



*Delft University of Technology
Faculty of Technology, Policy and Management
Management of Technology Master Programme*

MSc. Thesis
August 2012, Delft

Framework for Developing Innovation Systems in Small Island Developing States

Roadmap for turning Curaçao into the OTEC Centre of Excellence

Author: Tomas Prochazka

MSc. Thesis

Framework for Developing Innovation Systems in Small Island Developing States

Roadmap for turning Curaçao into the OTEC Centre of Excellence

Tomas Prochazka

4118677

Management of Technology MSc. Programme

Delft University of Technology

Faculty of Technology, Policy and Management

Section of Technology Dynamics & Sustainable Development

August 2012



Supervisors from the Delft University of Technology:

Chairperson	Dr. W. Ravesteijn	Technology Dynamics & Sustainable Development
First Supervisor	Dr. L.M. Kamp	Technology Dynamics & Sustainable Development
Second Supervisor	Dr. L. Hartmann	Technology, Strategy & Entrepreneurship
Exam Committee Member	Ir. M.W. Ludema	Board of Examiners

Supervisor from Bluerise B.V & Curaçao Airport Holding N.V.

External Supervisor	R. Blokker	Bluerise B.V.
----------------------------	------------	---------------

Executive Summary

Keywords: SIDS, Innovation Systems, Functions of Innovation System, OTEC, Evolutionary Theory

Recognized by the United Nations, **Small Island Developing States** (SIDS) are a distinctive group of 52 islands that face specific social, economic and environmental vulnerabilities. Some of the consequences of their small size, remoteness and strong dependence on imports are underdeveloped high-tech sectors, restricted R&D capabilities, dependence on foreign technologies and a general lack of well functioning technological innovation systems (TIS). TIS are defined as *complex systems or environments that support the existence and the development of a technology*. The topics of why TIS are in general non-existent in SIDS or how they could be developed there are not addressed in the literature. Yet, it is acknowledged that they could have vital influence on the islands' economies and may present substantial economic opportunities for entrepreneurs. The objective of this thesis was to explore the topic and *to design a generically applicable framework for guiding the development of TIS in SIDS*. Existing theories formed the bases of the framework but important changes were derived from a cross-case study of five island based innovation systems and an in-depth case study of Ocean Thermal Energy Conversion (OTEC) technology on the island of Curaçao.

The Scientific Background was provided by a theory known as the Functions of Innovation Systems (FIS). FIS evolves from the Evolutionary Theory, which explains forces within nations on three levels: the exogenous landscape (macro level); the regime (meso level); and the niches where new TIS emerge (micro level). These three layers continuously interact and influence each other and ultimately define how economies, societies or TIS function. The landscape is a set of structural trends, standards, regulations or networks deeply embedded in the society or economy of a nation. Technological regimes are the engineering practices, skills, production characteristics or for example the education practices. The most turbulent level is the niches where technologies are developed and new TIS come to existence. The FIS are defined as a set of seven functions within TIS, that need to be properly served to let the TIS develop and function well. The seven functions are: Entrepreneurial activities, Knowledge development, Knowledge diffusion, Guidance of the search, Market formation, Resources mobilization and Creation of legitimacy. No explicit characteristics related specifically to the development of TIS in SIDS are discussed in the literature.

A Cross-Case Study of five different TIS in developed islands was used for data collection in the first part of the research. The TIS were analysed in order to identify how they are overcoming the islands' 'smallness' and 'remoteness' characteristics and to see how this could be applied in SIDS.

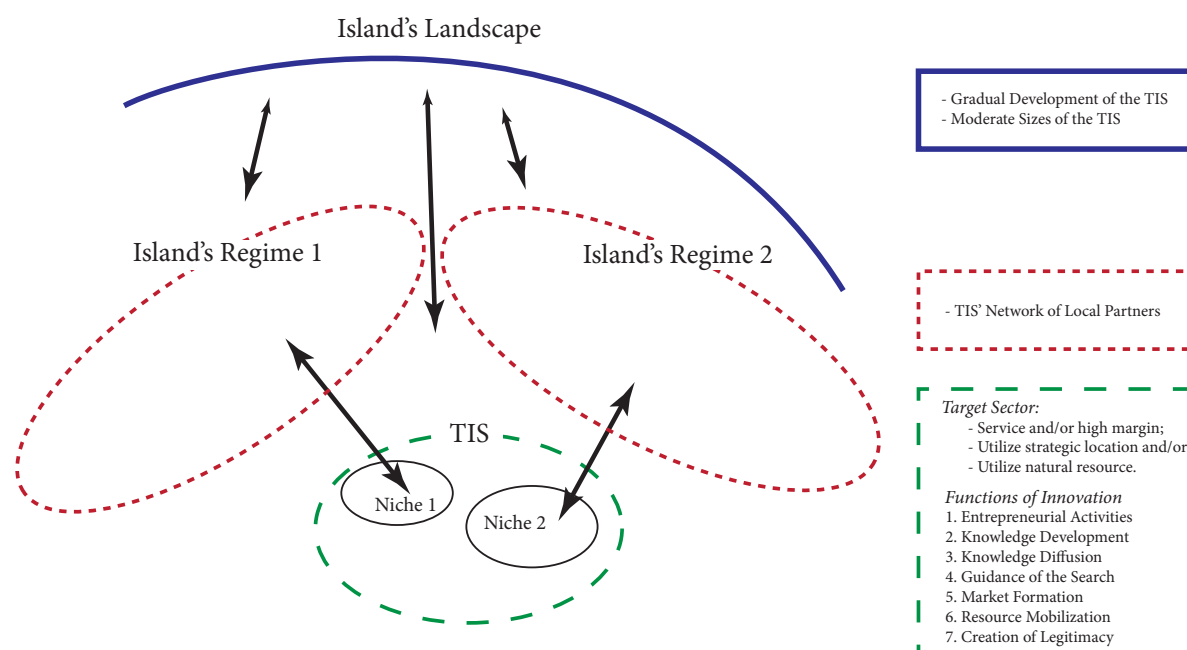
It was shown that TIS in islands do not compete in commodity or low-cost sectors where scale economies play crucial roles. Instead, they share one of three characteristics that allow them to sustainably retain their comparative advantages: they serve niche sectors and the parts of supply chains that are mainly based on utilizing human capital; they utilize the islands' strategic locations; or they make use of specific available natural resources. Additionally, it was identified that the TIS only came to existence by having the support of the islands' governments' policies such as favourable import duties or streamlined permits issuance. This support had 'enabling' effect and provided the necessary foundations for the TIS' existence. There is however a general insufficiency (depth) of data about existing island based TIS. Due to this lack of data, one can identify the general characteristics of the TIS but not the deep roots of the challenges and the hurdles that new TIS face in their development.

The In-Depth Case Study was the main source of primary data in the research. Over 30 interviews and other mainly written sources were used to evaluate the potential of developing OTEC technology on the island of Curaçao. The analysis was divided into three parts - the landscape, the regimes and the OTEC TIS (which was analysed using the FIS). OTEC is a renewable energy technology that captures the thermal energy stored in the world's oceans. The technology itself is in the pilot stage of development and calls for the establishment of R&D, educational and (pre-)commercial facilities. Curaçao Airport Holding N.V. (CAH), is currently developing a Sea Water Air-Conditioning (SWAC) system that will be utilizing the same natural resource as OTEC would require. As a result, CAH joined forces with Bluerise B.V., a high-tech startup from the Netherlands to explore the feasibility of their shared vision – to turn Curaçao into the OTEC *Centre of Excellence*, a TIS that supports state-of-the-art OTEC education, research, operation and advisory. The analysis confirmed that Curaçao suffers from most of the disadvantageous characteristics that other SIDS do. The island has symptoms of brain drain, non-existing R&D sector, lacks sustainability awareness and specifically related to OTEC it currently has neither OTEC experts nor potential suppliers. On the other hand, Curaçao is a favourable location for business operations due to its Dutch judicial system, undemanding legislation towards OTEC, progressive energy policy and the government is supportive of initiatives that promote smart tourism. Past technology related projects struggled due to a lack of cooperation among the key stakeholders and due to attempts to 'push technology' rather than gradually integrate it.

Recommendations for the in-depth case study were based on the (limited) knowledge in the literature, findings from the cross-cased study, and the recommendations given by local experts. A bottom-up approach with strong involvement of local stakeholders is recommended. This will help gain the necessary support from the government and other local decision makers. Additionally, by educating and subsequently engaging locals, the technology developers will build knowledge base that can be sustained on the island in the long-term. Specifically, cooperation with the university, the local airport (SWAC developer) and the utility provider should be established. Efforts aimed at developing an educational programme should be initiated immediately – focused on creating a clear blueprint that would lead towards the establishment of a specialized OTEC and SWAC MSc. programme between the Dutch 3TU and the local university. Research should be strongly linked to the education and already in the very early stages should a demonstration unit or facility be placed on the island. Specific focus should be put on attracting local students currently studying abroad. The OTEC related education and research should attract components suppliers and other OTEC technology providers. Scaling

up the research efforts should lead to the development of a state-of-the-art pre- and potentially also a fully-commercial facility.

The Final Conclusions are that similarly to developed states, also in SIDS must the FIS be well served in order for the TIS to develop. Additionally however, there are two factors that need to be put in place. Firstly, only specific technologies should be targeted – high-margin or service sectors, and the ones that utilize strategic locations or specific natural resources of the islands. Secondly, due to the characteristics of SIDS the innovation systems' integration into the landscape and regimes of the islands is essential – the links between the TIS and regimes and landscapes are much stronger in SIDS than in developed states. Therefore strong network of local partners should be established in order to guarantee sufficient support from the islands' regimes. Also, due to the potential impacts on the islands' landscapes, projects that are parts of the TIS should be of 'moderate' sizes so that they do not make the SIDS overly dependent on the success or failure of the technology. Furthermore, the innovation systems should be developed gradually in order not to disrupt the fragile economies of the islands. By following this set of rules, close relationships between the sectors and the islands' regimes and landscapes can be established. This results into a win-win situation where the TIS can develop as it benefits from the island's support (permits, policies, tax exemptions etc.) and the island itself reaps socio-economic benefits. Without this win-win situation, the TIS will struggle to develop. The framework below summarizes the recommendation.



Framework for guiding the development of new innovation systems in SIDS.

Preface

Acknowledgement

The outcomes of this thesis would have not been achieved without the help of a number of experts, supervisors and other professionals. Hereby, I would like to thank everyone for their support, advices and inspiration. I would like to devote a special recognition to the people and companies that have provided me with technical and financial support throughout the entire duration of the project:

Dr. L.M. Kamp and Dr. L. Hartmann, Dr. W. Ravesteijn

First and Second Supervisors, Chairperson; Delft University of Technology

D. Acevedo, R. Blokker, P. Dinnissen and B.J. Kleute

Bluerise B.V.

M.Adriaens and S. Kloppenburg

Curaçao Airport Holding N.V.

Additionally, I would like to thank the dozens of professionals and academics that provided with their support in the form of interviews.

Contents

Executive Summary	iii
Acknowledgement	vi
Contents	ix
List of Figures	xi
List of Tables	xiii
Nomenclature	xv
Introduction	1
1 Research Introduction	3
1.1 Research Background	3
1.2 Research Problem & Objective	4
1.3 Research Relevance	4
1.4 Research Approach	6
1.5 Research Questions	7
1.6 Research Methodology	7
1.7 Research Boundaries	9
2 Literature review	11
2.1 Small Island Developing States	11
2.2 The Evolutionary Theory	16
2.3 Technological Niches	20
2.4 Summary	27
3 Cross-Case Study of TIS in Island States	31
3.1 Geothermal Energy in Iceland	32
3.2 Textile Industry in Mauritius	33
3.3 ICT industry in Malta	34
3.4 Manufacturing Industry in Cyprus	35
3.5 ICT industry in Taiwan	36
3.6 Summary	37
4 OTEC in Curaçao Case Study	41

4.1	Case Study Background	42
4.2	Socio-Technical Landscape of Curaçao	51
4.3	Socio-Technical Regimes of Curaçao	57
4.4	OTEC Innovation System	67
5	OTEC in Curaçao Case Study Recommendations	85
5.1	Research	86
5.2	Education	89
5.3	Operation	91
5.4	Production, Services & Advisory	93
5.5	Preconditions and Risks	94
5.6	Benefits	96
5.7	Roadmap and Summary	97
6	Conclusions	101
6.1	Scientific Contribution	106
6.2	Generalizability and Reliability	108
6.3	Discussion	111
6.4	Further Research	113
	Written Sources	115
	Interview Sources	129
A	Geothermal Research and Educational Activities in Iceland	133
B	Electricity production facilities in Curaçao	135
C	Interviews	137
C.1	Timo Brouwer	137
C.2	Bluerise B.V.	139
C.3	Richenel R. Bulbaai	140
C.4	Andres Casimiri	141
C.5	Steven Coutinho	143
C.6	Isabelle Delcour	144
C.7	Margo Guda	145
C.8	Fiorina A.M. Hernandez	147
C.9	Johannes I. M. Halman	148
C.10	Simon Kloppenburg	150
C.11	Anthony Kool	152
C.12	Marc Marshall	153
C.13	Gilbert Martina	155
C.14	Joanne Nicastia	156
C.15	Surldric F. Rojer	158
C.16	Franklin J. Rosheuvel	159
C.17	Paul Stokkermans	160

C.18 Julissa Tromp	162
C.19 Karel Tjuehuth	163
C.20 Tim van den Brink	165
C.21 Chris van Grieken	166
C.22 Bertine Vermeer	168
C.23 Bart van Weijsten	169

List of Figures

1.1	Research Approach	6
2.1	Multilevel perspective	18
2.2	Boundary relations of Innovation Systems	19
2.3	Functions of Innovation Systems	25
2.4	Integrated Approach	26
2.5	Preliminary framework	29
4.1	OTEC Center of Excellence	44
4.2	Stakeholders and technologies	45
4.3	On- and Off-shore OTEC Facilities and OTEC principle	47
4.4	Principles of OTEC	48
4.5	SWAC costs and working principle	48
4.6	Costs of OTEC electricity.	50
4.7	Caribbean Region and Curaçao	52
4.8	Electricity demand	58
5.1	Roadmap for establishing OTEC Centre of Excellence in Curaçao	99
6.1	Final Framework	102

List of Tables

1.1	Research Questions Specifications	8
2.1	Vulnerability Indexes for different groups of countries	12
2.2	Indicators used to map FIS	23
2.3	Blocking mechanisms	24
3.1	Characteristics of innovation systems in island states	39
4.1	OTEC water in/outflow requirements for a 10 kW and 10 MW plants	46
4.2	Operational, repair and maintenance costs of OTEC plants	51
4.3	Contribution of selected sectors to GDP	56
4.4	Summary of the socio-technical landscape analysis.	57
4.5	Electricity prices in the region as of June 2011.	59
4.6	Electricity price changes in Curaçao	59
4.7	Feed-in tariffs in selected European countries, USA, Cayman Islands and Curaçao	63
4.8	Summary of the socio-technical regime analysis.	67
4.9	Summary of the identified cultural and island specifics.	81
4.10	Summary of the FIS analysis.	82
5.1	Estimated benefits of the OTEC CoE	98
B.1	Electricity production units of Aqualectra as of 2002	136

Nomenclature

3TU	Federation of the three Dutch technical universities in Delft, Eindhoven and Twente
A/C	Air-Conditioning
ANG	Netherlands Antillean guilder
BOO	Build Own Operate
BPM	Curaçao Business Council for Sustainable Development
BT&P	Bureau for Telecommunications & Post
CAH	Curaçao Airport Holding
CARENSOL	Caribbean Energy Solution
CARILEC	Caribbean Electric Utility Service Coporation
CARMABI	Caribbean Marine Biological Institute
CBCS	Centrale Bank van Curaçao en Sint Maarten
CC	Capital Costs
CC-OTEC	Closed Cycle Ocean Thermal Energy Conversion
CCCCC	The Caribbean Community Climate Change Centre
CSR	Corporate Social Responsibility
CTEX	Curaçao Technology Exchange
CURINDE	Curaçao Industrial and International Trade Development Company
CURISES	Curaçao Institute for Social & Economic Studies
CVI	Commonwealth Vulnerability Index
DCNS	Direction des Constructions Navales Services
DEMO	Demonstration prototype
DOE	Department of Energy
DSW	Deep Sea Water
DWLC	Deep Lake Water Cooling
EU	European Union
EVI	Economic Vulnerability Index respectively
FAPE	Fundashon pa Antiyano Energia
FDI	Foreign Direct Investment
FIS	Functions of Innovation Systems
FIT	Feed-In Tariff

GDP	Gross Domestic Product
HDI	Human Development Index
HSIP	Science-based Industrial Park in Hsinchu, Taiwan
HVAC	Heating, Ventilation and Air-Conditioning
ICC	InnovatieCentrum Curaçao - Innovation Centre Curaçao
ICT	Information and Communication Technology
IEA	International Energy Agency
IPP	Independent Power Producer
IT	Information Technology
kWh	Kilowatt Hour
LDPE	Low Density Polyethylen
LNG	Liquefied Natural Gas
LSC	Lake Source Cooling
MCR	Maximum Continuous Rating
MTS	Middelbare en Hogere Technische School
NCoE	Nordic Centre of Excellence
NEA	National Energy Authority
NELHA	Natural Energy Laboratory of Hawaii Authority
NGO	Non-Governmental Organization
NIS	National Innovation System
NOAA	National Oceanic and Atmospheric Administration
NRE	Non-Revenue Electricity
OC-OTEC	Open Cycle Ocean Thermal Energy Conversion
OMR&R	Operations, Maintenance, Repair and Replacement
OTE	Ocean Thermal Energy
OTEC	Ocean Thermal Energy Conversion
PET	Polyethylene Terephthalate
PPA	Power Purchase Agreement
PPP	Purchasing Power Parity
R&D	Research and Development
RES	The School for Renewable Energy Science
RET	Renewable Energy Technologies
REYST	Reykjavik Energy Graduate School for Sustainable Systems
RIS	Regional Innovation Systems
ROI	Return on Investment
SIDS	Small Island Developing States
SIS	Sectoral Innovation Systems

SME	Small and Medium Enterprises
SWAC	Sea Water Air-Conditioning
TIS	Technological Innovation System
TNE	Transnational Education
TU Delft	Delft University of Technology
UN	United Nations
UNA	University of Netherlands Antilles
UNU-GTP	The Geothermal Training Programme of the United Nations University
USP	Unique Selling Point
VC	Venture Capital
WTE	Waste to Energy

Introduction

Small island developing states are a distinct group of states that face specific social, economic and environmental challenges. One of the many consequences of the islands' characteristics is the fact that they have underdeveloped high-tech sectors and generally lack quality education and research programs. While the topic of small island developing states has received significant amount of attention from the scholars in the past decade, the existing literature still fails to identify strategies on how to **overcome the islands' disadvantageous characteristics**.

This thesis investigates how can a small island nation support the development and existence of a **technological innovation system**. An emerging technology, Ocean Thermal Energy Conversion and the island of Curaçao are used in this thesis as an in-depth case study and as the main source of data.

Chapter 1 provides introduction into the project, presents the research problem, the research question as well as the methodologies and boundaries of the research.

Chapter 2 then introduces the concepts that form the bases for this research project. Common characteristics of small island developing states are introduced and the key theories that will be used throughout the thesis are presented.

Chapter 3 studies the characteristics of five distinct technological innovation systems located in island states.

Chapter 4 uses the underlying theories the analysis of Ocean Thermal Energy Conversion technology in Curaçao in order to explore the challenges that small islands developing states impose on technology developers. **Chapter 5** then presents the recommendations related to the case.

Lastly, **chapter 6** concludes the thesis by summarizing the lessons that can be drawn from applying the theories to the case studies and answering the research questions.

“Innovation is the central issue in economic prosperity...”

M. Porter

1

Research Introduction

Research conducted in this thesis tackles the issues that new technological innovation systems (TIS) face when developing in small island developing states (SIDS). This chapter gives a short overview of the problems that SIDS face. The research objective, research questions, research relevance and the used methodologies are then presented. This chapter provides basis for the rest of the thesis – i.e. for the detailed literature review, the research case studies as well as the drawn recommendations and the theory implications.

