A Sustainable Energy Transition Case Study On Aruba

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A Sustainable Energy Transition Case Study on Aruba

Thesis Project

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Executive Summary

The risk of climate change and the need for a more sustainable world have attention in the 21st century. There is sufficient attention in the major developing and developed economies regarding secure, reliable, and affordable renewable energy (RE) (Jaramillo-Nieves and Del Río, 2010). However, SIDS are trying to balance economic growth, climate change impacts, and the fluctuations in energy prices, primarily because of their geographical location. Also, rising sea levels (climate change) directly affect islanders' lives, and thus, island governments have become strong advocates for reducing global CO2 emissions. However, while the potential of RE is immense in these regions, they are proceeding slowly; the Caribbean region is understudied. In most cases, especially, the socio-technical solutions are being left out of the research. Therefore, a sustainable energy transition (SET) case study on Aruba may provide opportunities to contribute to the transformation towards sustainability.

This research identifies opportunities to accelerate the SET towards a 100% RE based on Aruba. This thesis is structured in three parts: 1) a literature review to assess the main relevant theories. 2) A conceptual framework combining the Strategic Niche Management and the Multi-level Perspective is developed to analyse and compare case studies of RE technologies (Solar PV Rooftops, Electric Vehicle and Wind Turbines), including the external factors enabling or constraining this SET. 3) Finally, a roadmap is provided to accelerate the SET on the island of Aruba. Data collection is through literature review, desk research and semi-structured interviews with stakeholders in the actors' group (government, market and society).

The findings indicate that the development at the regime level on Aruba does not provide a "fully opened" window of opportunity yet since the developments are stabilised by using hedging and internal efficiency optimisation to cope with CO2 emissions, for example, shifting from HFO to LNG. Also, three internal complementary technologies are being explored within the regime to enable RE diffusion. The current energy mix on the island is 20% based on RE and 80% dependent on imported fossil fuel. However, landscape pressure is building because of climate change, oil dependency and the COVID-19 crisis, which may shift public opinion that could destabilize the regime and create more opportunities for the diffusion of the RE innovations.

There are two main drivers for the growth of RE innovations. One driver is the government vision related to the SDG's 2030 and 2050 goals. The second is the economic diversification that started in 2009 with implementing the first wind park Vader Piet.
There are barriers at all three levels constraining the SET on the island. The weak ties between WEB, Elmar, and users at the regime level is a barrier because the monopolistic state-owned utility company is responsible for bureaucracy and red tape, resulting in a fragmented energy policy and limited PV installation capacity policy. Also, RE backup is based on the fossil fuel source, and more EVs will require more RE. Still, electricity production is 80% dependent on fossil fuels. At the niche level, the demand side management is not ready to enable more RE and EVs, and there is a misunderstanding around RE benefits. There is resistance in society because some local NGO's can block RE (Wind turbines) projects, while there is limited land available on an isolated island setting. At the landscape level, Aruba is dealing with a refinery mentality.

Based on the barriers, possible actions are presented. To accelerate the SET: at the regime level, the **government** should introduce an independent entity and an energy policy where the network-related is aligned to support the targets and expectations. At the niche level, **utility managers** should implement energy storage and intelligent infrastructure to reduce the dependency on fossil fuels and enable demand-side management to create more room for RE penetration. At the landscape level, raising awareness, organise town hall meetings with pilot projects and demonstrations is necessary for society. Due to the limited space and land on the island, environmental impact assessments are required to mitigate the impact during the development process and **avoid social resistance**.
The education system should be upgraded to create new experiences, knowledge and information for **local society**. Hence, introducing a technical university is required but generally to change the teaching practice locally. The **government's responsibility** is to stimulate more research, create more RE demonstrations, and create funds.
The research conducted by the universities, local and international, could ultimately improve regulatory measures. **Utility and RE companies' managers** should consider that new business models will be necessary to survive in the new RE business environment. Other RET should also be explored, primarily because the current RET outcomes are unknown. The SET can be accelerated towards a 100% RE-based island by adopting these measures.

Acknowledgement

This thesis is a graduation project for the Master of Management of Technology. Working on this thesis has been challenging and rewarding. It would not be possible to complete this research without the help and guidance of many people. Our daily lives have changed drastically during these difficult times, and finalizing a thesis has not been easy. For this reason, I am deeply grateful for all the support I have received.
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I want to thank my parents, family members, and partner for their unending support, encouragement, and valuable advice throughout my years of study, especially while writing this thesis. This accomplishment would not have been possible without them. Thanks again to all who supported me for your countless love.

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List of Abbreviations

€:	Euro
AC:	Alternative Current
AWG:	Aruban florin
CO2:	Carbon Dioxide
COP21:	21st Conference of the Parties
CTA:	Constructive Technology Assessment
CWR:	Carbon War Room
DC:	Direct Current
DG:	Distributed Generation
DIP:	Department of Urban Planning
DTI:	Department of Technical Inspection
EV:	Electric Vehicle
GWh:	Gigawatt hour
HFO:	Heavy Fuel Oil
Hz:	Hertz
ICEV:	Internal Combustion Engine Vehicle
IGMS:	Intelligent generation management system
IPP:	Independent power producer
IRENA:	International Renewable Energy Agency
KEMA:	Keuring van Elektrotechnische Materialen te Arnhem/ Global energy consultant
kV:	Kilovolt
kW:	Kilowatt
kWh	Kilowatt-hour
kWp:	Kilowatt peak
LCOE:	Levelized Cost Of Electricity
LNG:	Liquefied Natural Gas
LOLE:	Loss Of Load Expectation
Max:	Maximum
MLP:	Multi-Level Perspective
MoT:	Management of Technology
MW:	Megawatt
MWp:	Megawatt peak
N.V:	Naamloze Vennootschap/ public limited liability
NGO:	Non-Governmental Organization
NIMB:	Not In My Backyard
PESTEL:	Political, Economic, Social, Technical, Environmental, and Legal
PV:	Photovoltaic
R&D:	Research & Development
RE:	Renewable Energy
RET:	Renewable Energy Technology
ROP:	Regional Official Plan
SDG:	Sustainable Development Goal
SET:	Sustainable Energy Transition
SIDS:	Small Island Development States

SISSTEM:	Sustainable Island Solutions through Science, Technology, Engineering, Math
SNM:	Strategic Niche Management
SUV:	Sport Utility Vehicle
TNO:	Applied Science Research Organization in the Netherlands
UA:	University of Aruba
UNDP:	United Nations Development Programme
V:	Volt
W:	Watt
WEB:	Water en Energie Bedrijf/Local utility company
WT:	Wind Turbine
WTTC:	World Travel and Tourism Council

1. Introduction

The risk of climate change and the need for a more sustainable world have attention in the 21st century. The Paris Climate Change Agreement, which entered into force on the 5th of October 2016, was a crucial moment for a transition (UNFCCC, 2016). The agreement marks the importance of a more environmentally friendly, largely decarbonized society. In order to do so, the energy sector needs to be seriously studied and fundamentally changed. One way to do this is by introducing more renewable energy (RE) into a country's energy mix. More RE establishes the need for a transition in the energy sector from fossil fuel to renewable energy.

Hence, the upcoming sections present a brief overview of the research scope and background. It starts with presenting the geographical scope overview of this thesis regarding the Small Island Developing States (SIDS) and provides some relevant contextual information on them.

1.1. Small Island Developing States (SIDS)

There is sufficient attention in the major developing and developed economies regarding secure, reliable, and affordable renewable energy (Jaramillo-Nieves and Del Río, 2010). However, this is not true for SIDS, which are arguably the most vulnerable to the global trends of population increase, rise in food and water, energy prices, and the creation of fragile ecosystems due to the ill effects of climate change (CWR, 2013). They rely terribly on fossil fuel imports for their energy needs and therefore are exposed to global price fluctuations that affect them severely. SIDS are trying to balance economic growth, climate change impacts, and the fluctuations in energy prices, primarily because of their geographical location. Due to this, they face isolation, remoteness, poor connectivity, and generally underdeveloped technological sectors (Daniel Arenas, 2013). Therefore, a sustainable energy transition (SET) will significantly help utilize local natural resources to power their energy sector. Also, the SET could incentivize the local economy by creating jobs in the electricity sector.

1.2. Common characteristics and problems of SIDS

SIDS face several issues in every sector; when narrowing down to the energy sector, the following can be said: There are approximately 52 of the 140 developing countries in the world that are islands and have a population of less than 5 million and a minimal gross national product (Alves et al. 2000). These countries have a unique set of economic, political, geographic, and environmental characteristics that set them apart from the larger developing countries. Insular and remote regions present some specific problems related to energy supply and share similar characteristics related to energy supply, including (Kristoferson et al. 1985):

- Lack of conventional energy sources
- Abundance of renewable energy sources
- Small size of the electricity market
- High dependency on fossil fuels
- Lack of economies of scale

The combined effect of these characteristics makes power production for SIDS expensive and bears financial risks in the long term (Hoyle, 1999; Mayer, 2000). Interestingly, SIDS can harness energy out of their renewable sources, which, as domestic resources, do not require costly fuel imports (Farinelli,1999; Weisser, 2004). The exploitation of such resources will be crucial soon to safeguard access to affordable and clean energy and preserve the island's ecosystem.

Moreover, there are other issues related to lack of a high tech sector or a lack of knowledge and skills, which are all familiar to SIDS and are inter-related to the energy sector's development and progress (Prochazka, 2012; UN-OHRLLS, 2011). However, the main paradox here is that even though SIDS have substantial RE potential, there has been limited implementation progress. Also, SIDS still rely on petroleum-based fuels for energy (Weisser, 2004). The following section discusses the problem statement that this thesis will cover.

1.3. Problem statement

Islands' dependency on imported fossil fuels and thus high electricity generation costs, combined with the most abundant renewable energy resources, makes a strong case for introducing renewable energy sources. Another practical reason to switch to renewable energy systems is to reduce dependency on imported energy carriers and change from centralized, monopolistic electricity generation towards a more decentralized, distributed production.

Also, rising sea levels (climate change) directly affect islanders' lives, and thus, island governments have become strong advocates for reducing global CO2 emissions. However, while the potential of RE is immense in these regions, they are proceeding slowly; the Caribbean region is understudied. Especially the socio-technical perspective are being left out of the research in most cases. A sustainable energy transition approach to the energy sector may provide opportunities to contribute to the transformation towards sustainability.

1.4. Aruba as case study

A connection is made to initiate a development that pushes towards a sustainable energy transition on the formally called Caribbean part of the Kingdom of The Netherlands, including Aruba, Curacao and St. Maarten, and the special municipalities Bonaire, Saba, and St. Eustatius. These islands are working hard to set and achieve their goals regarding moving towards a sustainable energy supply (CWR 2013). Aruba wishes to be a testing ground for innovative sustainable solutions (TNO, 2013) and a stepping stone for the Caribbean and South America (Gateway, 2013). Therefore, the choice has been made to focus on Aruba as a case study within this thesis. The next part states the activities that this thesis is going to cover.

1.5. Research activities

The research activities that will be analysed are the following:

1. Will present the current situation of the energy sector on the island of Aruba and provide the drivers and barriers regarding the sustainable energy transition to reach their target of 100% renewable energy-based from a socio-technical point of view.
2. Will zoom into multi-disciplinary stakeholders responsible for the energy transition and the linkage between them to speed up the transition.
3. Will present RE niches that play a key role during the energy transition.

4. Will use theories from SNM and the MLP to create a framework to analyse the situation.
5. Will provide a possible strategy to accelerate the sustainable energy transition.

1.6. Research objectives

This exploratory study will view Aruba's current energy sector situation. An analytical framework derived from the theoretical framework will support the empirical study during the analysis of drivers and barriers for the island of Aruba. Afterward, a recommendation is presented on accelerating the transition to achieve a 100% renewable energy goal. Based on the resource challenges that are characteristics of SIDS, this study will attempt to illustrate the opportunities to create energy security and new industry for the island. The knowledge gathered may add to the literature on renewable energy transition within the SIDS context.

1.7. Main research question

These objectives have led to the following research questions: **What is constraining the sustainable energy transition on the island of Aruba, and how can this be accelerated?**

Sub-research questions:

1. What is the current situation in the energy sector on the island of Aruba?
2. What are the main drivers and barriers that influence the transition?
3. Which niches/projects are being developed during the transition on the island?
4. How can the local government take action to accelerate the transition?

1.8. Research steps

Literature review: There is literature review initially conducted which gives two important parts of information. (1) The scope of the research and (2) the theoretical framework that can be used to perform the required research.
Conceptual framework: This will be implemented to perform the research and helps narrow the geographical scope down.
Data Collection: The research consists of primary and secondary data collection in order to answer the research questions. The primary data is based on interviewing key stakeholders within the electricity sector. The secondary data on the other hand will support the theoretical and analytical framework before and during the analysis process.
Implementation of the framework: The data collected by conducting interviews with relevant stakeholders will be analysed using the conceptual framework as indication.
Conclusion and Discussion: The discussions take place after the analysis section wherein the derived results will be compared to current literature. Then short conclusions will be presented, with a reflection on the used theoretical framework.

2. Theoretical Framework

The following chapter will present the relevant theories for this study. The theoretical framework consists of suitable theories to address the research problem to answer the research question. This framework will narrow down to transition management, the multi-level perspective model, and strategic niche management.

2.1. The Linear Model is not enough

One of the early theoretical frameworks developed for the justification of science and technology, that is also related to the economy, has been "The Linear Model of Innovation". The model states that innovation goes through a sequence of innovation diffusion. It begins with "Basic Research", afterwards "Applied Research and Development", and finally with "Production and Diffusion" (Hekkert and Negro 2011).

2.1.1. Neoclassical economics

The Linear Model has been very important. Academic institutions, as a lobby for research fund, and neoclassical economists, as expert advisors to policy-makers, had used this model to demonstrate, make people understand and to convince the government to support science (Hekkert and Negro 2011). Consequently, the linear model carried technology policies and academic studies for decades. Still, not a lot of people support such an understanding of innovation anymore: *"Everyone knows that the linear model of innovation is dead"*, claimed N. Rosenberg (Rosenberg 1994, Godin 2006). Actually, the phases defined in the linear model are real and important. However, these stages in innovation are influenced by a much broader environment in which the innovation process takes place and that due to this environment many feedback loops exist between the different phases (Hekkert and Negro 2011).

2.1.2. Evolutionary and Quasi-evolutionary economics

Evolutionary theories originally emerged as a reaction to the neoclassical economic theories. The main criticism they have on the neoclassical theories consists of three parts: 1) the use of information by firms were considered too simple, 2) the system was too static in a dynamic nature (no feedback loops), 3) and the exogeneity of technological development (Duysters 1995).

Schumpeter had introduced evolutionary theories in the 1930s and later on Nelson, Winter, Dosi, Lente and Rip in the 1970s, 1980s and 1990s further contributed on this topic (Raven 2005). Ideas about variation and selection of technologies and the concepts of technological niches also belongs to the evolutionary theories. According to Raven (2005), Strategic Niche Management and Constructive Technology Assessment can be considered part of the evolutionary theories on technological transition management.

As stated by Raven (2005), the quasi-evolutionary approach presented by Van den Belt and Rip (1987) consisted of three types of linkages. First, engineers and designers imagine the future *selection* within laboratories. They create *variations* on the idea of what they think the future selection environment will be. Thus, engineers' expectations is connected to the selection and variation context. Second, linkages can happen in a nexus, which means that the "selection and variation" processes are linked together in specific context. Third, actors can create a niche in order to have a protected space where the selection and variation process can occur without having too much competition or pressure from the current market. A niche is linked through users and/or other stakeholders who give input to engineers about the usage of technologies in practice in order to adjust the new technology to fulfil a certain vision created for a specific market.

2.1.3. Constructive Technology Assessment

SNM appears as a combination of evolutionary economics and Constructive Technology Assessment (CTA). The latter *"...was explicitly developed to explore methods for influencing technological development rather than for understanding and explaining it; it aims to derive policy and management consequences"* (Raven, 2005:35).
CTA was developed in a combination of different Technology Assessment methods in the context of a growing concern among several social groups about technology development, specifically regarding technologies with potentially large political, ethical or environmental consequences (nuclear power, DNA technologies) (Raven, 2005). It consists of three issues with reference to a new technology and therefore is likely to increase public acceptance. The first of these issues CTA takes into account, is the consideration of all stakeholders at the beginning of the technology's design phase (Schot, 2001). Secondly, CTA features *"...societal learning and anticipation of future consequences ... in the process of new technology development, including exploration of possible new linkages between a range of aspects such as designs, user demands, regulations, as well as societal acceptance and learning about underlying values and beliefs"* (Raven, 2005:36). Thirdly, CTA involves reflexivity during the process. Reflexivity means the ability of the actors included in the design process to imagine of the development of a technological and social design as two highly linked components. As a result, change in one design need to be analysed in terms of their influence on the other design (Schot & Rip, 1997; Schot, 2001).
Despite of its theoretical advantages, CTA hardly leads to benefits in practice, because stakeholders often face difficulties to present their demands in advance and if so, societal reasons are often not enough to change the design process (Schot & Rip, 1997). Consequently, SNM has been suggested as a combination of CTA and evolutionary economics that covers the drawbacks of both approaches (Schot & Rip, 1997).

2.2. Strategic Niche Management

SNM conceptualises the introduction of new technologies as the start of a broad and long-term transition process, in which widely used technologies with unsustainable factors are constantly replaced by more sustainable technologies in a dynamic structured process. The process implies selection and mutual adaptation of technology and societal factors, such as culture, institutions, consumption behaviour, regulations and political governance systems (Raven 2005, Van der Laak, Raven et al. 2007, Van Eijck and Romijn 2008).
SNM has been defined by Kemp and Schot et al. (1998:186) as: *"The creation, development and controlled phase-out of protected spaces for the development and use of promising technologies through experimentation, with the aims 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."*
SNM uses niches as a locus for connecting the variation and selection environment. It is a tool that can be used to analyse case studies (research purpose) and thereby understand the technology diffusion process. SNM can also describe energy policies (policy formulation) to guide technology development through desired directions and introduce breakthrough technologies in an existing regime (Raven, 2005).

The three internal niche processes according to Raven (2005) and Van der Laak al. (2007):
1) **Shaping of expectations**: Expectations are fragmentary and broad in the first place because different actors may have different perspectives and support different technological trajectories. The expectations are gradually shaped by the results of the experiments or by the participation of new actors. However, the most likely reason that causes the shift of expectations is the external factors. The expectations would become more powerful if specific, shared among different stakeholders, and supported by the experiments and research.

2) **Network formation**: The alignment in the network represents the scope of niche development. If alignment in the network is high, then the scope of niche development is more significant. Alignment does not occur naturally but requires extra effort. the composition of a network is essential for a niche to develop steadily. As mentioned before, there is a need for actors willing to invest in maintaining and expanding a niche. Large firms can take on this role as they possess capacities and resources. However, it is important to recognize if these established firms genuinely want to participate or have different reasons to join, perhaps disturbing the development.

3) **Learning processes**: An effective learning process could increase the chance of successful diffusion of the innovations by allowing improved technologies and social embedding. Many barriers hindering the development of a niche are related to uncertainty and perceptions. Hence, it is essential to learn about the needs and problems to overcome them, referred to as first-order learning. There are five dimensions that actors must focus on when performing experiments: Technical development and infrastructure, development of user context, social and environmental impact, industrial impact, and policy and regulatory framework. Also, there are four different learning categories: learning by searching, learning by doing, learning by using, and learning by interacting, respectively (Kamp, 2002). The purpose of learning by searching is to understand “why”, which is usually in a systematic and organized search for new knowledge. Learning by doing focuses on the “how”, which aims to gain tacit knowledge and the experience related to the artefact. Learning by using is intended to know “what”. This addresses the learning when using the product, which offers an experience and the characteristics from the users’ perspective. At last, learning by interacting is getting knowledge through the interactions with relevant actors in a physical or nonphysical meeting.

Interaction between the internal processes
It is crucial to understand the interactions between the three internal niche processes and how this paves the way to niche development. Figure 2.1 illustrates the dynamics between network formation, learning processes and expectations, transitioning a local practice into the emerging field (Geels & Raven, 2006).
Niche development is facilitated by sequences of projects that encourage frequent rounds of expectations, learning, and network building. Projects in local practices such as demonstration and pilot projects result in more outcomes and increase the involvement of actors (Geels & Raven, 2006). Stakeholders will lean towards investing more resources and requirements if there is a collective positive expectation of new technology, in line with shared cognitive rules, which will guide the project. More projects attract actors to expand the network and boost learning processes as actors share ideas among similar initiatives,

adjusting previous expectations. It is important to stress that the stability of expectations and visions depends on the interactions with learning processes and network formation. If outcomes of local projects are much below expectations, perceptions about a new technology initiative can quickly change, resulting in a shrinking network and decreasing resource availability. In turn, actors shift towards other technologies that have more potential to drive another innovation trajectory.
As all elements are interlinked, excluding one of the niche processes will block development. It also reflects that a niche is settled in the broader context to diffuse successfully into society. These specific layers must be identified and explored.

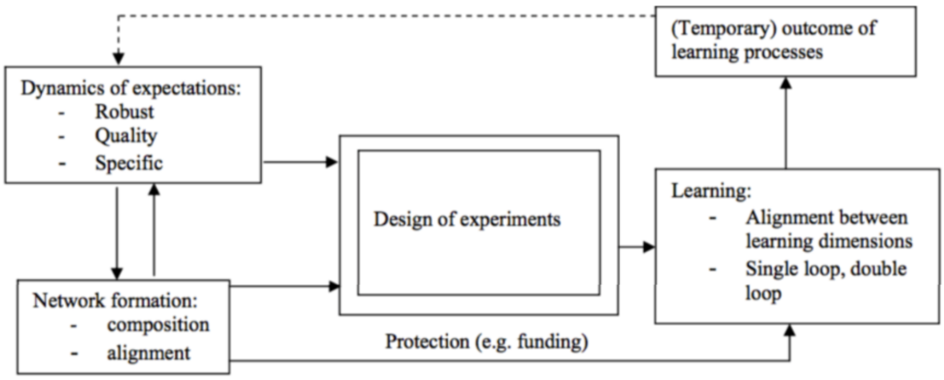

Figure 2.1: The SNM internal dynamic processes and feedback loop. Source: (Raven, 2005).

2.3. Multi-Level Perspective

In studies that focus on understanding technological transitions, the Multi-Level Perspective is dominant. The MLP studies the linkage between niche and the existing regime situated in a wider macro environment (Verbong and Geels 2007). The MLP consists of three levels. First, the macro level is presented as Landscape, second is the regime at the meso-level, and third is the niche at the micro-level. In order to have a technological Transition, all these three levels must interlink with each other. The following section discusses the four elements: niche, regime landscape and transition. The Multi-Level Perspective is illustrated in figure 2.2.

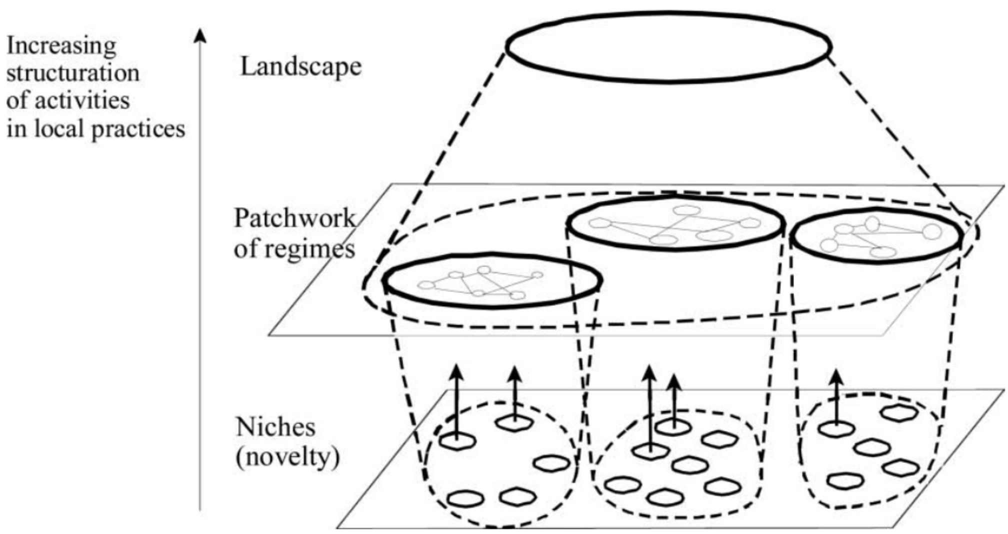

Figure 2.2: Multiple levels as a nested hierarchy. Source: (Schot & Geels, 2008).

