, which resulted in an ambiguous plan for technically integrating renewables to the grid. In fact, the national utility company was interested in maintaining the status quo to protect the interests of the parties benefiting most from its current state.

Social Network formation

The social network of the SWH niche started out small with research institutes and only one national government ministry. Gradually the network of actors became wider and more diverse and thus allowed for the involvement of new actors (such as from the private sector and NGOs). Yet, to be even more effective these networks have to be managed and coordinated by a key actor to prevent duplication and loss of resources. The analysis of the cases shows that for niche networks to be deep and to have the capacity to commit resources in the long term, the engagement of regime actors seems to be important. However, the way these actors committed themselves to the network seemed to be as outsiders to the niche. Under the funded projects workshops and meetings with other stakeholders of the direct circle of niche actors were organized as part of the project. The actor configurations and action plans varied according to the project and to the content discussed at project meetings. The establishment of such project-oriented networks started by the availability of funding (from international funding agencies) which shows that niches were not formed spontaneously, but were already largely supported by international aid organizations. Due to the high number of projects implemented in similar time frames, an overlap of niche networking occurred. This overlap resulted in more frequent exchange of knowledge, thus fostering learning processes.

On the national level, the number of SWH suppliers increased from 35 to more than 150 in 2014 after the GSWH initiative, and 124 PV suppliers (till 2017). This was deemed by interviewees to be an acceptable number to fulfill market needs.

One of the main successes of the GSWH program was that it used large amounts of funding, which tackled the niche formation from different aspects (financial, education, knowhow). With the availability of several funding bodies, most actors in the market became in continuous search of a funded program resulting in a high level of duplication and low coordination between distant actors.

The way inter-stakeholder trust was built and maintained, and how resources were distributed and allocated was highly related to the funding and the managing body, such as GEF and UNDP. In this case, companies and clients were encouraged to take part in such projects. Formal commitments such as providing technical teams or matching clients with companies are examples of formal structures observed in the solar PV case providing some stability to niche activities.

For the GEF funds to be granted requires the projects to be based and directly linked to government agencies, such as the Ministry of Energy. By this, the funding agency guarantees a higher level of coordination. However, other international donors such as the EU do not use this criterion. This might explain to some extent the level at which government agencies get involved in projects and the role that funding agencies play in niche formation.

Most of the interaction happened in the context of decision making processes during the development and project design phases. Once projects were granted approval or were executed, interaction between actors reduced and only formal commitments to operation were kept. The energy conservation center lacked a vital role of coordinating and maintaining the niche (also after projects ended). For achieving optimal results and improvement in market, the energy conservation center was required to provide a high degree of cooperation between ministries and between projects.

Learning

In the solar PV case, to bridge the knowledge-action gap concerning integrating large-scale solar systems, input was required from different types of actors such as consultancy firms, energy experts, and system providers. The demonstration projects served to bridge gaps by disseminating the required knowledge and crucial expertise. A mutual learning process (using workshops and roundtables that were visited by representatives of multiple funded projects) was initiated and led by a project manager from two large-scale funded projects, leading to informing other actors about project achievements and goal attainment. Although this supported mutual learning and collaboration initially, it was limited to a certain delineated circle of actors (i.e. those under or in close contact with the same project management organization).

The analysis of the SWH and the solar PV cases reveals that different types of learning occurred during the process of niche formation. Cross-niche learning occurred resulting in more efficient learning outcomes of experiments that would benefit the solar PV niche in the long run. For instance, solving technical problems and quality control of solar PV installations had a positive effect on the launch of the solar PV niche. In both cases, most of the project assessment and design activities were carried out by an internal team of consultants, whereas, the technical knowledge was provided by foreign consultants and experts.

In the SWH case, a local team of consultants - active in one of the projects - was able to develop skills in the application and assessment of design techniques and learned how to implement the system correctly. The same is true for the solar PV projects, yet due to the complexity of integrating the system with the high voltage national electricity grid, local consultants had to seek specialized foreign expertise to deal with the case and develop a guideline and project templates. This improved the technical knowledge of actors involved in project implementation which will positively reflect on designing and assessing future projects.

The analysis of SWH and the solar PV projects reveals that techno-economic learning has been linked to knowhow and that knowledge, skills and practices that can be transferred from one project to subsequent interventions regarding similar technologies in other projects. Based on the analysis of the cases, a key driver of successful replication of solar PV projects concerns techno-economic learning which seems to be the way knowledge was embedded into practices and implemented by actors, which were identical to each other, such as project managers of projects having a similar nature (i.e., PV off grid). The more project outcomes (i.e. new knowledge on how the technology is used when adjusted to specific country specific circumstances) were coordinated, the more the use of solar energy technology was likely to scale-up to mainstream practice, and from mainstream practice into regime practice. The replication of the PV projects eventually resulted to the emergence of local rules and practices. Therefore, practices and knowledge, and lessons will spread amongst various scales and across different actors.

In both in the SWH and solar PV projects the installation of solar plants was outsourced to private companies. This type of implementation provided companies with valuable lessons about the technologies and the system of operation which would comply with current regulations.

Based on the need to change ongoing practices and cognitive frames, second order learning occurred through experiencing and interpreting signs from the market (financing, and quality controlling) during the late stages of SWH niche formation and the early stages of solar PV niche formation through meeting the customers' needs and developing a financing mechanism to stimulate the market demand. Due to the barriers with the utility grid, a guideline was developed in one of the PV projects for grid

connections to pave the way for bigger projects with solar and wind farms. Given these facts, the learning in the PV niche was more reflexive than in the SWH niche. However, currently this complex issue still needs more attention. This could be related to the complex nature of the technology and its dependency on policies from uncooperative public officials.

Table 5.2 presents an overview of the SWH and solar PV niches vis-à-vis key SNM concepts.

Table 5.2: Comparative overview of SWH and solar PV internal niche process

Niche creation assessment criteria according to SNM		SWH case	Solar PV case
Expectations	a. Shaping expectations b. Shared between actors c. Supported by tangible results	<ul style="list-style-type: none"> • Unclear expectations at start which were reformulated with time by international actors • Actors shared specific expectations • Approaching specific targets in total installed capacity 	<ul style="list-style-type: none"> • Positive expectations of demonstrated and ongoing projects • Specific expectations are shared between actors directly involved via projects • On the project level, technical specifications and guidelines have been developed
Actor network formation	a. Diversity of actors b. Alignment	<ul style="list-style-type: none"> • Wide and diverse actor network (which grew more rapidly with the start of international funded projects at the national level) • Expectations took more time to align, especially with actors from outside the projects • Formal interaction in workshops and conferences • Involvement of outsiders varied across projects 	<ul style="list-style-type: none"> • Wide and diverse actor network (which grew more rapidly with the start of internationally funded aid projects at the national level) • High level of interaction between actors directly involved in demonstration projects • Formal and informal interaction through projects and national networking event • Involvement of outsiders is limited
Learning Process	a. First order learning (on technological performance and data and social alignment)	<ul style="list-style-type: none"> • Learning on techno-economic aspects with limited attention to social issues • Resulted in formulating a new 	<ul style="list-style-type: none"> • Learning about techno-economic aspects • To a certain extent involved higher level learning through

	b. Second order-reflexive-learning (reconstruct and reformulate)	financing mechanism and addressing quality control <ul style="list-style-type: none"> Limited degree of second order learning 	setting guidelines for electricity grid operators specific to the Lebanese case <ul style="list-style-type: none"> Formulating a guideline for connecting to the grid
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5.6. Discussion

The results show that the expectations of the SWH and solar PV cases were initially fostered by independent actors (in the case of SWH) and by international funding agencies (for both SWH and solar PV niche formation). Progressively, government agencies promoted the expectations for both technologies by developing an action plan with the policy goal that these expectations were shared by more actors across different sectors (from both the public and private sectors, and with local communities).

An important characteristic of expectations alignment is that higher expectations will be attained when they are backed by continuous experimentation and concrete results (Raven, 2005; Schot and Geels, 2008). In line with this claim the analysis of the Lebanese cases made it clear how results of SWH experimentation affected the extent to which expectations for solar PV increased in credibility and quality, in particular to attract potential actors (such as investors and private sector).

Another important result concerned poor horizontal collaboration and integration of niche activities. Neglecting horizontal integration - as discussed by Mdivani and Hoppe (2016) – often results from poor prioritization of topics by key actors (i.e., ministries only prioritizing their own issues and interests). This was observed in both cases, where there was only a minimum degree of inter-ministry coordination. This led them to not directly become involved in project implementation. This, in turn, led to problems in the information flow between the relevant public institutions. As a result, it affected decisions made to market development and to remove obstacles, related to policies and support mechanisms that are important to the technological and social embedding of niches.

Regular actor interactions were found to be rather problematic in the two case studies. Due to the nature of solar PV and its complex connection into the national electricity grid a lot of pressure occurred on getting the monopolistic national electricity grid

operator involved. In collaborating with semi-governmental organizations (in particular the Conservation Center), project managers played an important role in the network formation. For the emergence of healthy and sustainable niche networks, the role of a network manager who can coordinate all activities between different projects cannot be neglected (see for example Hoppe et al., 2015; and Mlecnik, 2012). However, networking was more linked to the funded programs (both by GEF and the EU) and hence, the previously set action plans and activities that were deemed necessary by the funding agencies. This meant that niche market development was heavily influenced by the agendas of the donors, the focus they had in these specific markets, and the targets they set for each available fund. This problem was also found in other studies, such as net zero energy niche formation in India (Jain, Hoppe and Bressers, 2016).

In the cases of SWH and solar PV, learning took the form of discovering problems and solutions, identifying the use of technology and adjusting the technology fit into the socio-technical system, while identifying potential clients and marketing strategies. This corresponds with results by Kemp et al. (2001). Learning across the two niches occurred which benefited the implementation process and dissemination of knowledge in the PV niche. This resulted in a more efficient use of knowledge in subsequent projects. The business companies involved in the installation of demonstration projects could distinguish themselves from possible future competitors by utilizing head start technologies (Mlecnik, 2012). In the two Lebanese case studies an example of this was found in the launch of innovative façade panels (for both solar thermal and solar PV).

For networks to be more effective in supporting niche formation, higher flexibility and capacity is required in taking into account particular context specific conditions. It is actors who help technology progress and improve through learning and gradual experimentation in order for it to become viable within an existing system (Smith et al. 2014). In a country like Lebanon where the government and public authorities can be rather considered weak institutional players, development agencies along with international donors play a prominent role in the support of the solar electricity niche. However, this sheds light on a critical fact that the involvement of stakeholders linked to program budget and available funds, while (national) financial resources are absent, could impact policy integration, which might support niche development support

actions, and reshape the market (a result also found in a study by Mdivani and Hoppe, 2016).

The results of the two case studies confirm that learning was both broad and reflexive, which is in line with Raven, 2005, Schot et al., 1996, and Schot and Geels, 2008. Although most of the learning processes can still be considered of first order nature, second order learning was also encountered in both case studies. An important aspect found in the two solar cases in Lebanon is on how to deal with inter-actor technology learning. There appears to be a gap in how to sustain the niche on the long term, especially with the absence of an actor coordinating between other actors (e.g. an intermediary agent like a 'network manager' or a 'niche manager').

The subsidized fossil fuel sources that are used for generating electricity (leading to a poor level playing field in terms of price setting) is still considered a major barrier. It is influencing the economic viability of the renewable energy investments. Yet, there is a lack of political will to remove it. This could be related to conflicting interests of politicians. The results show that there is instability in the system design and a lack of clear intentions from public officials, grid connections and state interference. This is in line with Wüstenhagen and Menichetti (2012) who discussed that all these and more create too much uncertainty for investors and end-users.

When introducing change to the energy sector or to address climate change efforts, several difficulties face related actions. There are slow and overlapping responsibilities between government institutions, and there is a lack of law enforcement, and a lack of monitoring structure. This was explained in the results of this study, the unstable government and frequent change of ministers affected heavily the implementation of laws. With the start of the functional period of the new ministers, new settlements were made - which is explained by the policy paper for improving renewable energy in 2010 (start of new electoral cycle) - and the removal of taxes on renewable energy technologies in 2017 (which is related to the appointment of new ministers). Like other developing countries, change of government could cause a serious delay in implementing policies due to absence of experienced civil servant staff in climate change policies (i.e. Mdivani and Hoppe, 2016) or changes in the interests of the new parties at the national level. This shows the role and interests actors can have in influencing the market. In a country that is suffering from security problems as well as

political instability, the deployment of renewable technologies is not a priority on the government's agenda. It is the case in Lebanon and in other developing countries where fulfilling societal needs and common interests is more dominant than environmental targets (Opazo, 2014). In addition to the lack of funding and capabilities of the national electricity grid operator that are necessary to upgrade and adapt the power infrastructure to any renewable technology, there is also an absence of public officials' will and skilled personnel to do so.