1.1 Research Background

Curaçao is an island nation driven mainly by the oil and tourist industries ([Curaçao Ministry of Economic Development, 2012](#)). The country has an underdeveloped high-tech sector, scarcity of natural resources, it is highly dependent on imports and it is experiencing brain drain ([United Nations Development Program, 2011a](#); [Curaçao Bureau of Statistics, 2012](#); [Centrale Bank van Curaçao en Sint Maarten, 2012b](#); [Curaçao Ministry of Economic Development, 2010](#)). Recognized by [United Nations \(2012\)](#), similar characteristics are however inherent to the majority of SIDS¹. As the detailed literature review in section 2.1 will further unveil, SIDS are a distinct group of developing countries that face specific social, economic and environmental vulnerabilities ([van Alphen et al., 2006](#); [Turvey, 2007](#)). The existing knowledge about these islands can be summarized by the statement of [Nurse et al. \(2001\)](#): ‘while good progress has been made in understanding the vulnerability and adaptation potential of SIDS, critical gaps and uncertainties still exist...’. This research investigates the challenges that SIDS impose on newly developing TIS and how these challenges can be overcome. The main source of primary data for the research will be an in-depth case study of Ocean Thermal Energy Conversion (OTEC) and its potential development on a SIDS of Curaçao.

¹There are 52 SIDS with a total population of ~60 million. See section 2.1 for more details.

1.2 Research Problem & Objective

Evidence from around the world shows that SIDS fail in diversifying their economies, supporting innovation and providing R&D or educational expertise in technology (Encontre, 1999). Available scientific literature acknowledges and in detail describes the disadvantageous characteristics of SIDS that lead to this state, but it does not identify strategies that could be used to overcome the existing hurdles (Easterly and Kraay, 2000). This thesis aims to contribute to the existing knowledge about the development of TIS in SIDS. The current situation can be summarized by the following **problem statement**:

There is no *fitting* framework or generic strategy that is *generally applicable* and that provides guidance for overcoming the specific characteristics of SIDS in developing and supporting the existence of *technological innovation system*.

The following aspects are central to the problem statement:

Technological Innovation System (TIS): Defined by Alkemade and Suurs (2011) as a ‘*dynamic network of agents interacting in specific economic or industrial areas under particular institutional infrastructures and involved in the generation, diffusion, and utilization of technologies*’. Simply put, this thesis uses the term to describe an ‘eco-system’ that supports the development and utilization of a technology on all levels of the supply chain - from education and research to manufacturing and the actual usage of a technology.

Fitting: While various theories about TIS exist, the challenge is in adjusting them to fit the specifics of SIDS.

Generically Applicable: It should offer guidance for developing various TIS in SIDS.

Based on the problem statement, this thesis’ **research objective** is:

To design a generically applicable framework for guiding the development of technological innovation systems in small island developing states.

1.3 Research Relevance

There are numbers of reasons why the knowledge about TIS in SIDS should be expanded. All these reasons are related to the struggles that SIDS face and include (Conway et al., 2010, p.363-365);(Kelly, 2008, p.7,8);(Read, 2010):

- Diversifying the vulnerable economies of the islands;
- Developing, testing and using technologies locally instead of importing the technologies that are tailored to the needs of the richer/continental countries that developed them;
- Creating and exploiting niche markets by entrepreneurs;
- Reversing brain drain;
- Utilizing the abundant (renewable energy) resources available on islands;

- Reducing the islands' dependences on oil (in case of energy related technologies).

It should be noted that the approach used in this thesis leads to recommendations that are mainly aimed at managers, i.e. not policy makers or governments. While the literature research as well as the case study will prove that governmental and policy support is indeed essential in the development of TIS in SIDS, certain common characteristics of SIDS will always remain unchanged and will be restricting the systems' developments. Given the fact that SIDS are in general technologically underdeveloped, it is the technology providers, scientists or academics from the developed countries that are in charge of transferring or supporting the transfer of knowledge to SIDS. This is where some of the main challenges in the development of TIS in SIDS appear to be. It is so because the usability of methods or techniques successfully applied in developed countries have limited functionality in SIDS. This point is also clearly demonstrated on the case of Curaçao where virtually all the interviewed experts agreed that *'things simply work very differently here [on islands/Curaçao] than elsewhere'*. This thesis focuses on how to deal with the specifics of SIDS from the perspective of managers or technology providers. The recommendations however do outline the nature of the support that is necessary from local governments.

This research has both **scientific** and **managerial** relevance.

1.3.1 Scientific Relevance

This research contributes to the existing body of knowledge by:

- Performing a structured analysis of the developments in a SIDS (Curaçao) with regards to innovation systems and thus providing a rich collection of primary and secondary data for further research (data that in both the depth and the breadth exceeds any other found published work on the topic);
- Addressing the existing knowledge gaps and with the support of existing theories as well as the collected data explaining the key characteristics that differentiate the development of TIS in SIDS and non-SIDS states.

1.3.2 Practical Relevance

In terms of practical implications, the results of this thesis have twofold benefits – for the project initiators as well as general business owners operating in SIDS.

Applicable to OTEC technology in Curaçao, the **project initiators** will comprehend:

- How favourable the environment of Curaçao for initiating complex OTEC activities is;
- The limitations of Curaçao in the areas of OTEC education, research, operation and advisory;
- How one should proceed in overcoming the characteristics of Curaçao and creating a prosperous OTEC innovation system.

In generic terms, **business owners** in SIDS will realize:

- How the specific characteristics of SIDS influence the development of TIS;
- How one should proceed in overcoming the specifics of SIDS when initiating the development of a TIS.

1.4 Research Approach

Figure 1.1 presents the approach that is used in this research in order to fulfil the research objective.

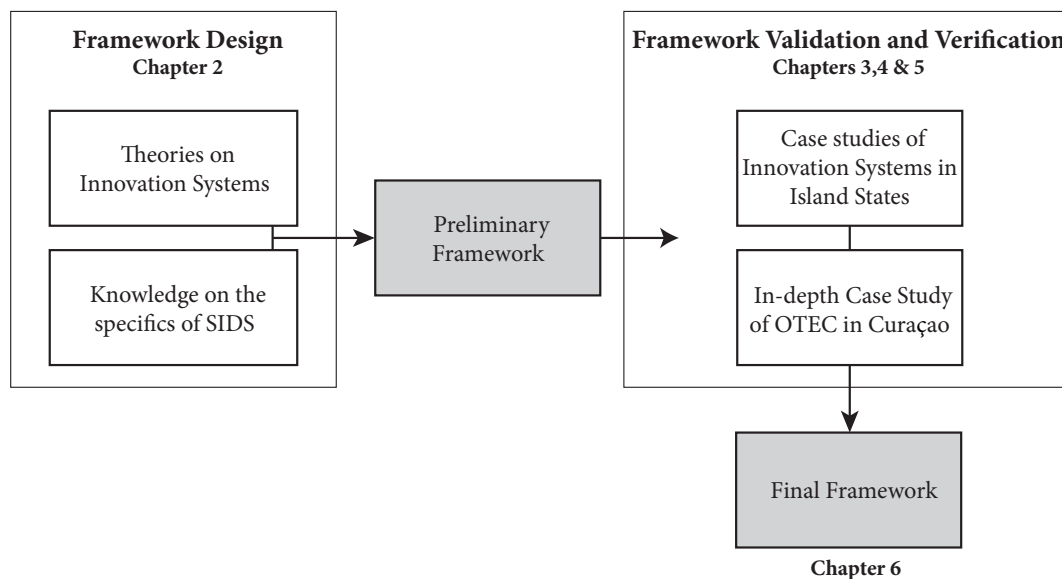


Figure 1.1: Research Approach.

There are two main two steps that will lead to the designing the final framework:

Framework Design: The framework will be based on the concepts already present in the existing literature. Namely, the framework will combine the existing theories that describe how TIS function together with the specific characteristics of SIDS and the existing (though limited) knowledge about TIS in these states. The framework can be understood as a hypothesis that describes how the development of TIS in SIDS should happen based on the available knowledge. The result of this first step is the ‘preliminary framework’ presented at the end of chapter 2.

Framework Validation and Verification: The preliminary framework will then be applied to the in-depth case study of OTEC technology in Curaçao (chapters 4 and 5). Additional insights will be taken from several TIS in island states (chapter 3). The purpose of chapters 3-5 will be used to **verify and validate** the framework and refine it when the collected data proves it necessary. In other words, the framework that is presented in chapter 2 will be applied to the real cases to see if it is *doing the right thing* (if it can be used to guide the development of an innovation system) and if it is *doing it right* (if it is practically usable and generally applicable). The in-depth case study will be the main source of data in the

process of validation and verification. See section 1.6 for the data (interview) sources that are used for that purpose.

In chapter 6 a synthesis is made as how the ‘literature based’ framework fit the actual situation in SIDS and other islands states and what the final framework is. Discussion is then presented on how reliable and generalizable the results are.

1.5 Research Questions

To achieve the research objective one main research question was formulated. To answer it, a total of eight sub-questions were proposed. Questions A.1-A.3 are aimed to be answered by reviewing available literature and developing a hypothesis – the preliminary framework. This hypothesis will be tested by applying it to questions B.1-B.5 in which already existing innovation systems in island states and particularly the in-depth case study of OTEC technology in Curaçao are scrutinized:

1. How can the disadvantageous characteristics of SIDS be overcome when developing new technological innovation systems?
 - A.1 What are the key characteristics of SIDS that influence the development of new TIS?
 - A.2 What methods can be used to analyse and consequently influence the development of new TIS?
 - A.3 Within the field of TIS in SIDS, where exactly does the existing literature fall behind?
 - B.1 What are the common characteristics of the existing island based TIS?
 - B.2 How does Curaçao currently stand with its potential to support state-of-the-art OTEC research, education, operation and advisory?
 - B.3 What are the limitations of Curaçao in creating an innovation system that provides OTEC education, research, operations and advisory?
 - B.4 How have the past and existing technology related projects been influenced by the SIDS characteristics of Curaçao?
 - B.5 What steps should be followed in order to develop a state-of-the-art OTEC TIS in Curaçao?

Table 1.1 summarizes what data collection methods will be used for answering each of the sub-questions and where the answer to the questions can be found. The following section elaborates on the used methods further.

1.6 Research Methodology

The **theoretical background** of this thesis is based on desk research of scientific articles. The literature review of the key theories and concepts used throughout the thesis is presented in

Table 1.1: Research Questions Specifications.

RQ	Data Collection	Area	Chapter
A.1.	Desk Research	Characteristics of SIDS	2.1
A.2.	Desk Research	Innovation Systems	2.2-2.3
A.3.	Desk Research	Literature Gaps – Innovation Systems in SIDS	2.4.1
B.1.	Cross-case Study	Existing Innovation Systems in Island States	3
B.2.	In-depth Case Study	Analysis of OTEC in Curaçao	4
B.3.	In-depth Case Study	Analysis of OTEC in Curaçao	4
B.4.	In-depth Case Study	Analysis of OTEC in Curaçao	4
B.5.	In-depth Case Study	Recommendations for OTEC in Curaçao	5

chapter 2. The data collected for the purposes of the case study is based on written sources and interview.

In total over 30 interviews were conducted for the purpose of the in-depth case study. The interviewees included stakeholders operating in the field of renewable energy technologies (RET), governmental officials, utility provider, regulators, policy makers, academics, non-energy related large businesses or environmental organizations in Curaçao. Focus was put on interviewing stakeholders in the fields of energy and related regulations, legislations and education. However, in order to get a broad understanding of the current situation in Curaçao, environmental organizations and energy-unrelated companies were involved as well. Summaries of all officially conducted and approved interviews are included in Appendix C. The list of the interviews that agreed to be listed is on page 132. Several highly relevant interviewees did not desire to be officially quoted, mainly in order to avoid tackling sensitive political issues - their insights are indirectly used in the analysis but are supported by other documents and interviews. Several interviewees are not referred to with their names but instead as interviewee XY (XY being a number) – their field of expertise is stated in the list of interview sources.

Written sources used in the data collection include policies, annual reports, economic outlooks, reports of various international and Curaçao based organizations as well as press releases and news articles. A large proportion of official documentation on the island (especially over the past 5 years) has been published in English. Based on the experience from this research project, it should however be brought into attention that the overall availability (and existence) of well documented official data and reports on the island is poor. Official consumer data, transparent reports on market developments, comprehensive statistics and registries, central repositories of documents such as laws and regulations either do not exist or it is significantly more difficult to be accessed than in Europe. This differences lead to the amount of qualitative data greatly exceeding the amount of quantitative data.

This has made the collection of data (and verification of this data) rather difficult. This is also one of the reasons why the amount of qualitative data (from the interviews) in the analysis greatly exceeds the quantitative portion.

The framework that was developed based on the existing literature was **verified and validated** with the support, the experience and the insights of several key interviewees – Coutinho (2012); Guda (2012); Halman (2012); Nicastia (2012); Tromp (2012); van Weijsten (2012). These in-

interviewees provided critical input into the research project due to their experience with the challenges that not only Curaçao but also other SIDS face with regards to TIS' development. The interviewees are a mix of energy and non-energy related experts and include representatives of investment banks focused on the Caribbean (SIDS) region, project developer focused on under-developed markets of the Caribbean and Central/Latin America, local energy regulator and participants in technology and academic related projects that have taken place on the island of Curaçao². Their insights and comments are presented in chapter 4 and ultimately the final framework presented in the final chapter reflects on them. Secondary input for the framework validation is provided by the cases studies of the several TIS in island states in chapter 3. Due to the lack of credible data and lack of time, their analyses lack the details of the main OTEC in Curaçao case study. However, the general insights into their developments provide solid data for the validation.

This master thesis is an individual **case study** and the methods applied to it follow the recommendations on increasing the reliability of case studies as identified by Yin (2008) with focus on: triangulation (use variety of sources) and when possible gathering longitudinal data. The analysis of Curaçao is based on evaluating the **current situation** on the island (so called **functionality analysis**). However, some data are also drawn from the **past** – mainly the experience with past RET projects in Curaçao and the review of the past energy related policies on the island. The analysis is therefore of **both functional and longitudinal nature**. Its generalizability across various types of TIS and SIDS is discussed in section 6.2

1.7 Research Boundaries

The general boundaries of this thesis are delineated by the definition of two terms: SIDS and TIS. By definition, **innovation systems** cover a limitless range of systems and it is well understood that capturing characteristics that would be generalizable to all of them is challenging. However this thesis picks up on the extensive amount of already existing knowledge and attempts to extend its applicability to the context of SIDS. The group of **SIDS** is in the literature perceived as a relatively homogeneous group of islands when it comes to the general economic and political indicators (though culturally and historically they often significantly differ). This thesis departs from the fact that SIDS are relatively homogeneous. While several TIS in islands states will be reviewed (chapter 3), the core of data collection, analysis and recommendations are based around one technology (OTEC) in one SIDS (Curaçao). The extent to which the insights from this one case study are generalizable to other cases is extensively discussed in section 6.2.

The in-depth case study of OTEC in Curaçao was initiated based on **already existing partnerships** and resources available on the island (discussed in section 4.1). Focus is therefore put on exploring resources (natural, human, financial, existing networks etc.) and the potential of the island itself rather than performing a direct comparison of Curaçao with other islands. The **boundaries** of the case study for the analysis and the data collection are therefore determined by the 'physical' borders and location of Curaçao. However, data from other (mainly regional)

²Summaries of the interviews with them can be found in appendices C.5, C.7, C.9, C.14, C.18 and C.23 respectively.

countries are considered as well due to the international reach of technologies. These exceptions are made in the following cases:

- Data from other countries are used to set a benchmark or set data from Curaçao into the context (e.g. is the value of X in Curaçao favourable or discouraging in the global context?);
- A certain factor has an essential influence on the developments in Curaçao and should be considered (e.g. presence of another OTEC related project in the region);
- The functioning of the envisioned TIS requires collaboration with other countries due to the limitations of Curaçao or it is highly desirable to involve institutions from abroad (in order to allow for proper functioning of the TIS).

“Innovative high-tech environments are made possible by creating favourable relationships among entrepreneurs, government policies, the society and the local environment including commercial institutions, physical, human and capital resources ...”

Feldman, 2005

2

Literature review

This chapter provides an overview of the relevant literature on the topic of innovation systems and SIDS. Firstly, SIDS are introduced in section 2.1 with a detailed review of the specific characteristics that the islands share. The general conditions for the development of TIS in these states are presented and the potential benefits that the islands can reap from their presence of are discussed. Sections 2.2 and 2.3 then follow with the introduction of the general theory that describes how societies function and how innovation systems develop.

The literature review unveils a gap in the available literature - namely the lack of knowledge about how the specifics of SIDS can be overcome when developing new TIS. The existing theories are therefore combined in section 2.4 to form a framework that aims to provide guidance in how the specifics of SIDS can be overcome. This framework will be tested and refined in the subsequent chapters.

2.1 Small Island Developing States

The characteristics of SIDS to a great extent delineate the scope of this research project. The following paragraphs describe the origin and the implications of the specific characteristics that SIDS share.

2.1.1 Description of SIDS

Despite the globalization and the emergence of large regional trading blocs, numbers of countries remain highly vulnerable and in disadvantageous positions with regards to their growth, technological and economical development. This led to the search for an indicator or an index

that would be comparable across different countries and could be used in designing international development policies (Guillaumont, 2009) Briguglio (1995) developed the Vulnerability Index that has been accepted and further adjusted by both the Commonwealth (Easter, 1999) and the United Nations (2006, p.20). The adjusted indexes are referred to as the Commonwealth or Composite Vulnerability Index (CVI) and the Economic Vulnerability Index (EVI) respectively. The organizations use the indexes for identifying the least developed and the most vulnerable countries. The indexes are determined based on a large number factors such as: gross domestic product (GDP), purchasing power parity (PPP), population, (geographical) size, the share of transport costs in trade, insularity/remoteness, size of the domestic market, the strength of regional markets or environmental vulnerability (e.g. proneness to natural disasters).

A comparative study of 114 states performed by Briguglio (1995) showed that: *'SIDS are more vulnerable than other developing countries and other countries in general'*. It is recognized by Armstrong and Read (2003) that *'the used data tend to be quantitative and economic rather than political/strategic or environmental because of measurement problems relating to qualitative variables...and may result in some inconsistencies between the findings of alternative indexes'*. However, based on the *'consistent political recognition of the problems of small islands'* (United Nations, 2004), SIDS became in 1995 a recognized distinct group of developing countries facing specific social, economic and environmental vulnerabilities (United Nations, 2012). Table 2.1 shows the vulnerability indexes of several country categories, including the SIDS. While the absolute numbers have little meanings without a detailed understanding of the indexes' compositions (see Briguglio (1995) for details), the key is the relative comparison of the various country categories that demonstrates the vulnerability of SIDS.

Table 2.1: Vulnerability Indexes for different groups of countries (Briguglio, 1995, p.1622). The lower the number, the less vulnerable the economy is (1.0 being the least and 0.0 being the most favourable result). Complete list of the 114 analysed countries is available from (Briguglio, 1995, p.1631)

Country category	Number of analysed states	Vulnerability Index
Small island developing states (SIDS)	21	0.624
Other island developing states	8	0.479
Non-island developing states	63	0.411
Developed states	22	0.278
All states ^a	114	0.447

^a The average Vulnerability Index of all the 114 analysed states.

SIDS of the United Nations has 52 member islands divided into three regions (Asia & Pacific, Africa, Central America & the Caribbean). In total, roughly 1% of the world's population lives in SIDS (United Nations FCCC, 2005). Aruba, Bonaire and Curaçao (as well as the former 'Netherlands Antilles') are among the SIDS nations. It is recognized that some larger, non-island and non-SIDS member states share *'some'* of the characteristics of SIDS (United Nations, 2004). However, it is the **overall** vulnerability and disadvantageous characteristics determined by the CVI and/or the EVI indexes that define whether a state is or is not SIDS. 40 out of the 52 SIDS states have populations of less than 750,000 inhabitants (UN Department of Economic and Social Affairs, 2007). There are several important exceptions to that such as Cuba, Haiti or Dominican Republic that have significantly over 1 million inhabitants. Regardless of their

relatively large size¹ these countries are still considered to be SIDS based on the overall CVI and EVI indexes' results (Commonwealth Secretariat, 2000). Economically SIDS predominantly rely on the tourism industries and the financial sectors by providing offshore financial services. Substantial share of manufacturing in GDP is rare (Nurse et al., 2001; Guillaumont, 2007).