2.3.1. Landscape

The socio-technical landscape consists of heterogeneous external factors, such as the rise of oil prices, economic growth, wars, broad political coalitions, and culture and environmental issues. Such events can occur during an extended period and are more difficult to change than regimes. The socio-technical landscape impacts regime dynamics and niches. It is greatly responsible for the regime's destabilisation, where the radical technology within a niche can make a shift to become a dominant one (Verbong and Geels, 2007, Rotmans et al., 2001, Geels, 2002). It is essential to mention that little can be controlled at the macro level of the socio-technical landscape, and changes are partially predictable.

2.3.2. Regime

Regimes can be considered broad but organized since they are based on incremental innovation and optimization between different actors using a dominant (selected) technology in a relatively stable atmosphere. The definition of the technological regime by Kemp and Schot (et al. 1998):182): "The whole complex of scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, and institutions and infrastructures that make up the totality of a technology."
The regime consists of three interlinked dimensions, according to Verbong and Geels (2007): a) a network of actors and social groups, b) formal normative and cognitive rules, and c) material and technical elements.
Since the regimes are mostly stable, the prior interest of scholars, such as Rip, Kemp and Schot, was in regime shift (transitions) and the circumstances that lead to the destabilization of existing regimes and the upcoming of new regimes (Markard, Raven et al. 2012). As mentioned before, a niche technology gets a chance to make a shift when a window of opportunity presents itself the moment a regime becomes unstable. Nevertheless, it is a long battle process for a niche technology to become dominant within a regime. Also, the incremental innovation in the existing regime creates an extra barrier for new radical technology to become dominant. External factors, such as climate change, oil prices, and wars can destabilize a regime. These external factors are embedded in the landscape level of the MLP.

2.3.3. Niche

The niches function as guidance in the take-off of a new regime and later for adaptations and learning processes around the new technology ecosystem (Rotmans, Kemp et al. 2001). Niches are vital for technological diffusion because new technologies will not survive without a niche. Building a protected space for an upcoming technology will allow the new technology to develop from an idea into an implemented technology. The new technology in practice is essential for the articulation and the learning process, learning about the potential of the new technology, and building a network around the product.
Since new technologies score low from the economic and technological perspective, protection is needed by small networks of players, such as entrepreneurs and start-ups, who are willing to support the development of the new technologies (Raven 2005). The most critical processes within a niche are 1) the building of social networks, 2) learning processes, and 3) the articulation of expectations to coordinate the learning processes (Raven 2005).

2.3.4. Transition

The internal dynamics in the niche are important, but they are not sufficient for a transition (Geels and Raven 2006). For a transition to occur, all three levels (niche, regime, landscape) must be aligned in order to reinforce each other (Rotmans, Kemp et al. 2001); (Geels 2002). Also, developments that cause instability at the regime and landscape need to occur, presenting a “window of opportunity” for the new technology to transition from a niche to a new regime. However, these opportunities do not occur at once. It is a cycle process that builds up slowly by following paths of niche-accumulation, i.e., experimentation, learning processes, adjustments, and reconfigurations in different niches (Geels, 2002). There are three phases at the niche level before the radical innovation can become a new regime:

1. The technological, niche where radical technologies are still in their early stage of development, for instance, Research & Development and demonstration.
2. The market niche, where there’s a variation of radical innovations that are available for selection, however, in a protected environment.
3. The existing market, where a niche technology has the possibility to be selected to become a new or part of the existing regime.

See figure 2.3 below. Therefore, the development of market niches will not automatically lead to regime shift (Hoogma et al., 2002). Such a broad transition cannot solely occur through niche development. It results from a combination of successful Strategic Niche Management, niche development, changes taking place on a broader scale within society, and the further development of more mature technologies.

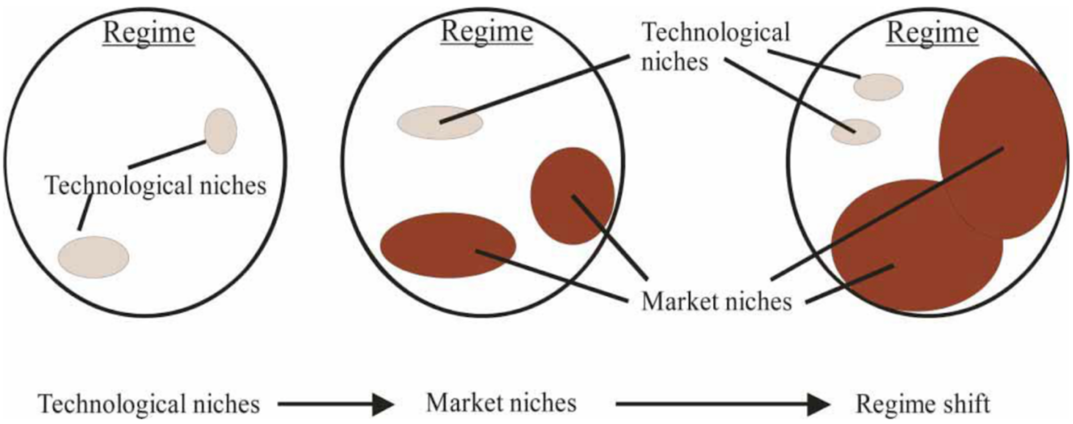

Figure 2.3: Transition from technological niche to a regime shift. Source: (Schot and Geels 2008).

Figure 2.4 is one of the most commonly used figures to demonstrate the MLP on transition. Two developments must occur for a market niche to diffuse into the regime. First, drivers such as price reductions due to economies of scale, complementary technologies, supporting infrastructures, positive attitudes toward technology, or an engaging actor-network are required. Secondly, landscape developments destabilizing a regime will create “windows of opportunities” for new transformation (Geels, 2002, Geels & Schot, 2007). As a result, a regime shift will appear to alter the dimension framework until stability is secured. Adjustments will include changes in lifestyles, policies, and regulations and are perceived as ‘normal.’ The new regime will ultimately influence the current landscape.

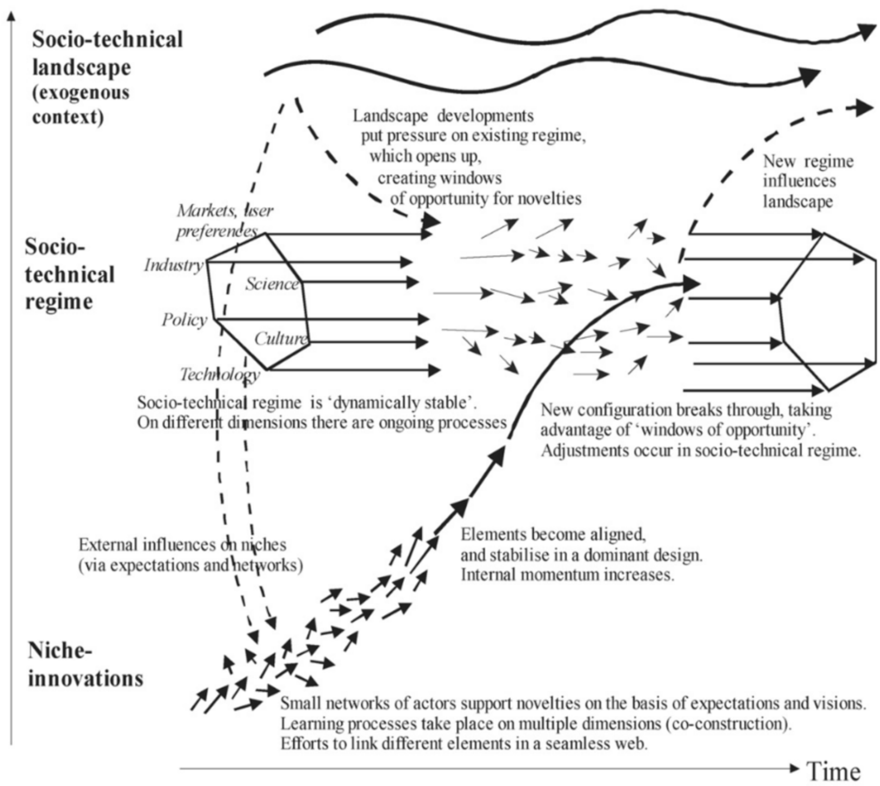

*Figure 2.4: The Multi-Level Perspective on transition. Source: (*Geels & Schot, 2007*).*

2.4. Conclusion

The SNM framework identifies three important internal processes within a niche: network formation, learning processes, and voicing expectations. The development of the RE niches is explored by studying the process interactions. SNM can be used both as research and as a policy tool. The latter is applicable to present the final roadmap to policymakers for accelerating the SET in Aruba.

A broader perspective is required to provide a clear roadmap through the different transition levels. Raven (2005) argues that for a niche to interact with the regime, solely adopting a SNM perspective is considered oversimplifying. Recently, numerous scholars have conducted research integrating the SNM with the Multi-level Perspective to provide a comprehensive analysis of the development of a specific niche. MLP looks at two additional levels in the socio-technical environment, namely the landscape and regime. As a result of pressures exerted by the landscape level, an unstable regime will create windows of opportunities for a niche to emerge, ultimately leading to a new regime configuration.

This argument implies that the SNM and MLP framework must be combined to examine the SET effectively. The interactions between these two frameworks will be discussed extensively in the following chapter. Ultimately, this will lead to the conceptual framework design applied to evaluate the case studies.

3. Conceptual Framework and Methodology

Based on the conclusions of the literature review and theory chapters, Chapter 3 will synthesize the information into a conceptual framework (3.1). The research methodology is subsequently developed and presented (3.2).

3.1. Conceptual framework

As aforementioned in chapter 2, a combination of Strategic Niche Management and the Multi-level Perspective is applied in this study. The two theories create a lens to analyse the SET in Aruba. The MLP facilitates the system analysis at the three levels, while the SNM focuses more on the niche and internal processes. Putting all together will obtain a comprehensive picture of the current situation. The conceptual framework is illustrated in figure 3.1.

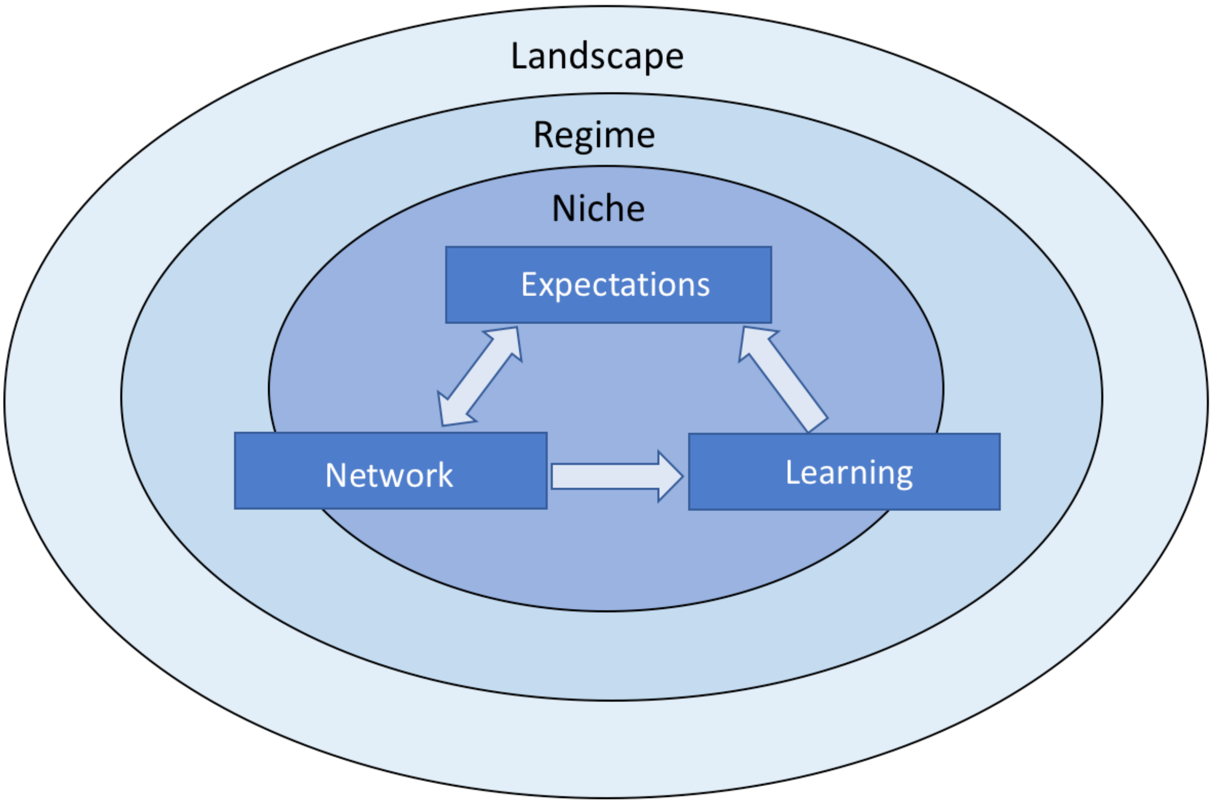

Figure 3.1: The analytical framework to analyse the SET on Aruba. (Source: own illustration).

3.1.1. The identification of the three levels

The first step is to identify the three MLP levels of the SET in Aruba. Currently, no comprehensive applied method could identify the three levels. Geels and Schot (2007) acknowledged that the empirical level of the research object should be demarcated before operationalizing the three levels. In this study, the levels were distinguished based on the research objectives and scope:

1. The cases are selected in the context of Aruba.
2. The regime level is decided to be the whole Aruban electricity sector.
3. The niche level represents Aruba's renewable energy systems, while the landscape is the external environment over the Aruban electricity sector.

3.1.2. Landscape and regime analysis

The first step identifies the changes and trends at the landscape level that stabilise or pressure the regime and niche. The second step is the stability of the regime and the factors at the regime level that could block or facilitate the breakthrough of the niche. The landscape and regime analysis should be performed before the niche analysis to give an overview of the drivers and barriers in the exogenous environment.

The socio-technical landscape

For the landscape layer, external factors include the rise of oil prices, economic growth, wars, broad political coalitions, culture, and environmental issues. All these factors are being obtained that influence Aruba's electricity regime and could destabilise the current regime and create a window of opportunity where the RE niches can diffuse.

The socio-technical regime

The regime consists of three interplayed dimensions, according to Verbong and Geels (2007): a) a network of actors and social groups, b) formal normative and cognitive rules, and c) material and technical elements. Therefore, for the regime analysis, three categories are presented according to Verbong and Geels (2007) and adapted to the Aruban context:

- **Network for actors:** Local government, market and society. A stakeholder analysis will obtain the required information.
- **Institutions:** Rules and belief systems, standards regulations, policies.
- **Technologies:** Reciprocate motors, stream turbines, wind turbines, solar PV.

Stakeholder analysis

There are three groups of actors:

1) *Local government*: Ministerial departments of government such as advisory committees, legislative and regulatory bodies, planning departments.
2) *Market*: vertically-integrated supply companies and private market based companies e.g. hotels, renewable energy installers and private consultants
3) *Society*: non-governmental organizations (NGOs), trade unions, and end users of products supplied by market.

The MLP aim to focus on innovation from all three groups of actors and is inclusive of a broad range of coalitions of actors that create dynamic supply and demand networks. Actors can be international institutions, such as development banks, local government ministries or even local residents.
Also, it is important to categorize the actors that are interested in this research. For the Management of Technology program it is important to give recommendations to government, managers and society. Therefore, these three groups are connected to the stakeholder analysis and is also connected with the conceptual framework.

PESTEL framework

In this research the PESTEL framework will be utilized to give a broader perspective during the transition phases. PESTEL stands for Political, Economic, Social, Technological, Environmental and Legal; this analysis method is widely used in business to understand the macro environment that they are working in. First, the framework will be used to classify the interview questions. Second, during the interview, the framework is used as a checklist to make sure that all fields are discussed. Third, once the interview data are collected, the framework factors' will be applied to categorize the results for the barriers and drivers that were encountered. So in this context, each term could be defined as the following (Widya Yudha, Tjahjono et al. 2018). The political factors (P) that establish the extent to which the government may influence the energy industry. The factor for this can be whether there is consensus within the different political parties regarding the policies for the energy industry, and whether there is political stability. The economic factors (E) that directly or indirectly affect the energy industry. The factors can be economic growth, interest rates, exchange rates, inflation rate, unemployment rate and many more. The social factors (S) are cultural trends, environmental concerns of the public, usage of public transport, adopting energy efficient measures, age distribution, population growth rate, education level and many more. The technology factors (T) are R & D, maturity of technologies, potential of technologies, rate of technological innovation and diffusion, current sources of energy, current sources of consumption of energy, etc. The environment factors (E) are weather, climate, forests, dunes, lagoons, climate change, and many more. Basically, if any RE infrastructure needs to be implemented, then it needs to take into consideration all of this. Lastly, the legal factors (L) are laws, regulations and rules that are specifically made for the energy industry. These different pressures can then be utilized in the MLP to identify the landscape, regime and niche factors.

3.1.3. Niche analysis

The niche analysis includes the analysis of the three niche internal processes: shaping expectations, network formation, and learning processes, see figure 6. As aforementioned in chapter 2, most SNM research analyses the success and failure of the niche experiments through the performance of these internal niche processes (Raven, 2005; Schot and Geels, 2008). Each of the three processes is an important characteristic of the overall niche development. The analysis of these processes could help identify the problems of the niche development in a more comprehensive and structural way. In this study, the niche analysis is divided into two parts: the historical development and the current development of the SET in Aruba.

Network Formation

In this research, the network analysis is aimed at understanding the network composition of different niches in the SET and identifying whether the interaction between stakeholders is aligned (the network alignment). To understand the composition of the network, a stakeholder analysis will be performed to identify the involved stakeholders. The dynamic and the alignment of the network will be identified and analysed based on the qualitative data collected from online resources and the interviews. The outcome of the network analysis could help to understand the SET regarding the niches/projects and provide the basis for the expectation and learning analysis.

Network Composition: a stakeholder analysis is conducted to identify the network composition. The analysis of the composition eventually focuses on 1) the stakeholder composition in the current stage of the niche; 2) how these stakeholders are related to the SET.

Network alignment: the strength of the network is analysed by its alignment. Network alignment could be enhanced by the close connections between different stakeholders. It is evident that the well-managed interaction between stakeholders can strengthen the linkages and contribute to the stability and robustness of the network (Van der Laak et al, 2007). In this study, the alignment of the network is evaluated by identifying and evaluating the interactions between different stakeholders, such as whether the interactions between the stakeholders have stimulated engagement, trust and results on certain issues.

Table 3.1: Network formation indicators

Networking	
Composition:	Stakeholders with resources and multi-disciplines
Alignment:	Refers to the degree to which stakeholders' strategies, expectations, beliefs, practices, visions, and so on go in the same direction, run parallel.

Shaping of expectations

Hoogma et al. (2002) stated that the shaping of expectations are good if the expectations are shared (robustness), credible (quality), and specific. The evaluation of these three different characteristics (robustness, specificity, and quality) could contribute to analysing whether the expectation is powerful enough to guide future niche development. However, prior to the evaluation, the expectations held by different stakeholders should be firstly identified from different categories. These categories will be introduced in the "learning process" section. Identifying the expectations could help identify whether the expectation in each part has promoted the corresponding learning process and generated any knowledge.

Robust: the robustness of expectation refers to the number of stakeholders that share the same expectation. The expectations are more robust if more stakeholders share them. A more robust expectation could contribute to establishing the mutual interest between stakeholders, enhancing the actors' commitment and the stability of the network. The robustness of expectation will increase if the expectation is shared by more and different kinds of stakeholders (Raven, 2005).

Specific: If the expectation is specific, it could be evaluated by whether the actors in the network have a clear view of what step should be taken next to develop the technology to realize the expectation. A specific expectation is more trustful and could give more precise guidance on the niche development (Raven, 2005).

Quality: the quality of expectations is closely related to the robustness and specific side of the expectation. It could be evaluated from whether the expectation is supported by several experiments or research reports (Raven, 2005). The quality of expectation is good if the expectation is backed up by the trustful results from the long-term experiment (Van Eijck and Romijn, 2008).

Table 3.2: Expectations and indicators

Expectations	
Robust:	When a larger variety and larger number of relevant actors share the same expectations
Specific:	Clear which step should be taken in developing the technology to realize the expectations

Quality:	More experiments to support actors expectations

Learning processes

Experiments on a certain technology can be conducted for instance to learn from a technical or economic perspective. In a common situation actors learn from experiment and then improve technical or social aspects. Therefore, the connection between experiments and learning is a constant loop that is connected from each other. The four learning dimensions by Kamp (2002) in combination with the SNM learning processes by Hoogma et al (2002, as cited in Raven, 2005) are presented in order to have better understanding on the learning processes, expectations and network.

The four learning categories presented in table 3.3 are adapted to Aruba's energy and transport sectors and will also analyse the niche experiments. The learning processes indicators are a combination of Kamp (2002), Hoogma et al. (2002, as cited in Raven, 2005) and Geels (2004):

Learning by searching

In search for new knowledge/market during research and development process, also known as R&D, searching for new technological/market options, testing them, and testing their feasibility. Searching for a distribution network, complementary technologies, and required infrastructure. They are also known as technical and market development and infrastructure.

Learning by doing

Also known as know-how, learning by doing generates knowledge. This address the learning at different industrial sectors (production, distribution, maintenance) and business model when the technology has been implemented in the market, also known as industrial development.

Learning by using

The learning by using involved users and developers of the technology. The learning about user characteristics, their requirements, their meanings to new technology, and their barriers when using. Also, the societal and environmental impacts are taken into account during this learning process.

Learning by interacting

Learning this aspect entails regulations (which produces trust), quality norms, laws, policies and possible incentives. Developing government policy, regulatory frameworks and collaborations are crucial in this learning process.

Table 3.3: Learning processes indicators

Learning processes	
Learning by searching	Market research and development
Learning by doing	Capacity building for industrial development
Learning by using	Awareness and social acceptance
Learning by interacting	Policies regulations and collaborations

3.2. Methodology

The research consists of primary and secondary data collection in order to answer the research question. The primary data is based on interviewing key stakeholders within the electricity sectors. The secondary data on the other hand will support the theoretical framework before and during the analysis process.

3.2.1. Case Study Selection Criteria

Criteria for selecting the case studies include individual projects located on Aruba categorized as RE technologies and are part of the SET on the island. The case studies were selected through an online website and the author's curiosity. The Solar PV Rooftop, Electric Vehicle, and Wind Turbine technologies were selected as cases. The three technologies/projects are all located on the island of Aruba and meet the criteria.

3.2.2. Primary data collection

Data should be collected from different sources. Therefore, different interview questions are made to answer the research questions. The three levels from the conceptual framework are used as a guideline to formulate the interview questions, see appendix A. Other stakeholders were selected as potential interviewees based on the experts' recommendations. This approach is also known as snowball sampling. Several semi-structured interviews will be carried out to obtain the necessary data for this study. The list of interviewees that participated in the primary data collection for this research is presented in table 3.4.

Table 3.4: List of interviewees that represent the electricity sector on Aruba.

Ref in text	Function
Stakeholder #1	Technical affairs manager at WEB. Working for 22 years at WEB.
Stakeholder #2	Director for 2 years at Utilities Aruba. Electrical engineering as background. Policy advisor at Utilities Aruba. Working for 3 years at Utilities Aruba.
Stakeholder #3	Business policy and development at Elmar. Worked in the refinery for 5 years as senior project engineer production and distribution.
Stakeholder #4	Technical support at WEB with 10 years of experience.
Stakeholder #5	Operation manager at WEB, chemical engineering background.
Stakeholder #6	Private solar installation company. Electrical engineering background.
Stakeholder #7	Private consultancy in sustainability. Ex TNO employee. Chemical engineering background.
Stakeholder #8	Private engineering company: Ace Firm, managing director. Chemical engineering background.
Stakeholder #9	Head of department for power generation. Has 28 years of experience.
Stakeholder #10	Technical support at WEB, with 14 years' experience in WEB.

Stakeholder #11	Private company: Wernet solar solution. Operation manager with nine years of experience. Mechanical engineering background.
Stakeholder #12	Private company: Activated Power. Managing director.
Stakeholder #13	Department of infrastructure and planning: Director.