We would like to argue that this paper adds to the literature on niche development of renewable energy technology in developing countries (Byrne, 2009; Romijn, Raven and de Visser, 2010; Xue et al., 2016). We introduced the role played by donor agencies which besides their previously set agenda contributed to the niche development and actively engaged with Lebanese public institutes. Furthermore, we discussed the dynamics of internal niche processes and addressed the critical role played by donor agencies to trigger the formulation and implementation of national policies and financing mechanisms. This paper also contributes to the SNM literature by pointing out the weak alignment between public actors, and ongoing power struggles between institutions in a developing country's context. The actors' networking in this context is often initiated and triggered by international parties, which affects to a large extent the directions in which future markets are to be developed.

5.7. Conclusion

The aim of this paper was to review and compare niche formation of two solar technologies in Lebanon, SWH and PV, with a focus on internal niche processes. The results are manifold. First, the case studies revealed that the network supporting niche development was quite diverse and could establish all its activities, yet with limited user involvement. The expectations for the solar PV niche were ambitious from the beginning. Initially, learning processes for both technologies were focusing on improving techno-economic performance. Both niches lacked a single manager taking care of all three processes (expectation, social network, learning), yet each project did have a leading actor. However, there was poor collaboration between the ministries involved. There were also existing 'regime' barriers such as poor quality of the electricity grid, and subsidized electricity tariffs. For instance, the cheap electricity tariffs were making both solar energy technologies (SWH and PV) uncompetitive, drawing

potential investors away from investing in those technologies. In the light of the geopolitical situation and the absence of an active national government, there was poor prioritization of climate change mitigation and renewable energy on the national agenda. The funds provided by international agencies played a significant role in providing a breakthrough in the network initiative and in the innovation plan (national action plan launched by the ministry of energy). The format of the funding scheme pushed the actor network in SWH and PV cases towards collaboration. Initially, learning processes for both technologies were focusing merely on improving techno-economic performance.

The development of the solar PV niche depended on existing players and stimulating synergies leading to the development of skills and knowledge. The formation of both the solar PV and the SWH niches in early phases has been taken to a more international context, such as selecting consultants or experts from Western countries in which niche maturity of solar energy innovations is more mature. Lebanon, as many other developing countries, is viewed as a high-risk country for big investments due to its political instability and lack of sound policies. It can be argued that donor agencies were taking a high risk by supporting niche formation to make solar energy technology more attractive for private investors and prompt a market change (and hence, a change at the regime level), a phenomenon also seen in other cases (i.e. Nygaard, 2010).

Although donors play a key role in the market development, an important issue to be addressed is the unpredictability of such interventions. This shows that donor programs adjust to the local circumstances, and that the continuation of donor related programs when implemented in certain regions is highly uncertain. Due to the unstable situation in these regions (related to key geopolitical events), most upcoming funds and projects are not any more focusing on the development of the technologies themselves, but on other goals such as supporting communities hosting refugees. This might result in a delay in niche formation processes especially in the absence of governmental commitments.

Another fact we came across is the reluctance to cooperate between different ministries who are not directly involved in funded projects. This could be related to the fact that ministries have a closed system in which very little information is shared and are also

not open to share internal details with other ministries or receiving advice from actors having external interests which might lead to changing policy.

5.8. Limitations

The analysis of the two solar energy cases is constrained to particular contextual conditions of the country. More countries exist in the MENA region of similar climatic but different socio-economic conditions. Therefore, more research is needed to understand the determinants of diffusion of renewable energy technologies from that specific region. This paper considers power struggles and protection of political interests; yet more room is still available to develop a more politically oriented literature to study SNM in areas of the world like the MENA region.

Building on the results, the study discussed the crucial role of donors in niche formation and in pushing for policy interventions. The role played by some local public officials was not always supportive and did not address ongoing challenges for development to some extent. In this respect, we feel that the influence of the geopolitical situation and the objectives of funds provided from international funding agencies need more research to improve the understanding of the influence of the donor's agenda on the market development in unstable regional circumstances. The comparison of two technologies from an SNM perspective offers a great potential for future research to improve the understanding of the nature of the technology on international provided funds and hence, indirectly on their diffusion.

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Chapter 6: Integrating business models into the transition studies literature: a conceptual approach using an illustrative case of solar energy technology niche development in Lebanon⁷

6.1. Abstract

The market of renewable energy technologies plays a considerable role in the transition to a sustainable market. In fact, the end users are the main players involved in the uptake of the renewable energy technologies. Although the business model is not isolated from the sociotechnical context, it has a prominent effect on it. We argue that the market value of renewable energy technologies will increase, when the business models focus on the user. This paper combines the business model literature with the transition literature and presents an illustrative example from solar energy niches in Lebanon. Particularly, we discuss that for business models to contribute to a sustainable transition, it needs to integrate the sociotechnical and user related context. We develop new opportunity paths that will be applied in a developing country context.

6.2. Introduction

Renewable energy sources have a crucial role in lowering carbon emissions and creating a sustainable environment. Supporting this recent reduction in the manufacturing costs of renewable energy technologies alongside clean energy incentives provided by the governments are creating opportunities for new business models (Huijben and Verbong, 2013; Frankel, Ostrowski and Pinner, 2014). This has resulted in increased integration of distributed energy technology such as solar photovoltaic (PV) and smart meters. However, radical technologies like solar PV require protected spaces i.e. “niches” to keep them from regime pressures to which they are not competitive (Kemp et al, 1998; Smith and Raven, 2012). Niches can help these technologies to develop, scale-up, and alter the status-quo. However, niches are driven by different kinds of support. When addressing these different kinds of support Kemp et al. (1998) and Smith and Raven (2012) address the level of niche shielding,

⁷ This chapter is based on a paper which has been submitted to be considered for publication in a peer reviewed journal.

by mentioning that it is the amount of financial support, which determines the economic competitiveness of new technologies by not only protecting them from the regime pressures but also creating space for novel business models to be developed. The importance of business models lies in their ability to commercialize technology and in implicit rules that apply among actors (Doganova and Eyquem-Renault, 2009; Baden-Fuller and Haefliger, 2013). In this way business models structure the activities in the niche, and allow for value creation of a technology (Doganova and Eyquem-Renault, 2009). In sum, new business models contribute to diffusion of niche technologies.

Both scholars and practitioners are interested in understanding sustainable transitions, i.e. large-scale disruptive change of economic sectors, such as transport or housing (Geels, 2002). Although transition research mainly focuses on the role of technological innovations, it is recognized that technological innovations alone are not sufficient to induce socio-technical change (Bidmon and Knab, 2014; Korhonen and Seager, 2008). Similarly, the IEA (2014) argues that market uptake of energy efficient technologies is not moving fast, assuming that when the industry and the residential sector adopt such technologies it will reduce the energy demand considerably. According to Johnson and Suskewicz (2009) business models have an intermediary role between the consumption and the production sides of markets. The core component of a business model is creating value for customers by finding a solution for a current problem in their lives (Tolkamp, 2015). However, to understand and apply a business model perspective, Provance et al. (2011) argue that contextual factors need to be taken into consideration to understand their influence on the business model. Huijben and Verbong (2013) address the importance of the contextual factors by referring to the policy context which they found to have an impact on entrepreneurs and the business model they operate in. From a broad perspective, policy makers acknowledge that their expertise in business model innovation needs a lot of improvement, since they believe that business models play a crucial role in bringing sustainable innovation to the market and promote dissemination (OECD, 2012). Wainstein and Bumpus (2016) shed light on new business models in markets, in particular through focusing on its capability to increase customer participation. The importance of user participation in the diffusion of technologies was previously discussed by Vargo and Lusch (2004), who claim that user needs and social practices need to be understood in order to provide solutions for problems consumers experience. Moreover, user needs and practices become much

more clear when the user gets actively involved in understanding and shaping business models (Berland, 2015). However, only recently scholarly attention arose to highlight the role between business models in sustainable transitions (Bidmon and Knab, 2014; Huijben et al., 2016).

According to Engelken et al. (2016) there are only few studies that discussed opportunities business models can create in markets. Jolly et al. (2012) discussed the opportunities of new business models by reflecting on the chances social entrepreneurs can have by addressing solar PV systems as a possible solution to giving households access to electricity supply. Yet there is still little conceptual integration between the business model concept and socio-technical transition concepts. Therefore, we will try to contribute to this emerging research domain by combining business model concepts with concepts from the socio-technical transition discipline. By exploring the role of corporate firms' business models in socio-technical transitions, a wider understanding of the latter is likely to occur. In order to achieve this goal, this paper seeks to discuss the relevance of new business model concepts in sustainable transitions, by providing an illustrative case study of solar energy niches (i.e. solar thermal systems and solar photovoltaics) in Lebanon. The main research questions in this paper are: (1) What is the role of business models in the transition towards decentralized renewable energy driven systems? And (2), What are the promising opportunities for business model in a developing country context?

To answer the research questions of this paper several steps were taken. A starting point was a number of papers in both the transition and business model literature. Articles combining both areas of research were of main interest. Given the nature of the topic, we use the case of solar energy technologies cases in Lebanon as an illustrative example. We intend to focus on solar energy technology (i.e., solar thermal systems and solar photovoltaics) because they form an excellent example of ways to change the socio-technical system, and make it more sustainable. That is, developments in energy efficiency and the wider use of renewable energy sources (Sarasini and Linder, 2017).

In the following section we discuss the theoretical framework for this paper consisting of insights from both the literature on sustainable transitions and the literature on

business models. Next, section 6.4 presents the illustrative case study, and section 6.5 concludes the paper and discusses recommendations for further research.

6.3. Theoretical background

6.3.1. Socio-technical transitions

Socio-technical transition theories are used to study the shifts within large socio-technical systems (Geels and Raven, 2006), transportation (Geels, 2013) and other societal utilities (van der Brugge, R., Rotmans and Loorbach, 2005). Transition theory perspectives employ a common set of concepts such as sociotechnical systems, niches, regimes and landscapes in order to study the dynamics of sustainable transitions. Socio-technical approaches to transitions often focus on the role that technology and technological innovation play in fulfilling societal functions. These approaches stress that other, social factors, play a significant role in sociotechnical systems (Geels, 2004). We focus on combining constructs from transition theories with those from a business model perspective.

Theoretical frameworks on sustainable transitions strive to understand and explain system transformation, and address how to manage sustainable system transformations. Strategic Niche Management (SNM), for instance, focuses on niche-level activities such as learning, networking and visioning (Kemp et al., 1998; Schot and Geels, 2008). Moreover, breakthrough technologies are likely to change the mainstream market which consists of existing infrastructure, user preferences and has multiple cultural meanings attached to it (Kemp et al., 1998; Smith and Raven, 2012a). These technologies will start to develop within niches, which can be seen as protective spaces, and which operate within a unique set of rules (Huijben and Verbong, 2013). Niches are described as protected spaces where experimentation takes place resulting in innovations that become seedbeds for socio-technical transitions. Geels (2004) discussed that the system into which those niche-innovations are inserted – that is the socio-technical regime – creates resistance to innovations trying to diffuse into a wider societal context. Therefore, a technological transition implies a radical reconfiguration of a sociotechnical regime through considering certain niche-innovations.

There are certain functions that support the development and diffusion of technological innovations (Edquist, 2004). These functions include activities such as research and

development, financing of innovation process, and fostering new field for innovation development (such as entrepreneurial experimentation).

From a socio-technical perspective, technological innovations themselves play a key role in fulfilling societal needs, but the functioning of a technology in a socio-technical system basically depends on other elements, such as regulations, user practices, or cultural meaning (Bidmon and Knab, 2014). That is, transition will not only involve changes to the technology itself, but also changes to the environment in which it has a function, and other elements of a socio-technical system, such as user practices and regulations (Geels, 2010).

Business models for solar energy technology can support niche processes by handling perceived risks and removing investment barriers, such as the high up-front costs and unavailability of a suitable roof for solar energy systems (Huijben and Verbong, 2013). Moreover, business model innovation dynamics are considered important drivers in accelerating the low carbon power system transition (Wainstein and Bumpus (2016).

From a market perspective, renewable energy technology requires business models that have the ability to effectively commercialize them and make them compete with available – mostly conventional - technology. Therefore, given the importance of the activities niche actors have in disrupting socio-technical regimes, we will reflect on the business model concept for transition.