It is essential to understand is that vulnerability is not the same thing as poverty or economic underdevelopment. Some islands (e.g. Iceland, Malta or Singapore) have established infrastructures that enable them to overcome and/or manage the disadvantageous characteristics of small islands. Iceland or Malta for example naturally share certain characteristics with SIDS as they are small islands with populations below 500,000 inhabitants. However, the countries have been able in the past to diversify and strengthen their economies to the extent that their infrastructures, industries or international networks allow them to remain economically strong and thus overcome their smallness and remoteness characteristics (Baldacchino, 1998; Baldacchino and Bertram, 2009). This is supported by Read (2008) who states '*...there is no statistical evidence that 'islandness' itself has significant negative impact upon economic growth*'. The University of the West Indies (2002, p.6) argues that vulnerability indexes can actually be used to monitor the states' economical progress. It is in this sense that the concept of the SIDS is used throughout this thesis – it is the 'islandness' characteristics in combination with the socio-economic development of SIDS that make this group of islands distinguishable from others.

Chapter 3 presents practical examples of several island nations that do not qualify to be SIDS, shows how innovation systems came to existence there.

2.1.2 Specifics of SIDS

SIDS differ greatly from larger and not-isolated regions and the main differences include:

- SIDS typically have limited markets, scarce physical resources, shortages of technical skills and a weak bargaining power for inter-state agreements (Yu and Taplin, 1998; United Nations, 2012);
- Government and public sector play a dominant role in the economy (specially in scientific and technological affairs) (Nurse et al., 2001; Hadjimanolis and Dickson, 2001);
- The economies are less diversified than non-SIDS (Streeten, 1993);
- Dis-economies of scale in electricity production, making power production not only extremely expensive but also bearing financial risks in the long term (Nurse et al., 2001; Weisser, 2004a,c);
- With respect to energy, most of the islands depend on import of oil and its related products. In some cases, there is no way to link the islands to continental energy networks, making it difficult to guarantee the security of supply (Duic and da Graca, 2004; Monteiro Alves et al., 2000).

¹There is no general consensus as to what 'small' state is. The Commonwealth uses 1.5 million and UN 1 million inhabitants as the upper limit for small states (Commonwealth Secretariat, 2000; Armstrong and Read, 2003).

As [Turvey \(2007\)](#) concluded, ‘economically, socio-politically and geographically [natural disasters, ecosystems fragility etc.], SIDS are more vulnerable compared with large-island countries’. The vulnerabilities resulting from the above listed points are based on the lack of resilience in the face of outside forces: heavy dependence on imports, dependence on a narrow range of exported products, limited ability to influence prices (they are price takers), limited ability to exploit economies of scales, limited domestic competition or problems of public administration ([Briguglio, 1995](#)).

2.1.3 Technological Innovation Systems in SIDS

In general, it is only the topic of RET that has been well covered in the literature and relates to innovation systems in SIDS. Authors such as [van Alphen et al. \(2006\)](#); [Duic and da Graca \(2004\)](#); [Monteiro Alves et al. \(2000\)](#) studied the numerous cases around the world where SIDS attempted to integrate RET. However, as [van Alphen et al. \(2006\)](#) concluded in the case of Maldives ‘like most SIDS, the republic of the Maldives is blessed with abundant renewable energy resources, yet it depends overwhelmingly on petroleum imports’. It is a paradox that most SIDS have abundance of renewable energy resources, but do not utilize them ([Weisser, 2004a](#)). This issue is well covered by for example [Duic and da Graca \(2004\)](#); [Mitra et al. \(2008\)](#) that predominantly focuses on the technical aspects of RET integration (energy decentralization, grid issues etc.). [van Alphen et al. \(2006\)](#); [Monteiro Alves et al. \(2000\)](#) on the other hand emphasize the social, economic and environmental aspects. [Jaramillo-Nieves and Del Rio \(2010, p.801-811\)](#) present a table with an extensive overview of the SIDS that have been studied with regards to their potential for the development of RET. It is very clear that the challenges of RET in SIDS are of a broad socio-technical nature rather than solely technical or economical.

With regards to the general situation in the field of technology and innovation in SIDS, the following characteristics have been identified in the existing literature:

- Institutions for the promotion of technological innovation, such as technological intermediaries, research establishments, and prototype facilities, are weak or underdeveloped; ([Hadjimanolis and Dickson, 2001](#));
- The ‘high-tech’ sector is invariably underdeveloped or non-existent, i.e. ‘there is nothing to start with’. ([Encontre, 1999](#); [Weisser, 2004b](#));
- Indigenous R&D capabilities are restricted and, in consequence, SIDS are dependent upon technologies created in larger countries that are generally tailored to the needs of those countries ([Easterly and Kraay, 2000](#); [Kristoferson et al., 1986](#));
- Domestic demand is insufficient to reach the minimum scale necessary for efficient output. This means that the unit cost of the local production of many goods and services is higher than in larger states ([Armstrong and Read, 2003](#));
- The small area of most small states often means that physical natural resources are likely to be limited and undiversified ([Armstrong and Read, 2003](#));
- High transport costs of goods have negative impact on the prices of both imports and exports making the countries less internationally competitive ([United Nations, 2004](#));

- The shortage of specialized technical labour, and weaknesses in the supply of technical services ([Hadjimanolis and Dickson, 2001](#));
- Lack of effective and competitive support and infrastructural services, such as telecommunications and venture capital ([Baldacchino, 2005](#)).

In order for the export sector in small states to remain internationally competitive, local firms need to find their comparative advantages. Since it is difficult to reach economies of scale, [Armstrong and Read \(2003\)](#) argue that local firms need to *'specialize in activities that are less reliant upon scale economies and utilize human capital intensively, including natural resources and higher value-added niche manufacturing and service activities'*. In other words, SIDS need to find niche technologies that stem from their comparative (and maintainable) advantages. The opportunities for manufacturing are however limited by the constraints of scale economies ([Briguglio, 1998](#); [Armstrong and Read, 2000](#)). As [Baldacchino \(1998\)](#) concludes, *'manufacturing in small island states is best seen as an extension of services, rather than the other way round'*.

2.1.4 The Benefits of Technological Innovation Systems in SIDS

The roles of TIS and in general the roles of manufacturing or industrial activities on SIDS have not been explored on any substantial level. The available knowledge can be summarized by the works of [Armstrong and Read \(2003, 1995\)](#); [Read \(2008\)](#); [Basu and Das \(2011\)](#). It is argued that FDI into technology can provide a critical impetus to economic growth of SIDS because it embodies technology, know-how and organisational techniques in addition to financial capital. Tourism is on the other hand seen as a key source of employment but similar to agriculture it is associated with relatively poor growth and low levels of income. Higher level of skill and technology intensive manufactures help increase GDP per capita in developing countries. As [Basu and Das \(2011\)](#) state, *'developing countries should underscore the urgent need for trade-policy support along with emphasizing on augmenting domestic investment for high quality of human capital development and increasing institutional efficiency as a necessary component to improve productive capacity for harmonious economic development'*. Lastly, [Armstrong and Read \(1995\)](#) identified that *'the relationship between sectoral specialization and growth in small states is significantly and consistently associated with a rich natural resource base and a strong service sector'*.

The benefits of the TIS' existence are naturally not only shared by the islands themselves but also by sectors (technologies) and the entrepreneurs and other organizations. As [Conway et al. \(2010\)](#) summarize niche markets can be exploited by entrepreneurs creating substantial economic opportunities and the technologies that are designed for SIDS can actually be developed there under local conditions and with the support of their (future) users.

Due to the lack of theories or concepts that would specifically focus on TIS in SIDS, the rest of the literature review focuses on the general characteristics of TIS. Firstly a theory that in general describes the processes and interactions within countries' societies and economies is covered - the Evolutionary Theory. Secondly a theory that can be used to analyse and influence TIS is introduced - the Functions of Innovation Systems.

2.2 The Evolutionary Theory

Two contrary views exist on what drives technology - constructivism and determinism. **Determinism** states that it is only the technology (i.e. not society) that determines the future technological developments (Winner, 1980; Fleck and Howells, 2001). This view forms bases to the 'linear model' – a model in which the characteristics of a given technology are far superior in its developments to the social or political surroundings. Social **constructivism** is the exact opposite view as it emphasizes the importance of socio-economic aspects in technology development (Pinch and Bijker, 1984). The key aspects of the literature review on SIDS undoubtedly showed that the ideas of constructivism are more suitable for the case on hand.

Energy systems are considered to be socio-technical systems – i.e. large scale systems that directly affect or change the way society functions (Geels, 2002, 2004). The transformation of such system is referred to as Technological Innovation System (TIS)² – the theory underpinning this concept is known as the **Evolutionary Theory**. The Evolutionary Theory has been strongly advocated by Geels (2002, 2004); Geels and Raven (2006); Geels and Kemp (2007).

TIS are characterized by a large number of connected related parts or components that are often centrally controlled (Whitworth, 2006). The concept of TIS is particularly applicable to the fields of transportation, communication, and energy. The concept can be easily demonstrated on the example of a transformation of a fossil fuel driven economy to a renewable driven one. Such transformation is not only about 'unplugging' a coal plant and replacing it with windmills, solar panels or OTEC plants. Such change is associated with very complex structural changes that can include decentralization of energy generation, changes in the technical infrastructure, changes in supply chains, education and even changes of entire national economies. This implies that change in TIS happens generally over extended period of time (years or even decades) (Kern and Smith, 2008; Verbong and Geels, 2007).

2.2.1 Economy and Technological Change

Socio-technical systems function under the so called **technological regimes** – guidelines, beliefs or routines that direct the efforts of engineers (and organizations). Technological regimes are embedded in engineering practices, skills, production characteristics or even in the way how problems are defined. Geels (2002, 2004) demonstrated this principle on the example of Moore's law that 'prescribes' the long term development of computer components. In the field of energy systems, the technological regimes are represented by the use of fossil fuels or centralized electricity grids. Technological regimes do transform on their own but only **incrementally** – for example by gradually increasing efficiencies of turbines in coal plants.

Emerging **technological niches** attempt to disrupt the regimes by providing alternative solutions (they are referred to as **radical innovations**). In the case of energy systems, the technological niches would for example include the utilization of solar, biomass, wind, wave or other renewable sources. The niches are somewhat protected or insulated from the regular market

²Technological Innovation Systems (TIS) is often referred to as Technological Systems of Innovation (TSI). The term Technological Innovation System is invariably used throughout this thesis.

selection practices as they are the ‘incubators’ of new developments – their role is to slowly shape the perceptions and roles of technology developers and incumbent technologies (Schot and Geels, 2007; Hommels et al., 2007). They often have lower technical performance or are more expensive but the learning process associated with their development might eventually result in technological performance superior to the one of technologies located in regimes. The pressure technological niches put on the regimes modifies the **technological trajectories** – the direction in which the community of engineers searches for solutions to technological problems (Geels, 2002).

The technological trajectories are located in **socio-technical landscapes** – set of deep structural trends, routines, standards, regulations, networks etc. In case of energy systems, these would include the actual physical grid, the deep roots of fossil fuels embedded in the economy structures, subsidy systems or regulations (Malerba, 2002).

Figure 2.1(a) shows the hierarchy within the socio-technical system³ – regimes are embedded within landscapes and niches within regimes. Figure 2.1(b) shows the interactions among the layers – novelties that emerge in niches slowly influence the regimes and regimes shape landscapes. The process of how niches become parts of regimes is discussed in section 2.3.

2.2.2 Variations of Innovation Systems

An innovation system is defined as a dynamic network of agents interacting in specific economic or industrial areas under particular institutional infrastructures and involved in the generation, diffusion, and utilization of technologies (Alkemade and Suurs, 2011; Carlsson and Stankiewicz, 1991). The central features of technological systems are economic competence (generating revenues), clustering of resources, and institutional infrastructure (Carlsson and Stankiewicz, 1991). Innovation in general is characterized by uncertainties, high risks and late returns on investment. This is particularly true in the case of innovations for sustainability where market forces alone are not sufficient to come to a more sustainable socio-technological regime (Alkemade and Suurs, 2011; Jacobsson and Bergek, 2004; Rennings, 2000).

There are number of views on how innovation systems work or how it can be analysed, influenced and directed. According to Chang and Chen (2004); Markard and Truffer (2008) the main three approaches to innovation systems are:

National Innovation Systems (NIS) where the technology development is mainly the result of relationships and interactions defined by cultural, technical and linguistic characteristics in one single geographical space and controlled by one central state;

Technological or Sectoral Innovation Systems (TIS or SIS), where the technological interdependence plays a crucial role. The economic dynamics of technology development and inter-industry flows are the most relevant aspects in determining how technologies evolve;

Regional Innovation Systems (RIS), where the importance of the local supply of managerial and technical skills, accumulated tacit knowledge, and knowledge spillovers is stressed.

³Due to the three layers that are present (niches, regime, landscape), the hierarchy is often referred to as **multilevel perspective**

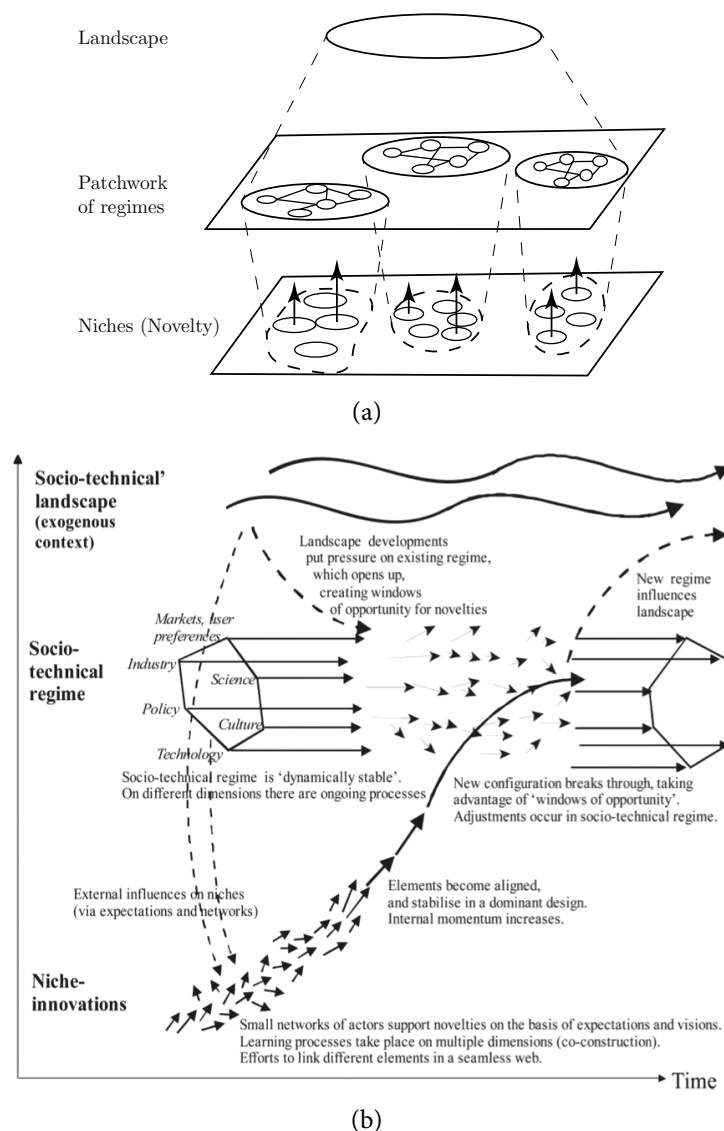


Figure 2.1: (a) The multi-level perspective – Relations among niches, regimes and landscape. Adapted from Geels (2002); (b) Multilevel perspective (Schot and Geels, 2008).

The three approaches are useful as they make it possible to understand and explain the processes of innovation. More importantly, they identify factors that actually shape and influence them. However, according to Markard and Truffer (2008); Carlsson and Stankiewicz (1991) there is no right or wrong way to draw system boundaries in delineating an innovation system, (i.e. distinguishing between the system and its environment). Figure 2.2 demonstrates this by showing how geographical and technological boundaries are interlined. So is there always a particular approach that is more suitable for a certain technology?

Markard and Truffer (2008) suggest that making the right choice in system delineation should be dependent on the research question and the purpose of analysis (referred to as *descriptive delineation*). Even then however, it is an iterative process with continuous adjustments to system boundaries as the understanding of the system increases over time. Whatever boundary is

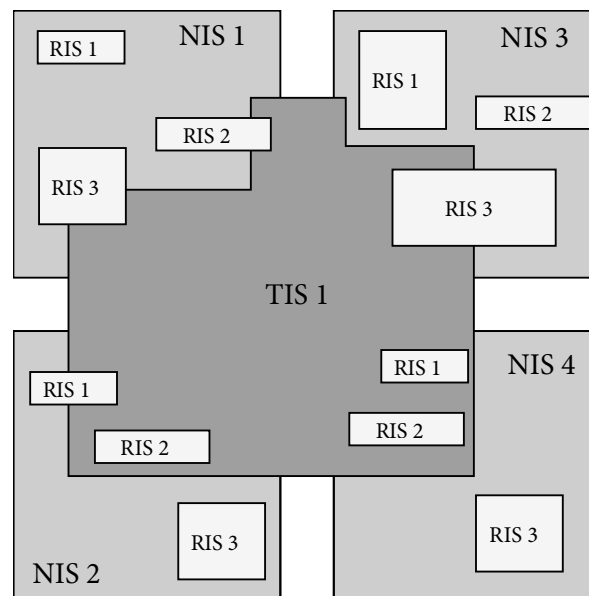


Figure 2.2: Boundary relations National, Sectoral and Technological Innovation (RIS - Regional Innovation System, NIS - National Innovation System, TIS - Technological Innovation System). Adapted from [Hekkert et al. \(2007\)](#)

chosen with regard to technology, system delineation will always encompass a further specification in spatial (geographical) terms. This makes identifying the right approach crucial and challenging task ([Bergek et al., 2008b](#)).

[Patel \(1995\)](#); [Pavitt and Patel \(1999\)](#) stress the importance of country-specific factors that have an influence on creating national technological advantage – namely, the competitive climate, financial system and education, public policies, training and basic research institutions. This is mainly due to the tacit nature of the knowledge that drives innovation in industries and that forces companies to locate themselves (geographically) close to where the knowledge is being generated ([Carlsson, 2006](#)). However, the role of internationalization to certain extent diminishes these advantages as some previously regional or national activities are transferred to international networks ([Niosi and Bellon, 1994](#)). Additionally as [Malerba \(2002\)](#) notes, investments are often closely interrelated and span over different technologies or activities.

[Chang and Chen \(2004\)](#) conclude that these methods provide complementary views, rather than substitutive ones and should be used in conjunction, i.e. should be combined in order to perform a comprehensive technology evaluation. This view will be respected in the rest of the thesis. Since this thesis is focused on the development of sectoral innovation system, their boundaries innovation systems will be essential. However, the roles of the national influences will be respected as well. See section 2.4 as how to this will be accomplished.

2.2.3 Structure of Innovation Systems

According to [Malerba \(2002\)](#); [Bergek et al. \(2008a\)](#); [Hekkert and Negro \(2009\)](#); [Alkemade and Suurs \(2011\)](#) the basic elements of innovation systems are:

Products or services that are the subjects of scrutiny.

Agents or Actors are firms in the technology's value system (e.g. suppliers). They also include organizations such as universities, research centres or organizations of interests (environmental organizations etc.). Each new entrant of the system brings new knowledge, capital or other resources to it, this is referred to as 'filling gaps'.

Institutions cover legal and regulatory aspects that regulate interactions between actors, define the value base of various segments in society and structure learning process. This logically implies that companies do not only compete for their market share but also for influence on political ground.

Knowledge and learning processes including the knowledge base of innovative and production activities of a given sector or region – knowledge has different degrees of accessibility and the opportunities of gaining this knowledge for firms is greatly influenced by the external environment that surrounds the company.

Basic technologies, inputs, outputs and complementaries including vertically and horizontally related sectors. Their interdependencies and complementaries define the real boundaries of the systems. Technology-product matrix that links the products of a given technological sector to a range of technologies provides good foundations for delineating systems.

Mechanisms of interactions within and outside firms including market and non-market interactions – these interactions are influenced by specific beliefs, expectations, competencies of users, suppliers and other firms. link actors, e.g. manufacturers and suppliers, users and producers, producers and university researches etc., and form an important means of transfer of tacit and explicit knowledge. Networks do not necessarily need to be of technology related types, but can also be of political or environmental nature (e.g. influencing political agenda). Additionally non-firm organizations (universities, regulators, government agencies, banks etc.) also have a strong influence on the results of innovation, diffusion and they shape the understanding of technology among .