3.2.3. Secondary data collection

The literature review will be conducted using different tools. The search engines, such as Google Scholar and Scopus, are used to gather relevant articles. Nevertheless, keywords are used to narrow down the plotted results, while citation can also be an important factor in determining an article's relevance. The focus during literature search should be on the most cited articles and the latest to guarantee an up-to-date study.

3.2.4. Research ethics

Before each interview, the interviewee will be asked for permission to record the interviews, and their decision will be respected. Furthermore, all respondents will be asked if they would like to receive an interview transcription after the interview. Additionally, the respondent will be asked for their name to be used while quoting their statements in the thesis.

3.2.5. Data Processing

In table 3.5, the actors' groups are illustrated with the interviewed stakeholders. Transcriptions are coded according to the SNM and MLP indicators using Excel sheets. The SNM framework codes are used to code the case study actors' group interviews. Instead, the MLP framework codes were used primarily for the external actors' group but could also be identified in the prior group of actors.

Table 3.5: Interviewed case study actors group and external actors group

Actors group	Stakeholders number
WEB	#1, #4, #5, #9, #10
Elmar	#3, (#12 ex-employee)
Utilities	#2
Private Solar PV installation company	#6, 11
Private EV company	#12
Private engineering company	#8
Consultancy/ex TNO employee	#7
Spatial planner institute (DIP)	#13

3.2.6. Expected research sequence and reporting

The main research question is supported by four research sub-question. These sub-research questions that will answer the main research question. Below each sub-research question, the main topics are presented that will be discussed in this research.

1) What is the current situation in the energy sector on the island of Aruba?
   - Socio-technical landscape analysis
   - Socio-technical regime analysis
   - Socio-technical niche analysis

2) What are the main drivers and barriers that influence the transition?
    - Additional enablers and barriers
3) Which niches/projects are being developed during the transition on the island?
    - Network formation analysis
    - Shaping of expectation analysis
    - Learning processes analysis
    - Cross-case analysis
4) How can the local government take action to accelerate the transition?
    - Acceleration roadmap

3.3. Conclusion

The methodology and the conceptual framework is presented above. The conceptual framework is a combination of the SNM and MLP that are suitable to filter the information gathered in different steps. First, the three levels of the system are identified. Second, the relevant actor groups are brought into picture. Third, the drivers and barriers are mapped. Fourth, the RE niches will be presented and compared based on the SNM's indicators. Finally, a roadmap and strategy towards a SET based on interviews and secondary data will be presented.

4. Multi-level Perspective Analysis

The analysis of the socio-technical levels continues by studying the socio-technical landscape and regime levels in section 4.1 and section 4.2, respectively.

4.1. Socio-technical Landscape Analysis

The landscape level includes the developments occurring at the macro-level that in turn (de)stabilize the regime (Smith et al., 2010). Here, the landscape is defined as the national landscape of Aruba.

The Aruban economy is almost completely dependent upon its tourism industry. According to the World Travel and Tourism Council (WTTC) in 2019 tourism accounted for 73.6% of Aruba's GDP of AWG. 3,8 billion (€1,9 billion) and generated 84.3% of all employment (WTTC, 2020). Aruba has a labour force of about 58,000 persons. The WTTC estimated that visitors spent AWG. 3,5 billion (€1.75 billion) in Aruba in 2019 (WTTC, 2020). Over 1.5 million tourists per year visit Aruba with 63% of those from the United States (WTTC, 2020). The corona crisis has impact the tourism economy around the world and especially SIDS that are heavily dependent on this industry resulting in an economic crisis on Aruba (IMF, 2021). In the past the oil refinery represented major economic activity on the island too. Since 2012 there was no refinery operation anymore on the island. Nowadays, oil products are imported for the electricity generation and for transportation. Total imports of oil products amounted to AWG. 285 Million in 2017 of which AWG. 170 Million for fuel imports for electricity production (Rethink, 2019). The energy-sector is therefore relevant as a potential driver for enhancement of the balance of payment and also for stimulating overall economic growth. Moreover, the oil dependency brought many challenges as oil prices became unstable and many threats to the environment made it clear that this dependency was not the solution for the future of the island and that the transition to a sustainable economic development is a more responsible path to take.

4.2. Socio-technical Regime Analysis

Regime consists of three interplayed dimensions, according to Verbong and Geels (2007): a) a network of actors and social groups, b) formal normative and cognitive rules, and c) material and technical elements. Therefore, for the regime analysis three categories are presented according to Verbong and Geels (2007) and adapted to the Aruban context.

4.2.1. Institutions and policies

Aruba's electricity sector is characterized by state-owned utilities. WEB Aruba is the power generation company and N.V. Elmar is the distribution company. Both are owned by the government holding company, Utilities Aruba N.V. The overview of the local utility structure is presented in figure 4.2. These stakeholder can be consider key stakeholders in the electricity regime and are discussed in stakeholder map in section 4.2.3.

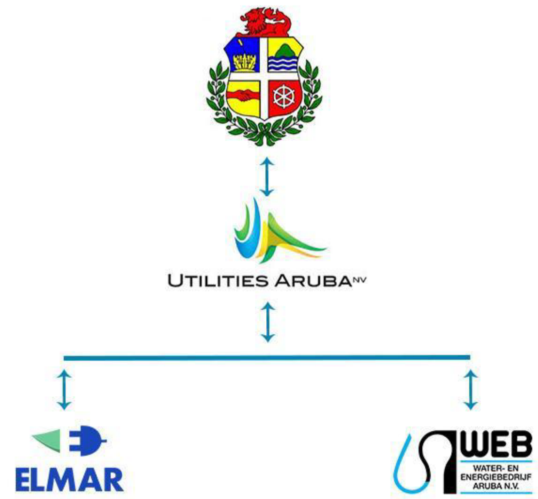

Figure 4.1: Local utility structure (WEBARUBA, 2019)

Aruba, as a Small Island Development States, has long acknowledge that the dependency on fossil fuel and its historically volatile price fluctuations creates uncertainty for cost of living and for economic growth. However, Aruba remains dependent on import of fossil fuels since 80% of electricity is being generated by heavy fuel oil. This leaves Aruba vulnerable to global oil price fluctuations and underscores the need to further pursue the sustainable energy transition. This section present a perspective of the energy sector on the island of Aruba.

The current consumer (tier 1) price tariff is a standard at rate of AWG. 0.31, or € 0.15 per kWh (Elmar, 2020) compare to € 0.15 per kWh in the Netherlands (GPP, 2021). In figure 4.2 the price (AWG.) of 590 kWh electricity usage a month is illustrated on different islands in the Caribbean. Aruba has the lowest price compared to the other island that are also dependent on fossil fuel to generate electricity.
In Aruba, there is no distinction between a day / night tariff . The electricity grid operates at a standard outlet 120 voltage single phase and 220 voltage two or three phases. Most homes however are equipped with a 220V outlet, for e.g. an air-conditioning unit and the grid frequency of 60 Hz.

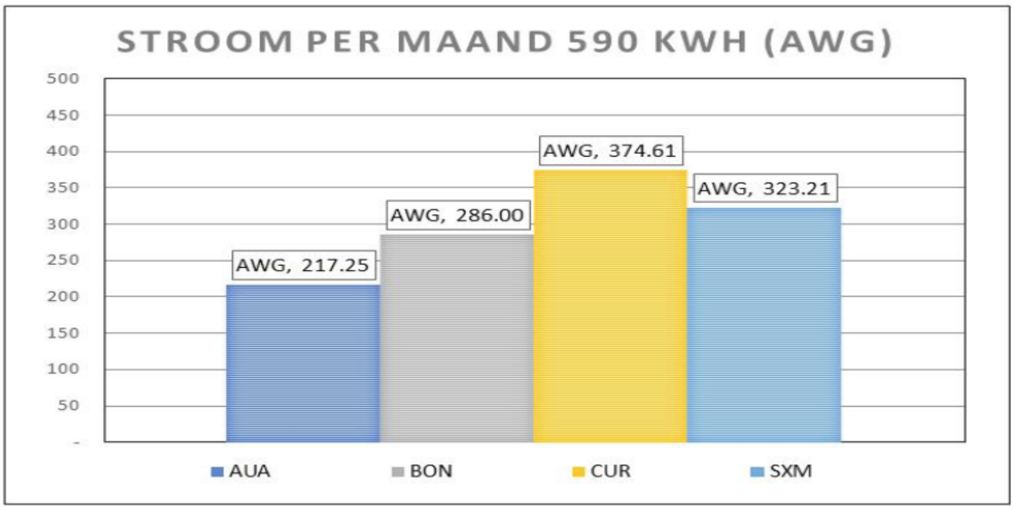

Figure 4.2: Electricity price in Aruba, Bonaire, Curacao and Sint Maarten (WEBNV, 2019)

The electricity generated by WEB is currently based roughly 80% fossil fuel and 20% renewable energy, see the left pie chart in figure 4.3. The energy consumption is represented by three sectors, residential by 40%, small commercials by 27%, and large commercials by 31%. It is important to mention that this overview does not represent the distributed generation (DG) technologies such as Solar PV Rooftops. The DG will be discussed next.

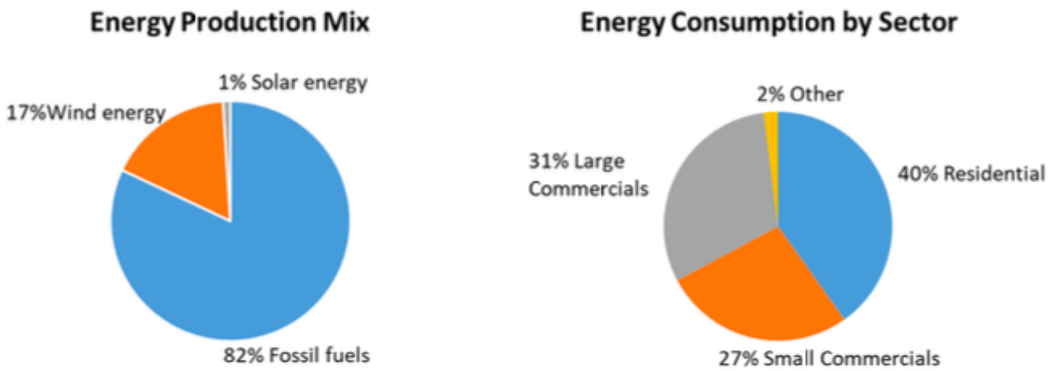

Figure 4.3: The energy mix and the energy consumption per sector (WEB, 2018).

The tourism/commercial sector is responsible for a third part of energy demands with the large hotels on the island. In addition, there are various smaller hotels and tourism establishments such has restaurants and entertainments.

Distributed generation

The government of Aruba introduced a Distributed Generation (DG) policy in 2012. The DG-policy allows for residential and commercial solar and/or small-scale wind. The policy restricts residential installations to a capacity of 10 kW max and commercial installations to 100 kW max. The DG-policy has led to an uptake between 2014 and 2019 of approximately 6.0 MW installed capacity, see figure 4.4. However, according to Elmar, the total solar rooftop PV installed capacity is 10+MW (Stakeholder #3). Probably, the government took the first step in the beginning, to lead by example, and could be explain for the missing 4MW installed capacity not presented in this figure below.

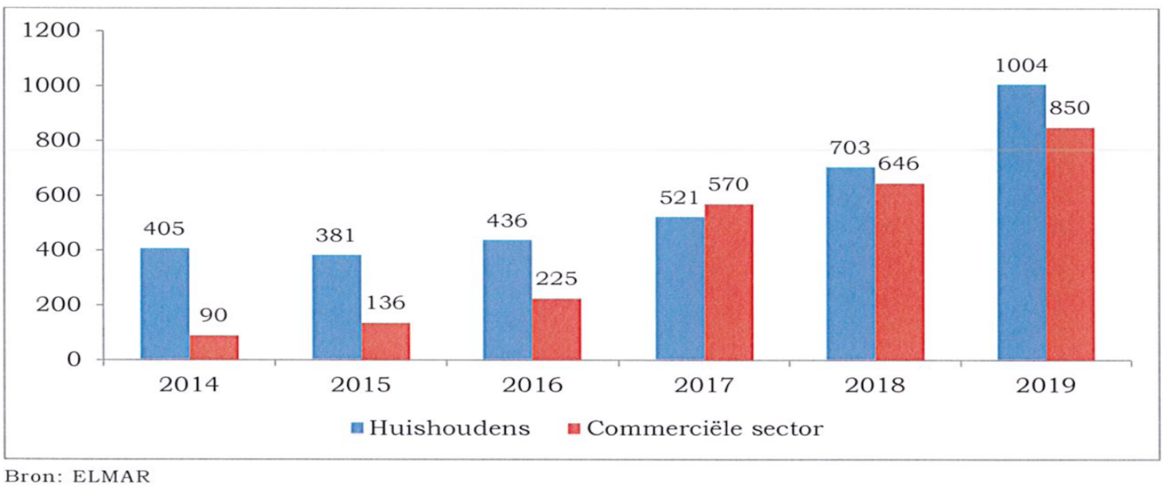

Figure 4.4: Total solar PV capacity installation in kW (SER 2020).

4.2.2. Technologies

The electricity system represented by WEB Aruba has an installed generation capacity of approximately 230 MW and is characterised by an approximate 107 MW average production, although a multi-year estimate of 100 MW has been widely used in communication. These numbers result in 934 GWh of energy consumed per year. Only 860 GWh of this produced electricity is delivered to consumers, the rest can be accounted to grid transmission and distribution losses (8% loss) (Bluerise 2013). All the relevant factors of the electricity generation system is presented below in table 4.1.

Table 4.1: Overview of electricity generation system

Factors	Quantity	Unit
Total installed capacity	230	MW
Average production	107	MW
Total generation	934	GWh
Renewable share	20%	

Power production

The electricity system is a stand-alone power system, which generates, transmits and distributes all of its demanded electricity to its end consumers. As seen in the previous section, different actors control different parts of the electricity system.

List of installed fossil fuel based technologies and capacity

• 2 Thermal Power Producers	2x30 MW	(60 MW)
• 16 Reciprocating engines	6x 17 MW	(120 MW)
	4x 11.3 MW	(45.2 MW)
	6x 7.8 MW	(46.8 MW)
• 1 Gas turbine	1x 22 MW	
• 1 Back-up diesel generator	1 x 20 MW	

Renewable energy system at large scale & DG

• 10 Wind turbines	10 x 3 MW	(30 MW)
• Airport solar PV park	14000x250 W	(3.5 MWp)
• Sun Rise solar PV park	24000x250 W	(6 MWp)
• Solar PV Rooftop	10+ MWp	

In the niche analysis of the Solar PV Rooftop will be discussed in chapter 5 and the Wind Turbine niche analysis will be discussed in chapter 7. The Solar PV parks are not part of this thesis research.

Operational efficiency and renewable energy

On the island of Aruba, the biggest progress in the energy system so far have been made through operational efficiency, more than with renewable energy. This implies replacing generation assets with more efficient machines. WEB projects in the last 10 years consists of replacing of it power plant generators meaning replacing steam turbines to reciprocating engines because of efficiency and more renewable energy friendly integration (Rethink,2019 Stakeholder #1).

These steam turbines and reciprocating engines currently use heavy fuel oil (HFO) as fuel and the latest reciprocating engines are compatible with liquefied natural gas (LNG) too. LNG is considered a transition fuel for WEB in the near future (Stakeholder #1, #2, #5). The estimated fuel consumption for the current situation - excluding renewable energy supply-related to electricity and water production is around 3300 barrels/day, while producing the same amount of electricity see figure 4.5. The CO2 emissions are around 1800 ton/day representing a value of roughly 750 g CO2/kWh (Moorman 2017),(using an annual production of 934 GWh).

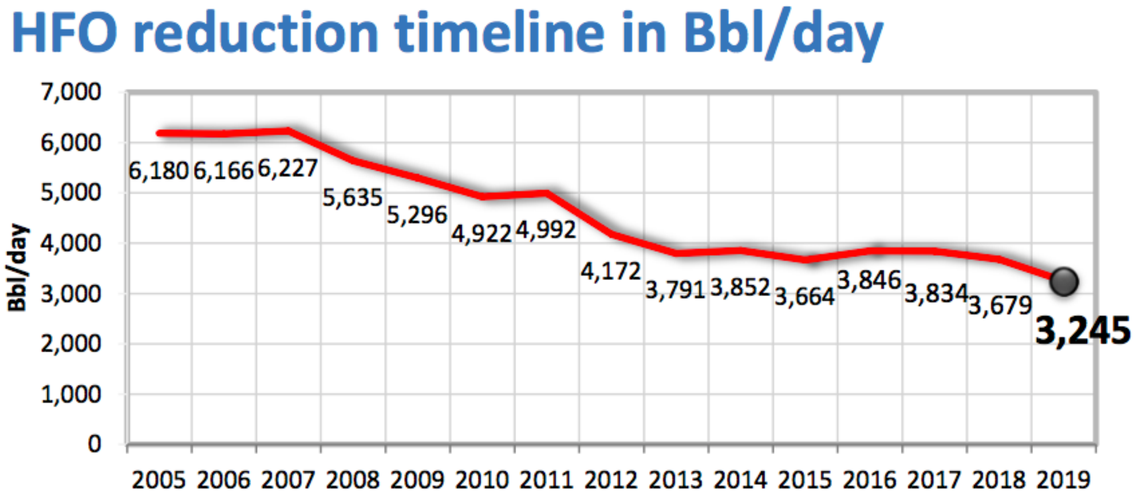

Figure 4.5: Timeline of HFO reduction, as part of electricity produced (WEB, 2019).

Renewable energy

In 2008, WEB has started with preparations for the integrating RE into their production mix and in 2009 the Vader Piet wind park came partly online. At Aruba's international airport, 14,000 solar panels are installed that cover the entire parking area and started operating in 2014. This entails a 3.5 MW installed peak capacity, which provides energy equivalent to the demand of roughly 500 homes (GreenDeck, 2015). The construction of the "Sunrise Solar Park" in San Nicolas is in its execution phase, with an investment of €10 million (AWG. 20 million) by WEB N.V (EPA, 2019). This solar park has a capacity of 6 MW peak. These renewable energy projects represent around 20% of the total energy supply, see figure 4.6.

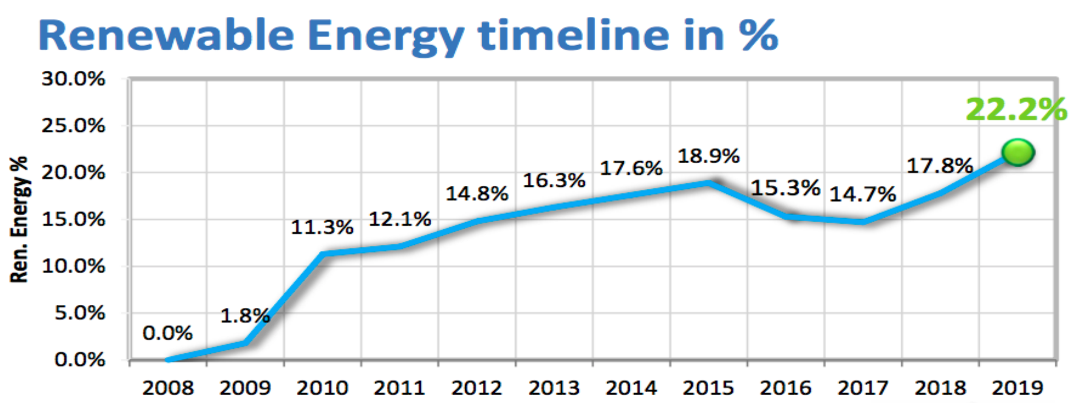

Figure 4.6: Timeline of growing renewable energy share, as part of electricity produced (WEB, 2019).

4.2.3. Actors groups

In this section, the stakeholder mapping is presented by analysing the social actor groups of the electricity system. These stakeholders influence the shaping and direction of the transition in various degree. Different elements of the transition and technologies are controlled or steered by various stakeholders and the implementation of the technologies also affect these stakeholders. These stakeholders are broadly categorized in social actor groups according to Verbong and Geels (2007): government, market and society.

Government

Local government

Local government plays an important role in stimulating renewable energy technologies for example Solar PV Rooftop, directly through subsidies and favourable policies and by creating appropriate innovation system on the island. While subsidies and tax benefits can be the most visible and direct form of intervention by the government to promote RE, long term policies to develop the innovation systems framework can be the most significant contribution from local government perspective. There are two ministries that are responsible for the development of these projects: 1) The minister of General Affairs, Integrity, Government Organization, Innovation and Energy. 2) Ministry of Regional Planning, Infrastructure and Environment.

Minister of General Affairs, Integrity, Government Organization, Innovation and Energy

The Minister of General Affairs, Integrity, Government Organization, Innovation and Energy has a pioneer role, but is also responsible to set the general government policies towards sustainable development including the energy policy.

The Ministry of Regional Planning, Infrastructure and Environment (DIP)

The Ministry of Regional Planning, Infrastructure and Environment is responsible for aligning its plans by brainstorming with different stakeholders to create a balance for sustainable (energy) development and the increasing population.

The Minister of primary sector and transportation

The minister of the primary sector and transportation is responsible for enabling the EV market and the minister of energy to facilitate the SET by aligning their visions within an energy policy.

Market

Utilities Aruba

This is the main company responsible for implementation. Utilities Aruba acts as an intermediary between the government and WEB and Elmar, and is sole shareholder of WEB N.V. and N.V. Elmar, and acted mainly, as a guarantor and/or to guarantee the loans of these entities (Utilities 2019a). Utilities' leading role is supervising the energy transition towards her working entities (Utilities 2019a).

WEB
WEB N.V. is responsible for Aruba's generation and transmission of the country's electricity. Power is also produced at another facility, and sold to WEB Aruba N.V., by other independent wind power producer (Utilities 2019a).

Elmar
N.V. Elmar owns the power transmission and distribution grid and is responsible for the distribution of the electricity that it buys from WEB N.V. On the sustainability target, regulations have been adapted, to permit renewable energy sources to be connected to the grid, and any "surplus" of energy by this source, is bought by N.V. ELMAR, while N.V. ELMAR is also buying in power from other independent solar power producer (Utilities 2019a).

Centre of Excellence
Centre of Excellence provides networks and platforms to export knowledge on sustainable development practices and renewable energy to other SIDS in the Caribbean and beyond (CoE 2016). Also assist countries in building roadmaps which involve issues arising from COP 21 in Paris. This organisation also helps with the implementation of the 17 sustainable development goals (SDGs) into the governmental policy making process.

KEMA
An energy consultancy company plays and important role when DG are being introduced. The grid capacity for the introduction of Solar PV Rooftops is crucial for Elmar in order to provide a DG policy (Stakeholder #3).

TNO Caribbean
The Dutch Organization for Applied Scientific Research (TNO) helps Aruba with projects as well as with identifying opportunities for the island and is supporting Aruba to achieve its goals for renewable energy with applied technology research together with (local) partners.

Solar PV installers
Companies which help in installing the Solar PV Rooftops who are important stakeholders of the SET. While installation may seem less complicated because the solar panels are located on the rails connected to the rooftop, yet new knowledge would be required to install the system as a whole.

Banks
Financial institutions such as banks can make loans to facilitate investments in solar PV Rooftops, EV technology, or other renewable energy systems. RETs are capital intensive and most banks could be a facilitator regarding the investment.

Society

Carbon War Room
Aruba's partnership with the Carbon War Room (CWR) started Aruba on the road to 100% sustainability. The CWR is an international NGO that attempts to find market-based solutions to the challenges of global warming. Aruba and the Carbon War Room work together to find solutions to the challenges that the transition to sustainable energy

brings. The CWR was later joined by the Rocky Mountains Institute, the Clinton Climate Initiative and the International Renewable Energy Agency (IRENA)

Environmental NGOs

Environmental NGOs, depending on their work areas, can have two different stakes about solar PV. On one hand NGOs work in energy sector promote RE as a source of clean energy and will be for it. On the other hand environmental NGOs work for flora and fauna might be against RE as it will have impact land used by birds and plants.

Citizens

The population on the island that need electricity to do their basic activities or business. Introducing renewable energy could mean more stable, and perhaps in the future a more affordable energy, and a cleaner environment for its citizens.

Prosumers/consumers

Distributed Generation (DG) regulations were stipulated and opened the possibility for consumers to install solar panels on their roofs, while any excess of energy, would be sold to the grid owner (Elmar). Households and business were therefore no longer passive consumers of energy provided by the grid, but instead became energy "prosumers".

Media

Issues such as climate change, sustainability and renewable energy are shaped to some extent by media reports, and media has sole role to play in creating positive amongst society and adopters regarding the technology. In such a way media plays a role in creating rhetorical space and creating attention towards RE, such attention can act favourably to attract researchers, motivate authorities, as well as persuade local inhabitants.