6.3.2. Business models

Business models are referred to by some scholars as “mediating devices” that capture the value of an innovative idea through linking it to customers’ needs (Chesbrough and Rosenbloom, 2002; Teece, 2010). Teece (2010) defines a business model to be “the design or architecture of the value creation, delivery and capture mechanisms.” Similarly, Bidmon and Knab (2014) argues that “a business model describes how a firm creates and captures value in a value network, which transcends the boundaries of the focal firm. Actually, it is both, a market device to commercialize innovative technology and subject to innovation” (Ibid., p. 4). Although ‘business model’ is a wide-spread, commonly used term it lacks a common definition. Zott et al. (2011) argue that the main reason behind this is that research on business models is only just starting to reach maturity. Business models have received various definitions and have been applied

from different theoretical perspectives (DaSilva and Trkman, 2013). Despite the fragmentation among definitions business models are described as market devices that shape how an organization creates, delivers and captures value (Zott and Amit, 2010). However, there is certain agreement on the basic conceptual meaning of a business model that describes how firms create and capture value (Korhonen and Seager, 2008). Business models not only deal with linear value creation of a firm from suppliers to customers, but also with complex transactions within value-networks concerning value creation to multiple parties in those networks (Zott and Amit, 2010). A business model consist of three core elements, i.e., (1) the value proposition, that is the value of the product or service provided; (2) the value creation, that is the process by which the value is developed; and (3) the value capture, which is related to the financial system of turning the value of a product into financial-economic profit (Chesbrough and Rosenbloom, 2002; Baden-Fuller and Morgan, 2010).

Innovative business models reshape the relationship between the product and the customer by shifting the value proposition of the existing business firm (Wainstein and Bumpus, 2016). Similarly, business model innovation enlarges markets by capturing new customer bases that find the new value proposition more attractive than conventional (outdated) alternatives (Markides, 2006).

6.3.3. Business models and socio-technical transitions

Bidmon and Knab (2014) base their business model definition on the functional perspective of transforming resources into outcomes. They propose that the core function of a business model within a socio-technical system is to commercialize innovative technology developed at a niche level. The most significant consideration of this would be the value creation and value capture by which a business model embeds a technology into a value network. Hence, business models serve as a link between firm-level activities and market outcome (Baden-Fuller and Morgan, 2010; Zott, Amit and Massa, 2011) and thus play a crucial role in the adoption and diffusion of technology. For instance, a study by Jolly et al. (2012) showed the importance of business model innovation for upscaling solar PV technology in India. More specifically, the study revealed that new business models can foster diffusion of renewable energy technologies to new markets, geographies, and new types of users. However, the study also showed that the implemented initiatives for PV upscaling still lag behind in

reaching the poorest segment of users, and that they failed in terms of fostering institutional change (i.e., ‘institutional upscaling’). In a similar vein, Drury et al. (2012) found that third-party ownership was important to business models vis-à-vis upscaling of solar PV systems.

Bidmon and Knab (2014) suggest that business models can be positioned in between the niche and the socio-technical regime levels, arguing that business models support the stabilization processes of technological innovation. A business model will allow to articulate value creation and the value capture mechanism for a technology among innovation actors. In addition, communication between different innovation network actors will not only support learning processes and social networks formation, but also attract consumer attention, and investors (Doganova and Eyquem-Renault, 2009)

According to Bidmon and Knab (2014) a viable business model might even be more important for a breakthrough than the technical superiority of an innovation. Since business models can arguably be seen as ‘value creation devices’ (Zott, Amit and Massa, 2011), they are more likely to create value for multiple parties in a value network (Zott and Amit, 2010). That is, business models will not only create competitive advantage for new technologies, but also for new actors in the network who succeed in commercializing new technologies in innovative ways (Wainstein and Bumpus, 2016). Thus, once a technology is coupled with an innovative business model, it becomes more likely to be adopted by (a greater pool of) different types of actors, and will diffuse across the system.

For instance, increase in electricity prices, reduction in renewable technology manufacturing costs, and government incentives, are creating opportunities for clean tech entrepreneurs and new business models, thus resulting in a greater integration of renewable energy sources and technologies, such as solar PV, and smart meters into the electricity market (Huijben and Verbong, 2013).

Bidmon and Knab (2014) explained that the business model niche incorporates the factors that drive business model innovation, such as new customer demands or novel regulations. Thus, they claim that developments at the level of the business model can also influence the technological niche, by leading to the emergence of dominant technological designs. This means that actors should not cling to current business model logics (e.g., relying on donor funds in the case of firms in many developing

countries) and should pave the way for new business models to break through. Chesbrough and Rosenbloom (2002) discussed this by explaining that business models can be viewed as market devices for innovations to compete with other technologies to become widely adopted. For instance, reaching wider diffusion of renewable energy technologies through using alternative financial schemes (Gelbmann and Hammerl, 2014; Tongur and Engwall, 2014). Similarly, Johnson and Suskewicz (2009) mentioned that technologies do not replace other technologies, but it is rather systems that replace systems. Therefore, instead of looking for solutions for a technical problem it can be argued that it is better to discover how to get consumers to switch from one technology to another. Regardless of all the advantages of a specific technology, change will only happen if a specific technology has its own, economically competitive network. Furthermore, peer-to-peer platforms can be seen as illustrative examples to make customers more active participants through engaging them in commercial activities (Belk, 2014). Similarly, joint value creation between networks of actors can potentially accelerate the maturity of certain innovations (Chesbrough, 2007).

Characterization of the business model in the solar niche cases

Boons *et al.* (2013) addressed the importance of business models and mentioned that it should be considered as part of the sociotechnical system. Given this, in order to create a higher market uptake of renewable energy technologies, better infrastructures, more customer oriented regulation and support mechanisms need to be applied due to their direct influence on the success of a business model (Huijben and Verbong, 2013).

Just as niche experimentations are designed in SNM to help the niche compete with conventional technologies in market, so is experimentation in the business model (Teece, 2010). This means that a business model will be regarded by itself as a lasting experiment which is open to learning and improvements (Morris *et al.*, 2005; McGrath, 2010). Thus, without experimenting and learning about a business model, a lot of market opportunities are basically missed (Tolkamp, 2015). With this experimenting, one can articulate the value creation and capture of a technology in market.

Just as demonstrations and experimentations occur at the niche level, business models are also shaped in experimental ways. As a starting point, hypotheses are generated to be tested later, to be elaborated and reformulated (McGrath, 2010). That is, after

experimentation is done, further evaluation, research and development take place to address market and consumer needs. This shows that business models play a significant role in facilitating various activities in internal niche process within the SNM framework. According to Tolkamp (2015) the SNM framework is important to business model development, because it provides guidelines for business model developers on how to organize certain niche activities.

For the purpose of defining a business model, Tolkamp (2015) argues that just like process taking place at the niche level, a learning process of trial and error takes place regarding business models. Since a business model takes the form of an experimental process, it can facilitate not only single loop learning, but also double-loop (second order) learning (Sosna et al, 2010), that is involved in the learning process at the niche level. Once certain lessons are learnt, a more customer oriented business model will develop (Teece, 2010). By this, the three core internal elements of the SNM framework (aligning expectations, networks formation, and learning) can be merged into the business model perspective (see Figure 6.1). Later in this section we will discuss how learning from the user will lead to a compelling business model.

Figure 6.1: Business model and niche internal processes integration

When combining the business model perspective with the broad societal context, the contextual factors influencing markets also play a crucial role in the success of a business model (Teece, 2010). This was confirmed by Huijben and Verbong (2013) who argue that when a business model concept and the societal context are combined, the contextual factors seem to become more important. However, from a business perspective the end user plays a crucial role in the diffusion of technologies. Since the technology is dependent on its intended use, this naturally links up with the end-user. It shows that the market for renewable energy technologies requires user-centered business models (Tolkamp, 2015). Moreover, it stresses that consumers can be much more than just end-users of energy yet be involved in the process to gain more knowledge, become a prosumer and add value (Verhees, 2014). However, even when

business models focus on fulfilling consumer needs, behavioural challenges might hinder market uptake (IEA, 2014b). A reason for this might be the gap between social practices and the service offered (Hargreaves, Longhurst and Seyfang, 2013).

In order to make consumers adopt a technology, it is important to tailor it based on their needs and abilities (Rohracher, 2005). For instance, consumers will not lower their energy consumption by only being offered a smart meter (IEA, 2014a). For these energy efficient technologies to be used, a better fit into the social and lifestyle context of the user is required (Boork, Thomtén and Brolin, 2014). Thus, the benefits of these kinds of technology need to be communicated to the consumer, before it can be accepted and used. This sheds light on the importance of involving consumers in the diffusion process (Crosbie and Baker, 2010). Sabatier et al. (2012) found that as technologies evolve, uncertainty decreases leading to more disruptive business models that will reshape value chains and user practices.

6.4. Research design and methodology

The Middle East and North Africa (MENA) region has abundant solar potential which makes it potentially attractive to countries in this region to adopt solar renewable energy plans and projects (Jablonski et al., 2012; Tsikalakis et al., 2011). However, up to our knowledge no empirical studies have reflected on the sustainable transition framework and business models from developing countries in this region. Because of this academic knowledge gap Lebanon is used in this study as an illustrative case. Despite its positive geographic and climatic conditions, the country still relies on imported fossil fuel for energy production. Lebanon shows a hostile environment to green innovations. This hostile environment is mostly related to the political and economic instability of the country (Thornton, 2016). Lebanon witnessed various national initiatives to develop renewable energy technology markets, in particular solar energy technologies. However, there is still a need among key market actors to trigger a sustainable energy transition in the country. This could be better achieved with the support of new business models that involve consumer participation. Based on that, Lebanon is selected to present a case study of the complexity of market development and to serve as an example case for other developing countries of similar geo-political and socio-economic dimensions.

The aim of this paper is to map the role that business model concepts play and the opportunities they create for solar energy transition in a developing context. To construct this conceptual framework we relied on two previously conducted empirical case studies that address the diffusion and transition of solar energy technologies in Lebanon (Elmustapha, Hoppe and Bressers, 2017, 2018a).

6.4.1. Business models of solar energy niches in Lebanon

This section starts with presenting a background of the Lebanese context in which the solar niche development took place. Then, specific business model aspects of the selected cases will be presented. In the end of this section, the main elements of the business model relevant to the Lebanese context will be summarized in Table 6.2. The demonstration projects that took place in the country positively influenced the development of the solar energy market. These projects helped increase the technical expertise of technology suppliers who were engaged in installations (Elmustapha, Hoppe and Bressers, 2018b). On the other hand, the demonstration projects at the niche level increased awareness of consumers. These projects pushed for financial support and for sustainable models in the solar energy market.

With the start of the solar thermal niche, investment projects were supported by non-governmental organizations and foreign countries such as China, Spain, Turkey, Sweden and Greece in the form of donations of individual systems from the nation states (Kinab and Elkhoury, 2012). From 2009 onwards more funds were provided to the Lebanese market. One of the key projects was a UNDP funded project which installed large scale solar thermals and PVs on public buildings. The installations were fully funded by foreign investors. The installed systems became owned by the end users who were in turn responsible for the maintenance of the systems. Aiming to increase the installations of renewable energy technologies, the government provided financial incentives for household and corporate installations. The financial incentives were in the form of interest free loans with cash grants for households, and low interest loans for corporations and PV systems. Due to the government based initiative, direct savings and simplicity of use, consumers became more aware of the solar thermal systems and more inclined to consider it (Elmustapha et al. 2018a). The demonstration projects and workshops funded by foreign investors also played an important role in increasing the awareness in market, and increase the technical know-how among technology providers (Elmustapha, Hoppe and Bressers, 2018b). However, currently

the PVs are still considered somehow expensive in comparison to the solar thermal systems and entail a more complex procedure for acquiring loans (Kinab and Elkhoury, 2012).

To move away from fully funded projects, two new funded projects (Med Solar and CEDRO 4) facilitated a more financially sustainable model which required the private sector to finance its investments (Harajli, Obeid and Nassab, 2016). Unlike the pure grant funding, this approach guaranteed a more sustainable business model to open up new market opportunities: a gradual move from entirely grant-financed solar energy projects to a more sustainable financing model which also increasingly engages the private sector to finance these investments. This shift was based on the need to change ongoing market approaches through experiencing challenges in the solar energy market. Thus, meeting the customers' needs was considered a crucial component in the transition and developing sustainable models to serve that need is important to trigger the market demand. This was mainly reflected in the need for financing. Before 2011, there was no financial support for consumers to acquire renewable energy systems in the country. This was one of the challenges that was hindering the development of the market.