Process of competition and selection involving competition between the incumbent and new entrant as well as between several new entrants. The entrepreneurs develop a set of variations (different products, technologies etc.) and then the selection of a particular technology within the socio-technical system is based on: cost/performance, expectations, regulation, interconnection with other technologies or demographic and cultural change.

2.3 Technological Niches

Technological niches are protected spaces that allow nurturing and experimentation with the technology and adjustment of regulatory structures. As [Schot and Geels \(2008\)](#) states, niches can only diffuse more widely if they link up with the ongoing processes at regime and landscape levels. Figure 2.1(b) indicates how niches influence regimes and regimes shape the technological landscape.

2.3.1 Analyses of Niches

Two theories can be utilized in analysing or transforming niche technologies and integrating them into the existing socio-technical systems: **Functions of Innovation systems (FIS)**⁴ and **Strategic Niche Management (SNM)**.

SNM noticeably covered by [Kemp et al. \(1998, 2001, 2007\)](#); [Schot and Geels \(2008\)](#) is a theory explaining how one can induce or accelerate a change in technological regime. SNM aims to make institutional connections and adaptations in order to stimulate the learning processes that is necessary for further development and use of the technology niches ([Caniels and Romijn, 2008](#)). SNM stresses the importance of enabling and protecting experiments in these niches ([Geels and Raven, 2006](#); [Raven, 2007](#)). However, the theory focuses on concrete technologies and artefacts that are already available and can be tested in a pilot. With emerging technologies, it is however not always the case that pilots can already be tested (as the in-depth case study of OTEC in Curaçao will for example prove). Additionally as [Mourik and Raven \(2006\)](#) state, SNM does not provide a clear structure nor concrete indicators (guidelines) for the analysis. Therefore SNM is not fully suitable for the case on hand.

In recent years, the concept of FIS has emerged. The so called functional perspective emphasizes the importance of what the system does and how it works in comparison to how it is composed or structured ([Markard and Truffer, 2008](#)). FIS have in detailed been covered by [Bergek et al. \(2008a,b\)](#); [Hekkert et al. \(2007\)](#). The theory provides a clear structure to the analysis of technologies (socio-technical systems) and the identification of weak areas to be tackled. FIS are not limited only to the use and operation of a technology, but can be extended to all the pillars (all parts of the supply chain) that a TIS can include – the theory will therefore be used in this thesis and is in detail described in the following sections.

2.3.2 Functions of Innovation System

The usefulness of FIS lies in identifying means of speeding up the system's diffusion by not only looking at the structural elements of the technology but also at what is actually achieved in terms of a set of key processes - these key processes are referred to as FIS ([van Alphen et al., 2006](#)). A function is a (positive or negative) contribution of a component or a set of components to the overall function of the innovation systems ([Hekkert et al., 2007](#); [Bergek et al., 2008a](#)). By empirically mapping these functions, system weaknesses can be identified and mechanisms that block or limit them can be tackled.

By analysing a large number of innovation systems, several general functions that are inherent to technologies were identified in the 1990's. These were then revised by a number of authors and stabilized on seven key functions that influence the development of innovation systems. Each function can have a number of indicators associated with them - their use is however dependent on the case on hand and can (should) be modified depending on the case.

⁴'Functions' of Innovation Systems are often referred to as 'Activities' of Systems of Innovation – the term 'Functions' is used throughout this thesis

The list and description of individual functions is given below. The main indicators that will be used in the actual analysis of Curaçao are shown in table 2.2. These indicators are mainly of qualitative nature due to the reasons discussed in section 1.6. Based on [van Alphen et al. \(2006\)](#); [Bergek et al. \(2008b,a\)](#); [Hekkert et al. \(2007\)](#), the FIS are:

1. **Entrepreneurial activities** function is related to how entrepreneurs turn potential of new knowledge, networks, and markets into concrete actions and how they take advantage of new business opportunities (includes both new entrants and incumbents). The presence of entrepreneurs is a prime indication of a potential innovation development, and should the entrepreneurial activities be lagging behind the other six functions might provide an explanation. This implies that entrepreneurs should not only focus on in-firm activities but also influencing their external environment. The measures used to map this function include: **the numbers of: new entrants, diversification activities of incumbent actors, experiments with the new technology**. There are three questions the a particular firm needs to answer:
 - (a) What functions will the firm perform (e.g. lobby for new supportive policies)?
 - (b) Which organizations should the firm link to or join forces with (e.g. who else will benefit from the new policies and might therefore support us)?
 - (c) Which organizations will the firm compete with on certain functions (e.g. who will compete for the same subsidies)?
2. **Knowledge development** functions is related to learning by searching (research) and learning by doing (production, testing, actual market operations). Knowledge is considered to be the most fundamental resource in modern economy and innovation, and learning is the process the enables its development.
3. **Knowledge diffusion through networks** function is related to how information and insight about the field is shared with policy makers, government, market and competitors - policy changes, establishment of standards or long term targets are some of the outcomes that the diffusion might bring.
4. **Guidance of the search** is related to the selection of technologies for further development, financial support, policy changes etc. Resources are always limited, and there are usually numerous technological alternatives available. The guidance of the search refers to activities within the innovation systems that can positively affect the visibility and clarity of specific wants among technology users. The hype and high expectations about a certain technology can for example drive research activities or investments in a certain technology field, or trigger development of policies that support such development. Governmental target of reaching a certain percentage share of renewables by a given date is another great example.
5. **Market formation** function is related to how well a given technology is capable of creating (entering, modifying) a market. New technologies frequently struggle to replace incumbent ones as their benefits are not always visible at the moment of introduction. In such cases, creating a (temporary) protective space for the new technologies might. This functions covers all relevant aspects that might positively (negatively) relate to market

entry and/or formation of a given technology.

6. **Resources mobilization** function is related to both financial and human (long-term) resources devoted to the development of a certain technology or field by government, industry and other organizations.
7. **Creation of legitimacy/counteract resistance to change** is related to how a new technology becomes part of an incumbent regime or even overthrows an incumbent technology. Resistance of such development (from the incumbents) is referred to as creative destruction. Having a support from other actors and institutions (*advocacy coalition*) creates environment in which new technologies can curtail the creative destruction.

Table 2.2: Indicators used to map FIS in the context of OTEC and Curaçao. Based on: [van Alphen et al. \(2006\)](#); [Bergek et al. \(2008b,a\)](#); [Hekkert et al. \(2007\)](#)

Function	Indicators
1. Entrepreneurial activities	<ul style="list-style-type: none"> - Past OTE efforts on the island - Current OTE efforts on the island - Regional OTE developments
2. Knowledge development	<ul style="list-style-type: none"> - Local OTE related expertise - OTE related investments - Incumbent's knowledge
3. Knowledge diffusion	<ul style="list-style-type: none"> - Past and current conferences and seminars - Existing cooperation - Education and its relations to RET
4. Guidance of the search	<ul style="list-style-type: none"> - OTEC branches and its suitability for Curaçao - Local awareness about the technology - Numbers of articles in journals/media about OTEC - Characteristics of the legislation - Local energy targets/visions
5. Market formation	<ul style="list-style-type: none"> - Local tax exemptions and incentives - Market size - Developments of competing niches
6. Resource mobilization	<ul style="list-style-type: none"> - Availability of technical experts - Methods for gaining technical expertise - Requirements for getting finances - Specifics of financing local projects
7. Creation of legitimacy	<ul style="list-style-type: none"> - Legislation related to incumbent's resistance - Support of education

2.3.3 Vicious and Virtuous Cycles, Blocking Mechanisms

Any changes in the components structure (new entrance of actors, changes in the governmental institutions) might trigger a set of actions that can push the system forward. And as [Bergek et al. \(2008a\)](#) argues, distortions to the regular interactions among actors and institutions may induce

new market opportunities and generate positive externalities. For example, new entrants into the field can make networks more dense and thus lower entry barriers, or cause universities to expand their research in relevant fields. This concept forms bases for a self reinforcing set of events referred to as **vicious cycles** (lead to negative results) and **virtuous cycles** (lead to favourable results) (Hekkert et al., 2007). Suurs (2009) studied this concept extensively and used the term **motors of innovation**.

For an emerging technology it is important to identify **blocking mechanisms**, i.e. factors that present obstacles in the the development of powerful functions and thus help the incumbent technology to sustain itself. If the forces driving the cycles are of positive character, they are referred to as **inducement mechanisms (forces)**.

Table 2.3 outlines some of the blocking mechanisms and their roots (actors, networks or institutions). Figure 2.3(a) presents an overview of functions of innovation systems and demonstrates the concept of virtuous and vicious cycles with examples of blocking and inducement mechanisms based on the case of renewable technologies in Sweden.

Table 2.3: Some of the blocking mechanisms divided according to the components of innovation systems that cause them. Adapted from Jacobsson and Johnson (2000).

Component	Blocking Mechanism
Actors	<ul style="list-style-type: none"> - Poorly articulated demand - Established technology characterised by increased returns - Overwhelming demand - Market control by incumbents
Networks	<ul style="list-style-type: none"> - Poor connectivity - Wrong guidance with respect to future markets
Institutions	<ul style="list-style-type: none"> - Legislative failures - Failures in educational system - Skewed capital market - Underdeveloped organisational & political power of new entrants - Withdrawn support

2.3.4 Functional analysis

System dynamics of the functional approach can be analysed using three complementary approaches:

1. **Longitudinal analysis** that consists of drawing several functional maps of a given innovation system (and capturing its changes over time) – this is achieved by describing **what is actually going on** in the innovation systems in terms of key process. This includes not only mapping the present state of the function (i.e. how are markets performing), but also what their determinants are (i.e. what or who is driving the markets). The mapping indicators of each function introduced in section 2.3.2 provide suitable measures for such analysis.

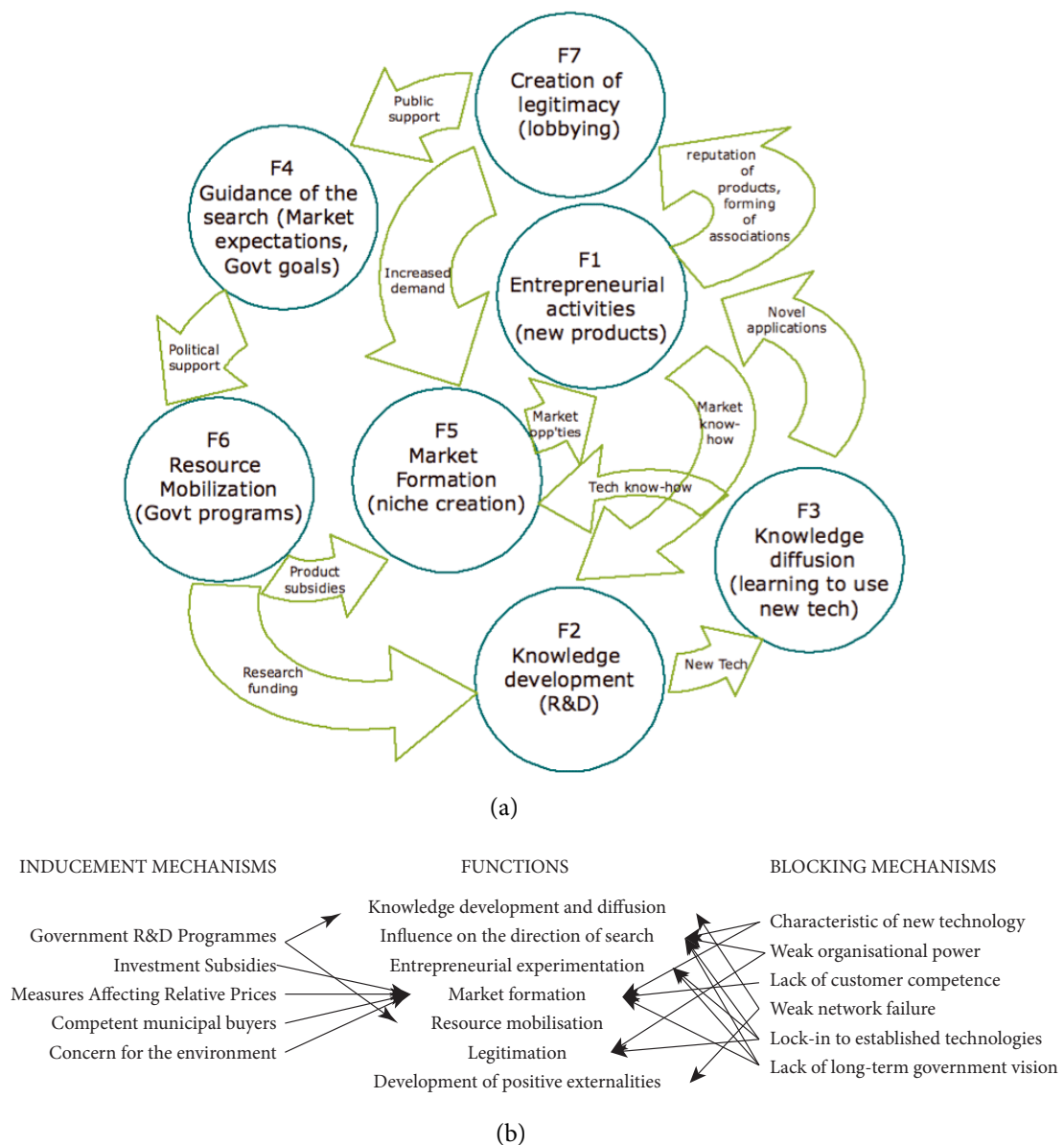


Figure 2.3: (a) Overview of functions in innovations systems and demonstration of vicious and virtuous cycles (Hekkert et al., 2007); (b) Linkages among blocking mechanisms, driving forces and FIS on the example of renewable technologies in Sweden. Adapted from Bergek et al. (2008a)

2. **Functionality evaluation** that captures **how well** the functions are served within the innovation system - goals are then formulated that help achieve desired developments. Assessing the goodness or a particular function is the most challenging part of the analysis. The function can be analysed by comparing current strength and weaknesses, and relating it to the particular needs. Innovation system may also be compared with already existing systems in other regions or countries.
3. **Linking driving forces and blocking mechanisms** to the functions for each innovation system that will determine the key issues for firm strategy or government policy. Bergek et al. (2008a) has demonstrated the concept of linkages among the blocking mechanisms,

driving forces and the actual functions on an example of renewable technology development in Sweden. Figure 2.3(b) schematically shows these linkages.

As a result, the functional approach can help achieve two targets:

1. Deliver set of targets for entrepreneurial activities (process goals);
2. Deliver specification of blocking mechanisms and driving forces of a particular TIS.

It is important to realize what [Bergek et al. \(2008b\)](#); [Kemp et al. \(1998\)](#) suggest and what was introduced in section 2.3. The phase of technology development is crucial in correctly assessing the technology potential. From the very nature of innovation, technologies in their early development stages cannot be directly compared with the incumbents using the same metrics (e.g. performance versus cost ratio). One must therefore distinguish between **formative (development) phase** and **growth phase**.

2.3.5 Combining TIS with the Multi-Level Perspective

[Markard and Truffer \(2008\)](#) presented their ‘integrated’ framework (figure 2.4) that builds upon the concepts of the TIS and the multi-level perspective. By building upon the complementarities of the two, their strengths can be combined. The framework works as follows: emerging niches form TIS, socio-technical regimes that represent the dominant production structure challenge the TIS; and a landscape with parameters that influence regimes and innovations without being influenced in turn. This conceptualization is therefore in alignment with the existent the general understanding of how TIS work with the exception that the role of the landscape and regimes is stressed.

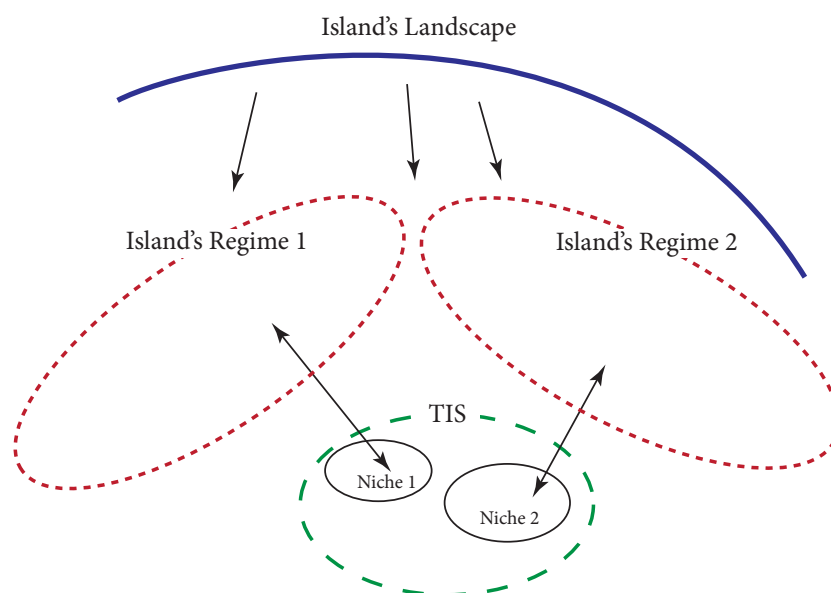


Figure 2.4: Integrated framework of TIS and multi-level perspective. Adapted from [Markard and Truffer \(2008\)](#).

2.4 Summary

2.4.1 Literature Gaps

With regards to technology and innovation only one topic has received a substantial amount of attention within the context of SIDS – the integration of RET and particularly the topic of electricity production decentralization and its technical implications.

While the existence of technology based industries (TIS) can provide significant benefits to SIDS they are generally speaking non-existent. There are however several examples of non-SIDS islands that are able to overcome the islandness specifics and that do in fact host TIS. This raises the questions of how those the TIS came to existence and how are they overcoming the specifics of islands.

The existing literature does not provide an answer to these questions. No implications of the well acknowledged characteristics of SIDS are drawn as to how they should affect the development of new TIS (e.g. how to overcome the inability to make use of scale economies in SIDS). It can be concluded that the implications associated with the creation of TIS in SIDS are not sufficiently covered in the existing literature. Based on the potentially significant socio-economic benefits that TIS can bring to SIDS and on the opportunities that these TIS can bring to entrepreneurs (see section 2.1.4) this thesis further researches the topic. The framework unveiled in the following section attempts to tackle the literature gaps. The following chapters will then be used to validate and verify it. The overall scientific contribution of the thesis is summarized in section 6.1.

2.4.2 Literature Summary

The general topic of SIDS has received a substantial amount of attention in academic journals. The disadvantageous specifics of these states are widely accepted and are related to the islands' small scales, economic underdevelopment and the resulting political and economical vulnerabilities. The vulnerabilities refer to the lack of resilience in the face of outside forces. They include limited ability to influence domestic prices, limited ability to exploit economies of scales or heavy dependence on imports. The characteristics of SIDS lead to the islands having almost invariably underdeveloped or non-existent high-tech sectors and being dependent on imported technologies. The literature is however explicit about the fact that 'islandness' on its own does not equal poverty or underdevelopment. Examples of non-SIDS islands such as Iceland or Malta and their states of economies show that the 'islandness' imposes specific conditions that need to (and can) be overcome and managed. The literature states that technology can provide a critical impetus to economic growth of SIDS and the higher set of skills and technology intensive industries help increase GDP per capita in these states.

While the amount of literature devoted specifically to the topic of innovation systems in SIDS is limited from the work of [Armstrong and Read \(1995, 2000, 2003\)](#) discussed in section 2.1.3 it is deduced that the key characteristics to consider in the development of TIS in SIDS are:

- Focus on service or high margin (rather than cost) based industries, avoid targeting the parts of the supply chain that require scale economies;
- Utilize strategic location for accessing specific markets and/or;
- Utilize a specific natural resource.

In terms of the general existence of TIS, the **Evolutionary Theory** is the most recognized theory describing the complex socio-technical interactions in states. As a part of its multi-level perspective, it divides the societies and economies into three layers: the socio-technical landscape (the macro-level), the regimes (the meso-level) and the niches where novelties and new innovation systems emerge (the micro-level). Given this division, innovation systems can be delineated by the boundaries of nations, regions or sectors (technologies). The **sectoral or technological delineation** is the most appropriate for the purposes of this research as it captures the over-reaching impact of technologies. New innovation systems develop in niches and it was identified that for the purpose of analysing and managing a newly emerging TIS the **functions of innovation systems** or **FIS** concept can be used. FIS is a set of seven functions that describe how innovation systems function and what their weak or strong areas are. These functions are: Entrepreneurial activities, Knowledge development, Knowledge diffusions, Guidance of the search, Market formation, Resources mobilization and Creation of legitimacy.