Inhabitants near installation sites

Society shapes the development of technology as it gives a culture symbol to technology. In such scenario, perception of inhabitants near the installation sites regarding aesthetics, safety and importance of RE can play critical role in determining market success for RE technology. Similar, conflict can arise in terms of land use for RE. On the contrary, RE can provide economic opportunities to the inhabitants near the installation sites.

4.3. Drivers and Barriers

Although some of the drivers and barriers involved in the SET have already been mentioned in section 4.1 and 4.2, here, additional drivers and barriers related to SET are listed according the PESTEL framework discussed in section 3.1.2:

4.3.1. Drivers

Environmental factor

Rising sea levels (climate change) directly affect islanders' lives, and most importantly the tourism economy most SIDS including Aruba, and thus, island governments have become strong advocates for reducing global CO_2 emissions.

Legal factor
The SDGs missions is to decarbonize the energy and transport sector, by 2030, a CO2 emission reduction of at least 45% is expected, and after 2030 to reach 'net zero' before 2050 to cope with the SDGs target (Stakeholder #1, NSP, 2019). Environmental factor.

4.3.2. Barriers

Political factor
According to stakeholder #5, the vertical integrated power structure in the local energy companies is responsible for bureaucracy and red tape. If there is no political will and/or knowledge, the course of the energy transition remain the same (Stakeholder #5, #9). Business model of state companies such as WEB and Elmar needs to change, but so far the companies are not allow to do so. As a consequence, companies are limited to their scope of doing business (Stakeholder #9). Long term political commitment is necessary to accelerate the SET (Stakeholder #9).

Economic factor
During the SET the electricity price should be affordable for everyone (Stakeholder #1, #2). Aruba has one of the most reliable electricity supply in the Caribbean and is key for the tourism industry (Stakeholder #2).
In general, RETs are more capital intensive compared to fossil fuel technologies (Stakeholder #3). Plus, energy storage systems makes levelized cost of electricity (LCOE) less attractive (Stakeholder #2).
WEB currently stabilizes the HFO price by implementing mechanisms such as hedging to guarantee a stable electricity production price (Stakeholder #3). However, this mechanism is not reliable for the long term nor the import of fossil fuel.

Social factor
According to Stakeholder #1, demand side management becomes important during the SET, meaning that the human factor is the biggest and slowest factor to change in the transition. Social equity is important, because, those who can afford RE, such as Solar PV Rooftop system, will have negative impact on those who have to buy electricity from the conventional system, because everyone has to pay for the infrastructure investment at the end of the day (Stakeholder #2). Collaboration is needed, companies are working on their own and clients are not being well informed (Stakeholder #4, #9). Another important aspect of SET is the NIMB (not in my backyard) phenomena (Stakeholder #9). During the assistance of TNO Caribbean on Aruba for the energy transition, it is mentioned that it was challenging to get all the stakeholders aligned to the same conceptual approach, that resulted in a gap between what was expected by the local government side and what was seen as achievable on the implementation side (CoE, 2017).

Technical factor
Energy storage is important for the SET when introducing intermitted RE on an island that is completely isolated form other backup systems (Stakeholder #1, #2, #3). This makes island grid more fragile compared to countries with interconnectivity. If the power generation is not well distributed, for example with intermitted energy, 5MW can be loss in a split second, this will affect the system's reliability (Stakeholder #9), meaning that RE affect the loss of load expectation (LOLE) directly (Stakeholder #2). In a specific case study done on the

island of Aruba, different challenges were mentioned. First, the government often get offers from outside parties on cleaner energy solutions without realizing the full impact that such decisions have on the whole electricity system (CoE, 2017). Second, one kWh of intermittent electricity is not the same as one kWh of baseload energy supply. Therefore, there is always extra cost when it comes the intermittent renewable energy supply such as wind and solar energy (CoE, 2017).

Environmental factor
The main goal of SDG's is to lower carbon emission (Stakeholder #1), the reduction is as follow, in 2018 emission were 8.4 metric tons (mT) CO2 per capita, while for 2050 a reduction of 1.0mT per capita is expected (Stakeholder #2, Nos Plan, 2019). The main air pollution is generated by electricity generation (60%) and transport sector (40%) (Nos Plan, 2019). Another issue is, an island has limited land, and RE systems require more surface compared to fossil fuel compact systems (Stakeholder #3).

Legal factor
With an energy policy in place, it doesn't matter which government is in place, the party can just execute the projects according to the planning, because it is transparent and long-term with clear goals, currently, that is not the case on Aruba (Stakeholder #4). Elmar has a solar/DG policy, but it is to static, it should be more dynamic with more options for clients, for example off-grid systems (Stakeholder #4). Curacao has it "energie wet" after the government had fail to manage their energy company properly during Gerrit Schotte period. There is no "energie wet" yet in Aruba (Stakeholder #5).

4.4. Renewable energy developments

The three internal complementary technologies that are being explored are: 1) intelligent generation management system (IGMS), 2) storage systems, and 3) demand side management. Once the RE share reaches a certain level, these three projects start to become crucial in order to grow the RE share of the total energy demand without jeopardizing a reliable electricity supply.

Intelligent Generation Management System (IGMS)
One automation project that WEB is doing is the intelligent generation management system (IGMS), this system will replace an operator to dispatch within the energy mix that they have on the island (Stakeholder #1). Moreover, the IGMS search for the optimum energy mix, efficiency is the key for the IGMS decision making (Rethink, 2019, Stakeholder #1, #2, #4). WEB partnered with ABB company for the IGMS project, the partnership brings knowledge regarding the technology, and WEB brings the energy mix operation on an island setting, and together they will achieve a final product that satisfied the requirements (Stakeholder #1).

Flywheel & Battery Storage systems
WEB has implemented a 1MW/4 hours Tesla battery and different flywheels with a capacity of 5MW/12min to collect data within the local energy system (WEBNews 2019, Stakeholder #1). According to Stakeholder #4, in the near future there will be high demand for energy storage. These systems are entails to catch fluctuations from intermitted RE systems to

create a more reliable energy production when introducing more RE shares to the energy mix (Rethink, 2019, Stakeholder #1).

Demand side management (tourism sector)
Since the tourism sector is responsible for a substantial portion of energy demands with the large hotels consuming about a third of the island energy, see section 4.1.4. It is therefore foreseen that the tourism sector can play an important role in demand side management (Stakeholder #1). Elmar should be able to regulate ice storage (air-conditioning) at the hotels, this is more a demand side management. If the island aims to go 100% on renewable energy, they need energy storage and demand side management, there is no other way around (Stakeholder #3). As a result, WEB has an ice storage pilot project for 5 years (Stakeholder #1).

Summary Multi-level perspective
The SET's phenomena can be witnessed by the numerous changes on the socio-technical landscape and regime level (see figure 4.7). Finally, the niches will follow a transformation path (Geels & Schot, 2007). Despite the COVID-19 crisis, there are no significant or sudden landscape changes in this pathway yet, but moderate landscape pressure is present. Niche-innovations cannot take full advantage of this situation because they have not developed sufficiently. Currently, pressure from the macro environment will not change the regime actors' activities and practices at once. New regimes emerge from old regimes through cumulative improvement and reconstruction. The electricity regime actors will survive by adding RET to the energy mix, creating a hybrid system.
Environmental concerns pressure the energy sector to lower its environmental impact on the landscape level. Moreover, raising awareness on climate change and unstable oil prices is essential in destabilizing the regime. Still, the electricity regime responds to landscape pressure by shifting from HFO to LNG, increasing oil dependency but lowering emissions. On different dimensions, various processes occur that influence the stability in the meso-level. Although the slow adaptation of innovation characterizes the current Aruban electricity regime, a shift in public opinion with ambitious goals could speed up the process. The SDGs could significantly impact the electricity regime if Aruba continues its collaboration with the UN and creates expectations on the niche level. Three internal complementary technologies are being explored within the regime to enable RE diffusion. Firstly, the intelligent generation management system (IGMS), secondly, the storage systems, and finally, the demand side management. These technologies are essential for SET. All in all, the future of RE is considered to be positive due to the developments mentioned earlier taking place.

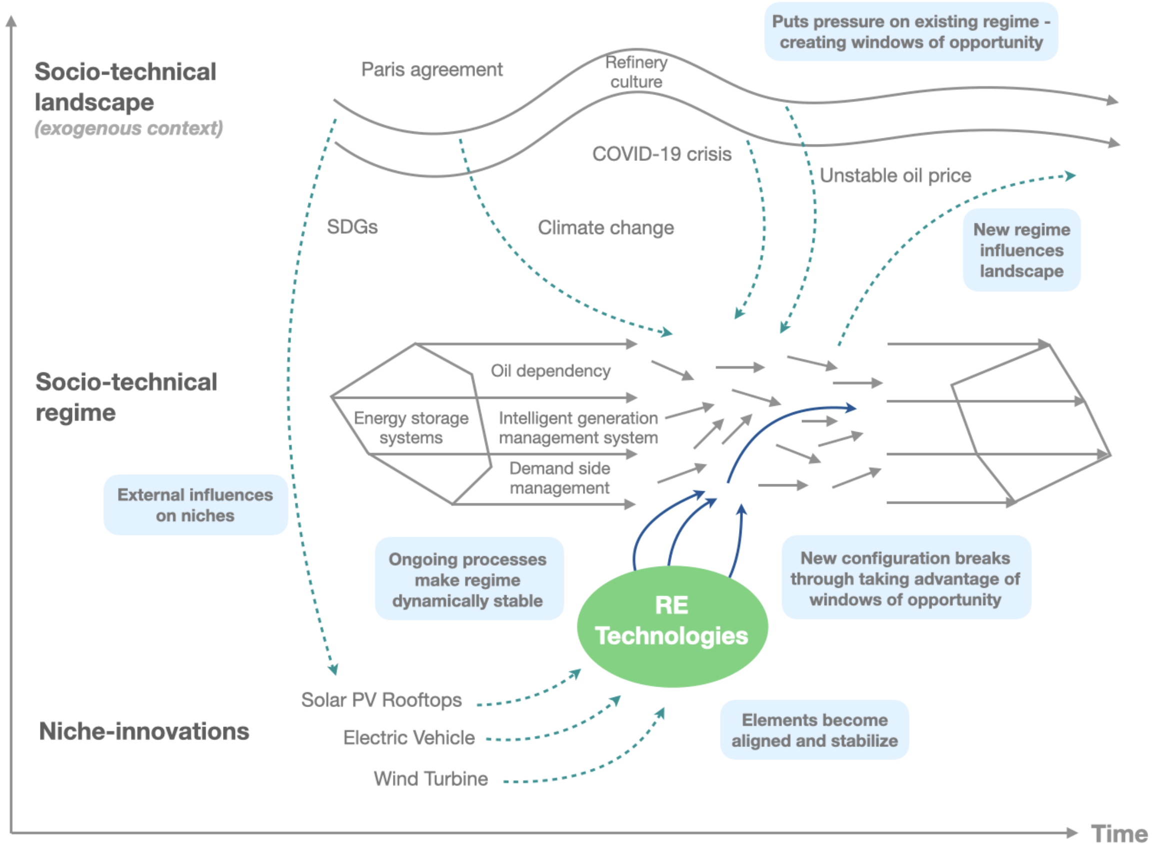

Figure 4.7: Multi-level Perspective of the electricity sector on Aruba (Source: Adapted form Geels & Schot 2007).

4.5. Conclusion

The development at the regime level does not provide a window of opportunity yet since the developments are stabilized by using hedging and internal efficiency optimization to cope with CO2 emissions, for example, shifting from HFO to LNG. Also, three internal complementary technologies are being explored within the regime to enable RE diffusion. The current energy mix on the island is 20% based on RE and 80% dependent on imported fossil fuel. However, landscape pressure is building because of climate change, oil dependency and the COVID-19 crisis, which may shift public opinion that could destabilize the regime and create more opportunities for the diffusion of the RE innovations.
There are two main drivers for the growth of RE innovations. One driver is the government vision related to the SDG 2030 and 2050, and the second is the economic diversification started in 2009 with the implementation of the first wind park Vader Piet.
Climate change and environmental issues have added additional aspects but cannot be considered the main drivers towards a 100% RE-based island.

5. Solar PV Rooftop analysis in Aruba

Strategic niche management is applied to analyse the Solar PV Rooftop (PV) technology development. This chapter presents the network formation in section 5.1, then the shaping of expectations in section 5.2. Next, in section 5.3, the learning processes are discussed. Finally, in section 5.4, the conclusion of the Solar PV Rooftop niche is drawn. The outcome of this chapter is part of the answer to the sub-question: Which niches/projects are being developed to reach the 100% renewable energy goal?

5.1. Network formation

This section presents the network responsible for the Solar PV Rooftop niche by using the analytical framework mentioned before in 3.1.3. The network formation consists of network overview and network composition & alignment. The discussion of each of these parts is next.

5.1.1 Network overview

The current development of the Solar PV installation started in September 2012 when the Aruban government began promoting renewable energy (GreenDeck, 2015). Before 2012, the Aruban people only knew about electricity generated by WEB and distributed by Elmar. The government of Aruba and Elmar announced to allow distributed generation, thus allowing consumers to sell energy back to the grid. These goals allow private businesses and consumers to contribute to RE use and decarbonize the economy.
In 2015, the local governement, together with Carbon War Room, TNO, Utilities, WEB, and Elmar, jointly tackled a Solar PV Rooftop project. The projection was to install an approximate 4MW of Solar PV Rooftop demonstration projects spread out over the island on schools rooftops (GreenDeck, 2015). This project would represent roughly 1% of total energy demand with an effective production of approximately 6 hours per day.
In 2009, the government of Aruba introduced a new strategy for WEB, prioritizing environmental concerns of SIDS and moving away from dependency on fossil fuel. This approach was translated into the 100% sustainable energy transition for 2020, announced at the RIO+20 conference in 2012 (Laboratory, N. R. E. 2015a).

The local government organized the first “Green conference” in 2010 (GreenDeck, 2015). Aruba has set its goal to become 100% independent of fossil fuels by 2020. In order to achieve this, diversification of the economy through renewable technology initiatives have to be taken, including diversification through sectors that have the potential for long-term sustainable growth and the ability to develop a knowledge-based economy.

In 2017, a new coalition consisting of a new political party took office (Overheid, 2017a). For that moment, RE, including Solar PV Rooftops, was not the main focus anymore. The government focus on cheaper electricity and digitalization (Stakeholder #8). The “Green conference” was stopped, and TNO Caribbean left Aruba because the current government stopped their contract (Stakeholder #6, TNO, 2019).

5.1.2. Network composition & alignment

The Solar PV Rooftop network consists of stakeholders that are connected direct or undirect. The collaboration between these stakeholders can be categorized as strong and weak ties. The strong tie's stakeholders are constantly interacting for every Solar PV installation connected to the local grid according to legal procedures. These stakeholders are suppliers, Elmar, DTI, Solar PV installation company, banks, and end-users. The rest of the stakeholders are currently not active, meaning that their ties are weak regarding the Solar PV Rooftops network. Nevertheless, the stakeholders could support or reject the technology niche regardless of their ties as illustrated in figure 5.1.

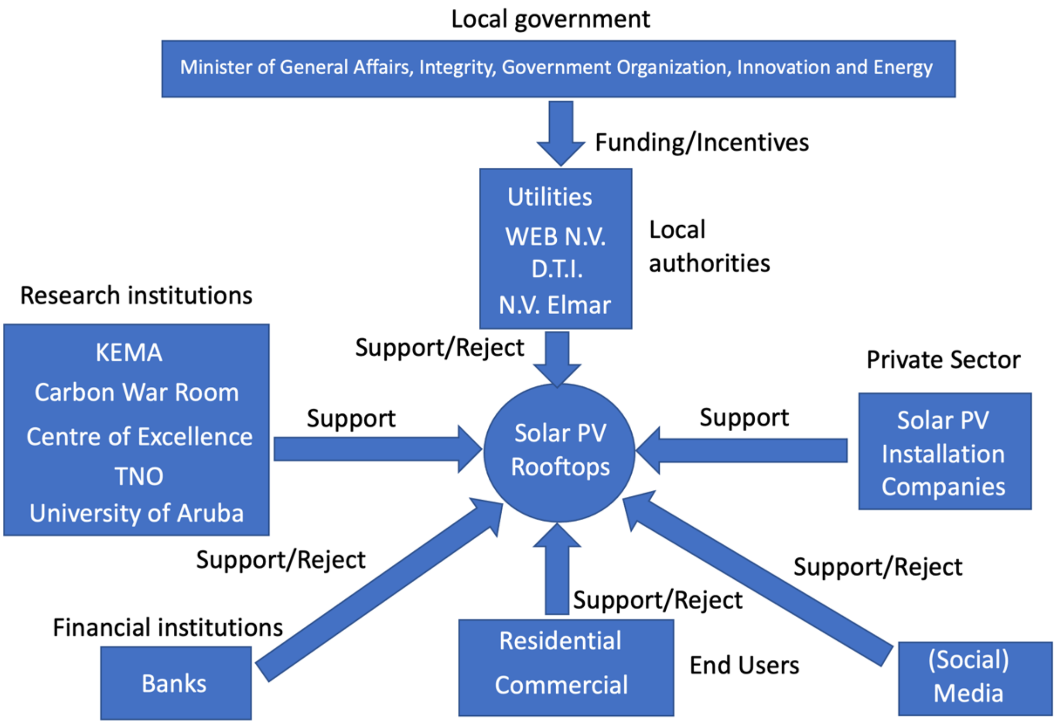

Figure 5.1: Solar PV Rooftops stakeholder map (Source: own illustration).

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Not all actors' groups are active because of low awareness of the technology and the ignorance by the local government regarding SET (Stakeholder #12). Solar PV Rooftops installation companies are rivals of WEB because both offer the same commodity in a limited energy market, which means that an increase in Solar PV Rooftops decreases WEB's market share (Stakeholder #3). Therefore, WEB is not a supporter of the Solar PV Rooftop technology.

On the international level, UNDP has a robust network and capacity-building activities involving many local and international stakeholders. UNDP is a top player in RE technology development and manages several grants provided by foreign governments destined to implement Solar PV demonstration projects (UNDP, 2020).

In collaboration with Arizona state university, TNO initiated a “Green Faculty” in 2012 (GreenDeck, 2015). The faculty offers different types of training in support of Aruba’s sustainable energy transition. In addition to technological diffusion, local capacity building is essential. The first training focused on increasing know-how in PV technology and was presented on the local technical college’s campus, Colegio EPI. The training created the opportunity to use this faculty to share knowledge, skills, and experience with the next generation of solar installers. The duration is one week of engineering and installation training. The course is regularly offered and marketed to professionals throughout the Caribbean region.
Accelerating the energy transition will need a workforce with the skill and capacity to support the island’s goal. To address this need, the University of Aruba, Green Faculty, and partnership and TNO, with the support of the local government, has increased educational opportunities for RE on the island (GreenDeck, 2015, Stakeholder #6). In cooperation with US and European partners and universities, Aruba Centre of Excellence plans to offer a bachelor’s degree in technology and engineering moving forward (UA, 2019). The umbrella organization such as the Aruba Centre of Excellence can play an important intermediary role for the network formation and knowledge sharing to scaling up the Solar PV Rooftop niche (CoE, 2016).

5.1.3. Conclusion network formation

There are key stakeholders in the Solar PV Rooftop niche with strong or weak ties with other stakeholders. From the financial perspective, banks have a weak tie within the Solar PV Rooftop niche, meaning that they are not entirely aligned. From the technical perspective, WEB feels that they are not involved in the decision-making process of the Solar PV Rooftop niche. WEB remains a key stakeholder for the Solar PV Rooftop niche because they provide the backup when there is no sunlight for the solar panels to produce electricity. On the other hand, the government is the sole shareholder of WEB and does not prioritize the Solar PV Rooftop because of conflict. Therefore, the composition of the network is not optimal.

5.2. Shaping of expectations

In the early niche stages, participants join the niche by investing effort, money and time because they have expectations of the future success. At this moment, stakeholders have broad and unclear expectations about the technology and different vision of its future. During time, expectations can change because of external factors (regime and landscape) and internal circumstances (e.g. results from experiments within the niche) (Raven, 2005).

5.2.1. Expectations at the niche level

The expectations of the Solar PV Rooftops niche are presented below. The two expectations found during this research are discussed using the analytical framework presented in section 3.1.3. The two expectations are scaling up the Solar PV Rooftops niche market and financial lease.

Robustness of scaling up
The robustness of this expectation is not optimal from the technological point of view. There are technological barriers to overcome, such as energy storage. Besides, some stakeholders have not completely shared this expectation, including WEB. However, there is constant growth in installed capacity, which means some stakeholders have strong ties. The study done by KEMA is used as a guideline to keep the grid reliable during Solar PV Rooftop penetration (Sint Jago, 2013). On the other hand, the installation limitation hampers the upscaling of the technology (Stakeholder #12).
Also, WEB is competing with the Solar PV Rooftop in the energy market, selling the same kWh product (Stakeholder #3). The Solar PV Rooftop clients still rely on WEB to provide electricity when there is no sun. That is the only backup that makes the Solar Rooftop PV technical and economically feasible.

Specificness of scaling up
The expectation is not specific regarding the necessity to lower PV costs. PV technology price reduction is not something that can be tackled locally. However, lower price and quality PV products enter the market, and results are less promising (Stakeholder #11). Quality control is necessary to avoid the negative results of experiments that could create negative expectations that hinder the desire of other actors to join the Solar Rooftop PV niche.

Quality of scaling up
The quality of expectation is low because lessons should be aligned to improve the expected quality. The linkage between actors (WEB, Elmar, and users) is weak, and the lessons are fragmented (Stakeholder #4).

Robustness of loans and leasing
Financial institutions are not supporting the Solar PV Rooftop technology with attractive loan interest (Stakeholder #11). However, the installation companies that provide the leasing option are the ones that are growing faster (Stakeholder #6). This expectation is not robust because local banks are not aligned.

Specificness of loans and leasing
The expectation is not specific because banks see the Solar PV Rooftop technology as a risky investment and offer a high-interest loan making the offer less attractive. Therefore, more awareness is necessary to scale up the Solar PV Rooftop market (Stakeholder #11). Installation companies/start-ups need to partner up with financial institutions to offer better deals to their clients.

Quality of loans and leasing
The user prefers a leasing mechanism in a market where borrowing money is not easy for these “risky” technologies. To increase the Solar PV Rooftop market share, the middle and lower class in the residential sector should have easy financial support, and currently, this is not the case (Stakeholder #11). Therefore, installation companies need to provide leasing contracts to their costumer, meaning a new business model. Innovation should also occur at these levels to boost the Solar PV Rooftop technology. The quality of this expectation is not high because more experiments are needed to increase the quality.

5.2.2. Expectations at the regime and landscape levels.

The three expectations found during this research are discussed using the conceptual framework presented in section 3.1.3. The expectations at the regime level are addressed together with the landscape level too because of international agreements and regulations such as SDGs and Paris agreement. The three expectations are uninterrupted electricity, cheap electricity, and societal & environmental friendly.

Robustness of uninterrupted electricity

The expectation is not robust because WEB feels that their company is not involved in the scaling-up process of the Solar PV Rooftops in order to provide an affordable and reliable supply of electricity. The distribution of demand and supply is a problem for grid stability. Therefore, WEB prefers to operate large-scale Solar PV systems such as “Sunrise Solar Park” and not small fragmented generators (Carib, 2017, Stakeholder #4).

Specificness of uninterrupted electricity

There is a solar/DG policy to present the Solar PV Rooftop installation guidelines (Elmar, 2020). However, the policy does not include WEB’s responsibility for the Solar PV Rooftop’s backup (Stakeholder #4). There are social consequences for those that did not destabilize the grid. Because the grid needs to be upgraded, and the cost is for everyone. As a result, this expectation is not specific.

Quality of uninterrupted electricity

In order to remain reliable after a certain amount of RE penetration on the grid, WEB needs to install extra equipment for (peak) a short time used as a backup. These investments could make Solar PV technology financially less attractive (Stakeholder #9). Therefore, more experiments are necessary to solidify the quality of the reliable expectation.

Robustness of cheap electricity

The price of the Solar PV technology is dropping, and this also is the case for large-scale installations (Stakeholder #6). According to WEB, Solar PV Rooftops are cost-effective without including the backup cost, such as battery storage or a diesel motor (Stakeholder #3). Since the backup is provided by WEB, the Solar PV Rooftop can be considered affordable, otherwise not. Therefore, the robustness is not entirely supported.