Unlike the pure grants offered in the start of the solar thermal and PV niches. A GEF funded project (DREG) provided a complementary grant co-financing scheme as an advancement in to the previous financing mechanism (Elmustapha, Hoppe and Bressers, 2017). This project triggered a transition away from pure grant-funding for renewable energy investments towards more sustainable business models to open up new market opportunities and increase commitment of end users. The applied model covered a portion of the solar system's investment cost through a grant while the remaining cost would be financed by the consumer by means of low interest loans. The solar energy system would be owned and maintained by the end users themselves. This was expected to lead to further market maturity, thus a gradual move entirely out of grants.

Among the applied empirical cases for solar energy market in Lebanon, Elmustapha et al. (2018b) showed that the applied models and financing incentives were successful in increasing the adoption rates across different energy consumer groups. However, new models that take into consideration the needs, capabilities and challenges facing

end users need to be considered. This shows the need for innovative solutions to handle ongoing challenges such as roof space availability and high upfront investment costs. For instance, on the corporate level future projects applying pPotential performance- related emission reduction payments will also be explored (UNDP, 2014). This opens new opportunities towards future viable market-based or performance-based instruments that can form a starting point for more sustainable business models. The results of the illustrative case show the need to have creative solutions that are tailored to the end users' needs to result in sustainable transition.

Table 6.1: Overview of business models applied in Lebanon regarding solar energy technology.

Type of model	Owner	Provider	Intermediary	Type of payment	Maintenance	Challenges
Donor aid business model	End user becomes owner	Chosen through funding governments or agencies	Local authority or project management of programs	Free	Consumers responsible for maintenance	Low awareness for maintenance or not enough financial resources
Local based collective model	End user becomes owner	Technology providers in market	project management of programs	Loan based	Consumer responsible for maintenance	
Collective micro-finance business model	End user becomes owner	Contracting collectively with same technology providers in market	Banking sector	Loan based	Consumers responsible for the maintenance	Maintenance and social challenges
Individual micro-financed business model	End user becomes owner	Technology providers in market	Banking sector	Cash sales/loan based	Consumer responsible for maintenance	Quality control

Donor aid business models

The donor driven approach was the first form of business models applied in Lebanon. Although it did not ensure financial stability in the implemented projects, the donor aid business model contributed to the launch of the solar energy market. This form of business model relied on foreign funds which does not ensure a sustainable financial flow as priorities of the funder shifted and implemented systems depreciate over time. The end users (both in the commercial and residential sector) directly benefited from the installed system either with low or no cost. End users were set fully in charge of the

system maintenance and usage. One of the drawbacks of such business models concerned low commitment of end users towards maintaining the solar energy systems in good functional state. Moreover, end users (residential and commercial) paid no attention to maintaining the systems over time. This resulted in deterioration and later complete dysfunction of the systems. These problems led to an initiative which included a partially funded format that was designed to increase end users' commitment. The value proposition of this business model promised end users no investment cost and full ownership of solar energy systems. In that case, customers had a passive role, and had to pay only for the maintenance of the solar energy systems over years.

The donor aid business model proved to be successful in introducing the solar energy systems to the Lebanese market and increasing the knowhow of local technology providers. The key resources in this business model are the financial power of the funders, the products of technology providers, the knowhow of the project managers, and the underlying network of actors involved in the projects' implementation. The key activities were finding potential end users for systems' installations and the actual interaction between different local and international actors, thus resulting in knowledge transfer from one party to another. The distribution channel to deliver these activities and to ensure interaction between network actors themselves and their potential customers, was done through the managing body of funded programs and the National Conservation Center. In its early stages the customer segment of this business model mostly involved the residential sector. At a later stage the corporate sector (public utilities) also became involved. Since the donor aid type of business model does not provide a basis for establishing a viable market on the longer term, key market players started seeking to different types of business model, especially those that would involve end-users who are willing to be actively involved.

Local based collective project business models

The main role of local based business model type is to pave the way to a more viable market and give end users a more active role in localized projects. This form of business model started after lessons were drawn from the use of donor aid business models. They aimed at creating a more active role for end users. While the donor-aid business model was based on financing projects on a full grant basis, the local based collective business model ensured a gradual move from an entirely grant financed

renewable energy system to a more sustainable financing model. In this model customers would finance their systems through low interest loans supported by the government. Yet, to make the investments more attractive to customers a foreign grant of up to 25% of the total investment was to be provided. This shift was based on the UNDP and funder specifications to engage the private sector in investments and to ensure their commitment to the projects through financing their own investments. This proved to be essential to increase end users' commitment to the installed systems. Previously fully funded systems were hardly ever maintained by the end users after the formal project implementation term had ended. The local based collective business model was mainly applied to private corporations (over different industrial sectors) and did include installations of large scale decentralized solar PVs. In this model end-users still have ownership over the installation. This led to higher interest from the demand side market actors because risks were by and large managed by the project funders. The financing process would then start by evaluating projects requesting the smallest grant contribution for the projected energy generation. This will be prioritized. The customers' proposals specify the financial and technical specifications of the systems along with the calculations of the annual yield (UNDP, 2014). Besides this, the National Conservation Center would approve and verify the proper installations of the systems prior to releasing the foreign grant.

Unlike the donor aid business model, the local based business model would require that end users co-finance the investment costs. This would ensure the end users' commitment to their installations and maintenance stages. By doing so, the beneficiaries not only benefit from a grant on their investment, but also cover the expenses of the investment through a low interest loan subsidized by the government. By the end of the projects' implementation term, the system would fall under the complete ownership of the end user who in turn becomes responsible for its maintenance.

This model was considered by project managers as a step forward towards a more sustainable business model away from the pure grant funding, thus paving the way for new market opportunities. The value proposition of this business model was mostly based on the ownership of a clean energy system with relatively acceptable cost of investment given the low interest loans and the grant. This was very attractive to end

users, especially since the implementation of the projects were typically managed by UNDP teams. The most common form of inter-actor interaction was between technology providers, project managers and funders on one hand, and between the technology providers and the end users on the other hand. Technology providers were interested in taking part in large-scale decentralized projects managed by UNDP provided by foreign funds. This improves their market status and increases technical knowhow. As from 2014, technology providers taking part in demonstration projects promised potential customers with relatively low cost and a high quality solar system. After getting approval from program managers and funders, the providers had to initiate contact with potential end users to also receive their approval and start the implementation process. The end users played a more active role in locally based collective business models, and they actively engaged in the interaction with providers and project managers. However, various coordination activities (such as reporting about potential customers or providing technical and financial studies of investments) occurred between the technology providers and the project managers. The distribution channels to cover these activities were managed by project managers who acted as intermediaries between the funders on the one side and the technology providers and customers on the other side. One on one interactions between actors of each side and the intermediary occurred through various monitoring and coordination meetings.

Micro-finance project-based business models

Micro-financed business models are based on 'in cash' investments and subsidized loans. This resembles residential and corporate end users who own and finance solar energy systems with full responsibility for installation and maintenance. Unlike the previous two business model types in which project managers are held responsible to coordinate with technology providers for the installation of solar systems, in then micro finance business model the end user is solely responsible for the installation of the systems. This business model aims to reduce high upfront costs, mitigate financial risk, and increase end users' access to renewable energy technologies. Thus, solar thermal technology financing mechanisms in this model act as catalysts for market development. In this model end users are subjected to subsidized loans (of 0% interest rate). In the case of solar thermal systems in Lebanon, residential end users received a 200\$ grant for the installation of qualified system from a selected technology provider. The bank then deducted this amount from the final installment of a qualified solar

system. In the case of collective solar thermal and solar PVs (small and large scale), another financing mechanism (through the National Energy Efficiency and Renewable Energy Action-NEEREA) was launched to the market in 2010. This financing mechanism offered end users subsidized loans for a period up to 14 years with a 0.6% interest rate. This financing scheme was offered at commercial banks and supported by the Central Bank of Lebanon targeting residential, commercial, and industrial users for all renewable energy systems. Thus, the launched initiatives aimed to accelerate the uptake of renewable energy systems installations in the Lebanese market. This was verified by the main value proposition used in this type of business model being 'Energy for free, and a solar thermal system for every household' (in the case of residential solar thermal systems). Although this model played a crucial role in developing the renewable energy market in Lebanon, it suffered from problems, such as lengthy procedures. For instance, in order to apply for a NEEREA loan, potential end users were requested to provide the commercial bank a technical report through a technology provider which included a feasibility study which should include complete technical and financial analyses. In some cases, enterprises interested in acquiring a renewable energy system reach out for micro-finance institutes to get technical and financial support to be granted a NEEREA loan. These institutes would then assist enterprises of promising growing potential in supporting drafting of a technical report. In turn it would provide guarantees for the bank, thus making the lending process less risky for the bank through ensuring reliability of customers in re-payment of loan. In turn, the commercial bank would send the report to the national conservation center for revision. Once a decision of approval or rejection was taken, the commercial bank could proceed in granting or rejecting the loan requested by the entrepreneur. On average this process would take between two and three months which was described by customers and micro-finance institutes as lengthy and dissatisfying.

The activities in this model took the form of search and interaction between customers and technology providers and banking institutes granting the loans. The customers were held responsible to search and contact technology providers and to select the commercial bank that would grant the loan for solar system installation. Thus, the customer played a very vital role. This also applied to technology providers who have an important role in increasing awareness of customers of the grant options. Furthermore, technology providers acted as intermediaries between customers and

banking institutes in case of renewable energy installations not being solar thermal systems. This was due to the fact that, loans for individual solar thermal systems were considered relatively small (up to 1500 USD), whereas investments in renewable energy systems (such as PVs) could reach to 20 million USD. In this case, technology providers would be asked to provide technical and feasibility studies of the installation to have the loan granted.

Table 6.2: Business model characterization of the selected cases.

	Value Proposition	Value Creation						Value Capture	
Illustrative Examples		Partnership network	Key activities	Key resources	Client relationships	Distribution channels	Client segments	Revenue flows	Cost structure
Donor aid	Solar energy systems at no investment cost	Coordination of actor network (funders, project managers, technology providers)	Demonstration projects, cutting prices, bidding	Building social network, funds	Historical relations, access to areas	Via local and international actors	Public building owners, customers of selected deprived regions	Fixed funds and specifications set by donors	Costs of Maintaining project, monitoring implementations, installations costs
Local based collective	Solar energy system at low interest rate loans and with a medium size grant	Customers part of the networking, interaction with technology providers and project managers	Monitoring of performance, interaction with customers to increase commitment	Building social network, funds	Personal assistance through technology providers and project managers...	Via local and international actors	Private entities across industries	Fixed funds, loans credited to end users	Costs of Maintaining project, monitoring implementations
Micro-finance	Solar thermal systems for every household, energy for free	Customer part of the partnership and coordination with supplier and banks	Retail market activities, interaction with micro-finance institutes	Loans, cash, feasible studies	Trust and keeping customer loyalty, personal assistance	Via technology providers in energy market, banking institutes	All customer groups, including households	Interest free rates	Retail costs

6.5. Discussion

To understand the diffusion of renewable technologies one needs to study the economic, environmental, social, and technical aspects of a technology (Biswas et al., 2004; Hultman et al., 2012). Engelken et al. (2016) found out that research from developing countries focuses on simple business models with attention to financial aspects without addressing many other but important pillars of business models. On the other hand, most business model research that focused on industrialized countries revealed a more complex business model for renewable energy than research focusing on developing countries. Thus stressing on the need to differentiate between business models across regions and economic statuses. Especially the factors driving or hindering renewable energy technologies diffusion are highly specific to certain geographic regions.

By mapping the business models applied in the illustrative case of Lebanon and the ongoing challenges, the opportunities of new business models focusing on the end users provides a great potential for development. This brings us back to the similar aspects between business model and SNM. Both build on learning and experimenting as illustrated in the empirical cases of Lebanese initiatives. However, we agree with Huijben and Verbong (2013) that SNM can provide insights to the business models to help them broaden their context of operation and tackle ongoing challenges in the market.

Building on this, the illustrative examples from the solar energy niches in Lebanon (exemplifying a developing country context for niche development) were presented in this paper. We identified the most key models that shaped the solar energy market. On the one hand, the government supported in the form of financial subsidies, on the other hand there have been various national and international initiatives to increase the uptake of solar energy technologies. For instance, solar PV received more attention in a developing country like Lebanon due to its flexible application and the higher number of hours of sunshine. However, few studies focused on solar thermal energy technology, wave, ocean, or geothermal energies regardless of the important role they might potentially play in the future energy mix (Engelken et al., 2016). And so are the factors influencing the business models which appear to be different between developing and developed countries. Similarly, Martinot et al. (2002) and Kolk and van

den Buuse (2012) mentioned that often the basic needs in developing countries are unfulfilled. This is reflected in the case in Lebanon, where the need for efficient electricity access was high, as most areas still experience blackouts due to shortage in supply from the national grid. In addition, there were various pressing circumstances that surround the country and shape the priorities that the government and energy market actors need to handle. For instance, various projects which were being implemented in the country needed foreign aid and government support to sustain the cash flow and guarantee the completion of the projects. Yet, to ensure a sustainable market transition there is a need to shift from donor based to market based orientation as suggested by Kolk and van den Buuse (2012) and Martinot et al. (2002). This was reflected in the micro-finance business models which were applied in Lebanon as a follow-up to the donor-aid business model. The micro-finance business model was based on customers' decisions to make the investment decision, which were in turn completely responsible for the investment and maintenance costs of the systems. However, this confirms the need to change from a donor based to a market based perspective (Martinot et al., 2002; Kolk and van den Buuse, 2012).