2.4.3 Proposed Framework

Given the existing knowledge presented in this chapter, a framework for the support of the development of TIS in SIDS was designed and is shown in figure 2.5.

The framework is based on the FIS. Since there are no indications that the actual functioning of TIS there would lack any of the parameters outlined by the functions, the functions' roles remain unchanged from how they are described in the existing literature. It is however argued that the specifics of SIDS impose two special requirements on the TIS – regarding the **choice of the TIS** (sector) and regarding its **integration into the national (island) landscape and regimes**. Overall, the proposed framework can therefore be seen as a modification of the integrated approach presented by [Markard and Truffer \(2008\)](#) that combines the FIS with the multi-level perspective.

Targeted Sectors

Firstly, the proposed framework implies that due to the TIS that are to be developed in SIDS need to be comply with one of the three specific aspects that have been already identified by several authors and discussed throughout this chapter. They should:

- Be either service sectors and/or high margin production focused sectors should be targeted;
- Utilize the strategic locations of the islands into their comparative advantage;
- Utilize specific natural resource sustainably available on the island.

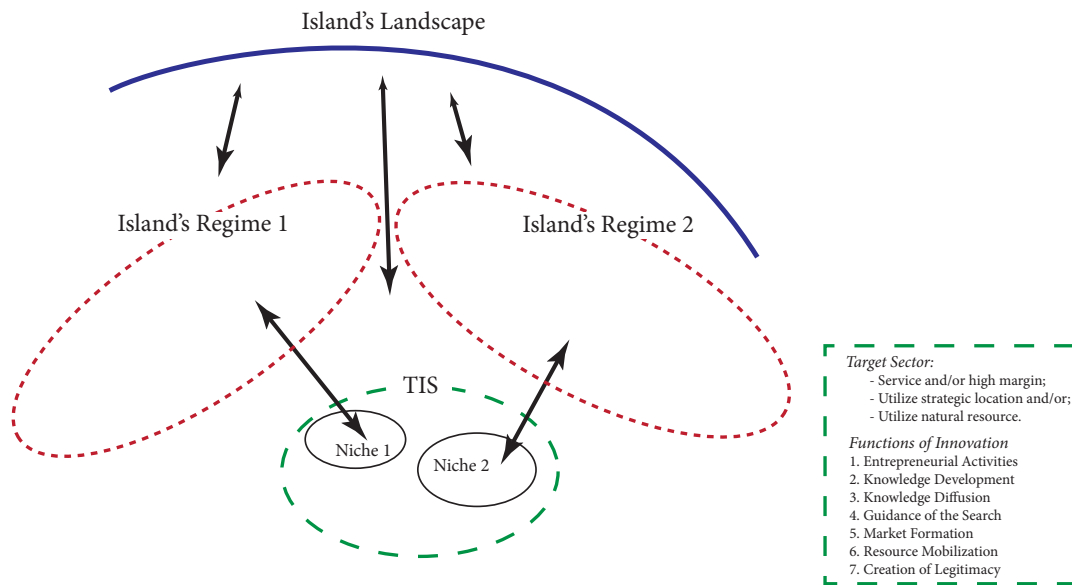


Figure 2.5: Preliminary framework for the support of the development of innovation systems in SIDS.

Without satisfying these requirements, it is argued that the TIS cannot sustainably exist on the islands.

Integration of the Innovation System into the Islands' Regimes and Landscapes

Secondly with two differences, the outlined framework proposes to integrate the multi-level perspective with the TIS concept in a similar way as [Markard and Truffer \(2008\)](#) did. The underlying reasons for this integration and the two difference are following.

First of all, the literature states that many of the institutions, facilities or policies that are generally positioned in the regimes or landscapes to support the existence of TIS are in SIDS non-existent. In order to built up a new TIS, some support must therefore be put in place. This support will vary depending on the technology but could include a development of a new (up to now missing) policy, using and adjusting facilities of local institutions, issuing specific permits etc. With newly emerging technologies, this will naturally be the case for SIDS as well as developed states. However, due to the limited markets of SIDS and restricted capabilities of their public sectors, the importance of this relationship with the relevant actors and organizations is much greater in SIDS than in the developed countries. In the framework, the importance of maintaining these strong relationships is shown by the thickness of the arrows.

At the same time, due to the vulnerabilities of SIDS, the potential impact that any TIS may have on islands is much greater than in developed countries. Disruptions in productions, closures of plants or for example shortened supplies of certain materials have have immediate and potentially substantial impact on islands. As a result, the relationships between the TIS and the regimes is not one-directional but mutual with its strength being more substantial than in developed countries. Additionally and also due to the 'smallness' and vulnerabilities of SIDS, it is argued that to a certain extent the TIS' may potentially have direct impact on the islands' land-

scapes (be it for example the structure of their economies). This is in contrast with developed countries where the landscapes are almost invariable in the short term. Once again, the importance and the directions of the relations among TIS and regimes and landscape are shown in the framework with the thickness of the lines and arrows.

This framework will now be validated and verified in chapters 3-5, i.e. seeing if the right framework was designed and if it adheres to the objectives. In chapter 3, five island based innovation system are analysed there in order to validate the core ideas behind the framework. The aim of the chapter will be to verify that the main characteristics of the proposed framework (sector choice and integration into the islands' landscapes and regimes) really hold. Afterwards, the framework will be applied to an in-depth case study of OTEC technology in Curaçao in chapters 4 and 5. This case study will provide an in-depth analysis of the island with focus on the current situation on the island, past projects and the real hurdles that the island imposes on a specific innovation system (OTEC). The lessons learnt from these cases will provide input for adjustments to the framework. In other words, the hypothesis that the framework can guide the development of an innovation system in SIDS will be tested. Discussion on the generalizability of the framework and its reliability is presented in section 6.2.

“The way to succeed is to double your failure rate...”

IBM founder Thomas J. Watson, Sr.

3

Cross-Case Study of TIS in Island States

This chapter analyses a total of five TIS in five island states. The goal of analysing these systems is to validate the main ideas that are embedded into the framework in figure 2.5, page 29. In other words, the goal is to identify how the existing island based TIS adjust to the island characteristics and if the proposed framework is accurate. The analyses consist of reviewing the general landscape and regimes of the states (islands) and then reviewing the key characteristics of the TIS. Section 3.6 summarizes the key insights of this chapter and their implications on the proposed framework.

Out of the five analysed cases, only Mauritius was found to host a recognizable TIS. And in fact, it also happens to be an island that is at the forefront of SIDS in terms of economic development ([United Nations Development Program, 2011b](#)). The analyses of TIS' in non-SIDS is still however highly beneficial, as their existence demonstrates existence of TIS on small sized islands is essentially possible. As their analyses show, certain limitations are however imposed by the islands. These limitations and the insights of how the TIS came to existence can be directly confronted with the proposed framework.

With the exception of ICT in Taiwan (island with a populations of 23 million) the TIS are located on small islands¹. They are geothermal energy in Iceland (a population of 300,000 inhabitants), textile industry in Mauritius (1.3 million), ICT industry in Malta (400,000), manufacturing sector in Cyprus (830,000). With the exception of textile industry in Mauritius, none of the analysed islands is a SIDS.

The cases for the analyses have been selected in order to represent a diverse mix of sectors. However, the choice was very limited. The selection was based on searching for small islands with: world-wide recognized industries, significant share of exports in the GDP; or significant share of industrial activities in the GDP (rather than the share of the financial or the tourism

¹The term 'small island' is used to address an island with a population of less than 1,5 million inhabitants as defined by [Commonwealth Secretariat \(2000\)](#) i.e. not necessarily indicating that the island is a SIDS.

sectors that are generally strong on islands).

An important factor to realize is that it is increasingly difficult to find credible literature with the decreasing level of the development of a particular sector in a given country or island – the less renowned the TIS, the less literature available. This makes not only the data collection more difficult but also leaves certain areas rather obscure. For example the beginnings of the Mauritius' textile or Malta's ICT industries are not sufficiently covered in the literature. Conclusions therefore need to be made based on general rather than detailed information. The lack of secondary data therefore supports the need for an in-depth case study that would allow a thorough understanding of the issues in SIDS with regards to innovation systems (chapters 4 and 5).

3.1 Geothermal Energy in Iceland

Perhaps the most prominent and well known example of a prosperous, diversified and technologically developed island is Iceland. *'In the course of the 20th century Iceland was transformed from one of Europe's poorest economies, with almost 2/3 of the labour force employed in agriculture, to a prosperous modern economy employing 2/3 of its labour force in services'*. Iceland places 14th in the world according to the Human Development Index (HDI)² of [United Nations Development Program \(2011b\)](#). The contribution of the various sectors to the GDP is distributed among services, financial sector, construction, fishery and other industries - mainly aluminium processing and energy ([Ragnarsson, 2003](#); [The Central Bank of Iceland, 2005](#)).

With a population of only 300,000 inhabitants Iceland is a member of the Energy Development in Island Nations (EDIN) organization that helps islands across the globe adopt energy measures and deploy RET. Being almost entirely dependent on fossil fuel imports, the oil crises in 1973 and 1979 caused Iceland to change its energy policy, reducing oil use and turning to domestic energy resources, hydropower and geothermal heat ([Iceland Geosurvey, 2012](#)). In 2008, practically all stationary energy and 82% of primary energy, was derived from indigenous renewable sources (62% geothermal, 20% hydropower). Nowhere else does geothermal energy play a greater role in providing a nation's energy supply. This not only has positive environmental but also economic benefits. It is estimated that Iceland saves about 91% of the total import of refined oil products that way (an equivalent of 11% of the total state expenditure) ([National Energy Authority of Iceland, 2010](#)). Iceland further utilizes the geothermal resource also for heating greenhouses, aquaculture, and other industries.

The research facilities and multidisciplinary research environment of National Energy Authority (NEA) have given the institution a status as one of the leading geothermal energy research institutions in the world ([Fridleifsson, 2003](#)). Its main responsibilities are to advise the Government of Iceland on energy issues and related topics, promote energy research and administrative development and exploitation of energy resources ([NEA, 2012](#)). Another institution, Iceland GeoSurvey is a leading research institute providing specialist services to the Icelandic power industry, the Icelandic government and foreign companies in the field of geothermal science and

²HDI is a composite statistic used to rank countries by level of 'human development', or often referred to as the 'standard of living' and/or 'quality of life'

utilisation. Iceland GeoSurvey is a self-financed, non-profit government institution that operates in the free market like a private company. It gets no direct funding from the government but operates on a project and contract basis (Iceland Geosurvey, 2012).

As stated by Taxell et al. (2009, p.20), 'Iceland clearly is too small of an economy to be internationally competitive in all areas of science, technology and innovation'. It therefore targets specific sectors that can be explored on a profitable level in local conditions. Geothermal resources are abundant in Iceland, but even within the geothermal energy sector, only certain parts of the value chain are exploited. It is mainly in exploration, drilling, engineering and construction that the Icelandic companies are among the most prominent in the world. R&D and component manufacturing are not the main domain of local firms (US Department of Energy, 2009). Their operational and engineering excellence allowed them to play the main role in the drill of the first well of the deep drilling project in Iceland into a superheated geothermal reservoir in northern Iceland (over 5km deep). The project is unique worldwide and is being watched by scientists from around the world (Iceland Geosurvey (2012)). Because of the considerable international scientific opportunities provided by this project, the US National Science Foundation and the International Continental Scientific Drilling Program will jointly fund it. The government provides a number of tax incentives and other investment benefits to support development of private companies.

The geothermal industry is deeply linked to the educational system. In 2009, the Minister of Science, Education and Culture ordered the establishment of a national task force to further embrace the future of Iceland's education, research and innovation policy. Clear targeting of specific sectors with growth potential was made, namely: geothermal sciences, life sciences and creative industries/ICT. Investments are therefore made mainly in areas where Iceland has clear strengths and opportunities. Other links between the industry and local (international) education include training programmes under the UN, special oriented research programs or graduate programs (Taxell et al., 2009, p.20-22). List of theses programs and their description can be found in appendix A.

3.2 Textile Industry in Mauritius

As a SIDS, a population of 1.3 million and being located over 2,000 km from the continent, Mauritius defies its predestined status of a poor African island. Mauritius exhibits one of the highest per capita incomes among African countries, its GDP per capita increased almost sevenfold in the past 30 years and its financial sector is positioning itself as a platform for investments linking East Africa with India and China (Chuhan-Pole and Angwafo, 2011, p.91-106). It places 77th in the world according to the HDI (i.e. surpassing vast majority of African countries) (United Nations Development Program, 2011b). Mauritius stands at the forefront of SIDS with its economic growth and as Greig et al. (2011) states it is '*considered a success story to be read for salutary purposes by other SIDS*'. Its political stability, low level of corruption and favourable regulatory environment have played a key role in its success. Its diversified economy enables the island to manage/suppress its disadvantageous characteristics. Unlike most other small islands its core industries are not only tourism (~7% of its GDP), financial sector (10%) and

real-estate (13%), but also manufacturing and particularly the textile industry (18%) ([Republic of Mauritius, 2012](#)).

A clear switch can be observed on the island's economy that used to be driven by the low skill and low margin sugar cane agriculture (contributing 22% to the GDP in 1976 and only ~1.2% in 2012) ([Pereira, 2005](#); [Republic of Mauritius, 2012](#)). Mauritius is one of the largest fully fashioned knitwear producers and the third largest exporter of pure new wool products ([AEPC, 2008](#)). Three main determinants of the sector's success (on the national level) have been identified by [Joomun \(2006\)](#).

- Conducive environment for investment (incentives and concessions to enterprises exporting their products);
- Exogenous factors (e.g. fall in Taiwan's textile industry competitiveness due to the appreciation of its currency);
- Preferential trade arrangements (favourable terms of trade with certain countries or regions)³.

These aspects helped create favourable conditions for directing foreign direct investment (FDI) onto the island. Both domestic and foreign investors then created a solid textile and clothing industry. The great push that the industry has been receiving from the preferential trade agreements slowly expired in recent years ([Greig et al., 2011](#)). With growing competition from low labour costs Asian countries, Mauritius' firms must have refocused on high quality products manufacturing - *'the only solution is to move up-market or to find a niche market'* ([Joomun, 2006](#), p.10). The several decades of experience in the industry and the specialized education in the field of the textiles make this transition possible ([Frankel, 2010](#)). The sector is served the entire range of companies from raw material processing to final product manufacturing ([Teal, 1999](#)). While [Greig et al. \(2011\)](#) emphasize that the industry should remain cautious and that it is fragile and dependent on global market trends, Mauritius still remains the *'African success story'* ([Frankel, 2010](#)). The key to the success of manufacturing proved to be in the right timing (favourable global developments), the right geographical position (for importing the raw materials) and the ability of the investors to gradually adjust to the market needs – utilize the experience with the industry and educated workers in transforming the industry from being focused on low to high margin products.

3.3 ICT industry in Malta

With 400,000 inhabitants Malta is an archipelago of three islands, a member state of the European Union (EU), its GDP per capita places the island above the average among the EU state and it is 36th in the world with its HDI ([United Nations Development Program, 2011b](#)). The island has limited freshwater supplies and no domestic energy sources. Malta is no longer the crucial harbor it was in the past ([European Union, 2011](#)). Similarly to small islands in general, tourism has a major share in the state's GDP (35%) and so has the financial sector (20%). For a

³Mauritius particularly benefits from its preferential trade agreements with France and Britain (as their former colony) and the USA ([Joomun, 2006](#))

small island Malta however also has a strong manufacturing sector (18%) with particular focus on pharmaceutical products. *'In 2006 it had the fifth most open economy in the EU, and its average trade-to-GDP⁴ ratio hovered around 81% in recent years'* (Central Bank of Malta, 2007). The government has also introduced stimuli programs for ICT related opportunities in the past 10 years that led to the growth of the sector (currently ~6%). This diversification allowed Malta remain relatively intact during the economic crisis in 2008-2009.

Global Information Technology Report 2007 - 2008 ranks Malta third (after Singapore and Tunisia) in terms of government success in promoting ICT technologies. Between 2001 and 2004, the government introduced the 'e-Malta' project that aimed to make it a 'Smart Island' (IDABC, 2008). This has attracted ICT companies from around the world including Microsoft, Hewlett-Packard or Cisco. Due to its dedicated eGaming legislation it is now also the home of 10% of iGaming companies in the world (World Bank, 2009, p.111). In 2007, a private 'Dubai funded' US\$300 million 'SmartCity' project was initiated consisting of office and residential space focused on attracting ICT and media companies (SmartCity, 2012) being the largest foreign direct investment (FDI) in the history of Malta and committed to creating 5,600 jobs by 2016. This development has been made possible mainly by *'leveraging language skills, providing state-of-the-art infrastructure and strong legal systems'* (World Bank, 2009, p.111). With its programmes the government opened opportunities for international companies to enter the market but it was its human capital that allowed the local economy and population to monetize on them. Locals are multi-lingual and the universities have strong technology related programmes with specific grants for ICT students (Knights, 2008). With these qualities, Malta is able to capture the high end of the value chain and compete on quality on the international field (and against its small size).

3.4 Manufacturing Industry in Cyprus

With 830,000 inhabitants, Cyprus is a member state of the EU and places 31st in the world with its HDI (United Nations Development Program, 2011b). Cyprus is not on the UN's list of SIDS, it does however naturally share some of their characteristics. The economy of Cyprus is driven mainly by the services sector which contributes by 78% to the GDP (of which about 2/3 is being represented by the tourism and financial sectors), general industry contributes by 18% (manufacturing 6.5%) (European Commission, 2011). While it does not host any well recognized TIS, due to the efforts of Dickson and Hadjimanolis (1998); Hadjimanolis (1999, 2000); Hadjimanolis and Dickson (2001), Cyprus is one of the few small islands that have been in depth analysed with regards to innovation. It represents a valuable example in demonstrating what challenges small islands face in the development of TIS. Based on the several studies of these authors, the following barriers to innovation in Cyprus were identified (particularly in the manufacturing sector):

- The failure of the government to promote persuasively its proper role as a facilitator rather than as 'life saver' or provider;

⁴The trade-to-GDP ratio is the average of the ratios of imports and exports of goods and services to GDP

- Lack of specific incentives for cooperation or establishment of sectoral ‘resource centres’ and lack of strategies promoting ‘proactive’ innovation;
- Problems of local new product development financing, local construction of machinery, the shortage of specialized technical labour, and weaknesses in the supply of technical services;
- Weak linkages among the elements of infrastructure, e.g. university and manufacturing industry;
- Relative lack of variety in technology transfer modes and over-dependence on suppliers for technological knowledge.

Despite its current economic issues, Cyprus has managed in the past 3 years to increase its exports from the sector by almost 15% annually. This has been achieved by transforming the sector into being focus on specialized rather than low-margin products. This is particularly visible in the chemicals and instruments sectors (Cyprus Profile, 2012). The market is dominated by ‘small SMEs’ (Radas and Božić, 2009) that would in continental Europe be considered as micro firms (in 2001, firms below 10 employees formed 88% of all manufacturing firms (Hadjimanolis and Dickson, 2001)). As Cyprus Profile (2012) state, ‘Cyprus’ manufacturing sector is currently undergoing a facelift which will enable it to compete on the international stage’. The focus has been on making high-value advanced manufacturing products. While Efstathiades et al. (1998, 2000) identified Cyprus as being rich in human capital (i.e. educated on a general level), the island is being criticized for its lack of specialized experts and that the transfer towards the high end of the value chain has been too slow. Cyprus therefore remains to be an economy mainly supported by the tourism and financial sectors. While currently requesting a bail-out from the EU (The Economist, 2012b), Cyprus struggles to find a sector that will keep its economy running.

3.5 ICT industry in Taiwan

While Taiwan is not recognized by the UN as a sovereign country, it would place on the 18th place according to the HDI (Yen-Ju et al., 2011). Although with limited land and resources and a dense population, the country has developed to be a model in the eyes of international economists after World War II (Hsiung-Shen and Weng, 2010). One of the most significant factors contributing to this development is assigned to the changes in education – extended compulsory education in 1960’s and rapid expansion of high schools and universities (Liang, 2012). The early developments are also associated with Taiwan’s close dependence on trade with several large states – specifically China, Japan and the USA.