Specificness of cheap electricity

The price of the Solar PV technology is determent by the international market, meaning that there is little influence from the local actors. Nevertheless, the government has already lowered the import taxes to decrease the cost of the Solar PV technology and is still supported by current governments (GreenDeck, 2015, Laboratory, N. R. E., 2015a). Still, WEB should install extra capacity to back up the Solar PV Rooftop’s clients during the night (Stakeholder #1). The question is, who is responsible for this extra backup investment? Only the clients with solar PV technology or all the clients of WEB? Therefore, as RE’s share, including the Solar PV Rooftop, increases, these questions should be answered. As a result, the specificness of affordability is not clear.

Quality of cheap electricity
As the worldwide price of Solar Rooftop technology keeps dropping, more experiments will be performed in the context of Aruba. Solar PV Rooftop has a competitive price on the market right now and could be even more attractive soon (Stakeholder #6). The price of the backup capacity is a trade-off between reliability and affordability (Stakeholder #5). Therefore, the quality of this expectation is not high.

Robustness of societal and environmental friendly
The social part is not well known since the Solar PV Rooftop is unavailable for everyone, but only for those who can afford it. The outcome of such technology contributes to inequality (Stakeholder #4). Therefore, the robustness of the societal expectation is not solid.

Specificness of societal and environmental friendly
The long-term goals of the Solar PV Rooftop are now well defined. From the environmental perspective, it is not easy to grasp. However, the Solar PV electricity does not pollute during electricity generation. Solar PV technology is still early to know their environmental impact (Stakeholder #7). Therefore, the expectation is not specific enough.

Quality of societal and environmental friendly
Those who cannot afford the upfront cost of a Solar PV Rooftop installation are the ones who will have to pay a higher electricity price (Stakeholder #4). Moreover, WEB's monopolistic centralized energy market will shrink, and the economy of scale is not applicable anymore. Perhaps the introduction of EV will force WEB to shift to RE to remain in business and gain a new market. Therefore, the expectation quality is not clear yet.

5.2.3. Conclusion expectations
From the technical perspective, WEB expects to be involved in the Solar PV Rooftop diffusion too since the development of this technology affect WEB's business operation directly. From the market point of view, stakeholders expect a price reduction on the international market and more attractive loans or leasing contracts to diffuse the Solar PV Rooftops niche. The government collaborated with different international institutions to scale up the Solar PV Rooftops niche and expect to lower the dependency on fuel import. The PV technology expects to decarbonize the energy sector from the social and environmental perspectives. The solar/DG policy expect to be revised to increase solar PV rooftops' maximum installation capacity from the policy and regulation perspectives.

5.3. Learning processes
The learning processes influence the niche by affecting the expectations and aligning them. A good learning process is reflexive and focuses on many aspects (Raven, 2005). The learning data gathered is presented according to the conceptual framework.

5.3.1. Learning by searching: Market research and development
Solar electricity generation in Aruba follows the positive global trend favouring solar PV technology. Solar PV technology is becoming more competitive as their declining cost facilitated the expansion of Aruba's Solar PV Rooftop niche market (Stakeholder #6). Solar electricity solutions are still a niche even if the demand rises since most Aruban citizens cannot afford the product. Those who currently invest in Solar PV Rooftop

technology are the residential sector consisting of early adopters that are motivated by making savings and have a strong environmental consciousness (Stakeholder #6). However, reducing the electricity bill and the opportunity to become independent or semi-independent in electricity generation is a strong motivation (Stakeholder #11).
According to stakeholder #12, in 2008, there were only 2 to 3 houses on the island with Solar PV Rooftop installation, currently, the installed capacity of Solar PV Rooftop technology has reached 15 MW because, in the beginning, the Solar PV Rooftop system was expensive. The price is so cheap that the only limitation is the maximum installed capacity that Elmar allows a client to install (Stakeholder #12).
The local Solar PV Rooftop niche market has grown as the technology has become more and more available with more local suppliers than a few years ago. There is serious competition among solar installation companies selling Solar PV technology to provide the best services at the lowest price (Stakeholder #6).

5.3.2. Learning by doing: Capacity building

In the solar PV case, the demonstration projects at Colegio EPI served to bridge gaps by sharing the required skills, knowledge, and crucial expertise (Greendeck, 2015). TNO played a vital role in this process initially, together with other international agencies.
The lack of know-how and skilled labour that usually characterizes an underdeveloped market is no longer the case in the Solar PV Rooftops niche. Because firms have trained engineers and experts who acquired experience by working with TNO or/and international agencies on previous demonstration projects (Stakeholder #6), the growing trend on the supply and demand side has a positive impact on the learning process.

5.3.3. Learning by using: Awareness and social acceptance

The decentralized demonstration projects such as Colegio EPI and others are essential (GreenDeck, 2015). The objective of these decentralized demonstration projects was to experiment with solar PV technology on a small-scale level and acquire technological and social feedback. Such demonstration projects increase the visibility of solar PV technology and help expand the diversity of actors involved in the solar niche network by including the private sector.

5.3.4. Learning by interacting: Policies, regulations and collaborations

The first KEMA recommendation study permits 5% penetration of Solar PV Rooftop technology, meaning residential could install 5 kWp, and commercial 10 kWP (Stakeholder #3). During the years, the limitation changed, while technology changed, everything changed. Elmar did another study with KEMA, the installed capacity of Solar PV Rooftop technology upgraded for residential to 10 kWp and commercial use 100 kWp (Stakeholder #3).
The import taxes on Solar PV Rooftop products were reduced to 2% to lower the price and give the niche a competitive advantage against the fossil fuel-based products (GreenDeck, 2015). Although, regulations that are supposed to facilitate the diffusion of new technology such as Solar PV are still inadequate, not adapted enough, or not put into action (Stakeholder #12).
Local universities and policymakers are not involved in the electricity sector. However, different international universities were involved in other renewable projects research (GreenDeck, 2015, CWR, 2013). According to Stakeholder #12, the government plays a

crucial role in the learning process. The ego effect seems to be a factor that hinders this process towards scaling up the Solar PV Rooftop market (Stakeholder #12).

5.3.5. Conclusion learning processes

Learning by searching focused significantly on market development and not on technical development because no technical university or industry on the island can perform such research. Nevertheless, the market development is studied by local and international institutions while the Solar PV Rooftop technology is imported (technology transfer) and not locally developed.
The collaboration between local and international entities was implemented to support capacity building on know-how for local and other SIDS engineers and experts interested in being part of the Solar PV Rooftop business community.
Initially, awareness and social acceptance were done by exposing demonstration Solar PV Rooftop projects. It is crucial to visualize these projects to avoid social rejection and market failure.
The local and global collaboration created the Solar PV Rooftop niche market. Based on the grid capacity and reliability, the DG/Solar Policy was introduced. KEMA played a crucial role in determining the maximum capacity of the end-user in the residential and commercial sectors. Also, import duties were lowered to give the Solar PV technology advantage in the local market. These incentives were only possible because of searching by interacting between local and international authorities. The umbrella entity that should manage the knowledge and produce more policies is somehow missing or not functioning correctly. This entity could be the Centre of Excellence that functions as a knowledge broker.
The Solar PV Rooftop niche could become a part of the regime if storage in the form of batteries or EVs are integrated into the system. Therefore, in the following niche analysis, EV technology will be discussed in the context of Aruba.

5.4. Conclusion Solar PV Rooftop niche analysis

The Solar PV Rooftop niche could gain market share faster with better collaboration between the government, WEB, and financial institutions. The government could facilitate the Solar PV Rooftop niche by prioritizing the RE agenda and being more proactive in the decision-making process. Leasing contracts and awareness campaigns should also help to increase the market share of the Solar PV Rooftop technology. The trade-off between affordability and reliability remains, and here is where the battery technology could overcome the technical barrier of the Solar PV Rooftop technology. However, this technology development takes place on the international market. A knowledge broker should be created to keep stimulating the Solar PV Rooftop transition to the regime energy mix.

6. Electric Vehicle analysis in Aruba

Strategic niche management is applied to analyse the Electric Vehicle (EV) technology development. This chapter presents the network formation in section 6.1, then the shaping of expectations in section 6.2. Next, in section 6.3, the learning processes are discussed. Finally, in section 6.4, the conclusion of the EV niche is drawn. The outcome of this chapter is part of the answer to the sub-question: Which niches/projects are being developed to reach the 100% renewable energy goal?

6.2. Network Formation

This section presents the network responsible for the EV niche by using the conceptual framework mentioned before in 3.1.3. The network formation consists of network overview and network composition & alignment. The discussion of each of these parts is next.

6.2.1. Network overview

Electric Vehicles (EVs) are becoming popular globally in different markets, with over 6 million EVs in operation around the globe (IEA, 2021). EV sales are expected to increase as the world's population reduces its dependency on non-renewable fuel resources. Although the EV does not consume fossil fuel directly, it does consume a large amount of energy to charge their battery to perform. Moreover, the battery charging process demands a large amount of energy, which will change the energy demand pattern. Therefore, WEB and Elmar need to be prepared for such a demand to maintain a reliable energy supply. Also, Aruba will import less fuel (gasoline and diesel) for transportation on the macroeconomic level if the EV enters the market at a large scale. On the other hand, WEB should increase the capacity to produce electricity to cope with the extra demand regarding EV charging. Since the EV uses electrical energy as its primary source, Elmar and WEB need to know how much extra energy is needed. Since EV consumes significantly more energy than an average house, WEB and Elmar need to estimate the maximum capacity that can be supplied besides the regular demand. However, the island's demand is not static; it fluctuates with a predictable pattern during the day. Area 1 presents the scope where the EVs can be charged, see figure 6.1 (Stakeholder #4).

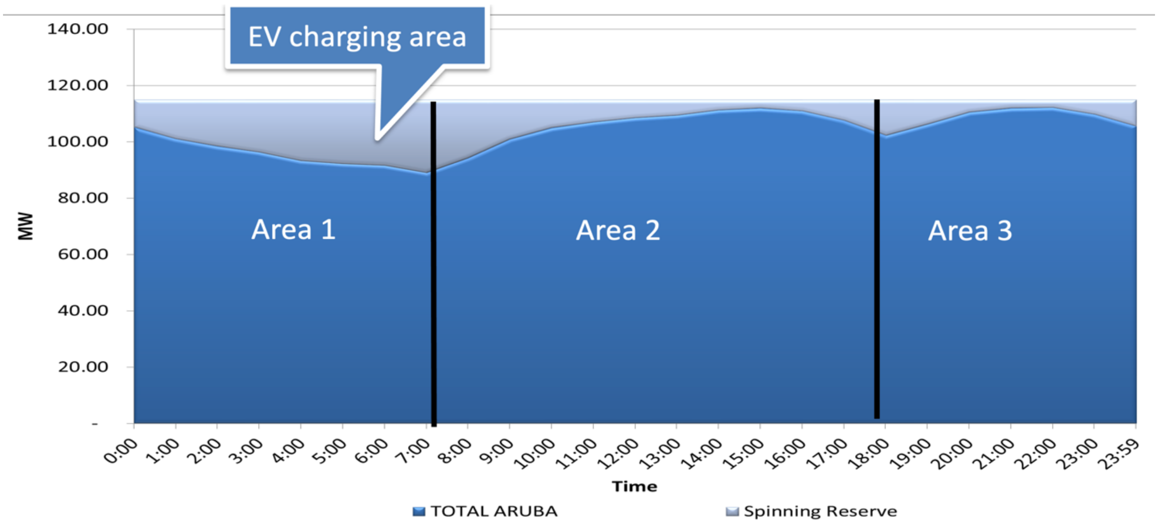

Figure 6.1: Aruba's electricity demand pattern and spinning reserve Source: (Croes, 2015).

The "Spinning reserve" is the maximum capacity that can be used to charge the EVs. The maximum capacity is different in every area. The amount of EVs can be estimated depending on the level of the charger. Suppose, for some reason, the total energy (Aruba and EV) is larger than the supply capacity (what WEB can supply at the moment). In that case, the energy supplier will have to control the demand by opening the main breakers to prevent a brown or a blackout. A power outage will have severe consequences for the entire island of Aruba and should be prevented by limiting and controlling the charging of the EVs on the island. Therefore, demand-side management and incentive are necessary to convince users to charge during midnight to provide a reliable energy supply (Stakeholder #3, #10, #12).

6.2.2. Network composition & alignment

An overview of the prominent participants in the EV niche on Aruba, a stakeholder map is presented, which includes all the stakeholders mentioned above. Their relations can be observed in figure 6.2. WEB is responsible for electricity production, while Elmar distributes electricity to all end users. Moreover, Elmar provides the grid to their consumer to charge their EV with electricity. Logistic companies import EVs for their customers or local car dealers. The user of EV can charge their car using a charger connected to the grid according to the local and international norms for all safety reasons. The inspection of the charger installation is done by the technical inspection institute (DTI). The banks provide financial support to their clients who is investing in an EV.

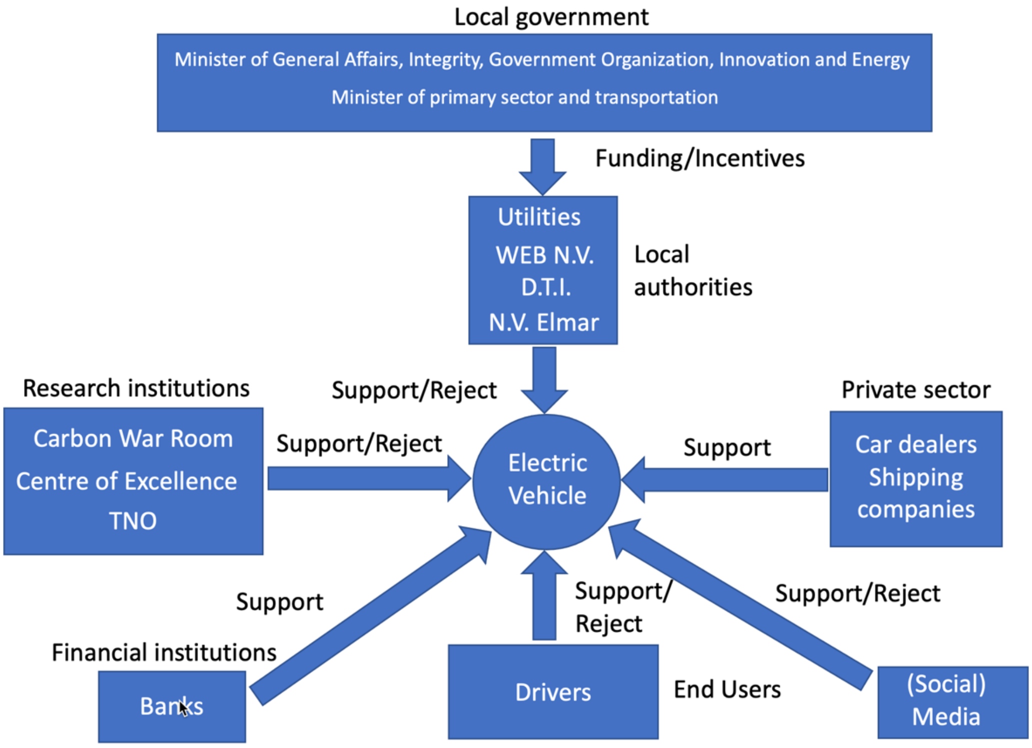

Figure 6.2: Electric vehicle's stakeholder map (Source: own illustration).

The local government is responsible for the transport and energy sector towards the SDGs goals for 2030. To show some support, the government of Aruba bought one EV, the Hyundai Ionic (Stakeholder #12). In 2014 Elmar and the government installed the first level 3 charger on the island (GreenDeck, 2015). One company that focuses on EVs from the beginning is “Activated Power,”, especially on imported second-hand EVs. However, “Activated Power” does not represent one specific brand but narrows down to Nissan Leaf and Ford Focus to give an optimum service (Stakeholder #12). Another local car dealer is “Garage Central,” which introduced the Hyundai Ionic, and currently is dominating the market very well (Stakeholder #12). Depending on the budget and preferences, clients choose for new EVs, and others, for second hand one, for example, a new Ford Focus is more or less €42.500,- (AWG. 85.000,-) and a three years old one is, €17500,- (AWG. 35.000,-) (Stakeholder #12). The second-hand EV market provides an affordable price for early adopters on the island of Aruba with more or less 40% price reduction.

Road transportation is responsible for 30% of total local emissions (NSP, 2019). Passenger cars represent the most significant amount of vehicles and are responsible for most emissions between vehicles type (CWR, 2013). Therefore, this analysis will focus on the current transport sector regarding passenger vehicles. The other types of road vehicles on the island are not included, for example, buses, trucks, and heavy equipment. Table 6.1 presents an overview of the vehicle's registration on the island.

Table 6.1: Vehicles registered in Aruba by type (Source: CBS, 2020).

Types	Amount
Passenger cars	77,877
Irregular-transportation cars	310
Trucks	1,296
Busses	139
Tour busses	303
Taxis	450
Rental	4,803
Government cars	549
Other cars	32
Motor-cycles, incl. mopeds	2,746

In 2009, the local government had introduced tax incentives to import EVs and favourable road tax for EVs. The tax incentives are still in place, meaning that the decarbonization of the transport sector is a long-term vision. The responsibility of Elmar is to enable an intelligent charging infrastructure that can support the introduction of EVs. Without upgrading the infrastructure to a smart one, the reliability of the grid and the energy production is not robust. Therefore, introducing EV technology on the island requires responsible organization and strong ties between stakeholders to decarbonize the transport sector.

In the beginning, Elmar had installed 6 EV (public) chargers around the island as a pilot project to support the EV market (ArubaBank, 2020). Currently, Elmar plans to install a charging station within a radius of 5 km where the client can charge unlimited for a vast monthly fee (Stakeholder 12). According to stakeholder #2, if WEB is not ready, Utilities cannot push for EVs. Still, Utilities expects the international market price of EV to become competitive with ICEV in short term. After the price reduction of EV, the island could expect a load increase that requires more smart charging stations and more electricity demand.

Financial institutions are essential for the EV niche. Currently, the local banks on the island are well aware of EVs on the market and are financing this technology with full support. Some banks offer "green car loans" of 6%, while ICEV's loan is 7% (Stakeholder #12, ArubaBank, 2020).

Table 6.2 presents three levels of chargers for EV. Levels 1 and 2 can be considered residential chargers because they do not require a special adjustment from the grid. For a level 3 charger, a commercial setting is necessary to support the capacity of this load on the grid.

Table 6.2: Overview of different EV charge levels, comparing Aruba and EU (adapted: Moorman, 2017)

Power level	Aruba	Based on:	Europe	Based on:
Level 1	1.75 kW	120 V, 16 A	3.5 kW	240 V, 16 A
Level 2	7 kW	220 V, 20 A	17.5 kW	240 V, 80 A
Level 3	>50 kW	500 V, 100 A	>50 kW	500 V, 100 A

According to a study done by TNO in 2014, CO2 emissions from passenger cars on Aruba were estimated to be 260 to 390 g/km, significantly higher than the Netherland average of 175g/km (NSP, 2019). The high emissions value on the island is because of the lack of restriction on standards for vehicle emissions, a relatively high fraction of light trucks (SUVs), constant air-conditioning usage, and low-quality fuel (Moorman, 2017).

Nowadays, oil products are imported for electricity generation and transportation. Total imports of oil products amounted to AWG. 285 Million in 2017, and AWG. 170 Million for fuel imports for electricity production (Rethink, 2019). The collaboration between WEB and Elmar is crucial if the island wants to lower its import of fuel that impacts the macroeconomics on the island.
Since the EV is more efficient than the ICEV on power consumption, it will impact the macroeconomic level (Stakeholder #12). The EV goes hand in hand with the RE shares in the energy mix because EVs can store electricity that plays a crucial role in the SET and the decarbonization of the transport sector.

Carbon War Room proposed that the ultimate goal for Aruba should be to achieve high penetration levels of EVs (ROOM,2015). However, significant amount of EV will increase electricity consumption and could overload the existing system. Surely this will be the case for Aruba when all vehicles are charged simultaneously after EV drivers arrive home at the end of the day. A valley of 50 MW is available on the current local electricity system, where 5000 EVs using a level 2 charger could charge (Moorman, 2017).

6.2.3. Conclusion network formation

The EV clients/drivers have a direct connection/relation with Elmar but not with WEB. However, the EV affects the production pattern directly. Therefore, a stronger tie is necessary to support the EV niche market diffusion, which is not the case yet. Research institutions are documenting the decarbonization of the transport sector, but valuable data is missing to do proper academic research to make policies and better decisions.

Nevertheless, banks grant loans with attractive interest rates to stimulate the EV market. Car dealers and shipping companies follow the international market but depend on government incentives, attractive bank loans, and electricity price reduction to diffuse the EV technology on the island. The media should create more awareness on emissions, climate change, and decarbonization of the transport sector. As a result, the network ties are weak, and Utilities is committed yet.

6.3. Shaping of expectations

In the early niche stages, participants join the niche by investing effort, money, and time because they expect future success. At this moment, stakeholders have broad and unclear expectations about the technology and different vision of its future.
During the time, expectations can change because of external factors (regime and landscape) and internal circumstances (e.g., results from experiments within the niche) (Raven, 2005).

6.3.1. Expectations at the niche level

The expectations of the EV niche are presented below. The two expectations that were found during this research are discussed using the conceptual framework presented in section 3.1.3. The three expectations are scaling up the EV niche market, new market, and storage for RE.

Robustness of scaling up

There are technological barriers to overcome, such as charging infrastructure and RE generation. According to Stakeholders #2 and #3, EV price is expected to decrease soon. A price reduction makes the EV competitive with the ICEV, meaning that it could increase the niche market of EV. However, WEB and Elmar need better communication and collaboration. Currently, the EV clients are only dealing with Elmar and not WEB. Nevertheless, WEB is responsible for this vast impact that EV diffusion takes on the generation side. Therefore, the robustness of this expectation is not optimal.

Specificness of scaling up

There are some shared expectations regarding the necessity to lower EV costs, which cannot be tackled locally. However, a lower price second-hand EVs market increases the expectation (Stakeholder #11). Moreover, quality control is necessary; otherwise, negative results of experiments could create negative expectations that hinder the desire of other actors to join the EV niche market. The local government has done its part to reduce the import duty of EVs, and the rest of the price reduction is determined by the international market. Moving forward to increasing EV’s market share is unclear; therefore, this expectation cannot be considered specific.

Quality of scaling up

The quality is low because lessons should be shared between actors to improve the quality of expectations. WEB is outsourcing research to model the impact of EVs on the local energy system. However, the linkage between WEB, Elmar, and users is still weak, and the lessons are fragmented (Stakeholder #4).

Robustness of new market
The new WEB market is not robust because there is only a problem shifting if the EV is not charged with RE. Moreover, the RE share should increase in shares together with EV diffusion. To do so, the users, Elmar, and WEB should all work together to optimize the transport and energy sector.

Specificness of new market
Since the generation side at WEB has a maximum capacity, the current grid and production capacity cannot function properly with an aggressive diffusion of EV. An increase in sales is not the final goal (Stakeholder #4).As a result, this expectation is not specific

Quality of new market
The quality is low because experiments are still going on. WEB is currently researching the effect of EV penetration on their energy mix at the generation side. Also, a 1 MW Tesla battery pilot is implemented to gather data to model the current electricity production system during charging (Stakeholder #4).

Robustness of storage
EVs are batteries on wheels essential for energy storage, especially RE such as wind and solar. However, smart infrastructure must integrate the RE production with the storage/EV. WEB and Elmar are working on their islands, isolated. Collaboration is needed and a clear strategic plan (Stakeholder #4). As a result, the expectation is not robust.

Specificness of storage
According to stakeholder #4, WEB and Elmar are still in the early stage of integrating both systems to become one system as a whole, where more RE share can be installed due to EV storage. The expectation is not specific since there is no roadmap or policy yet.

Quality of storage
Elmar and WEB their experiments are done separately. WEB claims that the EV benefits are for Elmar, while the biggest challenge and risk are on the supply side. Awareness and incentives are also necessary to make the EV technology work as storage (Stakeholder #9, #12). WEB could use this storage to avoid curtailment. EV is expected to create an opportunity for load shifting. However, more experiments and research are necessary to increase the quality of this expectation. Therefore, the quality of this expectation is low.

6.3.2. Expectations at the regime and landscape level
The three expectations found during this research are discussed using the conceptual framework presented in section 3.1.3. The expectations at the regime level are addressed together with the landscape level too because of international agreements and regulations such as SDGs and Paris agreement. The expectation is decarbonization of the transport sector.