The results of this study show that one of the important aspects in the Lebanese solar market development was the transfer of technical know-how during local trainings and workshops from firms and experts in the developed countries to the developing countries. Through these workshops the local actors became more aware of relevant elements of new business models such as the collective business model and collective smart metering. In addition, there is the performance based approach that will give consumers a more active role in the energy transition process. The importance of the learning process was also reflected in the shift from donor-aid business models to local collective business models. Thus moving away from fully funded models to create more sustainable markets. Thus, we agree with Doganova and Eyquem-Renault (2009) who addressed the importance of communication between different innovation network actors that enriches the learning process and social networks formation, but also attract new investments. This is in line with Martinot et al. (2002) who agreed that to increase the growth of renewable energy markets in a developing country, an increased technical know-how will be required to maintain technologies and to build local manufacturing industries. This transfer of knowledge and expertise helped to establish a solid technical ground in the market. Yet in order to achieve a sustainable

development on the national level, a shift to innovative business models for renewable energies might result in a strong ‘business-society relationship’ (Escobar and Vendenburg, 2011). Addressing the social context creating more active roles for consumers in the market through business models that address ongoing challenges is a crucial component to sustain the solar energy niches in Lebanon. This is due to the fact that the country still lacks the resources to sustain these niches in the longer term, especially with the absence of an actor coordinating between different actors.

A common approach for business models in developing countries involves targeting the customer side, where products and services are designed to fit customers’ preferences (Mahama, 2012; Bocken et al., 2014), such as social entrepreneurship business models addressing the same customers (Jolly, Raven and Romijn, 2012; Bryant and Romijn, 2014). Another way is involving consumers as information sources (Cui and Wu, 2015), so that users will be more likely to innovate and aid in the development of a certain technology in the market (Oliveira and von Hippel, 2011). This segment of users is what Rogers’ diffusion model of innovation defines as lead users as innovators and early adopters, while the main stream segment will have significantly different attributes which can be anticipated upon (Rogers, 2003). This emphasizes that users might have different roles in the diffusion of a technology and an eventual transition such as co-producers (pro-sumers) or innovators (Tolkamp, 2015).

The challenge that surrounds certain business models in developing countries is the low security of current energy supply (often resulting in numerous blackouts). This situation offers interesting opportunities for more innovative business models with value propositions supporting decentralized technologies and less reliance on inadequate centralized systems. This makes it difficult to implement innovative business models for renewable energy sources into fragile infrastructures (Buchholz et al., 2012; Harish et al., 2013). Such is the case in the Lebanese unreliable electricity grid and the bureaucratic system around it. However, this low level of security also offers entrepreneurial opportunities for the development of new decentralized energy systems for specific communities. However, the main obstacle lies in the current regulatory framework which includes specific laws to support renewables in general. For instance, there are still unclear terms on the concept of producing electricity through renewables and distributing it to a certain neighborhood. Thus, we agree with Huijben and Verbong

(2013) that to achieve higher market uptake of renewable energy technologies, better infrastructures, more customer oriented mechanisms need to be applied. That directly lead to more successful business models.

Reflecting on the Lebanese solar energy market, a crucial dialogue occurred between a key banking institute and a consumer representative organization. In addition to the bank's core function of providing flexible loan terms to the customer, the banking institutes were indirectly reflecting on the quality of the system through showing the link with the national conservation center that monitors the whole process. In an effort to target new customers and expand their business models, technology providers highlighted the importance of microfinance (Martinot et al., 2002; Balachandra et al., 2007; Singh, 2009). Furthermore, microfinance institutes which act as nongovernmental organizations (NGOs) might often become the point of contact with the customers, that not only provide customers with loans yet often help the firms identify the prospective customers and act as sales channels for renewable energy technology supply (Harish et al., 2013). As reflected in the Lebanese case, corporate end users need to provide a feasibility study for the banking institute granting loans for collective solar energy systems. In cases where enterprises need to provide various financial proofs for the lending institute, micro-finance institutions act as a guarantee for the banks to process the loans. These micro-finance institutes not only support the financial feasibility of enterprises, but also assist them in preparing technical reports for the lending banks, thus to assure approval on loans.

As shown in this paper, from a business model perspective, a change in value proposition can target an untapped mainstream customer segment. In that sense the illustrative case revealed that the segment of collective solar systems is still emerging and consumers are not yet in the phase of taking active new roles that will help the niche to develop and scale up. This takes into account the importance of customer needs regarding their social position and lifestyle (Boork et al., 2014).

Due to the autonomous control of many consumers vis-a-vis their energy use and the continuous decline in the prices of renewable energy technology (Banks, 2015), there is a potential to shift to performance based approaches given the intention of future projects in the Lebanese market. These approaches will promote the shift from cost of service to the value of service and eventually provide an opportunity for consumers and

service providers to meet their goals. Some developed countries such as the Netherlands and UK provided monetary rewards for consumers based on their energy savings which motivates their involvement in energy efficient practices and results in lower energy demand on the utility providers.

6.6. Conclusion and implications

Innovative business models taking place within or beyond niches represent change and development in the market (Sarasini and Linder, 2017). Hence, by combining insights from transition studies and business model perspectives, scholars can speed up the transition process by combining the knowledge and resources required for future research agendas. It is important to start combining the user interface in the literature on business models and societal transitions (Engelken *et al.*, 2016).

When users are given the required information, they will form better awareness of the environmental problem possibly resulting in specific behavioural change (van der Werff and Steg, 2015). Whereas knowledge about user needs might help in product and service design, a firm needs to be more aware of existing user practices when steering for behavioural change (Hargreaves *et al.*, 2013). In addition, it is important to enable entrepreneurs to create business model design options that could exploit the financial incentives offered.

Not all households have a suitable roof or the financial resources for covering the high initial investment costs. Therefore, it is important to start thinking of projects in which multiple households collectively finance a PV system i.e. through community shares. As long as levels of subsidy are high, there won't be a pressure to come up with new market concepts for higher uptake. Regarding the PV, a paradigm shifts from a centralized versus a decentralized technological paradigm, and a societal shift from passive to active users are needed. Wainstein and Bumpus (2016) showed that a change in value proposition can target a previously untapped mainstream customer segment, such as a third party financing and shared ownership of collective solar PV.

Although the renewable energy development is more advanced in developed countries, several developing countries have at least managed to have either governmental or donor support. As is the case in Lebanon, where the funds provided by donors played a significant role in providing a breakthrough in the niche development of solar energy

technologies. The opportunities, drivers and barriers for business models for renewable energies are of high interest for policy makers. Opportunities for business models in the developing world are primarily based on promising concepts of bottom of the pyramid and microfinance. Therefore, political support should start focusing on entrepreneurship support to enable new business model concepts to develop. In the light of ongoing challenges and the weak and unstable role that the government plays, creating a bottom up social innovation approach will respond closely to community needs and interests. For instance, the need of creating a financing scheme that serves poor communities is crucial. Currently, few funds are allocated for providing solar energy technologies to cover the needs of those communities (Kaphengst and Velten, 2014). The access to capital development and the introduction of new financing instruments for the implementation of renewable energy technologies for the poor in society should be addressed in-depth. However, in the long term this needs to be complemented by market based mechanisms that secure finance. This can be achieved through promoting community based initiatives that will be the linking point between finance providers and the end users. The collective concept (launching large scale system for large groups of end users) might also help to solve both the roof space problem and the high investment cost. Yet due to the individualistic culture that end users live in, there is a need to establish trust among individuals contributing to this initiative. For instance, high upfront investments are often regarded as a key barrier to the adoption of renewable energy technologies. As was revealed in the Lebanese case study, investment costs are a major challenge to the corporate sector. To achieve higher adoption rates in the Lebanese solar energy market it is important to address policy measures for the end users from the demand side, and also for the providers from the supply side. Thus, when applied simultaneously, higher demand and more supply will occur under market transformation (Killip, 2013).

6.7. References

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Chapter 7: Conclusion

This concluding chapter starts with summing up the results of the four studies that were undertaken and answers the research questions relevant to each case. These summaries are integrated to form the overall conclusion of this thesis. This leads to answering of the main research question, which will be discussed further at the end of this chapter. Finally, I will conclude this chapter with possible recommendations to policy makers and marketing professionals, and suggestions for future research.

7.1. Main results

Chapter 3, in the context of the overall dissertation, aimed at answering the following research sub-questions:

- 1.1 What are the stakeholders' views, roles and influence on the diffusion process of solar energy technologies in Lebanon?
- 1.2 What are the specific socio-cultural factors that influence adoption?

In this sub-study, understanding the influence of socio-cultural dimensions on the diffusion process of solar energy technologies was of key importance. The research conducted in this study conceptually draws on the diffusion of innovation theory (Rogers, 1962) and its limitations. Drawing primarily on the previous body of research (e.g., Urmee, 2016; Eseonu and Egbue, 2014), this sub-study sought to explore the importance of the socio-cultural dimension in the diffusion of solar energy systems. This premise seems to enrich innovation studies that often ignore the significance of the socio-cultural dimensions and relevant consumer needs. This is because technology adoption is multi-dimensional by nature, and does not only the result from the influence of technical and economic factors. Yet, it also entails behavioural, social, and cultural factors that directly influence consumers' adoption decision-making.

For the elaboration of new insights to the body of literature on adoption of renewable energy technologies, grounded and critical theoretical approaches were used in the sub-study. Building on the stakeholders' view, interests, and influence it was clear that certain market related factors along with the socio-cultural dimension influenced consumers' decisions. The results of the study indicate that demonstration projects in

the solar energy field contributed to market development at various levels. For instance, the foreign funded demonstration projects increased the observability of the solar energy systems and improved the technical experience of installers and technology providers who were involved in these projects. It seems that the demonstration projects also raised the awareness and trust levels in solar technology among stakeholders, in particular end consumers. However, technology related attributes (relevant to the diffusion of innovation theory) were not the only variables influencing the uptake of solar energy technology. In addition, social interactions between the consumers and the wider community were found to be of great importance. Furthermore, important influential factors corresponding to the technology, socio-demographic, and socio-cultural dimensions were found among individual and corporate end users. The result revealed that individual characteristics of decision makers were among the most important aspects.

To answer to the research question posed in sub-study 1, it is socio-cultural, technical and economic aspects that play a significant role in the adoption of solar energy technologies. The results show the importance of social influence, particularly the influence of recommendations from friends and neighbours on households' decisions as to whether to adopt solar energy systems. Furthermore, the interest of end users and other stakeholders in reflecting a specific social identity appeared to be of significance in influencing the adoption process. However, the individualistic culture among households appeared to create a challenge for the collective concept (launching large-scale systems for large groups of end users), which is ideal to solve both the roof space problem and the problem regarding high investment costs. The ongoing cultural and economic challenges require solutions that are tailored to the end users' needs and situational circumstances. This stresses the importance for new policy approaches to address these issues and create a clear connection to the ongoing contextual and situational circumstances, along with the social structures and relevant preferences of local actors. In Chapter 4 the research question that was addressed in the context of the overall dissertation was:

1.3 To what extent do selected theoretical drivers explain household adoption of SWHs in Lebanon?

Both theoretical concepts from both Rogers' 'Diffusion of Innovation' theory (Rogers, 2003), and other relevant models from the domain of environmental psychology (see e.g. Jansson et al., 2010; Steg et al., 2005; Stern et al., 1999) were used. It was evident from the theoretical body of literature that the diffusion of innovation theory had shortcomings not taking into account personal norms and attitudes of consumers. An empirical study was conducted with a full incorporation of innovation diffusion and environmental psychological concepts to enrich the understanding of 'green' consumer behaviour and green innovation adoption decision-making. This integration was done so as to find out whether the explanatory power of the model would increase by adding contextual and behavioural factors to the model.