Taiwan’s semiconductor industry generates over €20 billion, ranking fourth in the world, behind only the US, Japan, and Korea. Liao and Hu (2007) characterize the industry as specialized and vertically collaborative where both upstream and downstream players are each dedicated to specialized technologies in their own domain. Tung (2001) indicates that the success of the Taiwanese semiconductor industry was triggered by the market entrances of General Instruments, Philips and several other firms that built there semiconductor production plants in 1960’s. The

following decade, the government supported these industries and started promoting its own technological developments. In the 1980's the government owned R&D facilities were diffused to the private sector (Chen and Sewell, 1996). Quickly after that, local companies found their niche and began to focus on integrated circuits fabrication. Further, the Science-based Industrial Park in Hsinchu (HSIP) was established in 1980, close to two leading engineering universities. Inspired by the success of California's Silicon Valley, the HSIP was expected to foster indigenous technological activities and to attract high-tech manpower, especially the overseas Taiwanese who had studied or worked abroad. The governmental efforts can be summarized in the following points (Tung, 2001; Chen and Sewell, 1996; Liu, 1993)

- Tax incentives (holidays) and other support of investors;
- Human capital investments (investment in education);
- Reversing brain drain by attracting overseas Taiwanese;
- Providing incentives at the industry level, not the firm level.

Tung (2001, p.280, 285) further concludes that government ownership of the companies without any actual management influence management allowed for better capable of handling a new and changing technology. Additionally, it was the proper public policies the helped absorb the initial risks and lower the entry barriers.

3.6 Summary

Innovation Systems in Small Islands

The review of the island based TIS showed two important characteristics related to:

- The role of the government;
- The positioning of the TIS within the value chain.

While the analyses focused on TIS it was evident that the **governments** of the respective islands (and their relevant policies) have had important enabling influence on their development – be it with their FDI incentives, export and import duty exemptions, preferential trade agreements (mainly with the islands' former colonialist countries) or other sectoral benefits. While it might come natural that the government's support is required, it should be emphasized that is only the supported sectors that thrive. With the exception of Iceland, where the targeted sector was determined based on the abundance and accessibility of a natural resource, no clear pattern was identified in how the other islands arrived at their favoured sectors. The sectors slowly developed and the government support came along the way at various 'strengths' – e.g. in the case of Malta the push of the ICT sector is very significant while in Mauritius the government only started supporting the textile industry when the transformation from the low to the high margin part of the value chain was needed. Overall the size and the remoteness restrictions of the islands require some 'enablers' on the national level to support the innovations systems.

All of the island TIS compete internationally using a (potentially) sustainable competitive advantage – access to natural resource or strategic location in combination with strong human capital. The need for diversification and overcoming their vulnerabilities compels island based TIS to target high-value added products and services. As a result, one of the greatest differences between the island and non-island based TIS appears to be in their positioning within the **value chain**. On islands, production is only performed on specialized or small scale bases and low margin activities are not present. Production that has been performed on the islands (mainly) due to low labour costs in the past (e.g. textile in Mauritius or currently manufacturing in Cyprus) is now becoming uncompetitive due to the rise of more cost oriented producers in Asia.

Common Characteristics of the Innovation Systems

Overall, table 3.1 summarizes the key points deducted from all the explored TIS. The characteristics in bold are the ones that are shared among all the reviewed cases. The starting points (and the underlying ‘Aim’) of the systems were of various origins - brain drain, high dependence on oil, lack of **economic independence** and naturally also the efforts of **entrepreneurs**. The benefits (‘Results’) that these islands and sectors reap are manifold - prestige, educational quality, research excellence, **economic competitiveness** and **leading firms**. The ‘Means’ that enabled their existence were of a broad socio-technical nature and contained support from the government, financial institutions as well as the market itself. They all have however benefited from a very strong link to **education**, **strategic location**, support from the **government**.

Implications for the Proposed Framework

It can be concluded that the preliminary framework does indeed capture the main aspects that influence TIS. It however appears that the integration of the systems into the islands’ landscapes and regimes is even more significant than anticipated. There is a very clear link between the TIS and the islands’ ‘favourable’ policies. This supports the notion that only with the islands’ support can the systems exist. As a result not only can the firms operate but also do the islands become more resilient towards their vulnerabilities. Regarding the target sectors, the first two outlined factors (high-margin sectors, utilizing strategic location and resources) hold for all the cases. Utilization of specific natural resources is naturally only applicable to certain technologies. Overall, the framework appears to capture all relevant characteristics. The in-depth analysis of OTEC in Curaçao will however provide much clearer understanding of the important factors that influence the development of TIS in SIDS.

Table 3.1: Characteristics of TIS based in islands states (characteristics in bold are shared among all the studied systems).

	Characteristic
Aim	Increase economic competitiveness & independence Private companies' operations Reduce dependence on oil imports Reverse brain drain & Attract high-tech manpower Promote RET
Means	Governmental investment incentives and other sectoral benefits Linking education and the target sectors Focusing on the higher end of the supply chain Strategic location Availability of specific natural resources Utilizing colonial heritage and/or preferential trade agreements Entrance of large firm(s) Provide competitive funding Streamlining permit issuance
Result	Island's economic 'independence' Companies leading in particular parts of the supply chain/technology Showcase projects attracting worldwide attention Hub for international companies in high-tech development Internationally recognized educational programs & courses World leading research institution(s) Environmental benefits

“Prior to 10/10/10, Curaçao had no policy, no goals, no visions, very old legislation and no regulations in the energy market...”

G.Schotte, 2012

4

OTEC in Curaçao Case Study

Based on the framework developed and exhibited in figure 2.5 on page 29 this chapter presents an in-depth case study on which the introduced concepts will be applied and from which lessons will be drawn in order to validate and verify the framework. As presented already in chapter 3, there is a general lack of credible data related specifically to SIDS and innovation systems. The depth and the breadth of the primary and secondary data collected for the purposes of this case provide a unique insight into the hurdles, challenges and opportunities of this SIDS.

Ocean Thermal Energy Conversion or OTEC is an upcoming renewable energy solution for harvesting the ocean's energy. The technology is particularly suitable for tropical island states. A SIDS of Curaçao located in the 'Dutch Caribbean' has been identified by two private companies as a potentially suitable location for the establishment of OTEC related activities. Their ultimate goal is to develop there the OTEC *Centre of Excellence*. It is specifically the OTEC technology in Curaçao that is of focus in the data collection. However in accordance with the proposed framework, the case study also covers broad socio-economic situation of the island and describes the socio-technical landscape and regimes. It draws upon the experience from past technology (science) related projects on the island and uses the insights of government officials and other professionals with experience from a variety of fields as well as other islands (see section 1.6 for more details on the data sources).

The case study is introduced in section 4.1 where the stakeholders, their visions and the technology overview are given. Sections 4.2 - 4.4 present the analysis of Curaçao relevant to the establishment of OTEC activities on the island. The analysis is based on the proposed framework and therefore features analyses of three 'levels' – the socio-technical landscape, the regime and the OTEC TIS which is in detail scrutinized using the FIS framework. This is followed by chapter 5 that gives the recommendations, the limitations and the roadmap for turning Curaçao into the OTEC Centre of Excellence.

4.1 Case Study Background

By occupying nearly three-quarters of the Earth's surface, the oceans are the world's largest solar energy collector and storage system (Bregman et al., 1995). Yet, the existing technologies are not capable of fully utilizing this energy (Turner, 1999). OTE technologies encompass all possible uses of the potential energy captured from the sun and stored by the world's oceans. This section provides the description of OTE technologies, presents the stakeholders and the vision of OTEC activities on the island of Curaçao.

4.1.1 Technology Background

As War (2011) states, the thermal energy can be extracted from the oceans for the purposes of:

- Electricity generation using the OTEC technology. OTEC is a RET that is currently in the pilot stage of the development and is not used anywhere in the world on commercial bases.
- Air-conditioning (A/C) or cooling using the SWAC technology. SWAC is a technically and commercially feasible technology used in number of places around the world.

Both technologies utilize Deep Sea Water (DSW) that is pumped from the depth of 800-1000m at a temperature of about 5-8°C (Avery and Wu, 1994). The suitability of using OTE technologies is location specific. The key factors determining the economic and technological feasibility include local climate, energy prices, steepness of the seabed profile and seawater temperatures (Lennard, 1995).

Working principle of OTEC is described in section 4.1.5. Working principle of SWAC is briefly introduced as well in section 4.1.6.

4.1.2 Key Case Study Stakeholders

Bluerise B.V. is a technology provider in the Ocean Thermal Energy (OTE) market and is located in Delft, the Netherlands. The aim of their ongoing R&D should lead to the deployment of a medium-scale sized OTEC power plant in the near future. Bluerise also provides consulting and engineering services to project developers, energy companies and utilities. Bluerise has recently opened its miniature OTEC demonstration plant at the Delft University of Technology (Bluerise BV, 2012a).

Curaçao Airport Holding N.V. (CAH) is responsible for overseeing the Curaçao airport operator and its adherence to the standards and agreements set forth in the agreement signed with the government of Curaçao. CAH's vision is to turn the airport into a 'hub' connecting Latin America to other continents (CAH, 2012).

In 2010, CAH started developing a project with the aim to build a SWAC system for the airport's and surrounding facilities. In late 2011, CAH has ordered a seabed survey that evaluated the technical suitability of laying out a DSW pipe in the vicinity of the airport. The survey had

positive results and labelled the Curaçao Airport as a suitable location for construction of a SWAC system. Ecopower International is in charge of the project development (Kloppenburger, 2012).

Also in 2011, Bluerise, CAH and a group of four master's students from the Delft University of Technology were engaged in the **Curaçao Ecopark**¹ project that conceptualized an eco-friendly industrial park on the island. The Ecopark would 'host' tenants (technologies) who would utilize the DSW that will be used by CAH SWAC system (OTEC is one of these technologies) (Bluerise BV, 2012b). Additionally, CAH is explicitly stating that its intentions are not only to provide the DSW but also land and infrastructure that would enable information exchange among different technologies. By doing so, CAH hopes that the success of the Ecopark companies would drive their own business and support the island's economy in general (Kloppenburger, 2012).

4.1.3 Project Vision – 'Centre of Excellence'

The interests of the project initiators lie in investigating the opportunities for the development of OTEC technology in Curaçao that goes beyond the establishment of one facility. As stated by Bluerise, the OTEC developments should be supported by an environment that has the following characteristics:

An environment in which most, if not all, OTEC related resources are available (directly or indirectly) and on a state-of-the-art level. This includes educational, R&D, construction and maintenance, as well as legal and financial expertise.

In alignment with the definition presented in section 1.2, this environment should be a fully functioning OTEC **innovation system** embedded within the economy and society of Curaçao. This innovation system should enable and support OTEC developments on a **state-of-the-art level**. The project initiators refer to this innovation system as the **Centre of Excellence (CoE)**.

In this thesis, the term CoE will be used in the context of OTEC and Curaçao. In the academically focused chapters, the more general term innovation system will be used.

The OTEC CoE should enable the creation and the existence of relevant expertise, education as well as facilities in the four areas described below:

Research and Development (R&D) by the means of performing testing, optimization and actual research of the different OTEC enabling technologies and processes, potentially in cooperation with other organizations.

Education by the means of providing facilities and opportunities for educational activities such as training, coaching, or tutoring in the field of OTEC in cooperation with other organizations (universities, research centres).

Operation by the means of providing electrical energy on commercial bases and maintenance services to OTEC facilities. Further, the available expertise should enable design, (partial) production, (partial) assembly and (partial) maintenance of new OTEC facilities.

¹The author of this thesis was one of the students participating in the Curaçao Ecopark project.

Advisory by the means of providing relevant expertise on legal, technical and financial issues of OTEC development.

Figure 4.1 outlines how the envisioned OTEC CoE should be embedded within the island of Curaçao.

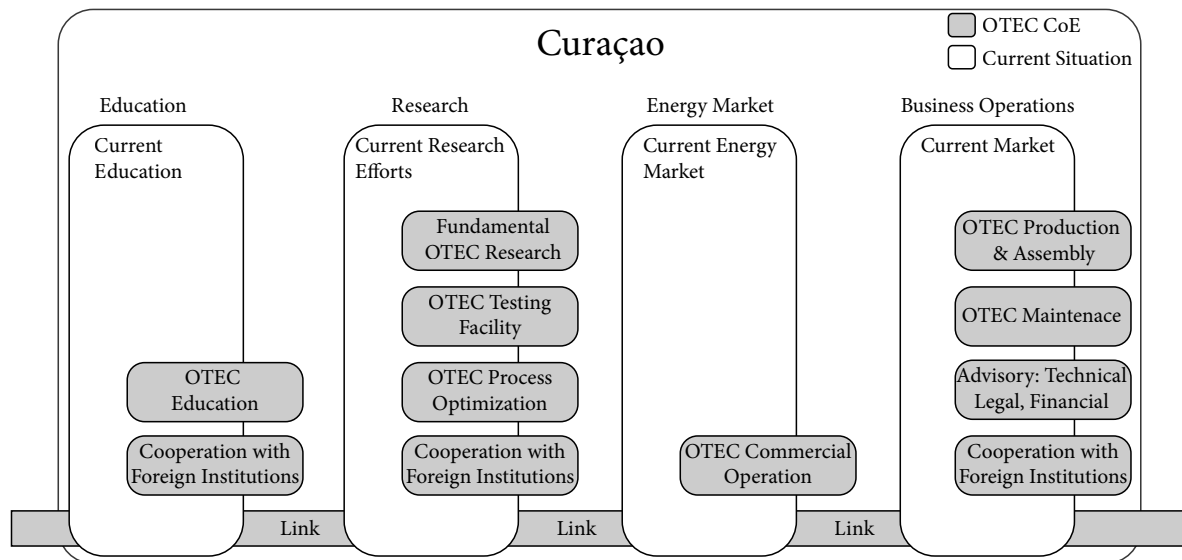


Figure 4.1: Diagram showing how the OTEC CoE should be embedded within the island of Curaçao.

The future roles of the project initiators can be of various forms and are not defined in this thesis. The focus of this thesis is on investigating the opportunities for OTEC development in Curaçao regardless the ownership rights of any of the actors that are being discussed.

4.1.4 Other Stakeholders Related to the Case Study

Figure 4.2 presents a comprehensible overview of key the stakeholders on the island within the energy and the academic sectors and the currently existing relationships among them. Relationships and interactions among the initiators of the case study have been introduced already in section 4.1. The following paragraph summarizes the key relevant currently existing interactions. The rest is discussed throughout the sections 4.2 - 4.4.

Bureau for Telecommunications and Post (BT&P) is the energy policy maker and regulator on the island, overlooking both the the only electricity distributor on the island (Aqualectra Distribution). The electricity producers that supply to the network include the incumbent (Aqualectra Production), NUCapital (wind-park operator) as well as small scale in-feeding energy producers (Niche Technologies). As an autonomous country, Curaçao has its own Government with appropriate ministries in charge. The Government is the main shareholder in the largest companies on the island (the ISLA refinery, Curoil, Harbour, Airport) and naturally imposes laws and regulations on the rest of the industries (including both Small and Medium Enterprises (SMEs) and Large Industries). University of the Netherlands Antilles (UNA) is one of the four university institutions on the island, but the only one providing engineering education. As further

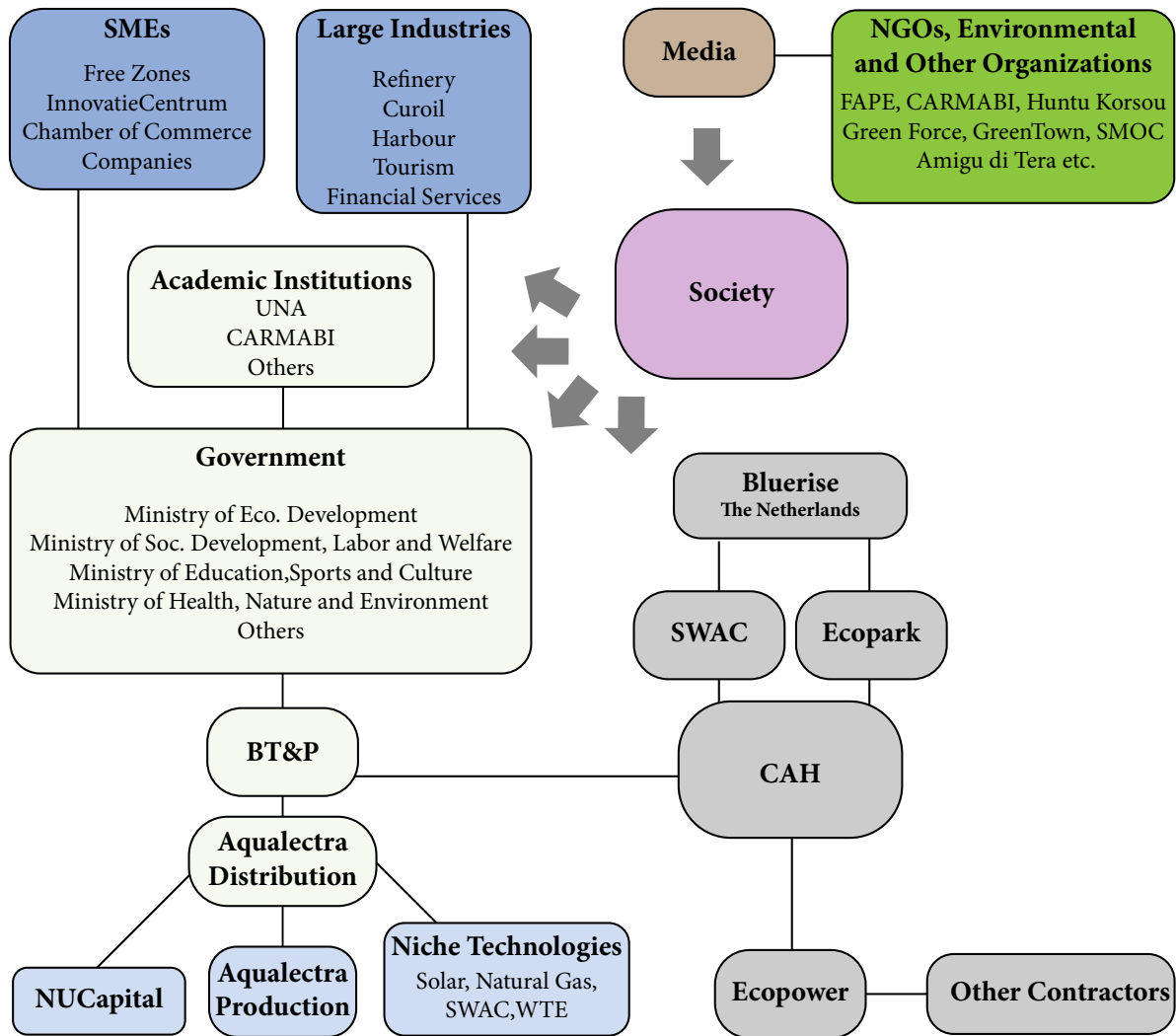


Figure 4.2: Stakeholder overview (including relevant technologies) and the currently existing interactions among them.

explained in later sections, Environmental Organizations and Non-Governmental Organizations (NGOs) use their competencies almost unanimously to communicate only via Media and the media subsequently influence the public opinion (Society).

4.1.5 OTEC Working Principle

As [Magesh \(2010\)](#); [NOS \(2010a\)](#) state, OTEC utilizes the temperature difference between the warm surface water (26-28°C) and cold deep sea water (4-6°C), see figure 4.4(a) for a schematic diagram that shows how the sea water temperatures change with the depth ([Bergman, 2011](#)). Countries in the tropics that not only have warm surface water, but also steep profile of the sea bottom (such as Hawaii, Japan or Curaçao) can utilize this temperature difference for the purposes of electricity generation ([Bregman et al., 1995](#); [Uehara, 2004](#)). The greater the temperature difference between the DSW and surface water, the higher the efficiencies of the system, lower operational costs and thus greater suitability for using OTEC.

OTEC makes use of warm surface seawater and cold seawater to vaporize and condense a working fluid, such as anhydrous ammonia, which drives a turbine-generator in a closed loop producing electricity. This system is referred to as Closed-Cycle (CC-OTEC) (see Figure 4.3(b)) ([Magesh, 2010](#); [Uehara, 2004](#)). There is also a less researched and more technologically demanding Open-Cycle (OC-OTEC) that has no working fluid. Instead, the warm seawater directly drives the turbine ([NOS, 2010b](#); [Dodoros et al., 2009](#)).