Robustness of decarbonization
From the environmental perspective, the EV technology expects to have the potential to decarbonize a significant part of the transport sector with the support of RE. According to Utilities, the electricity generation system representing the RET is not ready to support a

significate demand for EV charging because the share of RE within the energy mix is not sufficient (Stakeholder #2). Although EV is more efficient than ICEV, an increase in EV charging is expected to result in more import of fuel to produce electricity to charge the EVs and a decrease in RE share (Stakeholder #4). Therefore, the share of RE goes hand in hand with the EV implementation. As a result, the expectation is not robust.

Specificness of decarbonization
The expectations are more or less specific. The collaboration between WEB, Elmar, and the user is necessary to introduce complementary technologies and tools to decarbonize the transport and energy sector (Stakeholder #1, #3, #4, #12). For example, smart grids with smart charging systems, demand-side management, a new business model, and dynamic tariffing. Nevertheless, WEB and Elmar are well aware of the changes that should be done to decarbonize both sectors mentioned above.

Quality of decarbonization
Experiments on EV technology to decarbonize the energy and transport sector are well known. However, integrating the transport sector with the energy sector in an island-specific setting is unique and will require more experiments (Stakeholder #4). Therefore, the quality of this expectation is modest, and to increase the quality, more experiments are necessary.

6.3.3. Conclusion expectations

From the technical perspective EVs are expected to be charged with RE and expecting an increase electricity demand/storage. The international EV market expects a price reduction in short term. The EV is expected to lower dependency of fuel import to result in a decarbonization of the transport sector from the economic and environmental perspectives. The EV tax policy is expected to remain the same to give the EV a competitive advantage on the market using legal frameworks.

6.4. Learning processes

Learning influence the niche by affecting the expectations and aligning them. A good learning process is reflexive and focus on many aspects (Raven, 2005). The learning data gathered is presented according to the conceptual framework.

6.4.1. Learning by searching: Market research and development

EV technology becomes attractive once the price is competitive with the ICEV, and the EV niche market in Aruba follows international trends and developments. Cars manufacturers are already increasing their share of EVs compared to ICE (Stakeholder #3). If the market starts demanding EVs, there will be considerable penetration. There are around 400+ EVs on the island, and these are the early adopters (Stakeholder #3). Aruba is number one in EV per capita in the Caribbean (Stakeholder #12). A local EV dealer called “Activated Power” has five years of existence, and when they started in 2014, there were less than ten EVs on the island (Moorman, 2017). They brought an EV from the US before the company started to experience the technology and said this is something for Aruba, including the benefits. Moreover, stakeholder #12 decided to start a company to sell new and second-hand electric cars. Activated Power marketed the EV, and now there are more than 400+ EVs on the island. Now that the market has developed, people have started demanding more EVs

(Stakeholder #12). The car dealers on the island have started to import EVs, the (Garage Central) Hyundai Ionic and (Top Car) Nissan Leaf. If there is an EV with a 100 miles range price, this will significantly impact the local market of Aruba. A short distance is a limited market that big companies like Tesla and Nissan are not focusing on (Stakeholder #12). Electric cars go hand in hand with the solar energy diffusion, with only 2kWp Solar Rooftop PV installation capacity is sufficient to charge an EV completely (Stakeholder #12). Nevertheless, Elmar has a robust grid on Aruba because there is a 3 phase grid configuration at every house on the island. A robust grid is not the case on other islands in the Caribbean. Most of the grid capacity was used before for Air Conditioning, but now with the introduction of inverters AC, there is enough grid capacity to connect the EV charger at home. Smart meter, demand-side management combined with EV, and incentives will also provide a significant opportunity for more RE penetration. According to Stakeholder #12, before the WEB company invests in storage, the company should invest in demand-side management in combination with the EV charging system.

6.4.2. Learning by doing: Capacity building

One of the biggest challenges is the infrastructure available for EV diffusion. The lack of know-how and skilled labor that usually characterizes an underdeveloped market is no longer the case for EV technology because Elmar has trained engineers and experts who acquired experience by working with TNO or/and international agencies on previous pilot projects (Stakeholder #12).
An EV's maintenance is lower than an ICEV, only AWG 250,- (€125,-euro), because the EV service is based on protecting the connectors for corrosions (Stakeholder #12). Therefore, the mechanics need to upgrade their knowledge to deal with the EV transition.
There was training in Barbados presented by a UK entity. The EV service style is a craft on its own, and the mechanic has to isolate the electrical parts before working on it. Because of the training that stakeholder #12 had, he was invited by the fire department of Curacao to give a presentation to show how someone should act according to safety issues addressed by the Occupational Safety and Health Administration (OSHA) in case of an emergency. Elmar is keeping up with the charging infrastructure by facilitating a swipe card where the user can charge their car anywhere on the islands, and at the end of the month, the user will receive a bill to make their payment, but this is still a pilot project. During the years, Elmar bought four different EVs to experiment with the charging and driving experience (Stakeholder #3).
Smart charging infrastructure makes use of existing transformer capacity. Depending on the demand for EV charging, the intelligent charging system divides the capacity equally to avoid overload on the transformers. This philosophy saves Elmar from investment in new infrastructure just for EV charging. Now Elmar integrates the intelligent charging stations with the existing spare capacity from the transformers (Stakeholder #3).

6.4.3. Learning by using: Awareness and social acceptance

EVs require charging instead of refuelling at a pump station. Charging takes more time than refuelling but could be done at home. However, charging at home will impact Elmar’s grid and WEB’s electricity load pattern (Stakeholder#4). To avoid an overload, EV drivers’ should be aware of the consequences when charging their EC without an intelligent coordinated system. In the beginning, there is always a lack of public chargers. Hence, most charging takes place at homes/residential and is uncoordinated. At a certain point, cumulative charging of EVs could overload the grid and increase peak demand that will require a significant investment that is catastrophic for business (Stakeholder #4). The main goal is to flatten the load curve to minimize the grid and production side load (Stakeholder #9). Hence, WEB and Elmar incentives are necessary to stimulate social acceptance to change their charging behaviour.

6.4.4. Learning by interacting: Policies regulations and collaborations

In 2011, as an additional incentive to promote EV toward SET, the Government of Aruba introduced tariff reductions on the import of EV from 40% to 2% and cut road taxes for electric vehicles to AWG. 75,- (GreenDeck, 2015). The normal road tax for a gasoline car is AWG. 375,- and diesel is AWG. 625,- (Stakeholder #12).
Once Elmar has the demand-side management installed, dynamic tariffing becomes possible. In the case where WEB has an overflow of RE production, for example, between 9 pm and 1 am, WEB already knows the scenario of overproduction due to the forecasting system. If the island demand cannot handle the energy supply, WEB could curtail the wind park, which is not the best option. Instead, demand-side management plays a key role with dynamic tariffing. Elmar and WEB can predict that tonight the electricity price will be low because there is an overflow of electricity and can incentivize application usage, for example, EV charging at a specific time when the energy is cheap. As a result, it is a win-win situation for WEB, Elmar, and the client (Stakeholder #12).

6.4.5. Conclusion learning processes

On the island of Aruba, most technologies are imported from foreign countries. The R&D is not done on the island, meaning that technology such as EV should make techno-economic sense to be considered. The competing technology of EV is the ICEV. Once the price is right, the demand for EVs will increase. Second-hand EVs was also a market in the beginning to initiate the decarbonization of the passenger cars (transport sector). In 2014, there were around 10 EVs, and in 2019 was 400+ EVs on the island. To compare the Caribbean SIDS on EV per capita, Aruba has more EV per capita than Barbados. Also, EV enables the RE market locally. With only two kWp Solar Rooftop PV installation, EV users could charge their car with RE and contribute to the decarbonization of the transport sector, which is 20% responsible for the island's CO2 emission.
The know-how is no longer a problem for the EV introduction. Elmar and other international research institutions like TNO collaborate for the EV introduction. Also, the private sector contributes to EV diffusion by educating their staff on EV maintenance and how they should act in case of an emergency or accident.
The introduction of intelligent chargers minimized the investment in the current generation and distribution system. Users' development is necessary since the charging takes more into account than refuelling. Moreover, a behaviour change is required to operate an EV. The impact on the current system is enormous if there is no coordination on EV charging. Therefore, awareness and social acceptance are essential during the EV diffusion, especially in island settings, to accelerate the transition and avoid catastrophic investment.
The government introduced tax incentives to support EV diffusion. Dynamic tariffing will also help with affordable charging fees and in a coordinated way to minimize the load impact on the current system. Moreover, dynamic tariffing creates a win/win situation for WEB, Elmar, and the government. During an overflow of RE production, EV users can be incentivized to charge their car to avoid a curtail.

6.5. Conclusion Electric Vehicle niche analysis

There is a crucial linkage between RE and EV technologies. The integration is at the technological level and in the network behind these technologies, which are crucial for accelerating the SET. The EV network is not optimal since not all stakeholders have a strong tie. Expectations are different, and the main goal of the regime actors is to have a larger share of RE within the local energy mix before starting to focus on the EV diffusion on the island. From the techno-economic perspective, the EV is close to price parity with the ICEV, which means the market will grow because of international developments. The development of the intelligent infrastructure and RE share growth in the energy mix should responsibly go hand in hand to avoid shifting problems. The final goal should be to decarbonize the energy and the transport sector by being less dependent on fossil fuels. Instead, local natural resources such as wind and solar should produce more renewable electricity locally. Therefore, awareness is vital during this EV diffusion to get users/drivers and all other relevant stakeholders onboard with shared expectations to accelerate the SET.

7. Wind Turbine niche analysis in Aruba

Strategic niche management is applied to analyse the Wind Turbine (WT) technology development. This chapter presents the network formation in section 7.1, then the shaping of expectations in section 7.2. Next, in section 7.3, the learning processes are discussed. Finally, in section 7.4, the conclusion of the WT niche is drawn. The outcome of this chapter is part of the answer to the sub-question: Which niches/projects are being developed to reach the 100% renewable energy goal?

7.2. Network formation

This section presents the network responsible for the WT niche by using the conceptual framework mentioned before in 3.1.3. The network formation consists of network overview and network composition & alignment. The discussion of each of these parts is next.

7.1.1. Network overview

One of the most affordable RE technologies today on the market is the onshore wind turbine. However, other aspects that are neither economic nor technical play a crucial role in the deployment process. Moreover, substantial amounts of open land are required to install wind turbines, and open space is something that a small island like Aruba does not have abundant. At present, Aruba has limited potential to deploy offshore wind farms because today's technology needs relatively shallow water and does not fit the offshore circumstances.

Nevertheless, Aruba has already reached a low level of renewable penetration by installing a 30 MW wind farm at Vader Piet. This low share of RE within the existing energy mix has required minimal changes in grid operations but added complexity to the energy supply because the RET, such as WT, is an intermittent energy source. Also, the current wind farm installed does not include any storage. Traditional generators run on Heavy Fuel Oil provide all spinning reserves and peak capacity.

Before 2009 all energy was imported from foreign countries based on fossil fuel sources (Stakeholder #12). In February 2008, WEB requested a proposal to "build, own, and operate" wind farm Vader Piet and supply all generated electricity to WEB. The Vader Piet wind farm consists of ten WT of the Vestas V90 type with a height of 105 meters and a blade diameter of 90 meters (Windbase, 2019). In total, the Vader Piet wind farm produces around 15% of Aruba's total electricity demand (GreenDeck, 2015). The rated power per WT is 3 MW, and the farm consists of ten WTs that sum up a total of 30 MW installed capacity. The project has more than ten years in operation and is performing well. Vader Piet Wind park produces around 126 MWh a year, and the price per kWh is fixed and sold to WEB (Windbase, 2019; Stakeholder #4).

7.1.2. Network composition & alignment

To give an overview of the main participants in the WT niche in Aruba, a stakeholder map is presented which includes all the aforementioned stakeholders, see figure 7.1.

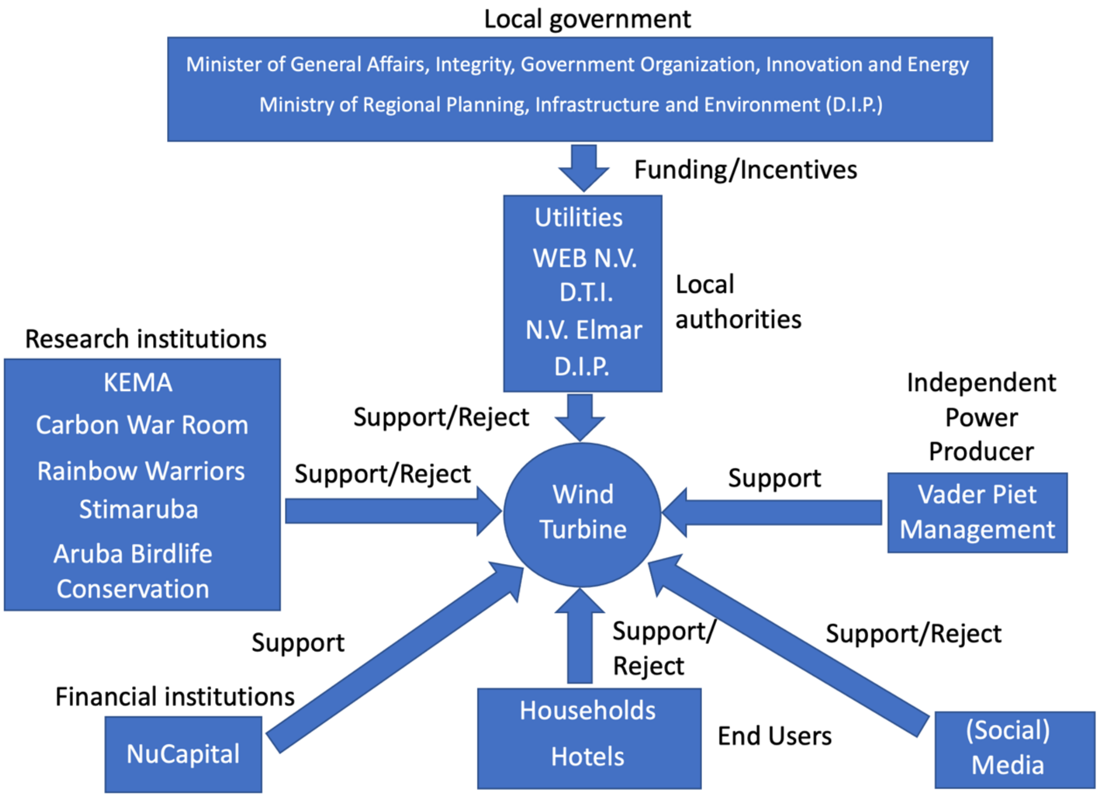

Figure 7.1: Wind Turbine's stakeholder map (Source: own illustration)

Discussion with electricity sector stakeholders (Utilities, WEB, Elmar, and NuCapital) on the island, including landowners, planners, local communities, and government, highlighted technical, social, and environmental issues to be explored if an island such as Aruba would like to expand its wind energy resource.

From the technical perspective, it is essential to mention that a second large-scale wind park with WT technology will require storage and intelligent infrastructure for a reliable electricity supply (Stakeholder #4). Analysing the infrastructure, such as an electrical integration study, will allow Elmar and WEB to evaluate their need for grid reinforcement, grid extension, and the storage required for balancing the demand with supply.
The planning department DIP has a critical role in developing wind energy markets. Also, wind farm zoning should be incorporated into physical development plans at the earliest opportunity so that future land-use changes will not impact identified wind energy zones. The involvement of local communities with wind energy is critical to ensuring the successful deployment of large-scale wind turbines, and local investment is key to ensuring that local economies are best impacted by this clean, reliable, and affordable form of electricity generation. NGO's on the island of Aruba was very active in the blocking of the second WT park in "Urirama" and cannot be ignored during the development stage. Because society shapes the development of technology, it gives a cultural symbol to technology. In such a scenario, the perception of inhabitants near the installation sites regarding aesthetics, safety, and importance of wind parks can play a critical role in determining market success for wind turbine technology. Similarly, conflict can arise in terms of land use for wind farms.

The local media should inform the population regarding the projects in development. The media also has the power to influence positively but also negatively to block or delay a project by informing or manipulating the population.

The local government and Utilities represent the SDGs goals, and one of the missions is to reduce emissions. Expectations are that by 2030, a CO_2 emission reduction of at least 45% is expected, and after 2030 to reach 'net zero' before 2050 to cope with the SDGs target (Stakeholder #1, NSP, 2019). There is a strong tie between the government, Utilities, and WEB regarding the decarbonization of electricity production. The expansion of the current wind park is already in the pipeline. This project, "Rincon," is expected to take two years and an estimated investment of €50 million (AWG 100 million) (EPA, 2019).

The infrastructure to transport the electricity generated by the wind park is part of WEB's responsibility. However, the transportation cable is connected to the substation in San Nicolas, and Elmar manages the substations. As a result, there is a strong tie between WEB and Elmar for the current and future wind park expansion.
Permission should be granted to deploy more wind parks since the island of Aruba is limited by land, and some restricted areas are protected by the Regional Official Plan (ROP) (DIP, 2019). According to Stakeholder #13, the director at DIP, to install a new wind or solar park, a "Wijziging bevoegdheid" permission should be requested from the minister of infrastructure. Also, an environmental assessment study (MER) needs to be conducted. Moreover, the expansion of the current wind park or a new wind park is an inter-ministerial collaboration. Therefore, strong ties are needed within the government and between other stakeholders to accelerate the energy transition.
Environmental NGOs can have two different stakes in wind energy depending on their work areas. On the one hand, NGOs in the energy sector promote RE as a source of clean energy and promote it. While environmental NGOs work for flora and fauna might be against such wind farms as it will impact the land used by birds and plans. As a result, NGOs should be included during the process of new wind farms to have the multi-disciplinary support of relevant players.
Available wind resource studies done by research institutions such as KEMA are essential to help identify the best suitable wind turbines for local conditions. Also, detailed measured wind data can prove to investors and financial institutions that a wind farm project will have a feasible financial projection (Klerk, 2013).
One can assume that stakeholders had strong ties to deploy the whole Vader Piet wind farm project successfully. However, the second wind park Urirama, closer to civilization on the island's west side, did not go according to plan. The project was stopped because of NGOs and local communities regarding the (not in my backyard) NIMB phenomena. Three NGOs on the island were involved in developing the "Urirama" wind park and had accomplished to stop the development of this project. They are 1) Rainbow warriors Aruba, 2) StimAruba, 3) Aruba Birdlife Conservation (WindWatch 2013). As a result, the (weak) ties between the project developers and NGOs are important and should be considered at an early stage. Also, the end-users have a weak tie with WT technology projects, and more awareness campaign is necessary to overcome social barriers.
Moreover, the end-users can be categorized in households and industry, and demand-side management is vital to be accepted by the tourism industry hotels because they are the largest single users (Klerk, 2013). International media and, most importantly, local media

needs to inform the local communities on the development and awareness of WT parks regarding the acceleration of RE towards the SET. Therefore, strong ties are necessary to educate and influence the population on the advantages and disadvantages of a WT park to create social acceptance.

The WT is imported and installed by an IPP (independent power producer), and all the produced electricity is sold to WEB. The electricity production remains centralized and monopolistic. The niche market is within the electricity regime created by WEB but is built and managed by an international company, NuCapital. Therefore, the WT niche is part of the electricity regime network on Aruba.

7.1.3. Conclusion network formation

It is essential to have strong ties with relevant stakeholders in the network formation. Especially when the WT park is close to civilization, the phenomena NIMB is at stake and could result in a discontinue of a WT park project. WT technology and its park are not new for the island and well known by the population. Nevertheless, the awareness campaign and social acceptance are crucial within the network to accelerate the WT niche market. Since the prior experience to construct a second wind park, “Urirama,” the collaboration between stakeholders remains crucial. The network will become more inter-disciplinary and more extensive. NGOs and end-users should have strong ties with the project initiatives because social barriers remain very sensitive compared to technical or economic barriers.

7.2. Shaping of expectations

In the early niche stages, participants join the niche by investing effort, money, and time because they expect future success. At this moment, stakeholders have broad and unclear expectations about the technology and different vision of its future.
During the time, expectations can change because of external factors (regime and landscape) and internal circumstances (e.g., results from experiments within the niche) (Raven, 2005).

7.2.1. Expectations at the niche level

The expectations of the utility-scale WT niche are presented below. The two expectations that were found during this research are discussed using the conceptual framework presented in section 3.1.3. The two expectations are scaling up the WT niche market and decarbonizing the electricity sector.

Robustness of scaling up

The robustness of this expectation is not optimal from the social perspective. Some NGOs are supporting the RE because the WT technology provides clean energy. However, other NGOs representing flora and fauna were not involved in the “Urirama” wind park process, and the inhabitants living near the wind park did not accept the WT project (WindWatch, 2012). Therefore, the “scaling up” expectation will also require NGOs to make this expectation more robust.

Specificness of scaling up

The expectation is not specific since there is not enough land available on a small island for WT installation, and currently, only onshore WT technology is affordable and available.

Moreover, the island of Aruba does not have shallow water near the coast; therefore, offshore WT technology is necessary to scale up the niche market (GreenDeck, 2015). As a result, the technology barrier of offshore WT will limit the scaling-up process of the local electricity market.

Quality of scaling up
The quality of the expectation is low because the lessons are unlearned. When more intermittent energy sources are involved in the local energy mix market, the quality of the expectation could increase. Storage and demand-side management are crucial for the scaling-up process where social acceptance, especially by hotel owners, are necessary (Klerk, 2013). Therefore, more experiments are required to increase the quality of the scaling-up expectation.

Robustness of decarbonization
The involvement of hotels regarding demand-side management will become important when the second wind park is in operation (Klerk, 2013). Decarbonization is not entirely possible if traditional fossil fuel engines support the spinning reserve. To do so, the hotels that are the largest electricity users on the island should participate in the SET by implementing cooling systems that WEB can manage. Nevertheless, this is not the case.

Specificness of decarbonization
From the technological perspective, floating offshore WT is not yet available on the market, and the current offshore WT is not affordable compared to the onshore WT. From the social point of view, there is not enough land available for wind farms without facing restriction or social conflict. Therefore, floating offshore WT is necessary for Aruba and other islands with less shallow water at their coast. The next step is not clear and makes this expectation less specific.

Quality of decarbonization
The current wind park at Vader Piet is responsible for mitigating 152783 tons of CO2 annually (Windbase, 2019). However, the coupling with the existing demand side is challenging because system integration towards the SET is complex. The combination of WT, storage, and demand-side management requires more experiments to increase the quality of this expectation.

7.2.2. Expectations at the regime and landscape level

The three expectations found during this research are discussed using the conceptual framework presented in section 3.1.3. The expectations at the regime level are addressed together with the landscape level too because of international agreements and regulations such as SDGs and Paris agreement. The three expectations are fuel import reduction, cheap electricity, and the environmental friendly of the electricity sector.

Robustness of fuel import reduction
WEB culture is based on mechanical engineers who keep their business as usual by investing in technologies with at least ten years of track record (Stakeholder #2). Moreover, these fossil fuel-based technologies create lock-ins that make the transition towards zero-emission more difficult. Elmar's company culture is more electrical engineer and is more

open for RET than WEB (Stakeholder #3). Therefore, the robustness of this expectation is not solid.

Specificness of fuel import reduction
There are two approaches to minimize the import of fuel, one is by scaling up WT technology, and the other is to increase RECIP motors' efficiency. However, the last one limits the impact towards reducing fuel consumption. According to stakeholder #4, in 10-15 years, WEB successfully reduced their fuel consumption from 6500 to 3600 barrels/day by making all the required changes. It is a significant HFO reduction on WEB's fuel consumption for the same production output. WEB invested in RECIP phase 4 motors that will lower fuel consumption from 3600 to 2700 barrels/day, reducing 900 barrels a day (Stakeholder #4). Also, RE penetration such as WT technology will help lower fuel consumption in the local energy mix. Nevertheless, these investments are lock-ins to the fossil fuel regime. Therefore, this expectation is not specific.

Quality of fuel import reduction
WEB follows the SDG targets to lower carbon emissions by 2030 related to the Paris agreement. The electricity and transport sectors are the most significant contributors to the island's emissions. According to WEB, the main objective of the SDGs is to translate these into technical aspects, meaning that WEB wants to become more efficient and cut off the usage of HFO while increasing the penetration of RE into the energy mix (Stakeholder#1). The measurement of emission reduction started in 2010 and is projected until the year 2030. During this time, WEB's goal is to reduce emissions by 45% within these 20 years. Therefore, the quality of this expectation is low because more experiments and results are necessary.