The main focus of the study was the empirical study which was conducted in the Metn area of Lebanon. The unique context of the Metn area created an interesting case to study the influence of theoretical and contextual factors on consumers' adoption decision. This area was selected due to the high adoption rate of SWH that ensured data collection among both adopters and non-adopters to identify drivers for adoption. The results of the study showed no statistical differences between adopters and non-adopters on most of the socio-demographic indicators, except for household size, and income. The area selected for empirical research was of relatively higher income levels than other Lebanese regions, and has a relatively higher proportion of SWH installations. Although education and employment status did not have any statistical significance, they reflected important characteristics of the households as shown in Chapter 2. Regarding perceived attributes of the product, the results showed that adopters perceive SWHs to be more advantageous, compatible with their values, and observable by others. Due to the technical simplicity of the SWHs, they were seen by adopters to be less complex to install and use properly, leading to higher adoption rates. Concerning attitudinal factors, adopters were found to have significantly higher levels of social norms, independent judgment making, and novelty seeking.

In the analysis the factors were divided into three research models: (1) perceived attributes, (2) attitudinal factors and innovativeness, and (3) a combination of them. The results indicated that relative advantage, observability, consumer novelty seeking, and independent judgement making were significant in all three models (1, 2, and 3). This was found to result in higher explanatory power when compared to the use of mono-

disciplinary models. However, social norms lost their significance when combined with perceived attributes of model 1. Accordingly, the answer to the research question is: the integrated model is more powerful than each of the models alone in explaining adoption of SWHs among households. This shows the importance of combining theoretical notions from innovation and behavioural studies to enrich the understanding of consumer adoption decision making. It is consequently reasonable to deduce that remarkable diffusion rates will likely require the integration of various technological, economic, social and cultural aspects, as well as policy and environmental perspectives.

For Chapter 5, the research questions were:

2.1 How have the solar water heater niche and the solar PV niche developed in Lebanon, and how do they compare?

2.2 In which ways does the Strategic Niche Management framework help us to understand the development of solar energy niches in a developing country's context?

The main focus in this study was the niche internal processes of Strategic Niche Management that shape the development of solar energy niches in Lebanon. I noted that the Strategic Niche Management framework was heavily characterized by the context of Western developed countries, and much neglected the global South where different contextual, institutional, economic, and cultural factors may also influence niche formation processes.

Drawing on this, this sub-study was based on solar thermal and solar PV niche development in Lebanon, being a developing country with various constraints that limit the development of promising technologies. Results of the Lebanon case study indicated that the start of niche formation in the SWH and PV cases was initiated and supported by an international funding body. It revealed the importance of donors in developing renewable energy markets in developing countries. The expectations of the solar thermal and solar PV niches were found to have been affected by one another, where the former increased the credibility and quality of the latter (i.e., the solar PV niche), in particular to attract investors and potential private sector actors. Furthermore, networking was found to be linked more to the funded programmes and, hence, the

previously set action plans and activities that were deemed necessary by the funding agencies. It was found that learning in both solar energy niches took the form of discovering problems and finding solutions to them. Thus, learning across the two niches occurred, benefiting the implementation process and dissemination of knowledge in the PV niche. This reveals the efficient use of knowledge in subsequent projects.

The answer to the research sub-questions posed in study #3 is that on niche internal processes unlike the solar thermal niche, the expectations for the solar PV niche were ambitious from the beginning. The network supporting niche development was quite diverse and could establish all its activities with limited user involvement. However, learning processes in both niches mostly focused on improving techno-economic performance. Certain differences between applying Strategic Niche Management to developed countries and developing countries occur. From the interviews and the documents reviewed it seems that in developing countries the deployment of renewable energy technologies is not a priority that is on the agenda of a national government administration. This is what leads international bodies to set expectations and visions, while initiating experimentation projects, in addition to the government delay in setting regulations, or introducing change to the on-going system. Thus, they help to create a more active role of donors in the market that influences niche development through development of projects and programs at the local level.

In Chapter 6, the research questions were:

2.3 What is the role of business models in the transition towards decentralized renewable energy driven systems?

2.4 And what are the promising opportunities for business models in a developing country context?

These questions were investigated firstly through a literature review, and secondly through illustrative examples from empirical research of the previous three sub-studies (i.e., the Lebanon case study). Given the important role business models play in bringing sustainable innovation to the market and promoting dissemination, it is worth considering their implications on the diffusion of innovations. Therefore, insights from the academic business model literature were integrated into the literature on sustainable transitions.

The main focus of this study concerned illustrative (empirical) examples from the solar energy market in Lebanon. From the theoretical body of literature, it was clear that business models for renewable energy technology can support niche processes by handling perceived risks and removing investment barriers, such as the high up-front costs and unavailability of a suitable roof for solar energy systems. This highlights the dynamic role of business models in accelerating clean energy system innovations (see e.g., Huijben and Verbong, 2013; Wainstein and Bumpus, 2016). Through various similarities between internal processes of Strategic Niche Management and business models on experimentation, networking, and learning levels, one can reason that business models play a significant role in facilitating various internal niche process activities and in market development. Furthermore, the two solar energy niches in Lebanon were used as illustrative cases highlighting the importance of contextual factors for the diffusion of innovations.

Against this background, the study examined the role of three business models applied in the Lebanese context. It was found that as a developing country, Lebanon witnessed various initiatives to stimulate growth of its renewable energy market. It was clear from the illustrative cases that demonstration projects at the niche level increased awareness among consumers. These projects pushed for financial support and for sustainable models in the solar energy market. Furthermore, this sub-study found three most commonly applied business models in Lebanon: (1) donor aid; (2) locally-based collective projects; and (3) micro-finance projects. The key differences between the three business models concern the financing process and ownership. The business models that were studied showed that a gradual shift from fully funded, to co-funded, and partly supported financial models. This stresses the importance of providing a viable market on the long term with active user involvement and sustainable financial means.

Based on the results of this study, the answer to the research questions is that business models played a significant role in creating a more sustainable solar energy market in Lebanon through partially shifting away from the donor aid-based business models. However, to achieve a more sustainable development on the national level, a shift to innovative business models is needed. It seems that shifting from passive to active users might result in a great potential for development. This brings me back to the fact

that it is important that support for entrepreneurship is politically supported to enable the development of new business model concepts. Therefore, leading to more community based initiatives that create higher interaction between end users within social communities, and between communities and financing institutes. This will likely result in higher interaction between end users, and help in achieving a higher sense of collective interests among consumers and within a community. When a group of consumers share similar interests, it will be more constructive to find solutions that serve the group rather than just the individual. To achieve higher adoption rates in the Lebanese solar energy market it is important to select and use policy instruments targeting the end users while taking into consideration the actual needs of the latter and the societal conditions in which they live.

7.2. Overall discussion

The results of the studies reveal a common understanding on the fact that technical and the economic factors only form a small part of explanatory variables explaining the diffusion of solar energy technology in Lebanon. Most of the factors that influence the adoption of solar energy technologies are related to either the socio-technical, political or socio-cultural dimension. The multi-disciplinary approach of this doctoral study, has presented a comprehensive understanding of the critical aspects hindering and triggering adoption of renewable energy technologies. The selected approaches aimed to represent a comprehensive set of concepts that aim to fill the gap in the diffusion of innovations literature. My analysis illustrates that achieving successful diffusion of renewable energy technology requires a comprehensive approach, in particular in developing countries. The empirical studies of this doctoral study were designed to focus on the phenomenon of eco-innovation adoption from different disciplinary lenses. In particular, taking viewpoints of multiple perspectives might serve as inspiration and perhaps a stepping stone for future projects of renewable energy technology adoption. At the same time, the results from my sub-studies confirm the claim that international funding agencies shape Lebanese renewable energy markets. It is apparent from the sub-studies that Lebanon case serves as one more case in which a significant influence from developed countries of the North, affecting the development of markets of developing countries in the global South, was found. Funding from these developed countries provides financial support to the government to subsidize loans for renewable

energy technologies. Moreover, international donors play a crucial role in niche formation and in pushing for policy interventions. This was revealed by bearing the high risk of investment to prompt market change and encourage private investors in the renewable energy market. The donor support was also reflected in the business models that were illustrated in the Lebanese case. However, this sheds light on the need for innovative business models that fit into a developing country context such as Lebanon, and thus create a sustainable option for diffusion of various types of renewable energy technologies.

Based on the results of the studies, I formulate an answer to the main research questions: *What is the set of drivers that explain the adoption of solar energy technology among different Lebanese stakeholders? And to what extent can SNM and other relevant theoretical insights on business models contribute to understanding the niche market development of solar energy technologies in developing country contexts, particularly Lebanon?* My answers would be: First, there is a comprehensive set of factors that influence the adoption of solar energy technologies. These factors include the right financing schemes that meet the needs and conditions of the consumers in the targeted society. The social dimension critically influences adoption of technologies, in particular the influence of the small social circle of the consumers. Evidence obtained in the empirical studies I conducted, indicate that the drivers are not only technology related (such as technology perceived attributes) but also behaviourally driven, such as consumer sense of innovativeness and environmental personal norms. It is also reasonably clear that the international donors from developed countries contributed to the development of solar energy niches, especially in the initiation stage. This was clearly revealed in supporting government institutes in renewable energy programs that increasingly triggered their interest in the niche and initiated their learning process. That is, the critical role played by funding agencies in triggering the formulation and implementation of national policies and financing mechanisms, and in influencing the dynamics of internal niche processes. Ultimately, this contributed to the SNM literature by pointing out the weak alignment between public actors, and on-going power struggles between different ministerial departments in a developing country's context. Based on the inter-related factors between SNM's internal processes (i.e. setting visions and expectations, network formation, and learning) and the business model framework, the business model analysis conducted in this doctoral study leads to

results, from which it can be deduced that in order to motivate potential adopters and foster diffusion of renewable energy technologies in the country, policy makers need to consider new policies to support initiatives at community level. Therefore, they should support local level consumers to overcome ongoing challenges of space and investment costs. However, these policy measures will not have the expected impact without continuously involving the local solar companies. The survival of such companies is crucial to the wide adoption of renewable energy technologies. Therefore, new policies to support existing local companies through novel business models are very important to help business enterprises ensure their survival and competitiveness in market over future upcoming technologies.

This study has provided a systematic analysis of the diffusion of solar energy technologies in Lebanon from a multi-disciplinary perspective. This is particularly important because, in doing so, the analysis starts from the understanding that the adoption of technologies is multi-dimensional. The consumer adoption decision making is only one part of the diffusion process, thus to foster diffusion of renewables I decided to incorporate both the social, cultural, behavioural, and business model dimensions. Through the analyses of the cases, I found that by linking the diffusion views from consumer and market perspectives, knowledge of a larger diffusion process would be developed. My doctoral study contributes to both innovation and transition studies, and behavioural research. This has been done through four inter-related approaches. First, this thesis provides an integration of social and cultural dimensions along with the diffusion of innovation theory to present a rich and comprehensive contribution to explain the diffusion of innovations. As such, using these dimensions offers innovative insights to the diffusion of innovations literature. I would like to stress that the scholarly literature often misses out on considering socio-cultural influences when studying the adoption setting of renewable energy technologies in a certain region.

The results of my doctoral study reveal the multi-dimensional nature of eco-innovations' adoption by pointing out to the significant role that socio-cultural, technical and economic aspects have in the adoption of solar energy technologies. As discussed in Chapter 3, the ongoing challenges are mainly culturally and economically embedded, and as such require creative solutions that are tailored to the end users' needs and situational circumstances. Second, putting the problem definition into perspective, my

research provides empirical evidence of the impact of consumer environmental behaviour on the decision to adopt solar thermal systems. The results of this study highlight the importance of consumer innovative traits too. This is relevant for mass media strategists to build on and persuading householders to adopt different renewable energy technologies. As such, the emphasis tends to be on the importance of consumer novelty seeking, independent judgement making, and social norms that are prevalent in a (given) social community to which consumers belong. Overall, I saw that the social, behavioural, and cultural dimensions have to be given higher priority in terms of renewable energy projects' implementation, and in promoting renewable energy technologies in the market. That is to say that by prioritizing this consumer related dimensions this will pave the way for innovative business models to be developed and used to foster diffusion of renewable energy technology. Third, my study has contributed to the SNM literature by providing insights from a developing country context. Unlike developed countries, when applied in developing countries SNM needs to capture the contextual aspects specifically related to these economies in a better way. For instance, in most developing countries, the deployment of renewable energy technologies is not a priority that is on the agenda of a national government administration. In general, developing countries face a lack of funding, capacity and capabilities to create change in the infrastructure and technologies to achieve ambitious renewable energy goals. This was reflected in the Lebanese case where the national electricity grid operator lacked the skilled personnel and financial resources to upgrade and adapt the power infrastructure to any type of renewable technology. Therefore, international bodies have the role to support in formulating expectations and visions, while initiating experimentation projects, in addition to the government constraints in introducing change to the on-going system in Lebanon and have influenced the diffusion of solar energy technologies. Lastly, the challenges that face the SNM framework in developing countries need to feed in innovative business models that will foster transition. The business model framework was not applied in transition studies until recently (see Bidmon and Knab, 2014; Huijben et al., 2016) although it plays a crucial role in bringing sustainable innovation to the market and promoting diffusion. In this study, I provided new insights into a business model approach through an example of solar energy niches in a developing economy, namely Lebanon. Thus, by linking SNM and the business model framework innovative approaches will develop which

focus more on the consumer, being the core stakeholder. This research offers a stepping stone for future research on the active role of consumers thus bringing transition through innovative business models in developing economies.