In essence, OTEC facilities can either be on-shore or off-shore (floating) as figure 4.3(a) shows. Research of onshore facilities is currently under a more intensive development and consists of a facility located on the shore and a DSW pipe going down the seabed to a depth of about 800-1000m ([Kleute, 2010](#)).

Table 4.1 summarizes the warm and seawater requirements for 10 kW and 10 MW OTEC plants - they grow approximately linearly (at about 3 liters per second (l/s) for 1kW of net energy produced). The diameter of the DSW pipe is in the order of 3-10 metres for 10-100 MW OTEC plants ([Blokke et al., 2012](#)) - figure 4.4(b) demonstrates the scale of components used for OTEC.

Table 4.1: OTEC water in/outflow requirements for 10 kW and 10 MW plants ([Blokke et al., 2012](#)).

	Cold water		Warm water	
	Temperature (°C)	Flow (l/s)	Temperature (°C)	Flow (l/s)
Water in - 10 kW Plant	5	30	28	30
Water out - 10 kW Plant	8	30	25	30
Water in - 10MW plant	5	30,000	28	30,000
Water out - 10MW plant	8	30,000	25	30,000

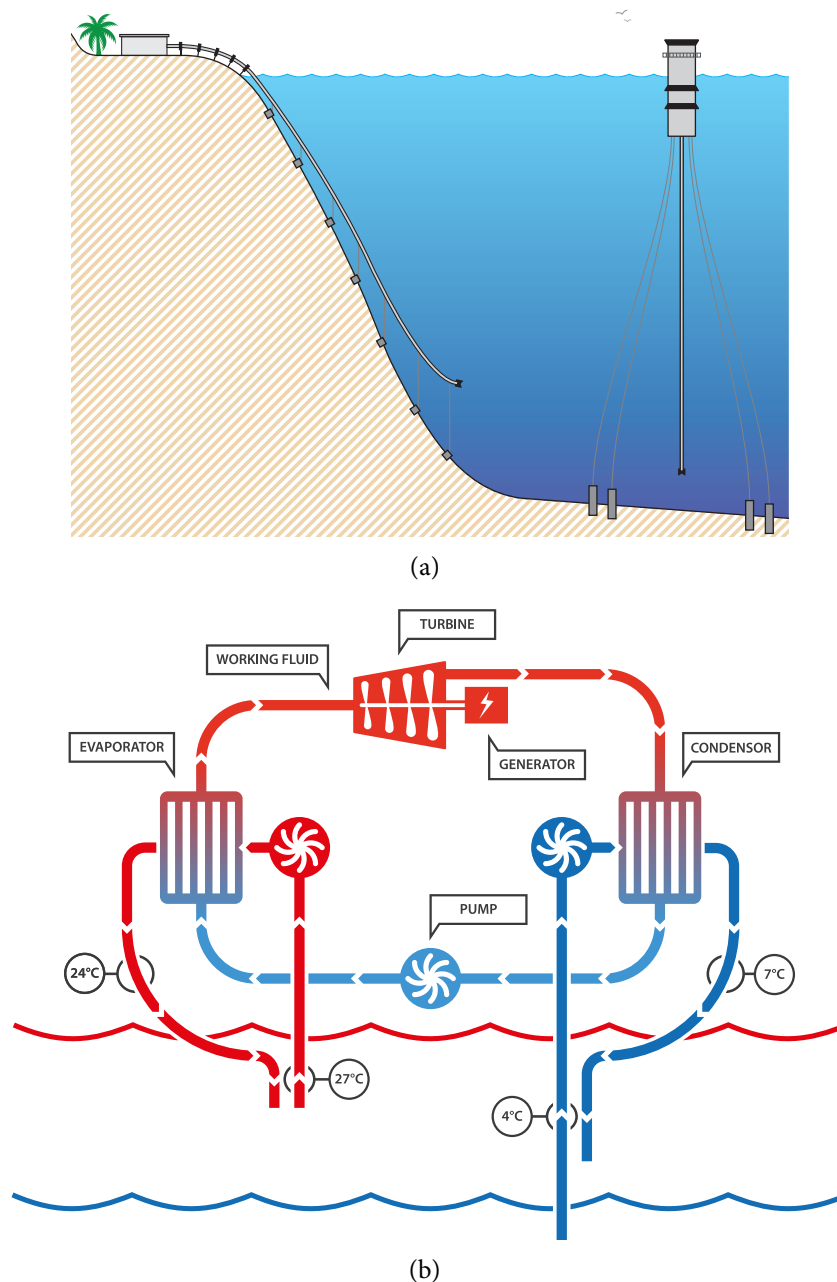


Figure 4.3: (a) OTEC systems: on- and off-shore facilities. Small off-shore OTEC plants are planned to be built using the so called SPAR design (on the picture), large OTEC plants would resemble oil platforms (Blokker et al., 2012); (b) Closed-Cycle OTEC system (Kleute, 2010).

4.1.6 SWAC Working Principle

SWAC is an alternate-energy system that uses DSW to cool buildings. SWAC's operational energy costs are around 10% of the costs of running conventional A/C systems (see figure 4.5(a) for comparison) (Elsafy and Saeid, 2009; Bellinger, 2009). As a result, SWAC is a particularly attractive technology for island nations that suffer from high electricity prices and the constant need for air-conditioning or cooling. However the installation costs and the associated risks for

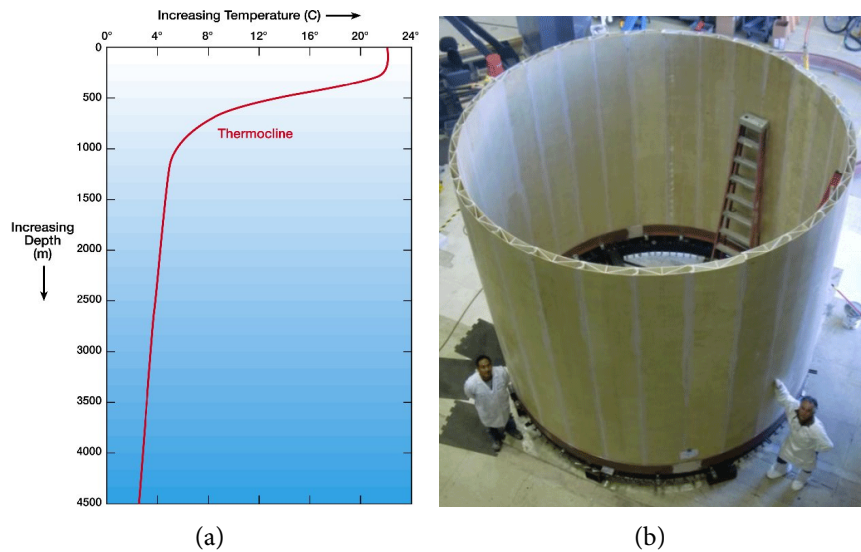


Figure 4.4: (a) Temperature gradient of the ocean (Bergman, 2011); (b) 4 meter diameter composite DSW pipe (Meyer et al., 2011).

the cold water pipe are high. This implies that one of the greatest challenges for SWAC is securing the future demand and commitments of users in order to guarantee returns on investments (Rosheuvel, 2012).

Figure 4.5(b) shows the working principle of SWAC. DSW is pumped to a ‘cooling station’ consisting of a large heat exchanger. In this heat exchanger, the DSW cools down the chilled water that runs through buildings in a closed loop cycle. The chilled water then cools down the buildings. Lake Source Cooling (LSC) or Deep Lake Water Cooling (DWLC) is the alternative of SWAC used in locations where cold water is available from lakes or rivers (the working principle remains the same) (War, 2011). Such lake source (district) cooling system is for example used in the Amsterdam Zuidas area (NUON, 2006).

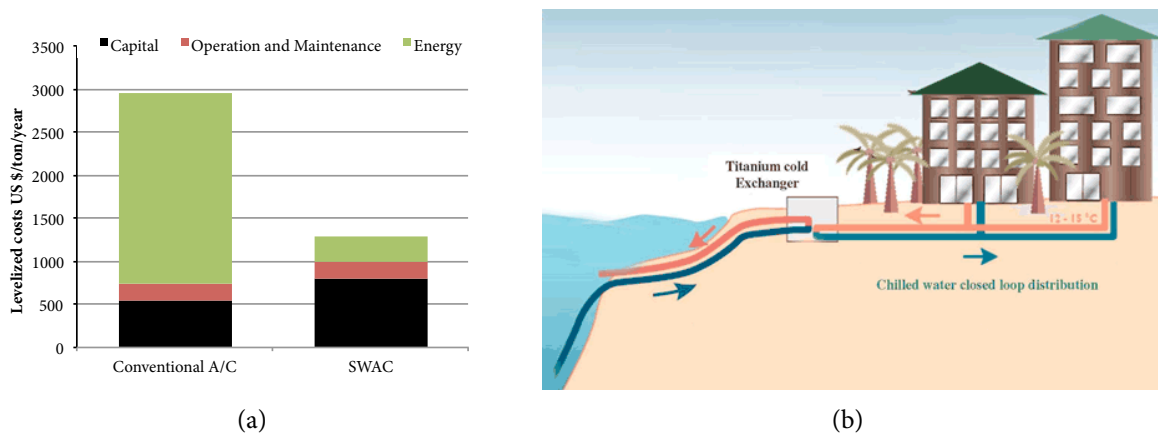


Figure 4.5: (a) Comparison of operating SWAC vs conventional A/C system over the span of their life time (Bellinger, 2009); (b) SWAC principle (Tetiara, 2011).

4.1.7 OTEC Benefits

According to [Magesh \(2010\)](#); [Holt \(2007\)](#); [Vega \(2010\)](#), the key benefits of OTEC are :

- Providing baseload electricity²;
- Independence on weather conditions;
- Independence on raw material (fossil fuel) prices;
- Negligible land requirements;
- Negligible ‘horizon pollution’;
- Projected low price per kWh of electricity³.

There have been several experimental OTEC plants built around the world (India, Japan, Taiwan and Hawaii), none of them are however operating on commercial bases. The facility that gained most substantial results in OTEC development is the Natural Energy Laboratory of Hawaii Authority (NELHA) in Hawaii. There are projects running in Japan, Hawaii, Barbados and the USA planning to build 1, 5, 10 and 13 MW OTEC plants respectively ([Magesh, 2010](#); [OTEC International LLC, 2012](#); [The Economist, 2012a](#)). All these projects are however currently in the planning stage.

4.1.8 OTEC Costs

Performance of both SWAC and OTEC systems are site specific as the DSW temperatures have significant impact on the efficiencies. The economic feasibility of OTEC is being questioned primarily due to the greatest drawback of the technology - high Capital Costs (CC) of establishing the facilities with the yet to be proven qualities ([Vega, 2010](#)). This is mainly due to the price of the Deep Sea Water (DSW) pipe. Some argue that the risks associated with OTEC are not at the moment offset by the potential benefits. Uncertainties regarding all costs, fabrication, transportation, infrastructure support as well long term commitment required from the involved stakeholders are yet to be overcome ([Forbes, 2012](#)). Figure 4.6(a) shows the estimated prices of OTEC generated electricity.

Figure 4.6(b) shows the proportions of electricity costs that are determined by CC and that are determined by operational costs - with the increased scale, OTEC basically only incurs fixed costs.

Economies of scale play significant role in OTEC. As stated by [Vega \(2007\)](#), the staffing requirement and the costs of the power-block are approximately the same for both a 10MW and a 100MW plant. The only difference lies in the fabrication and deployment of the seawater sub-system. As table 4.2 shows, estimated operational, maintenance and repair costs do not grow

²Baseload electricity supply is produced at a constant rate throughout the year or day except in the cases of repairs or scheduled maintenance, which guarantees stability of electricity supply. Baseload electricity is not supplied by some of the intermittent RET currently widely adopted (wind or most solar energy technologies).

³The projected price per kWh for a 100MW OTEC plant using currently available technologies is \$0.1-\$0.2 ([Siahaya and Salam, 2010](#); [Straatman, 2006](#); [Srinivasan N., 2010](#))

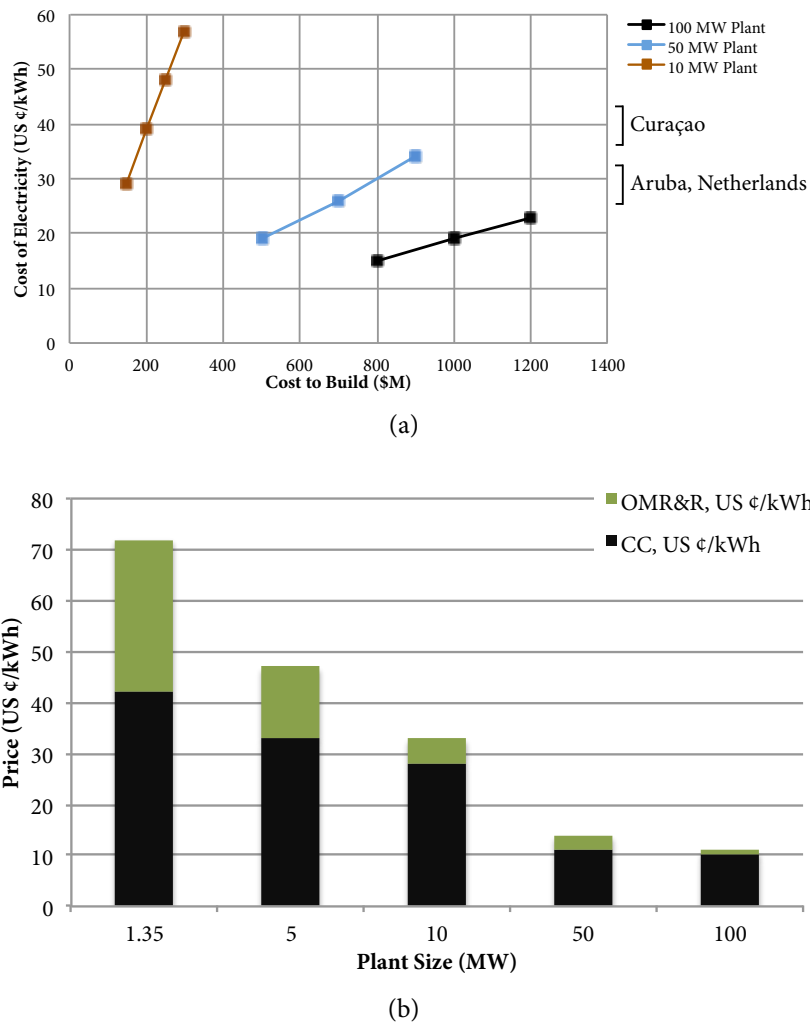


Figure 4.6: (a) OTEC - Cost of Electricity vs Cost to Build. The ordinate is the cost of electricity assuming Return on Investment (ROI) of 11% after 20 years. Horizontal axis shows various scenarios of overall CC. Electricity prices in Curaçao, Aruba and the Netherlands are added for comparison (Cooper et al., 2009); (b) Proportions of Capital Costs (CC) and Operations, Maintenance, Repair and Replacement (OMR&R). Inflation: 3%, Loan: 8% over 15 years. Based on (Vega, 2007)

linearly with the plant size but are significantly higher for small scale plants (when calculated per MW of energy produced).

4.1.9 OTEC Challenges

Besides the the economic challenges introduced above, OTEC also faces technology related challenges. The main one is related to the efficiencies of cycles (Magesh, 2010). The maximum possible Carnot thermal efficiency of an Ocean Thermal Energy Conversion (OTEC) power system is about 7%. This is due to the fact that it exploits the water temperature difference of only about 20°C. The overall efficiency of a multi-megawatt-sized OTEC electrical power

Table 4.2: Operational, repair and maintenance costs of OTEC plants (Vega, 2007).

Size (MW)	Labour (US\$mil)	Repairs (US\$ mil)	Replacement ^a (US\$ mil)
1.3	2.0	1.0	0.7
5	2.0	3.5	2.3
10	2.0	4.8	3.4
50	3.4	8.0	5.4
100	3.4	16.9	11.3

^a Equivalent to 30-year replacement.

plant, all inclusive from seawater to net electric power (i.e. including the ‘losses’ for pumping the DSW to the surface), is around 2% (Hurtt et al., 2010). As a result, the greatest technical challenges of OTEC lie in increasing the working efficiencies, especially of the heat exchangers. The challenge is in scaling them to the size required for large scale OTEC operation and finding the right materials of the heat exchangers that are not corrosive (possibly aluminium, titanium or plastic) (Blokke et al., 2012).

4.1.10 OTEC Market Players

There are several other organizations and companies working on OTEC development with majority of them located in the USA and Japan. Further, there are several manufacturers of OTEC components (pipes, heat exchangers) in China and Europe:

- Research institutes and organizations - most active ones are NELHA, USA and Institute of Ocean Energy at Saga University, Japan;
- Two (mainly) military and naval defence companies - Lockheed Martin, USA and Direction des Constructions Navales Services (DCNS), France;
- Makai Engineering, USA diversifying ocean engineering company having OTEC components among its products;
- Companies focused mainly on OTEC - Xenosys, Japan; Sea Solar Power, USA and OTE Corporation, USA.

4.2 Socio-Technical Landscape of Curaçao

This section of socio-technical landscape aims to provide a comprehensive overview about the island. It is divided into five areas: general overview, political, societal & educational and economic aspects. This overview is aimed at providing solid understanding of the essential characteristics of the island. However within those five areas, specific emphasis is put on addressing topics related to the development of RET - business relations, energy market, sustainability and technical expertise. Analyses of the regimes and niches in sections 4.3 and 4.4 built-up on the understanding of the socio-technical landscape and analyse Curaçao in greater detail.

4.2.1 General Overview

Since October 10th 2010 ('10/10/10'), Curaçao has been constituent country within the Kingdom of the Netherlands. As a result, Curaçao is an independent country but the Dutch government remains responsible for its defence and foreign policy, and is partially overseeing Curaçao's finances under a debt relief agreement. Further, there are five consensus-statutory laws that limit certain activities (e.g. there is a set limit on the borrowed money as a percentage of GDP etc.) ([Dutch Caribbean Legal Portal, 2010](#)). As stated by [Jansen \(2012\)](#), the greatest difference between the former and current legal status of Curaçao is that there is only one governmental layer – *'It eliminates a large number of political fights and speeds up approval and execution of projects'*.

The country is located 70km off the coast of Venezuela in the south part of the Caribbean region, has a population of almost 150,000 inhabitants and is the largest of the three so called ABC islands (Aruba, Bonaire, Curaçao). Curaçao benefits from its strategic position between Americas, has well-developed harbour and international airport (see figure 4.7 for its exact location). It is located outside of the hurricane belt, and has access to several sub-marine fiber-optic cables which is highly relevant to the Information and Communication Technologies (ICT). It has several 'free zones' and a multicultural and multi-lingual population. Papiamentu and Dutch are the official languages, but English and Spanish are widely spoken. Its jurisdiction is in clear compliance with the standards of the Organisation for Economic Cooperation and Development (OECD) ([Curaçao Bureau of Statistics, 2012](#); [Curaçao Ministry of Economic Development, 2010](#); [Koomey et al., 2009](#)).

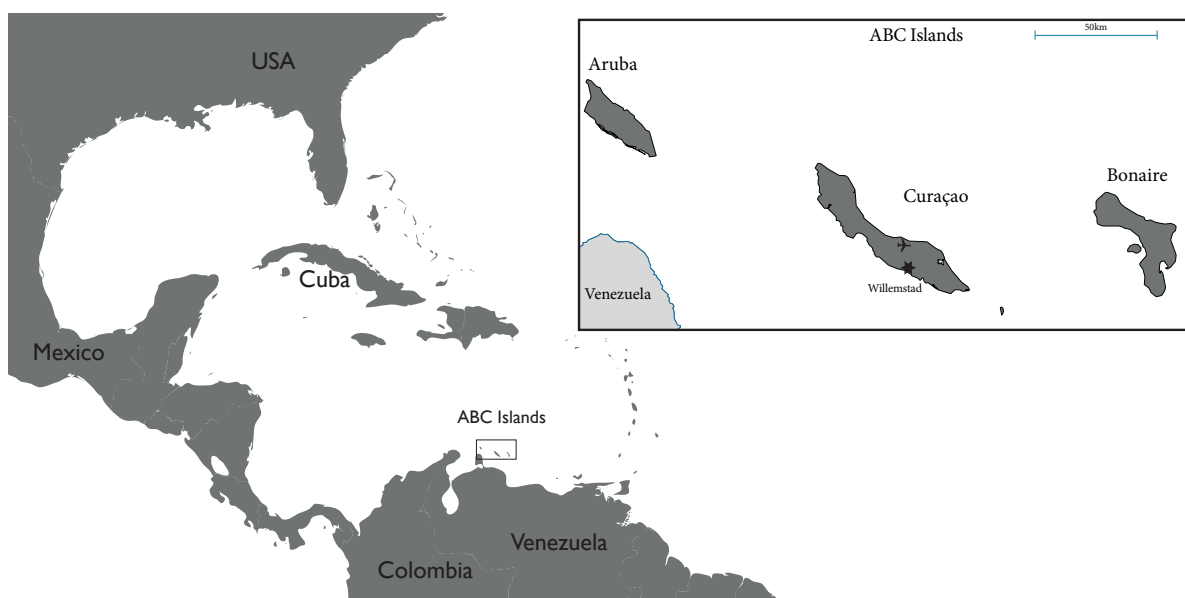


Figure 4.7: Caribbean Region and Curaçao

Curaçao's currency is Netherlands Antillean Guilder (ANG)⁴, that is pegged to US dollar at a rate of US\$1 = ANG1.79.