Robustness of cheap electricity
If the technology is not cost-effective compared to conventional technology, WEB will not implement it at a large scale (Stakeholder #2). Vader Piet wind park has over ten years of operation and has a flat price (Stakeholder #4). With a steady long-term price per kWh, WEB expects to provide their client with a constant price per kWh. Also, data is collected over the years where the IPP and WEB can negotiate for a fair price per kWh. On the other hand, the price proposed by the IPP does not include the storage, spinning reserve, and demand-side management. As a result, the expectation is not optimal because of hidden costs.

Specificness of cheap electricity
The floating offshore WT is expected to be a promising technology for the island of Aruba. As already mentioned, the technology is not yet available and makes the next step less clear. Therefore, this expectation is not specific.

Quality of cheap electricity
The installation of more WT parks is expected to involve hidden costs because intelligent systems and storage are required to provide a reliable electricity supply. There is a trade-off between affordability and reliability (Stakeholder #5). More experiments are necessary to evaluate if scaling up the WT is indeed affordable. Therefore, this expectation is not specific.

Robustness of environmental friendly
Some NGOs support WT because it is a RET and does not pollute the environment. Also, NGOs represent the land of flora and fauna that are against these types of projects. Moreover, the NIMB (not in my backyard) phenomena can also be responsible for blocking large-scale RE projects, such as the "Urirama" wind park initiation (WindWatch 2012; Stakeholder #9). At least the three leading NGOs responsible for blocking the "Urirama" wind park should be part of the network to discuss the expectations. Therefore, the robustness of this expectation is not solid.

Specificness of environmental friendly
As long as the spinning reserve and peak capacity are covered by conventional fossil-fuel technology, there is still a gap to close with storage and demand-side management that is more environmentally friendly and cleaner. Therefore, this expectation is not specific enough.

Quality of environmental friendly
The WT technology does not pollute the environment during electricity generation. The long-term consequences for the land of flora and fauna are not clear yet. Suppose the WT can kill birds hit by these WT's large blades. More experiments are necessary to understand the consequences of WT technology. As a result, the quality of this expectation is low.

7.2.3. Conclusion expectations
The WT technology is expected to cover a large share of the electricity supply on the island because of the natural resource that the island has and is currently the most cost-effective RET on the market. Also, WEB has more than ten years of experience with Vader Piet wind farm, where investors and local communities have a reference for future expansion. The WT technology seems to lower fuel imports and emissions. According to Utilities and WEB, scaling up the local wind farm is on the agenda. To do so, WEB and Elmar are expected to prepare the infrastructure regarding storage, demand-side management, and grid capacity to fulfil these expectations. The NIMB phenomena represent a social barrier since there is limited land available on the island of Aruba. The next expected step is to move offshore with the WT parks. However, there is a technological barrier because the floating offshore WT is not commercially available yet.

7.3. Learning processes
The learning processes influence the niche by affecting the expectations and aligning them. A good learning process is reflexive and focuses on many aspects (Raven, 2005). The learning data gathered is presented according to the analytical framework.

7.3.1. Learning by searching: Market research and development
The onshore market of WT is well known, but there is not enough land available to increase the RE share. Therefore, a new protected market for the floating offshore WT should be made. The floating offshore WT technology is not ready. However, the government, Utilities, and WEB can lay down the infrastructure to support offshore WT and other RET which require the ocean to generate electricity.

7.3.2. Learning by doing: Capacity building

Intermittent energy sources such as wind and solar energy are constantly fluctuating. The operators are challenged with more intermittent RE into the local energy mix. WEB and ABB are investing in an intelligent system that can make forecasting (solar and wind) and provide information to the operators to manage the energy supply while lowering the complexity (Stakeholder #4). Therefore, operators are provided with the latest technology to facilitate their job and enable the intermittent RE niche market at a utility scale. The automation system suggests the operator, based on the forecast and load demand which generators to start or turn off to maintain efficient energy production (Stakeholder #1 #4). Also, the demand side management is integrated into the intelligent system and can switch substations within the field to avoid blackouts (Stakeholder # 4). WEB and ABB are collaborating to create a new intelligent system that could later be transferred to other islands in the region with the same criteria as Aruba. There is no “one size fits all” setting available yet for SIDS on the market.

7.3.3. Learning by using: Awareness and social acceptance

The available land on the island is limited, and no one wants the WT in their backyard (COE, 2017). The Urirama case is a few years back, and more information is available regarding the whole SET on the island and the SDG’s target for 2030. Therefore, awareness campaigns are crucial for inhabitants, NGOs, and other local communities. to prevent social resistance. Also, the expansion at the coast of Aruba should be discussed.

7.3.4. Learning by interacting: Policies regulations and collaborations

Most of the land available for WT farms is a protected area. According to stakeholder #12, the minister responsible for urban planning should request grand permission to build a WT park within this area. DIP has its “Build with nature” policy that describes any project’s process within a protected area (DIP, 2021). Therefore, the process is inter-ministerial within the government and could make the process longer and more complex.

7.3.5. Conclusion learning processes

In search of an offshore market, the government, Utilities, and WEB should create a floating offshore WT technology platform. There is still limited available space on Aruba for the onshore WT niche. The intelligent system at WEB will enable the market for more intermittent RE sources such as WT technology. Also, WEB is educating their staff for the SET towards 2030 at the Utility-scale. The operators are learning how to manage intermittent energy within the current energy mix with intelligent systems.
Raising awareness is crucial to overcome the social barriers; otherwise, scaling up WT will be difficult. Stakeholders such as NGOs are experiencing the current WT installation at “Vader Piet,” positive feedback should be created to enable the following WT projects and market. Multi-disciplinary interactions between stakeholders outside and inside the government are necessary to create more available space for WT onshore and offshore technology. As a result, to have a better learning process, a closer collaboration between stakeholders is necessary to share lessons learned in a more organized manner.

7.4. Conclusion Wind Turbine niche analysis

The analysis of the WT niche in Aruba presents different opportunities and challenges. The WT niche can barely expand onshore because of the limited space on a small island like

Aruba. Also, most of the area that remains for WT technology is protected land. Hence, involving NGOs at an early stage is essential to overcome the current social barrier in Aruba. There is a technology barrier when the WT project moves to offshore wind parks because floating WT technology is not commercially available. Expectations to lower the fuel import and decarbonize the electricity sector show positive results towards the SET and the SDGs goal. In order to build with nature, it is vital to have a multi-disciplinary network to raise awareness and social acceptance to scale up the onshore and offshore WT niche market. Also, the relevant stakeholders should start searching and creating a new offshore WT niche market to be ready once the technology is available and affordable. The WT niche market is within the electricity regime because WEB and Utilities initiated and managed the technology.

8. Cross case analysis and acceleration

In this chapter, the analysis continues by examining the three RE technologies in the context of Aruba. The following sections present the results for the three internal niche processes; network formation, expectations, and learning processes, based on the similarities and differences. Section 8.4 will address the main barriers that delay the SET acceleration at all three levels. Finally, section 8.5 presents a roadmap to accelerate the energy transition to overcome the main barriers.

8.1. Network formation

Figure 8.1 presents a complete overview of the electricity regime and its network. What stands out in the case analysis is that the social network consists of almost the same group of stakeholders. All three networks are based on a small island and connect to the centralized, monopolistic market driven by the government. Also, most of the knowledge research takes place outside the scope/island. All the equipment/technologies are imported as well.

The differences are between financial institutions where local banks support or reject EV and Solar PV Rooftops and foreign investors support WT technology. Similar to EV and small-scale PV, both are dependent on the distribution network (Elmar's grid) to charge or feed-in. In comparison, the WT relies on the 60 kV transmission line provided by WEB and Elmar. The small-scale PV and EV owners deal with Elmar and not with WEB. Both technologies (small scale PV and EV) are directly impacting the business of WEB and their production. Small-scale solar PV and EVs create destabilization at the distribution and generation sides. Another difference is that the local private sector drives the small-scale PV and EV market, while foreign investors drive the solar and wind parks as independent power producers.

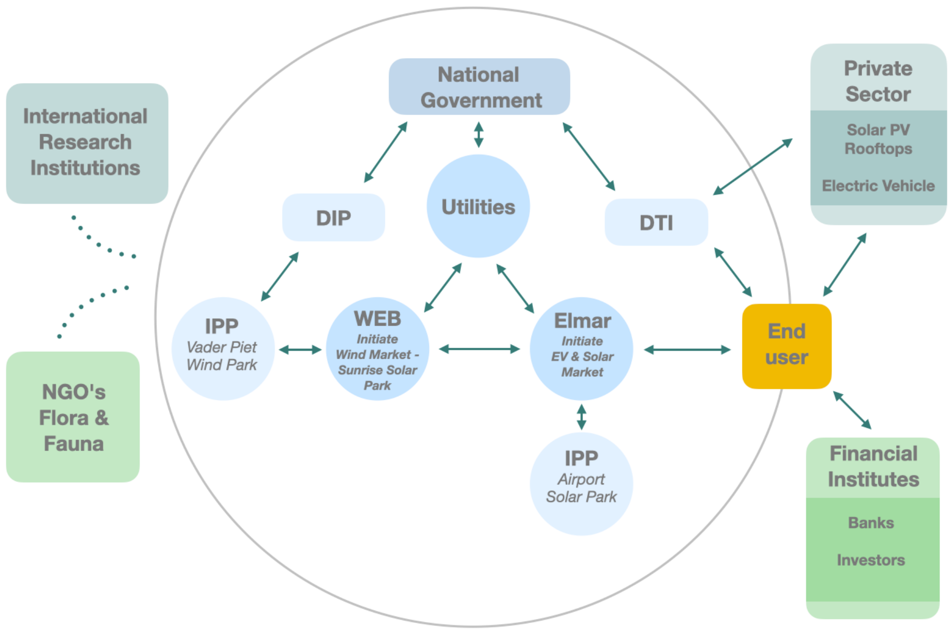

Figure 8.1: An overview of the electricity regime on Aruba (Source: Own illustration)

8.1. Expectations

Expectations are essential for SET development, creating arenas for stakeholders to collaborate, investing money and time into projects and experiments. This section analyses the main similarities and differences of expectations at all three levels for the cases studied, see table 8.1.

Table 8.1: Expectations similarities and differences

Factors	Solar PV Rooftop	EV	WT
Technical	• Backups/spinning reserves • Increase intermittent RE share	• Charging with renewable electricity • Increase electricity demand/storage	• Backups/spinning reserves • Increase intermittent RE share
Market	• Feed-in tariffs • Attractive loans and/or leasing contracts • Price reduction	• Price reduction	• Feed-in tariffs/IPP contract • Price reduction
Economic	• Lower dependency of fuel import	• Lower dependency of fuel import	• Lower dependency of fuel import
Social and environmental	• Decarbonization of the energy sector	• Decarbonization of the transport sector	• Decarbonization of the energy sector • Land available
Policy and regulations	• DG policy	• EV tax policy	• SDG targets

8.1.1. Main similarities

On the **technical** aspects, the Solar PV Rooftop and WT niche expect WEB to provide the infrastructure and backup as spinning reserve, and Elmar the feed-in tariff.
From the **economic** and **environmental** perspective, all three technologies, PV/EV/WT, are expected to lower the island's dependency on fuel import and decarbonize their industries/sectors.
From the **policy** point of view, the local DG and EV policy and SDG targets anticipate the enabling of the PV/EV/WT markets. At the same time, a price reduction is expected for all three technologies on the international market.

8.1.2. Main differences

From the **technical** and **environmental** perspective, EV expects to be charged with clean RE to decarbonize the transport sector, while WEB anticipates 100% RE based on the 2050 goal. From the **social** and **environmental** perspective, the WT technology expects to have available land while the Solar PV Rooftop does not share that problem.
From the **market** perspective, Solar PV Rooftop technology expects more attractive loans from local banks also leasing contracts to increase the market share. In contrast, EV technology already has attractive loans available.

From the **economic** point of view, Solar PV Rooftop and WT technologies expect to increase the RE share on the island. In contrast, the EV technology expects to decrease the RE share because of increased demand. However, the electricity and transport sectors anticipate merging and complementing one another in the case of PV, EV, and WT.

8.2. Learning processes

It is essential to learn about the barriers of the SET development and how to overcome them to facilitate the acceleration. This section analyses the main similarities and differences of the learning processes for the cases studied, see table 8.2.

Table 8.2: Learning similarities and differences

Factors	Solar PV Rooftop	EV	WT
Technical	• Intermittent RE source: backup still based on fossil fuel source • Storage remain crucial for the transition	• Allows more RE penetration because of battery storage (load shifting)	• Intermittent RE source: backup still based on fossil fuel source • Storage remain crucial for the transition
Market	• Driven by private sector • Allowing consumers to feed/sell energy back to the grid • Demand side management is not ready	• Driven by private sector • DSM is not available to increase RE penetration • Demand side management is not ready	• Driven by foreign investors • Most cost-effective RET • Allowing IPP to feed/sell energy back to the grid • Demand side management is not ready
Economic	• Lower dependency of fuel import	• Lower dependency of fuel import	• Lower dependency of fuel import
Social and environmental	• Decarbonization of the energy sector • Misunderstanding around cost, benefits and potential	• Decarbonization of the transport sector • Misunderstanding around cost, benefits and potential	• Decarbonization of the energy sector • Misunderstanding around cost, benefits and potential • Limited space available • Local NGO's can block projects
Policy and regulations	• Weak ties between WEB, Elmar and users	• Weak ties between WEB, Elmar and users	• Weak ties between WEB, Elmar and users

8.2.1. Main similarities

From the **technical** perspective, backup and spinning reserves for PV and WT technologies are based on fossil fuels. Moreover, storage remains crucial for the following large-scale RE projects (PV and WT). Also, smart infrastructure and demand-side management are not yet available but necessary. From the **economic** and **environmental** perspective, all three technologies, PV/EV/WT, lowered the island dependency on fuel import and decarbonized their industries/sectors. Foreign investors drive most large-scale RE projects (WT and PV). From the **societal** perspective, raising awareness is necessary since there is a misunderstanding around RE's cost, benefits, and potential (PV, EV, WT). From the **policies** and **regulations** perspective, WEB, Elmar, and users (PV, EV, and WT) require stronger ties and alignment. From the **market** perspective, Solar PV Rooftops and WT can feed/sell electricity back to the grid because of feed-in tariffs and IPP contracts. Also, Solar PV Rooftop and EVs are driven by the private sector while foreign investors drive WT.
From the **technical** perspective, integrating the electricity and transport sector enables more RE penetration because of EV/storage, but demand side management should support the load shifting. Moreover, users (hotel and EV) are not yet involved in the demand side management introduction from the **market** perspective.

8.2.2. Main differences

The WT technology has a different learning process than the Solar PV Rooftop and the EV. Next, the unique learning aspects of the WT technology are presented. From the **technical** and **economic** perspective, the WT is the most cost-effective RE innovation available on the market and for Aruba's wind energy resource. From the **environmental** perspective, limited open land is available for WT parks on the island, and in the case of offshore, no space is reserved yet. Local NGOs could block the "Urirama" wind park from a **social** perspective.
From the **technical** perspective, EVs require more (renewable) electricity to charge their battery to reduce fuel import and to decarbonize the transport sector.

8.3. Main barriers

This section provides the cross-case comparison of the three cases according to the SNM and the internal processes. Table 8.3 presents the s*hared* and *case-specific* encountered within the internal niche processes.

Table 8.3: Main barriers at the niche level

Factors	Shared	Case-specific
Technical	• Intermittent RE source: backup still based on fossil fuel source	• EV requires more (renewable) electricity
Market	• Demand side management is not ready	
Economic	• Fossil fuel dependent	
Social and environmental	• Misunderstanding around cost, benefits and potential	• Limited space available for WT • Local NGO's can block WT projects

Policies and regulations	• Weak ties between WEB, Elmar and users	• Limited installation capacity for PV

These barriers are categorized by the vital factors for accelerating the RE diffusion towards a SET. Table 8.4 combines the main barriers at the landscape, regime, and niche level.

Table 8.4: Main barriers at all three levels of the system

Factors	**Barriers**
Political	• The vertical integrated power structure is responsible for bureaucracy and red tape
Technical	• Intermittent RE source: backup still based on fossil fuel source • EV requires more (RE) electricity • Isolated island setting
Market	• Demand side management is not ready
Economic	• Dependency on fossil fuel
Social	• Misunderstanding around cost, benefits and potential • Local NGO's can block RE projects (WT) • Oil refinery mentality
Environmental	• Limited land available
Policies and regulations	• Weak ties between WEB, Elmar and users • Limited installation capacity for PV • Fragmented energy policy • Monopolistic state-owned utility company

Now that the main barriers are identified, possible solutions and actions can be presented. The following section will present a roadmap that categorizes these barriers into a time frame where possible solutions are presented depending on the complexity of overcoming these barriers. The roadmap presents solutions that were encountered during this research while interviewing stakeholders. To accelerate the energy transition, overcoming the obstacles are crucial; this part will be addressed next.

8.4. Roadmap to accelerate the SET on Aruba

The roadmap to accelerate the SET is studied, addressing the fourth research sub-question: How can the local government take action to accelerate the transition? The SNM and MLP analysis derived various lessons learned to draw up a fossil-fuel-free Aruba roadmap. A roadmap is developed for new projects to diffuse into the regime once it is destabilized. The recommendations based on the case analysis is presented in this section. The MLP developments and additional drivers and barriers are summarized in sections 4.3. The transition towards 100% RE is explained according to time frames: Short-term (2022-2028), Mid-term (2028-2034), and Long-term (2034-2040).

Short term (2022 -2028)	
• Create an independent entity	• Smart infrastructure
• Network alignment	• Demand side management
• National energy policy	• Townhall meetings

• Early involvement of stakeholders • Create targets (Expectations) • Implement energy storage	• Pilot projects • Demonstrations • Environmental impact assessment • Reserve available space/land

8.4.1. Institutional, policy and collaboration

The formation of any RE technology network relies on regulations. The government can create an independent entity that can help align Utilities, WEB, Elmar, and users. The initiator can be Utilities with their financial resources and connections to assist the project further. Moreover, such actors can establish a sense of professionalism amongst a network reducing the risk of conflicting views (keep political influences away). Introducing the national energy policy can help align the network, convincing the organizations to remain working together on the other RE projects. Involving stakeholders early in the RE projects, even those that might not be directly relevant from the start will create a sense of willingness to engage in the SET. By creating common expectations (targets), stakeholders will be more willing to act following the decision-making and all this remain the responsibility of the project initiator. Furthermore, an independent entity is required to define and communicate the RE project's expectations. With this in mind, a multidisciplinary network brings together multiple disciplines leading to more learning processes about the niche and creating better solutions for the energy transition.

8.4.2. Technical and economic

From the technical and economic point of view, complementary innovations such as energy storage, smart infrastructure (IGMS), demand-side management, should be implemented to start coupling systems and sectors, for example, EV, RET, and cooling. According to Geels (2017), sociotechnical transitions start accelerating when multiple innovations are connected, enhancing the functionality of each and performing in combination with the new system.

8.4.3. Social and environmental

Social acceptance, business support, and awareness campaigns such as town hall meetings by WEB are essential for the SET acceleration from the social, and environmental perspectives. Pilot projects and demonstrations are essential for the learning process. Stakeholders' involvement, such as NGOs, should be involved early in the RE project network. Environmental assessment for onshore and offshore large-scale wind and solar projects is necessary because of the limited space available. Here is where the DIP (spatial planning department) should reserve available land for large-scale RE projects within the ROP.

Mid-term (2028-2034)	
• Create (raise) awareness • Changing teaching practice • Introduction of a technical university	• Sharing experience, knowledge and information • RE demonstrations • Governmental financial incentives (Guarantee funds)

8.4.4. Knowledge and learning

From the social point of view, it was mentioned that raising awareness on the RE transition is most effective when starting to change the education and teaching system (Stakeholder #8). Currently, courses dedicated to energy transition are being introduced in the curriculum of SISSTEM (sustainable engineering) faculty at the University of Aruba (UA). Nevertheless, other RETs that are not PV or WT are still lacking. When students become familiarized with other RE and are integrated into the local electricity system, it gives them the tools, skills, experiences, and knowledge needed to accelerate the SET. The result is that the moment these graduates enter the labour market, they will tend towards RE instead of traditional fossil fuel-based technology facilitating the growth of the niches and acceleration toward the decarbonization of the local electricity sector.
Sharing experiences, knowledge, and information is vital on the social dimension (technology transfer); this can be categorized as a bottom-up learning process. Also, advice on which stakeholders could contribute to the network regarding financial capital or other resources is necessary.

8.4.5. Policy, regulation and collaboration

Governmental support is required to implement RE demonstrations on Aruba, linking to the political dimension. Suppose it is not clear which measures will cover all initiating projects, in that case, it is advised that the government implements financial incentives to compete with the dominant existing technologies by adjusting the current DG policy, import tax reduction, and feed-in tariffs. Also, additional subsidies can play a role in lowering the higher cost for an initiator/IPP.

Long term (2034-2040)	
• Research output	• New business model
• Improving regulatory measures	• Explore other RET niches

8.4.6. Science and research

From the technical outlook, research outputs of science programs conducted at universities and future research institutions on Aruba could ultimately improve regulatory measures to facilitate the acceleration of the SET. Recommendations for political leaders can be formulated about ways in which resources efficiently can be enhanced. Moreover, new business models can be discovered appropriate to RE businesses. However, it is uncertain which direction research will take and the exact outcomes specifically for the niches. Hence, it is advised not to rely entirely on the results but to wait for further developments and explore other RET niches.

9. Discussion

The research aim of this thesis is to address the current situation of the SET and identify opportunities to facilitate the acceleration of the transition regarding three niches on Aruba. These were a few constraints that may have impacted the findings of the research. However, the results of this study also suggest contribution in the broader context. This chapter reveals the methodological limitations (9.1.1), the conceptual reflections (9.1.2), the scientific contribution (9.1.3) and broader implications and relevance of this study (9.1.4).

9.1. Limitations of Research

9.1.1. Methodological limitations

Due to the uniqueness of this context, the conducted interviews are considered the most suitable data source for this thesis. The goal was to interview 15 stakeholders but a total of 13 stakeholder were questioned for the case study analysis. A minimum of two stakeholders were question per case study incorporate different perspectives. Moreover, most of the stakeholders who were questioned work or did work for the incumbent companies (WEB, Elmar, Utilities) but are involved in one of the niches. Nevertheless, the information that was collected is considered very relevant and important to the analysis.
During the interview process other relevant stakeholders were suggested as relevant for the information gathering, resulting in a snowball effect. All interviews were done in person and semi-structured interviews gave room for discussion in case of clarification.
The interviews were translated into English after being recorded into Papiamento which is one of the official languages on the island beside Dutch, translating the interview took significant time into account. Moreover, there is no translation software/app yet available for Papiamento.
Many interviewees were non-native English speakers, therefore, Papiamento, the native language was selected. The transcriptions were reviewed twice to verify the text and voice conversations.
By interviewing multiple stakeholder of actors groups and cross-relating their data help support the results representing a broad.

Limitations

Interviews were done pre-Covid-19 crisis, which significantly impacted the worldwide economy, especially Aruba, which relies heavily on tourism. Therefore, the data collected could be less accurate and affect the reliability of the result. However, the COVID-19 crisis is added as an event at the landscape level that will have impact on the regime.
The niche participating were limited during the interviews, as the ratio between the regime (WEB, Elmar, and Utilities) and niche (Solar PV and EV companies) illustrates in table 3.5.

Due to the time constraints, the roadmap acceleration presented in subchapter 8.5 has not been validated. The data derived from the interviews were carefully considered for this roadmap. However, it would have been interesting to determine if actors share the same idea as this thesis proposed. Parties might foresee a different future for different RET, such as co-existing with other sustainable innovations in the electricity, transport or energy sector or completely reconfiguring the old regime (Geels & Schot, 2007). A considerable stakeholder discussion should have been coordinated, questioning whether the proposed measures were feasible and implementable in the Aruban electricity sector.

9.1.2. Conceptual Reflections

In this thesis, two methodological frameworks were integrated, namely the Strategic Niche Management and Multi-Level Perspective. Prior studies discuss the importance of MLP-insights complementing SNM analysis (Schot & Geels, 2008). There are different publications that report on niches by applying both methodologies (Kamp & Verheul, 2015; van Eijck & Romijn, 2008; Raven, 2005). As such the conclusion can be drawn that the combination of SNM and MLP was a useful method to demonstrate the current and ongoing process in the RE niches and the SET. Simultaneously, it was an effective policy tool to identify further actions for further development within the Aruban electricity sector.