Due to their relatively high pricing, renewable energy technologies are usually not profitable without policy support (Jacobsson and Lauber, 2006). This implies that policy interventions are of vital importance for rapid diffusion of eco-innovations. It highlights the importance of the capacity of policies to create market niche expectations for environmentally friendly technologies, and foster diffusion through creating a more attractive product for potential adopters. My doctoral thesis could be used by policy makers and market strategists to focus on specific regulations and designs that will overcome the ongoing barriers and increase the relative advantage of sustainable innovations. For instance, to achieve faster diffusion, changes in societal discourses and challenges in values, behaviours, habits alongside infrastructural, institutional and organizational challenges, need to be addressed. This stresses the need for new policy approaches to address a clear connection to the on-going contextual and situational circumstances, along with the social structures and relevant preferences of local actors. Especially, since the role of consumers in the market is currently more passive, while ideally consumers are key stakeholders in the diffusion process. Therefore, it is important to consider their roles in designing future business models for renewable energy technologies taking various contextual factors into consideration.

7.3. Suggestions for future research

Further research within the particular context of this dissertation could address some of the encountered limitations linked to geographic scale and particular solar energy technologies. Although policies play a significant role in pushing diffusion of innovations forward, they are not the only way. The results discussed in this thesis show that specific behavioural and socio-cultural dimensions might trigger or hinder the adoption of renewable energy technologies. Therefore, future research could address closely the social and cultural dimensions of implemented energy projects, to understand the views from the individual actors in the local society. The results of this doctoral study could thus be considered as a benchmark on which future studies of innovation diffusion in developing countries could build to investigate the impact of cultural differences on innovation adoption.

This thesis is based on an illustrative case and has some limitations. For instance, it is only focusing on one developing country (Lebanon). Future research could address the diffusion of renewable energy technologies in the MENA region which is under emphasized in the transition literature, yet presents a rich case with particular challenges to adoption. Furthermore, future research could also focus on the competition between the two solar systems (solar thermal and solar PV) in terms of roof space and adoption decision making. For instance, consumers often were approached as adopters of either solar thermal or a PV system. However, detailed studies could target the decision to adopt one and not the other, or deciding to share the available roof space for the two. Therefore, it could be of value to focus on market competition between similar renewable energy technologies and relevant consumer perceptions of the uptake.

Future studies may also investigate new business models that can be applicable given the developing countries' challenges. This doctoral thesis very much focused on the role and potential of business models in the transition towards solar energy technologies. Therefore, it is important to study applicable business models that help to overcome ongoing diffusion barriers in Lebanon and in other developing countries with similar circumstances. For instance, focusing on innovative financing models for policy makers to overcome adoption barriers among low income householders, a group of potential adopters that theoretically has a high potential in market demand.

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Appendices

Appendix I

In depth interviews:

The in-depth interviews involved various local stakeholders encompassing Non-governmental organizations, public institutions, commercial banks, technology providers, managers of international funded projects. Data collected from the interviews focused on the factors influencing the adoption of solar water heating systems in Lebanon among various potential user groups from the view point of market stakeholders.

1. List of interviewees: Sub-study 1 (Chapter 3 of dissertation)

No.	Type of respondents	Number of respondents	Organization
1	Technical advisor	1	NGO
2	Project Manager-Energy and Environment Program	1	International Cooperation Agency
3	Energy consultant	1	Private
4	General Director of energy conservation center	1	Public
5	Energy End user	1	Hotel
6	Head of Engineering Standards Division	1	Public
7	Advisor	1	NGO
8	Solar technologies provider	2	Private
9	Head of Retail	2	Commercial banking sector

2. Questions

The questions of the interviews differed between interviewees according to their position, type of involvement in the topic, and any risen point during the interviews. However, the questions mainly focused on the following:

2.1 Can you tell me who are the main stakeholders in the SWH market in Lebanon, and how are they involved?

a. Who influences the SWH market most, and why?

b. What are the key stakeholders' interests in the Lebanese SWH market?

2.2 Who are the current and potential adopters of SWH systems in Lebanon?

- a. Why is adoption of SWH systems relevant to these potential adopters (dealing with different types of adopter groups)?
- b. Which potential adopter group can contribute most to increase SWH system adoption rates)?
- c. Would you rank the top three potential adopter groups and provide arguments for this ranking?
- d. Who are the major suppliers of SWH systems?

2.3 What are the major barriers and lessons learnt from the particular project you are involved in?

- a. What triggered evolution in adoption rates in the past years?
- b. What are the main driving forces for adoption SWH systems in Lebanon?
- c. Which lessons were learnt from setbacks and barriers that had to be overcome?

2.4 How would you describe the adoption rate of SWH systems in different Lebanese regions in the past years?

- a. Concerning SWH adoption projects and policies, what went right, what didn't, and what lessons were learnt from those experiences?

2.5 Which parties contributed to realization of SWH system installation?

- a. Who took the initiative, and why?
- b. What were his/her ambitions, and to which extent were they met?
- c. Which factor, in your opinion, could have made a difference in achieving a higher adoption rate?

2.6 What are the factors that would provide an explanation for the differences in adoption rates between different Lebanese regions?

2.7 What are the main policy instruments that are implemented in the SWH projects?

- a. What is the purpose of these instruments?
- b. How were they implemented, and to what extent the intended goals were met?
- c. What are the barriers that prevented goal attainment?
- d. In which areas did households and organizations benefit most from the loans in financial initiatives, and what are their profiles?
- e. How did the subsidies impact the level of SWHs installations?

2.8 What is the profile of potential residential end users who were interested in the installation of SWH systems?

- a. What are their motivational drivers?

b. What are the observed major barriers they face when they want to have an SWH installation installed?

2.9 To what extent do you think that regulating of SWH systems would help to attain higher adoption rates?

2.10 What marketing actions and/or strategies were used to spur adoption rates?

a. What kind of marketing strategy(-ies) was used, and to what extent do you believe it contributed to higher adoption rates?

b. Was it restricted to a certain area or certain category of SWH systems?

2.11 Would you kindly provide us with access to useful information sources, files and informants that could relate to this study?

Appendix II

Questionnaire survey

The survey targeted two categories: (1) households who previously purchased a solar water heater, and (2) households who did not purchase a solar water heater. The questions were designed to be answered by the head of household or another person who is involved in household decisions. The survey aimed to collect data on perceived attributes and behavioural indicators of consumers. The participants were kept anonymous in order to respect individuals' privacy by keeping all the information provided confidential and only of use for scientific purposes.

Section A:

Access to Information

1. Have you often heard or seen anywhere any of these technologies for household use? *(please tick)*

- a. Photovoltaic panels (PV) which are panels placed on a roof to produce electricity from sunlight ☐ Yes ☐ No
- b. Solar water heaters (SWH) which are placed on a roof to produce hot water from sunlight ☐ Yes ☐ No

2. What is your source of awareness? *(please circle)*

For PV:	a. Word of mouth	b. Newspaper	c. Billboards	d.TV	e. Internet	f. Not aware
For SWH:	a. Word of mouth	b. Newspaper	c. Billboards	d.TV	e. Internet	f. Not aware

Section B:

Personal Details

3. Place/Village Name: _____

4. Do you have and use a solar water heater (please tick)? ☐ 1. Yes ☐ 2. No

5. If yes, since how many years? _____

6. If yes, how satisfied are you with using it? *(Please tick)*

☐ Very Unsatisfied ☐ Unsatisfied ☐ Neutral ☐ Satisfied ☐ Very Satisfied

7. Do you use another kind of environmentally friendly technologies? ☐ 1. Yes
(specify) ☐ 2. No

8. I live in an?

☐ 1. Apartment in building of less than 5 floors

☐ 2. Apartment in building of 5 floors or more

☐ 3. Self-detached house

9. Is your house? ☐ a. Owned ☐ b. Rented

10. Total number of persons living in the house: _____

Financial Incentives

Please read the following statements and indicate the importance you give to each item mentioned below when considering purchasing a solar water heater. Using the scale provided please tick in the box which best describes your response.

	Not important at all 1	Not important 2	Neutral 3	Important 4	Very important 5
The importance of interest free loans for decision to buy solar water heaters					
The importance of financial subsidies for decision to buy solar water heaters					

Section C:

Perception of Solar water heating units

Please read the following statements and indicate how much you either agree or disagree. Using the scale provided please tick in the box which best describes your attitude towards the following:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
	1	2	3	4	5
To use a solar water heater would reduce my electricity bill					
To use a solar water heater means that I depend less on electricity from private generators					
To buy a solar water heater is a low cost investment					
To use a solar water heater means increase in the hot water comfort at home.					
To use an environmentally friendly water heater is in line with my everyday life style.					
When I use solar water heater in my house, I reduce national dependency on foreign energy sources					
Installing a solar water heater would lead to high annoyance (because of piping)					
It is hard to find a qualified person to perform maintenance for the solar water heater.					
Before deciding to buy solar water heater, I could draw on someone's experience who has installed it already					
By buying a solar water heater, I show people living nearby that I care about the environment.					
If I bought a solar water heater it would be noticed by people close to me					
To buy a solar water heater can mean a financial risk for me					
Solar water heater are risky since they often break (stop heating properly)					

Section D:

Attitudinal Factors

Please read the following statements and indicate how much you either agree or disagree. Using the scale provided please tick in the box which best describes your attitude towards the following:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
	1	2	3	4	5
I feel a personal obligation to prevent climate change, no matter what other people do					
People like me should do everything they can to reduce their emissions and help prevent climate change					
Personally, I feel it is important to reduce usage of electricity and fossil fuels to heat water					
Water heaters that operate on solar radiations are classified as environmentally friendly					
People close to me (my friends and family) think I should replace my water heater with an environmentally friendly water heater.					
The people in your life whose opinion you value most would encourage you to install SWH on your house					
People living nearby (such as neighbors) would not approve my installation of a solar water heater					
Before buying a new brand, I usually ask someone with experience from the brand for advice					
When I am interested in buying a new product/service I usually trust/rely on opinions of friends or close acquaintances who have used this product.					
I like newspapers and magazines that inform about new brands					
I continuously look for new products and new brands					

Section E:

Socio-Demographics

11. Gender: ☐ a. Male ☐ b. Female

12. Age: _____

13. Your Highest Education Level:

☐ a. Primary (Basic education or less)

☐ b. Secondary (high school)

☐ c. Bachelor Degree

☐ d. Master's degree or higher

14. Average monthly income:

☐ a. Less than \$500

☐ b. \$500 to \$899

☐ c. \$900 to \$1199

☐

d. \$1200 to \$1499

☐ e. \$1500 to \$1799

☐ f. \$1800 to \$2099

☐ g. Greater than \$2100

15. Employment Status: Are you currently...?

☐ 1. Employed for wages

☐ 2. Self-employed

☐ 3. Out of work

☐ 4. A homemaker

☐ 5. A student

☐ 6. Retired

☐ 7. Unable to work

Appendix III

In depth interviews:

These in-depth interviews build on the first set of interview questions and involved various local stakeholders encompassing Non-governmental organizations, public institutions, commercial banks, technology providers, managers of international funded projects, end users, and consultants. This research aims at understanding the challenges facing diffusion and long term transition of renewable energy technologies in Lebanon. Being a developing country with a particularly complex phenomenon, I am looking to gain more insights about solar energy technologies and projects implemented and their status in leading to long term shift in the country. Unlike the first set of interviews, this interview focused on two of these technologies; Solar thermal water heaters (SWHs) and photovoltaic panels (PV).