Context uniqueness for SIDS

The framework could be modified taking into account the following factors:
Beside the protected spaces for sustainable innovation, understanding the technology transfer capacity is more important on Aruba/SIDS than developing R&D technology. Meaning that learning by searching is related to searching for markets and protected space, while searching by doing is more related to create the capacity to foster the knowledge and information that are important during the technology transfer. Hence, it is important to map the distribution (network/knowledge/infrastructure) between the knowledge/technology producers and users on SIDS (Geels, 2004). Learning by using and learning by interacting is essential to understand the activities related to creation of awareness and policies to guarantee that the technology producer understand the context where the technology is going to be used.

Sequence of learning processes on SIDS/Aruba

The learning processes framework proposed by Kamp (2002) can be adjusted for SIDS or developing countries that import technologies such as RE. Most SIDS does not perform R&D but create markets in collaboration with international partners to attract knowledge/skills and technology. However, each SIDS uniqueness requires special attention to make the technology transfer successful. There is no “one size fits all” approach, but the learning sequence between developed countries and SIDS (developing countries) is different. As was experienced during the Solar Rooftop analysis, the UNDP helped implement the “Centre of excellence” that functions as a knowledge broker and mediator, closing the gaps between SIDS and developing countries like the Netherlands and the United States.

9.1.3. Scientific contribution

The concept of SET on SIDS have been discussed to some extent in scientific literature. The MLP barriers in 4.3 reveal similarities with the barriers identified for SET on SIDS (Dornan, Shah, 2016). For example oil dependency, monopolistic energy market, limited coordination and alignment between partners etc. However, the true novelty of this research lies in the combination of PV, WT and EV in the Caribbean, a unique aspect which has not been found in any previous publication yet, while using MLP and SNM framework. A small number of researchers detect the benefits of the combination of RET on SIDS and ultimately linking it to policy driven approach (Lee, Glick, Lee, 2020). Bakhuis (2019) focus on Curacao and on one single technology, namely the Solar PV Rooftop, while van Dam (2018) also focus on the same RET but on the island of Aruba. Both research miss the benefits of integration of more RET by performing a cross case analysis. However, the coverage of the topic is limited to highlighting the challenges and the role of the government. The thesis, adds to the challenges as well but more importantly, provides a guideline with concrete actions concerning the other involved stakeholders.

9.1.4. Broader Implications and Relevance

Broader implications of this study can benefit initiator of the RET demonstrations but also wider context. The thesis provides guidelines for initiators to engage in the SET on Aruba. It present key processes that can facilitate the development of the niches. To illustrate, the contribution of facilitating stakeholders and a multidisciplinary team approach, among other things, are essential factors for a successful acceleration of the SET. By analysing the internal barriers of additional case studies, it is possible that more opportunities are discovered. Furthermore, for WEB, Elmar, Utilities and RE companies, future solutions are touched upon but should be further explored in order to accelerate change towards a more sustainable energy system. When such players start to embrace this concept, it will start to have positive effect on the broader context, namely the electricity, transport and energy sector. There is a broader significance of this thesis, represented in particular by the acceleration roadmap that is highlighted in subchapter 8.5. The geographical boundary is considered to be Aruba identifying several development that are only compatible with such circumstances. However, it is possible to extend this scope to SIDS in the Caribbean or other SIDS around the globe. In principle, almost all short-term steps are considered relevant to accelerate the SET, regardless of the location. It is important to acknowledge the different RE projects that have been established at certain place. On some SIDS (Curacao and Bonaire), there may be far more RE demonstrators set up and therefore it is interesting to compare such RE projects with the cases presented in this thesis. Nevertheless, recommended governmental actions are considered different for each SIDS. In this context, innovation is driven by the industry instead of the government. Thus, an advice is presented to WEB, Elmar, Utilities, and RE companies, to intervene and transform business models, for example by leasing their products (Solar PV Rooftops and EV). Still it is crucial to assess the condition for each SIDS separately to assure that the proposed actions can be applied to that context.

Management of Technology relevance

The thesis outcome should help the stakeholders or the actors involved to implement the technology or the process qualitatively. The three actors groups relevant for this thesis are the government, managers, and society. Managing different technologies and their integration to implement or develop a new product or innovation is the core of the Management of Technology (MoT) programme. It requires understanding the views of different stakeholders and coming to conclusions with the best possible solution. This thesis aims to develop a roadmap to accelerate the SET towards 100% RE-based by integrating different technologies to help actors such as, the government, the companies related to the RE field, and the individuals responsible for implementing RETs on the island of Aruba. A roadmap divided into short-, med-, and long-term is presented to the actors' groups with different perspectives and filtered to relevant knowledge for actors is essential criteria for the MoT programme. The thesis uses scientific study and methodologies, which are part of the MoT courses, as ingredients for the SET case study on Aruba. Therefore, the research represents a scientific study that represents a socio-technical perspective of the sustainable energy transition, which aligns with the MoT course guideline.

10. Conclusion and Recommendations

10.1. Conclusions

Based on case study research, this thesis aimed to provide insights into the opportunities for accelerating the SET on Aruba. After conducting literature review and analysing a transition and an innovation frameworks, three cases of renewable energy technologies were investigated, ultimately, deriving a roadmap with recommendations for acceleration of the transition on the island. Four research sub questions structured the thesis.

The first research sub question is as follows:

1) What is the current situation in the energy sector on the island of Aruba?

The development at the regime level does not provide a window of opportunity yet since the developments are stabilized by using hedging and internal efficiency optimization to cope with CO2 emissions for example shifting from HFO to LNG. Also, three internal complementary technologies are being explored within the regime to enable RE diffusion. The current energy mix on the island is 20% based on RE and 80% dependent on imported fossil fuel. However, landscape pressure is building because of climate change, oil dependency and the COVID-19 crisis, which may shift public opinion that could destabilize the regime and create more opportunities for the diffusion of the RE innovations.

2) What are the main drivers and barriers that influence the transition?

There are two main drivers for the growth of RE innovations. One driver is the government vision related to the SDG's 2030 and 2050 goals, and the second is the economic diversification started in 2009 with the implementation of the first wind park Vader Piet. Climate change and environmental issues have added additional aspects but cannot be considered the main drivers towards a 100% RE-based island.
The barriers at different levels that are constraining the transition are presented. There are weak ties between WEB, Elmar, and users at the regime level because of the monopolistic state-owned utility company responsible for bureaucracy and red tape, resulting in a fragmented energy policy and limited PV installation capacity policy. Also, RE backup is based on the fossil fuel source, and more EVs will require more RE. Still, electricity production is 80% dependent on fossil fuels. At the niche level, the demand side management is not ready to enable more RE and EVs, and there is a misunderstanding around RE benefits. There is resistance in society because some local NGO's can block RE (WT) projects, while there is limited land available on an isolated island setting. At the landscape level, Aruba is dealing with a refinery mentality. All barriers are presented in table 8.4.

3) Which niches/projects are being developed during the transition on the island?

Niches selected to research in this thesis are Solar PV Rooftop, Electric Vehicle and Wind Turbines. The results of the cross-case for the three RE innovations are presented in Table 8.3, where the similarities and differences are combined to summarize obstacles that should be overcome to accelerate the SET. There is hope for all three RE technologies to diffuse once the regime destabilize.

Solar PV Rooftops

According to installation statistics, Rooftop installations are increasing on the island. PV installation costs are dropping while some companies offer leasing contracts. Yet, not everyone is aligned, including WEB, since they are responsible for the backup and reliability of electricity production. Instead, Solar PV Rooftop shrinks the market and creates new technical problems requiring more investments.

Electric Vehicles

Barbados have more EVs than Aruba, yet Aruba has more EV per capita in the Caribbean. However, stakeholders (Utilities and WEB) are not aligned because of EVs' impact on electricity production. Also, there is no demand-side management, which is essential for EV and RE growth. There are some drivers for the EV market, such as import and road tax incentives, but charging stations are still lacking. International price reductions on EV are expected, and to become cost parity with ICEV, this could translate into an increase of EV on the island.

Wind Turbines

Incumbent regime actors play a crucial role in the network supporting WT. This case can be considered a niche within the regime because of the incumbent actors' ambiguous role. WT is the most cost-effective RE innovation on the market and on the island. However, there are still technical, social and environmental issues to face. Available land and space on the island are the main barriers requiring more focus in the near future.

The fourth sub question was designed to provide recommendations for acceleration of the SET:

4) How can the local government take action to accelerate the transition?

The case study observations in combination with the regime and landscape developments and additional drivers and barriers formed the basis for the roadmap to accelerate the SET in section 8.5. and will be discussed in the final question below.

Finally, the main research question is answered according to the four sub research questions: What is constraining the SET on the island of Aruba, and how can this be accelerated?

Based on the barriers, possible actions are presented. To accelerate the SET: at the regime level, the **government** should introduce an independent entity and an energy policy where the network-related is aligned to support the targets and expectations. At the niche level, **utility managers** should implement energy storage and intelligent infrastructure to reduce the dependency on fossil fuels and enable demand-side management to create more room for RE penetration. At the landscape level, raising awareness, organise town hall meetings with pilot projects and demonstrations is necessary for society. Due to the limited space and land on the island, environmental impact assessments are required to mitigate the impact during the development process and **avoid social resistance**.

The education system should be upgraded to create new experiences, knowledge and information for **local society**. Hence, introducing a technical university is required but generally to change the teaching practice locally. The **government's responsibility** is to stimulate more research, create more RE demonstrations, and create funds.

The research conducted by the universities, local and international, could ultimately improve regulatory measures. **Utility and RE companies' managers** should consider that new business models will be necessary to survive in the new RE business environment. Other RET should also be explored, primarily because the current RET outcomes are unknown. The SET can be accelerated towards a 100% RE-based island by adopting these measures.

10.2. Recommendations

In this section, some recommendations for the local government, utility and RE companies and society involved in the SET. They are particularly aiming at the acceleration of the transition.

Firstly, the **government** should focus on *learning by interaction* by introducing an independent entity to overcome the bureaucracy and red tape in the vertical integrated power structure. Also, an energy policy where the network-related is aligned to support the targets and expectations to align WEB, Elmar and the users and start accelerating the SET. More research could improve the regulatory measures to facilitate the transition if the government pivot on *learning by searching* too. To shift the "oil refinery mentality", the government's responsibility is to upgrade the education system to create new experiences, knowledge and information for the local society. Moreover, to stimulate more research, develop demonstrations, and create funds.

Secondly, **managers** should concentrate on *learning by doing* within their companies. Managers can implement energy storage and intelligent infrastructure to reduce the dependency on fossil fuels and enable demand-side management to create more room for RE penetration. Also, **utility and RE companies' managers** should consider that new business models will be necessary to survive in the new RE business environment. Other RET could also be explored, primarily because the current RET outcomes are unknown.

Finally, the **local society** should focus on *learning by using* to create an alignment with the citizens and consumers during the transition. To raise awareness, organising town hall meetings with pilot projects and demonstrations is necessary. Due to the limited space and land on the island, environmental impact assessments are required to mitigate the impact during the development process and avoid social resistance.

For further research, recommendations regarding the analysed case studies and at the more general level are discussed.
To obtain more qualitative data about each technology, it is recommended to conduct more interviews with different stakeholders involved to draw more reliable conclusions.
It is recommended to analyse multiple case studies from other SIDS, specifically in the Caribbean, to identify if this thesis is applicable to other islands, maybe other regions and as such, prove its broader implications.
The conceptual framework and its integration of the SNM and MLP frameworks should be tested and improved by conducting empirical research through a repeated cycle of additional case study work. Finally, extensive stakeholder discussion should be conducted to validate the proposed actions in the Aruban electricity sector in terms of feasibility, value, and relevance.

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Appendix

Appendix A: Interview protocol

Date:
Institution:
Name interviewee:

Introduction

1. An Introduction of myself and this research.

I'm a master student in Management of Technology from TU Delft. I'm currently in the process of my graduation thesis research. The research is aiming to analyse the development of the sustainable energy transition (SET) in Aruba by applying strategic niche management (SNM) and the multi-level perspective (MLP). Besides, this research also aims to identify the potential problems regarding the current development of the SET in Aruba and to explore the possible solutions to guide the future development. (Interviewees who lack the proper knowledge/background in the respective/relevant field, will need an explanation of what SNM and MLP are for).

2. Explaining the objective of this interview, review of interview method, use of data and confidentiality.

The objective of interviews is to obtain information and gather perspectives from different types of stakeholders. All data is only for the purpose of this thesis research. It is the intention to record all interviews, but only with the permission of the interviewee.

3. Inquiry of the background of the interviewee.

First, let the interviewees give a brief introduction of themselves. According to the information the interviewees provide, some general questions will be asked in the form of an open dialogue. However, the open questions session is subject to change and could be skipped if there is not much time left.

- Previous and current occupation
- Specialization
- Experience in field (in years)
- Involvement in relevant projects:
  - ☐ Solar
  - ☐ Wind
  - ☐ EV
  - ☐ Ice Storage
  - ☐ Other: ________________________
- How does your organization/company work on renewable energy in Aruba or elsewhere? Or on energy in general in Aruba?

The energy & electricity sector

On a political, economic, social, technological, environmental and legal perspective:

- How has the energy and electricity sectors developed until now?
- What are the main developments within the electricity sector, which includes the energy sector and others, such as transportation sector, that are directly related to the field? (PESTEL checklist)
- How is renewable energy implementation developing on the island?

- Who are the most important stakeholders in Aruba with regard to energy & electricity sector and renewable energy implementation?
- What do you expect with regard to renewable energy implementation in Aruba?
- What are the major issues and opportunities?
- What needs to be done/changed to enhance/accelerate the renewable energy transition?

Renewable energy

On a political, economic, social, technological, environmental and legal perspective:

- How has the niche developed until now on the island?
- Which companies or institutions were involved during projects and what was their role?
- How was the cooperation between actors during experiments?
- Was there any changes in the group composition? If there was, what was the reason?
- Where there enough resource available during the experiment?
- Is there any visions underlying the project, what is your vision on it?
- What are your expectations with regard to project/pilot?
- What has been or can be learned from the project? What have you or your organisation learned so far?

Final personal statement

On a political, economic, social, technological, environmental and legal perspective:
Who are the actors that should make the necessary changes in order to accelerate the SET?

Appendix B: Potential renewable energy on Aruba

In their 2015 Energy Snapshot (LNRE 2015), the National Renewable Energy Laboratory (NREL) gives an overview of the different renewable energy sources and their potential for Aruba, this is presented in figure B.1. It can be seen that both wind and solar power have high potential, but the potential for the other sources is mostly categorised as low. As a result of this, both the NREL as well as the Carbon War Room (2013) indicate that *"Aruba will depend heavily on variable wind and solar to reach its renewable energy goals."*

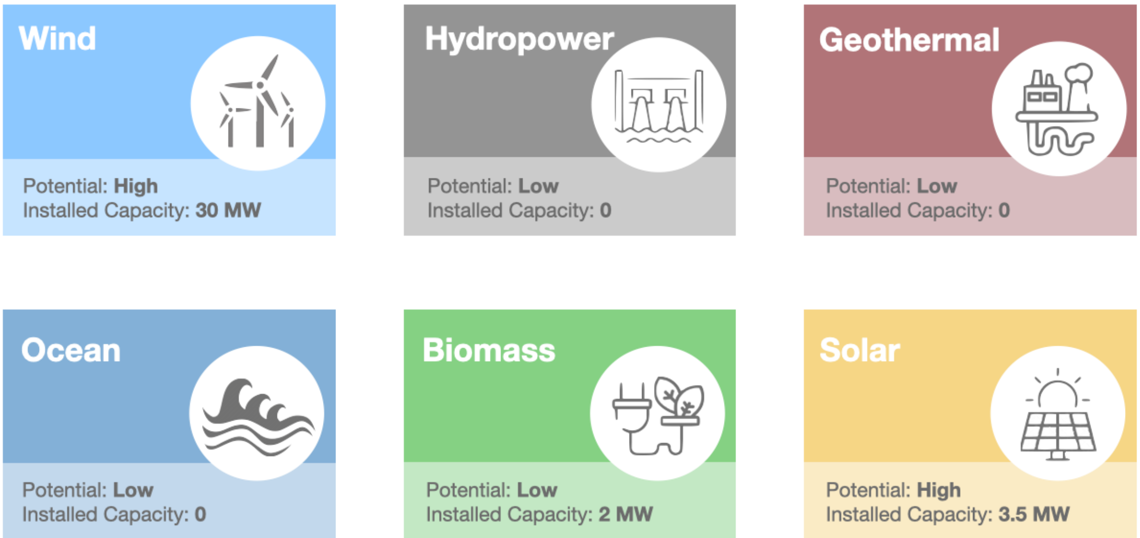

Figure B.1: Overview of various renewable energy sources and their potential for Aruba (Source: Adapted from LNRE 2015)

Although the potential of both sources is undeniable, WEB does not completely share this vision for implementation. In the following sections, the potential for each of these resources is explained in more detail. In general, the potential of each source is based on multiple year estimates.

Ocean energy

These resources include wave, tidal, ocean thermal, salinity gradient and aquatic biomass energy. Although clustered as one, the ocean energy resources are very different in nature, both intermittent (wave, tidal) as well as able to supply base load power (ocean thermal, salinity gradient, and aquatic biomass). The potential for these resources therefore varies per resource. In the case of Aruba, there are little to no fresh water streams (LNRE 2015), this means that there is negligible potential for exploitation of salinity gradient as renewable resource. Wave and tidal energy sources can be found around the island, but potentials are moderate for wave (Cornett 2008), and low for tidal. There is potential for growing aquatic biomass such as algae to produce biofuels, but no study has been found that gives a clear estimate. Therefore, in this thesis, these resources are not specifically considered. The island does however possess potential for the use of ocean thermal resources to produce electricity. This is done by making use of a difference in ocean water temperatures, mostly a result of a thermocline (a distinct temperature difference in surface and deep water ocean layers). This can be found in many tropical regions. This temperature difference can be exploited by means of Ocean Thermal Energy Conversion (OTEC) technology. This involves pumping up deep cold ocean water and exchanging heat with warmer surface water, this drives a Rankine power cycle to produce electricity. The technology is considered viable in areas where the year-round temperature differential is at least 20 degrees Celsius (Bluerise 2013).

Biomass
Due to its dense population, arid ground and dry climate Aruba lacks good biomass resources (ROOM 2013). The potential for biomass as stated by the NREL factually concerns the use of waste to produce electricity. This can be done directly by incineration to produce steam or indirectly by implementation of a pyrolysis based waste-to-gas plant. This gas can subsequently be used in a dedicated gas turbine, reciprocating engine or boiler. Before it can be converted to energy, the waste needs to be segregated, collected, transported, and, if necessary, pre-treated and/or stored. The potential for this resource is estimated at 10-15 MW (FESCA 2009). This is based on an average production of 400-550 ton of Municipal Solid Waste per day (FESCA 2009).

Hydropower
The potential for hydropower on the island is low (LNRE 2015). Aruba does not possess any significant potential hydropower sites because of its arid topology and geography. Therefore, in this thesis, this resource is not considered.

Geothermal energy
The geothermal potential is stated as low in figure 9. This is due to its geographical location, far away from the geothermally active arc roughly stretching north to south from Saba and St. Kitts until St. Vincent and Grenada (Weisser 2004). It should be added that the potential for geothermal energy is low, within the constraints of current technologies. In the future this may change when single well enhanced geothermal systems (SWEGS) can be deployed to extract heat from rocks deep in the ground and converting it into power using a closed-loop system (ROOM 2013). Due to lack of detailed research and tests, there is a high level of uncertainty regarding this resource. Therefore, in this thesis, this resource is not considered.

Solar and wind energy
Aruba benefits from rich natural resources such as over 2000 solar hours and over 5000 wind hours per year (Rethink 2019). These renewable energy sources are well explored at large scale installation capacity where wind energy is responsible for 18% and solar for 2% electricity production share on average a year (WEB 2019). However, at small scale level rooftop solar PV have a great potential to support towards the SET. Therefore, in the next chapter, the rooftop solar PV niche will be discussed in-depth.

Appendix C: Diagram of the Aruban Electricity System

The electricity system is a stand-alone power system, which generates, transmits and distributes all of its demanded electricity to its end consumers. As seen in the previous section different actors control different parts of the electricity system. As proposed in De Vries et al. (2010) "*it is useful to distinguish, on the one hand, the physical, technical side of the system and the economical, institutional side on the other hand. The technical system consists of the physical chain through which electricity flows, from the power plants in which it is generated, through the transmission and the distribution networks (with all their supporting equipment) to the apparatus in which the electricity is consumed, the 'load'*." Figure C.1 describes the electricity system according to this statement. The double pointed arrows indicate which actors control which parts of the physical system and also indicate the corresponding activities and/ or responsibilities. The arrows with the single point indicate the technical details of the physical system. This figure is based on the AES.

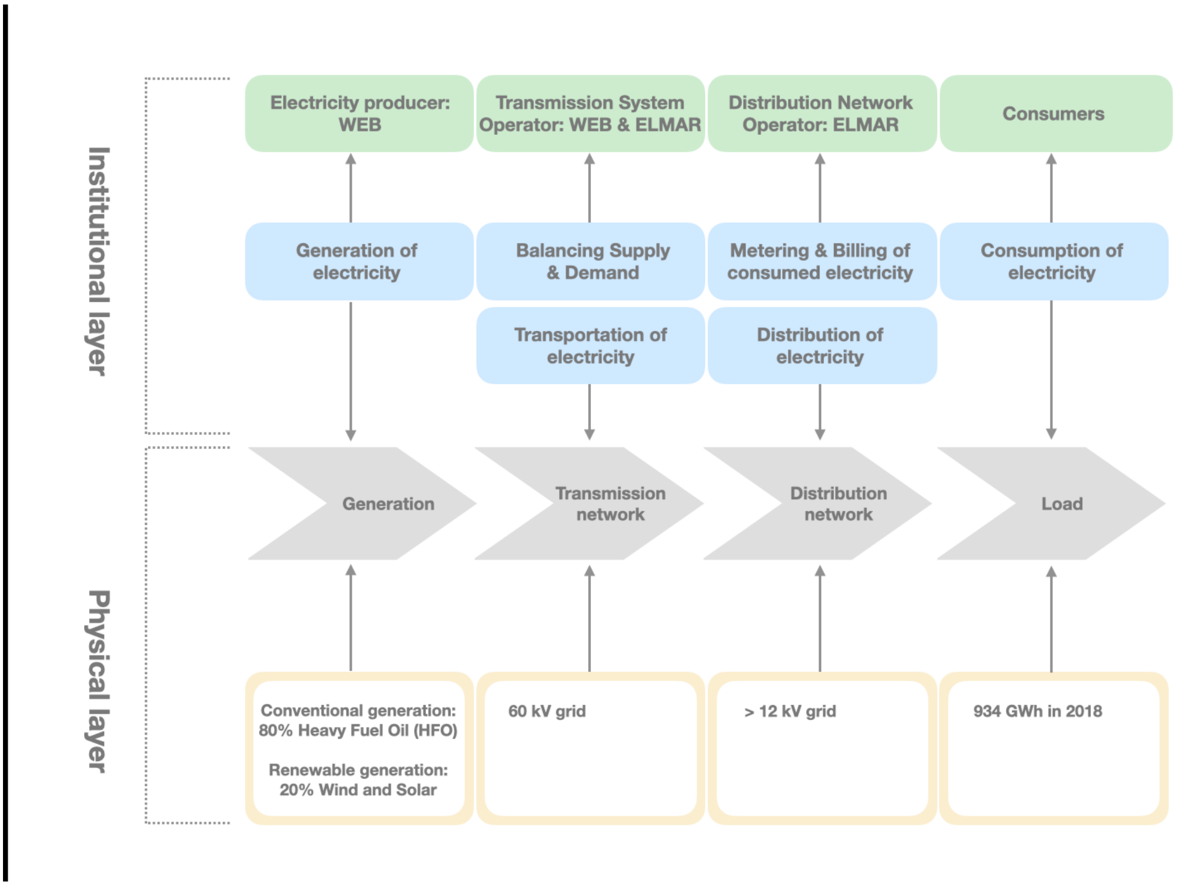

Figure C.1: Diagram of the Aruban Electricity System. (Source: Adapted from Klerk, 2013)