1. List of Interviewees for Sub-study 3 (Chapter 3 and 5 of dissertation)

No.	Type of respondents	Number of respondents	Organization
1	Project Manager-Energy and Environment Program	1	International Cooperation Agency
2	Project manager-Small Decentralized Renewable Energy Power Generation Project	1	International Cooperation Agency
3	Energy consultant	2	Private-NGO
4	Project Manager-SHAAMS	1	Private
5	Pre-Sales consultant	1	Private
6	Project manager-Financial support of strategic Projects	1	Private
7	Project Manager	1	International NGO
8	Energy Committee Member-Technical institute	1	Public
9	Technology and Development Director	1	Research institute
10	Energy End user	2	Local resident-Hotel
11	Energy engineer-Technical Support Unit	1	Public
12	Project Manager-climate change mitigation	1	Public
13	Solar technologies provider	1	Private

2. Questions

Section A:

Context and Project Development:

1. When did you get involved in renewable energy technologies? How and why did you/your organization become involved in solar energy projects?
2. What were main drivers/barriers of projects you were involved in? What was the experience of the project with existing/relevant policy?
3. Why and how is SWH project implementation different from PV from the perspective of your role in the process? (for actors involved in both projects).
4. What sorts of practices have been developed for SWHs and PVs? Do they have a particular role in creating confidence between actors? (divide this question for the three interview templates)

Section B:

Niche Processes

Expectations:

5. What has motivated you/your organization's participation in solar energy projects? What does your organization seek to gain from being involved in this kind of projects?
6. Who are the main actors involved in projects' implementation? Who was most/least influential? With what actors have you interacted most closely?
7. What is your personal opinion about the success or failure of the projects in which you have participated? How the project you worked on contributed to increase likelihood of similar projects to develop? What is the main reason behind this success/failure? What new applications could evolve in the field?
8. Do the SWH and PV projects fulfil public needs/demands? where their other needs not considered in development of projects?

Social Network:

9. What social network formation activities have been used in SWHs and PV projects? How and to what extent were they effective in supporting SWH and PV niche development? Who/which actors have been crucial in supporting this social network formation?

10. What type of work have you done? what type of work was most important in bringing actors together? With whom have you linked?

11. What type of resources have you contributed to the network of actors?

Learning:

12. What types of learning (by trying, by interacting, by doing) have been important in the development of SWHs and PVs projects? would you provide examples for each? How have you interacted with other actors? i.e. users /policy makers/technology providers, etc.)? what have you learned in the process?

13. What are the main lessons from the implementation of projects concerning:

- Institutional arrangements and institutional roles in the process?
- The role of standards, technical designs, infrastructure/user preferences and practices?
- Incentives and financial mechanisms?
- Training and access to information and knowledge about solar energy technologies? other crucial roles for implementation of project?

14. To what extent have previous projects with similar characteristics (technology/social context) influenced the implementation of subsequent projects? What were the key lessons from previous experience?

Closing questions:

15. Will there be new funding for new projects of SWH and PV?

16. Would you provide contact for other key actors who might provide valuable information about projects?

Summary

Adoption of technologies is multi-dimensional in nature, showing that multiple dimensions shape the diffusion of innovation. This study seeks to analyze the factors related to the consumer (namely behavioural, social, and cultural dimensions) and the market in which the uptake and development of technologies takes place. The geographical focus of this dissertation is Lebanon, which was selected as an illustrative case of a developing country context. This selection was based on the idea that diffusion of technologies is influenced by the context in which it is situated. As such, the research focuses on the adoption on two solar energy technologies; i.e, solar thermal and PV systems.

This dissertation is divided into four empirical studies that aim to answer the research questions developed to fulfill the objective of this research. The studies were conducted to understand how concepts from multiple disciplines help policy makers and market strategists to overcome ongoing challenges for the adoption of solar energy technologies. The results are based on a combination of both qualitative and quantitative methods, including 30 in-depth interviews with different groups of stakeholders; namely national government institutes, NGOs, banks, contractors, consultants, the public sector and end users, and a survey among 200 households in the Metn neighbourhood in Lebanon.

The first study sought to explore the importance of the socio-cultural dimensions in the diffusion of solar energy systems. This premise seems to be enriching innovation studies that often ignore the significance of the socio-cultural dimensions and relevant consumer needs. This is because technology adoption is a result of technical, economic, behavioural, social, and cultural factors that directly influence consumers' decision-making regarding technology uptake. Building on the stakeholders' views, interests, and influence, the findings supported the argument that certain market related factors along with the socio-cultural dimension influenced consumers' decisions.

In the second study on consumer adoption of solar thermal technologies, an empirical analysis was conducted in innovation diffusion and environmental psychological concepts to enrich the understanding of 'green' consumer behaviour and green innovation adoption decision-making. The results indicated that relative advantage, observability, consumer novelty seeking, and independent judgement making were

significant in all tested models. Thus, supporting the argument that combining theoretical notions from innovation and behavioural studies improves our understanding of consumer adoption decision making.

The third study analyzed the niche internal processes of Strategic Niche Management that shape the development of solar energy niches in Lebanon. This framework was applied to investigate the market formation of solar energy technologies from a societal context. The study compared between solar thermal and solar PV niche development and found that the expectations of one niche affected the other, and contributed to efficient use of knowledge from previous projects. The Strategic Niche Management framework still needs to address and/or embed important contextual aspects in developing countries. Overall, it was noted that international donors played an active role in the niche development through shaping programs in the country. This was clear in their support in formulating expectations and visions and in contributing to niche networking.

Related to the third study, was the fourth study on the role business models play in bringing sustainable innovation to the market and promoting dissemination, and thus their implications on the diffusion of innovations. Due to the similarities between internal processes of Strategic Niche Management and business models on experimentation, networking, and learning levels, the findings supported the notion that business models play a significant role in facilitating various internal niche process activities and in market development. Examples of the role of three business models applied in the Lebanese context were analyzed. Overall, it was noted that higher adoption rates in the Lebanese solar energy market will be achieved, when certain policy instruments for the end users are utilized, while taking into consideration the actual needs of the latter and the societal conditions in which they live.

Taking into consideration the focus of this research and the findings of its empirical studies, it is deemed important that by linking the diffusion views from consumer and market perspectives, knowledge of a larger diffusion process would be developed. As such, this doctoral thesis offers a multi-disciplinary analysis of the complex phenomenon of the diffusion of eco-innovations. Finally, the outcomes of this doctoral study provide insights to the academic literature in both innovation and transition studies, and behavioural research.

Nederlandse samenvatting

De invoering van technologieën heeft een multidimensionaal karakter, een weerspiegeling van het feit dat dimensies vanuit verschillende invalshoeken de verspreiding van innovaties vormgeven. Deze studie beoogt om de factoren te onderzoeken die gerelateerd zijn aan de consument- (namelijk de gedrags-, sociale en culturele factoren) en de marktfactoren die het gaan gebruiken en de ontwikkeling van technologieën regelen.

De specifieke context van dit proefschrift is Libanon, dat werd geselecteerd als een voorbeeld van de context van een ontwikkelingsland. Deze selectie is gebaseerd op het idee dat diffusie van technologieën wordt beïnvloed door de context waarin het plaatsvindt. De focus van het onderzoek spitste zich verder toe op de verspreiding van twee zonne-energie technologieën: zonnewarmte- en zonnestroomsystemen.

Dit proefschrift is verdeeld in vier empirische delen die beogen om de onderzoeksvragen te beantwoorden die zijn ontwikkeld om het onderzoeksdoel van deze studie te vervullen. De deelstudies zijn uitgevoerd om te begrijpen hoe concepten vanuit meerdere disciplines beleidsmakers en marktstrategen kunnen helpen om de bestaande uitdagingen bij de adoptie van zonne-energietechnologieën te overwinnen. De bevindingen zijn gebaseerd op een combinatie van zowel kwalitatieve als kwantitatieve onderzoeksmethoden, waaronder 30 diepte-interviews met verschillende groepen betrokkenen, waaronder nationale overheidsorganen, Ngo's, banken, aannemers, consultants, de publieke sector en de eindgebruikers, alsmede een enquête onder 200 huishoudens in de *Metn*-wijk in Libanon.

De eerste deelstudie beoogde het belang van de sociaal-culturele dimensies bij de diffusie van zonne-energiesystemen te onderzoeken. Dit uitgangspunt lijkt een verrijking voor innovatiestudies, die vaak het belang van de sociaal-culturele dimensies veronachtzamen. Dit is omdat de adoptie van technologieën het resultaat is van technische, gedragsmatige, sociale en culturele factoren die van directe invloed zijn op de besluitvorming van consumenten over het gaan gebruiken van technologieën. Voortbouwend op de gezichtspunten, belangen en invloed van de betrokkenen ondersteunt de deelstudie de bevinding dat bepaalde markt-gerelateerde factoren, samen met de sociaal-culturele dimensie, van invloed zijn op consumentenbeslissingen.

In de tweede deelstudie naar de adoptie van zonnewarmtesystemen door consumenten werd een empirische analyse uitgevoerd met concepten uit innovatie en diffusie- en uit milieupsychologische literatuur om “groen” consumentengedrag en besluiten tot groene innovatie beter te begrijpen. De verkregen resultaten lieten zien dat relatief voordeel, waarneembaarheid, voorkeur voor nieuwigheden en onafhankelijke oordeelsvorming in alle geteste modellen belangrijk waren. Dit ondersteunt het argument dat het combineren van theoretische noties vanuit innovatiestudies en gedragsstudies ons begrip verbetert van de besluitvorming van consumenten over het gaan gebruiken van nieuwe technologieën.

De derde deelstudie analyseerde de interne processen van “Strategisch Niche Management” die de ontwikkeling van zonne-energietechnologieën in Libanon vormgeven. Dit raamwerk werd toegepast om de marktvorming van zonne-energietechnologieën te onderzoeken vanuit een maatschappelijke context. De deelstudie maakte een vergelijking tussen de ontwikkeling van de marktniche bij zonnewarmte en zonnestroom. De resultaten laten zien dat de verwachtingen rond de ene marktniche van invloed waren op die rond de andere, en bijdroegen aan een efficiënt gebruik van kennis vanuit eerdere projecten. Het Strategisch Niche Management-raamwerk moet nog wel de contextuele aspecten van ontwikkelingslanden gaan omvatten. Al met al werd ook waargenomen dat internationale donoren een actieve rol speelden in de ontwikkeling van de marktniche door vorm te geven aan stimuleringsprogramma’s in het land. Dit was duidelijk bij hun steun aan het formuleren van verwachtingen en visies en door bij te dragen aan netwerkvorming in de niche.

Voortbouwend op de derde deelstudie, richtte de vierde deelstudie zich op de rol die bedrijfsmodellen spelen bij het introduceren van duurzame innovaties in de markt en het stimuleren van disseminatie ervan, en daarmee hun implicaties voor de diffusie van innovaties. Door de overeenkomsten tussen de interne processen van Strategisch Niche Management en bedrijfsmodellen op de gebieden van experimenteren, netwerken en leren, ondersteunden de bevindingen de notie dat bedrijfsmodellen een belangwekkende rol spelen bij het faciliteren van allerlei interne activiteiten in het nicheproces en bij de ontwikkeling van de markt. Drie voorbeelden werden uitgewerkt van de rol die bedrijfsmodellen in de Libanese context hebben gespeeld. Al met al werd

geconcludeerd dat hogere adoptieniveaus in de Libanese zonne-energiemarkt zullen worden bereikt door bepaalde beleidsmaatregelen voor de eindgebruikers die hun werkelijke behoeften in aanmerking nemen en de maatschappelijke omstandigheden waarin zij leven.

De focus van dit onderzoek en de bevindingen van de deelstudies in aanmerking nemend, wordt het als een belangrijk resultaat beschouwd dat de kennis van een omvangrijk diffusieproces wordt bevorderd door het verbinden van de zienswijzen op diffusie vanuit consumenten- en marktperspectieven. Als zodanig biedt dit proefschrift een multidisciplinaire analyse van het complexe fenomeen van de diffusie van innovatie. Tot slot bieden de uitkomsten van dit proefschrift inzichten in de academische literatuur uit zowel innovatie en transitiestudies en uit gedragsonderzoek.

About the author

Houda El Mustapha was born on March 3, 1989 in Tripoli, Lebanon. I am the youngest in a family of five. Looking up to my elder siblings often inspired me to achieve outstanding results in education. I obtained a Bachelor degree of Business Administration in Finance and subsequently completed a Masters degree in Marketing from the Lebanese International University in Lebanon. In my Masters' thesis I focused on consumer behaviour to environmentally friendly products in market and that was the time at which my interest in sustainable and green technologies started. After working for two years in an educational institute in Lebanon, I decided to continue my higher studies in the Netherlands. In September 2014, I started my PhD research at the Department of Governance and Technology for Sustainability (CSTM), University of Twente, the Netherlands. During my research I presented my work in a number of conferences and published my work in journals. I consider this as my starting point in the academic journey.