⁴Abbreviation NAF is also used to denote ANG.

4.2.2 Political and Legislation Developments

Curaçao's government led by the prime minister Gerrit Schotte claims that the island exhibits the maturity and the benefits of centuries of the Dutch administration and that its legal system modelled on that of the Netherlands. Its current efforts are focused on strengthening the connection between the education on the island and its core industries (specifically ICT), improving Curaçao's energy situation (section 4.3.1), reducing administrative hurdles of applying for permits (see below) and further opening the island to foreign companies (Schotte, 2011; El Hakim, 2012).

As stated by Jansen (2012); Nicastia (2012), *'perhaps the most important unique selling point of the island is the Dutch judicial system under which Curaçao operates'*. It allows companies to appeal to the Netherlands Supreme Court in the Hague guaranteeing transparency and objectivity that can often be questioned in developing countries. This eliminates fears from corruption that foreign companies often have in the region and attracts a significant number of companies to Curaçao rather than elsewhere in the region.

One of the most significant hurdles in performing business in Curaçao as perceived by local Innovation Centre (ICC) - has been the fact that *'receiving (any kind of) permits is often a very lengthy procedure'* (Vermeer, 2012), often taking several months. As Martina (2012); Brouwer (2012) confirm, the *'the systems dealing with permits, regulations and control are overly bureaucratic'*. This has been acknowledged by the ministry of economic development and led to significant changes consolidated under a program referred to as 'From Red Tape to Red Carpet'. The recently introduced laws guarantee off-shore companies to receive all permits within two weeks of application and other companies will receive a decisive answer within four weeks (Amigoe, 2012). According to Casimiri (2012), lobbying for new initiatives is absolutely essential but must be done in a very careful manner - reaching the powerful politicians indirectly (via intermediaries or media) is important as it could otherwise rise questions about ethical aspects behind supporting a given project.

Issues with corruption that have been brought up during one of the undisclosed interviews have neither been confirmed by nor implied by any other interviewee. There is however absence of any kind of supporting official reports or documents that would (dis)prove the corruption level in the country. In the brink of several corruption allegations within the political circles, Transparency International (2012) is currently conducting its widely regarded National Integrity System assessment for the long awaited evaluation of corruption risks in Curaçao.

Approved by the parliament in September 2011, the so called '80-20' law requires the employers in Curaçao to have at least 80% of its jobs fulfilled by locals workers, for the other 20% the employer is free in choice (VanEps Kunneman VanDoorne, 2011). This regulation is not intended to hinder or obstruct operations of companies employing foreign experts, thus there is the possibility for the Ministry of Social Development, Labor and Welfare to grant exemption from the requirements (Interviewee 02, 2012). However, the 80-20 rule is perceived by many as a regulation that brings imbalance into the economy as some insufficiently qualified locals might be selected for jobs over foreign workers (Amigoe, 2012).

Companies operating within one of the 12 free-zones on the island are fully exempted from import tax duties and sales taxes (normally 6%) and only 2% on profit from export is imposed

(instead of 27.5%). This is however conditioned to having at least 75% of company's revenues from export activities ([Curaçao Ministry of Economic Development, 2010](#)). Tax exemptions for companies located outside of the free-zones are considered on case-by-case bases ([Hernandez, 2012](#)). In general, available incentives for foreign investors include ([Invest Curaçao, 2006](#)):

- Duty free building materials, machinery and equipment;
- An annual investment allowance of 8% on the total investments for the first two financial years;
- Unlimited use of carry-over losses incurred over the first four years of the company's business.

Other incentives are limited to the minimum investment of US \$137,500 and creation of at least five permanent jobs for persons born in the Netherlands Antilles.

4.2.3 Society, Education and Sustainability

Report of the [United Nations Development Program \(2011c, p.22\)](#) shows the improvement of the Curaçao's level of economic development and living conditions in the last 20 years based not only on its GDP growth, but also on its performance in knowledge and health. However, the problem that Curaçao faces is in the overall inequality within the society with regards to income. In 2008, 33% of the population lived on or below the poverty line. This leads to a number of societal issues such as violent crime in certain communities and the fact that Curaçao is known as a drug passageway from South America to Europe and North America ([Foreign & Commonwealth Office, 2012](#)).

The educational system in Curaçao is primarily based on the Dutch system. Instruction from kindergarten through primary, secondary and tertiary level is in Dutch and Papiamentu. Curaçao has a relatively high number of people educated on university level - almost 25% of the employed population - which is higher than in the majority of central or eastern European countries. Four university institutions are located on the island with over 2,000 students enrolled ([Curaçao Bureau of Statistics, 2012](#); [Curaçao Ministry of Economic Development, 2010](#)). Details on education related to OTEC development are discussed in section 4.3.2.

'Brain Drain' has long been a very strong hindrance of Curaçao's economic development. Annually, around 300-400 students leave Curaçao to continue their studies abroad (mainly in the Netherlands). While this experience is highly valuable for business owners and employers ([Martina, 2012](#)), the problem is that only negligible 5% of these students (then graduates) return back to the island ([United Nations Development Program, 2011c](#)). The government is attempting to reverse the trend by introducing various measures such as promoting a Transnational Education (TNE) program that supports foreign universities in providing education on the island. Another stimulus for preferential employment of local employees is the '80-20' law introduced in section 4.2.2

Education on the topics of sustainability is almost entirely dependent on the activities of small Non-Governmental Organizations (NGOs) (see section 4.3.3 for further information). The income inequality together with lack of education on environmental issues result into '*almost no*

awareness whatsoever about green topics' (Marshall, 2012). This is reflected in the attitude towards environment - e.g. as observed by a local waste management company, 'ordinary people have other problems than recycling to take care of' (Interviewee 01, 2012). Survey of the Curaçao Business Council for Sustainable Development (BPM)⁵ showed that almost all of the 26 surveyed companies 'intend in the near future to invest (further) in sustainability', however that the companies generally lack awareness of broader implications of sustainability such as social and financial aspects (BPM, 2011, p.17). As a result, according to van Grieken (2012); Vermeer (2012) Curaçao has not yet reached the stage when green efforts or industrial certificates such as green labels would be attractive to companies (i.e. also to their customers). In general, it is the foreign companies and their local branches that promote and become involved in sustainable efforts (Brouwer, 2012).

According to Carbon Dioxide Information Analysis Center (2008) Curaçao was in 2008 (still as a part of the Netherlands Antilles) the fourth largest polluter per capita in the world - in the company of countries such as Qatar and United Arab Emirates. This is naturally due to the combination of Curaçao's low population and having a refinery on the island. However, the implications of long history of oil industry and the associated pollution have significant consequences on the mentality and habits of locals (Interviewee 01, 2012). 'Almost the entire population of Curaçao has some kind of a connection to the refinery and therefore does not see the reason for shutting it down and replacing it' (Casimiri, 2012). There seems to be no desire among the locals to search for alternative industries that would replace the refinery should it be shut down in 2019⁶.

4.2.4 Economic Developments

Curaçao's Gross Domestic Product (GDP) is about US\$ 3 billion (i.e. GDP per capita of ~US\$ 20,000). The largest sectors contributing to the GDP are tourism, international financial sector and oil-refining (see table 4.3 for details). The largest employer on the island is the local ISLA refinery⁷, formerly owned by Royal Dutch Shell, employing about 1000 people directly and another approximately 1000 indirectly (via supporting services, suppliers, harbour etc.) (Ecorys, 2011). The unemployment rate on the island is around 9.5-10% (Curaçao Bureau of Statistics, 2012). Despite the significant share of the international finance sector in the GDP, Curaçao Bureau of Statistics (2009, p.47) state that the overall financial sector employed only 7% of the working population which is half of what the tourism sectors (hotels and transport) employ.

The economy has been recording a persistent deficit on its balance of payments account as the import of goods and services consistently exceeds the exports (Centrale Bank van Curaçao en Sint Maarten, 2012b).

⁵BPM is a member of the World Business Council for Sustainable Development

⁶The government of Curaçao will face a decision in 2012 on (not)extending the operational permit of the refinery that will expire in 2019 (Casimiri, 2012) - the main alternatives are: complete closure, permit extension under the condition of significant upgrades, status quo (Ecorys, 2011).

⁷The local refinery, Refineria Di Korsou N.V., was established on a small island (i.e. isla in Papiamentu language) within the Buskabaai bay in Willemstad - it is therefore known as the ISLA refinery. The refinery has a maximum capacity of 320,000 barrels per day.

Table 4.3: Contribution of selected sectors to GDP. Estimates based on [Curaçao Ministry of Economic Development \(2010, 2012\)](#)

International Financial Sector	Tourism	Trade	Oil Refining	Transportation	Real Estate
19.2%	17.2%	11%	8.5%	7.8%	7.4%

On March 26th 2012, the Central Bank introduced a credit freeze for commercial banks for at least six months. Credit is however still available to the extent that is consistent with maintaining the stability of the ANG and the economy - *‘loans for projects that strengthen the economies of Curaçao and Sint Maarten will be exempted from this measure’*. Availability of credit for corporations should therefore not be influenced. As stated by [Centrale Bank van Curaçao en Sint Maarten \(2012a\)](#), *‘the main reason for this development has been the excessive credit extension by commercial banks caused by the over liquidity in the banking sector’*.

Interesting ‘episode’ in the history of Curaçao occurred in late 1960’s. The American giant Texas Instrument set up a production facility in Curaçao employing 2000 people, mainly because of the highly attractive tax incentives put forward by the government. Immediately after these incentives were lessened, Texas Instruments left the island causing a major economic disruption ([Berlew and LeClere, 1974](#)). This clearly demonstrates the fragility of the small economy of the island.

4.2.5 Summary

Table 4.4 summarizes the analysis of the socio-technical landscape. There is a long history of oil-refining industry, lack of environmental awareness among the public, and almost a third of the population lives on the poverty line. Curaçao however benefits from the fact that its judicial system is based on the Dutch one and that there is great intellectual potential of young talents that at this moment leave Curaçao for lack of opportunities. What brings potentially aggravating administrative inconvenience is the newly introduced ‘80-20’ rule - while exemptions are possible, it could potentially pose threats to highly specialized industries, such as OTEC. On the other hand, lack of evidence about corruption as well as simplification and acceleration of permit procedures are highly positive for businesses in general. With regards to the framework outlined in 2.4.3, the case of Texas Instrument’s plant very clearly demonstrates how too rapid and too large of a market entry/leave can have a very substantial impact on the entire economy. Similarly, the hesitancy to shutdown is associated with the major economic impacts (mainly employment) that it could have on the island. The substantial share of the financial sector on the GDP with a relatively low number of employees confirms that service sectors have tremendous importance for island states. Making the current legislation more progressive and streamlining permit issuance is associated with the government’s understanding that industrial sectors require certain enablers to be put in place. The interaction between industries and the island itself are proving to be as important as outlined in the framework.

Table 4.4: Summary of the socio-technical landscape analysis.

Area	Indicator
General	- Strategic geographical location - Multi-lingual population
Politics & Legislations	- European judicial system - Overly bureaucratic administrative procedures being remodelled - Corruption unconfirmed - '80-20' law restricts employment of foreigners (exemptions possible) - Incentives for foreign investors available
Society, Education & Sustainability	- Large income & education differences - Brain drain issues - Lack of sustainability education and awareness - Long history of oil refining, polluted air
Economy	- Largest sectors: Finance, tourism, trade, oil refining - Trade balance deficit - 6 month credit freeze introduced

4.3 Socio-Technical Regimes of Curaçao

This section of socio-technical regimes focuses on relevant developments within the energy sector and other directly related fields, including education and environmental organizations. The analysis is divided into three key areas - the most extensively studied Energy Sector & Relevant Legislation, Education & Research and Environmental Organizations & NGOs. The goal of this chapter is to provide a detailed description the environment where OTEC would operate - the energy market. Additionally, the level of academic and research activities is scrutinized in order to see how OTEC R&D and operational activities could be supported by local expertise. Lastly, the role of NGOs is explored in order to understand the impact that these organizations (might) have on operations of RET.

4.3.1 Energy Sector and Relevant Legislation

This section introduces the current situation in the energy sector with focus on the current state of electricity production and supply, overview of the main legislative developments and description of the incumbent technologies.

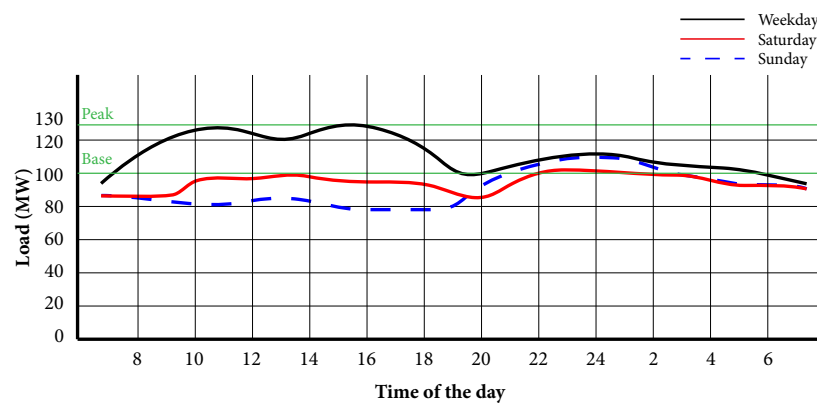
Electricity Production and Supply

Curaçao's utility company Aqualectra⁸ is operating in a naturally monopolistic environment. In transportation and distribution, Aqualectra is and will remain in the foreseen future the

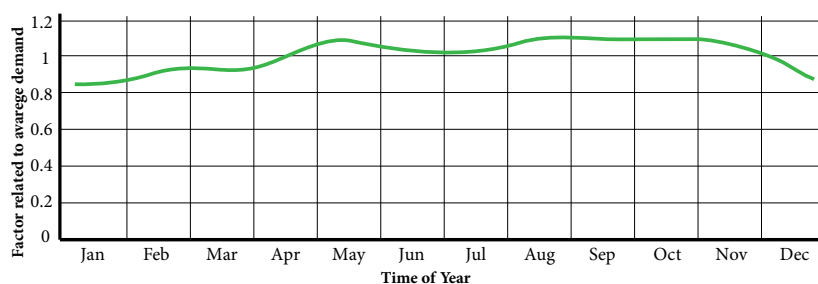
⁸Aqualectra consists of three operating companies: Aqualectra Production, Aqualectra Distribution and Aqualectra multi-utility company. *Aqualectra Production* is formerly known as *Kompania di Produkshon di Awa i Elektrisidat di Korsou (KAE) N.V.* and *Aqualectra Distribution* is formerly known as *Kompania di Distribushon di Awa i Elektrisidat di Korsou (Kodela) N.V.*

only operating company. In terms of production, Aqualectra's operations have on a very small scale been for the past years complemented by other producers. As described below, the latest legal developments however imply that entry of new producers into the electricity production is essentially possible (Government of Curaçao, 2011b).

Curaçao is characterized by having a base load electricity demand of 100MW and peak load of about 135MW occurring at 10am and 3pm, with lowest consumption on the weekends and businesses consuming about 60% of the entire capacity. From approximately November to April, the demand decreases by almost 20% as compared to the summer months due to lower temperatures, stronger winds and thus lower use of air-conditioning (see figures 4.8(a) and 4.8(b)) (Government of Curaçao, 2011b, p.19-20). The total capacity of the production units on the island is about 175MW (i.e. naturally higher than the peaks in order to guarantee sufficient quality). Despite proclaimed expectations of electricity demand growth⁹, (van Weijsten, 2012) estimates that the demand will not change significantly by 2020. This is mainly due to higher number of energy saving appliances and equipment.



(a)



(b)

Figure 4.8: (a) Electricity demand throughout the day. Approximate only; (b) Electricity demand throughout the year. Approximate only and based on data collected in 2004 - 2007. Both figures are based on Government of Curaçao (2011b, p.19-20).

The relevance of direct comparison of electricity prices among nations is questionable as it is influenced by a large number of local specific factors (from overall demand, country size, lo-

⁹Government of Curaçao (2011b) estimates peak demand of 200MW in 2020, this is however based estimates several years old.

cation, physical connection to other countries etc.) (Tujeehut, 2012). However, according to Government of Curaçao (2011b, p.6,22 and 27), the electricity rates are about 30% higher when compared to the cost-oriented countries within the region. Additionally, the quality of the supply is insufficient. According to local consumer protection board, Aqualectra has long been among the three worst companies on the island with regards to number of complains (mainly due to frequent blackouts and high prices) and the worst company of all in (not)reacting to them. There has however been notable improvement in Aqualectra's customer satisfaction due to the improvement in quality of electricity supply in the last two years (Marshall, 2012; Tujeehut, 2012). Table 4.5 provides an overview of electricity prices in the Caribbean region with electricity demand comparable to Curaçao. For comparison, it also shows average electricity price in European Union (EU). What is crucial to understand when comparing prices between continents is the (vast) difference in the purchasing power of individuals - e.g. an average Dutch citizen has approximately four or five times higher income than an average citizen of Curaçao. Table 4.6 shows electricity price changes in Curaçao between 2004 and 2009. The prices grow at a median of 11.4% every year (as compared to about 8.5% median growth in EU (Department of Energy and Climate Change, 2012)). The price developments (trends) in Curaçao are however comparable to other Caribbean countries and signal region's greater dependence (sensitivity) on oil prices than among the EU countries.

Table 4.5: Electricity prices in the region as of June 2011.

	Aruba	Bahamas	Barbados	Curaçao	St. Lucia	European Union ^b
Price ^a (\$/kWh)	0.284	0.154	0.328	0.389	0.268	0.236
Peak ^a (MW)	100	400	188	135	63	-

^a Based on the electricity survey made by Caribbean Electric Utility Service Corporation (CARILEC) (2011) in July 2011. Net peak demand load values are based on Nexant (2010), Schotte (2012) and Bahamas Electricity Company (2012).

^b Taken as average of the 27 countries in European Union (Europe Energy Portal, 2010).

Table 4.6: Electricity price changes in Curaçao (Government of Curaçao, 2011b, p.90).

Year	2004	2005	2006	2007	2008	2009	2009
Date	Jan 1 st	Feb 2 nd	Jun 3 rd	Jul 4 th	Jun 1 st	Feb 5 th	Sep 7 th
Rate (US \$) ^a	0.232	0.262	0.284	0.323	0.365	0.329	0.393
% Change	-	+13%	+8%	+14%	+13%	-10%	+19.5%

^a Aqualectra charges different rates to its 'household' customers depending on consumption (US \$0.347-0.434 at the moment). The trends of price changes are however almost the same for all consumers.

As a part of the new energy policy development in Curaçao, an extensive analysis of the production, transport and delivery of electricity on the island was made. It was concluded that the **production facilities** are not efficient (and thus expensive), inadequate and very unstable. The **transportation and distribution network** installed '*seems to be qualitatively sound*', however the quality of the network varies greatly within the districts (Government of Curaçao, 2011b, p.23). Aqualectra's **network management** control centre that supervises the state of the transportation and distribution complies with the basic functionalities of a smart grid¹⁰ and can support small

¹⁰Smart grid - electricity grid that among others promptly responses to the changes of electricity supply. Integration of smart grid technologies implies a fundamental re-engineering of the electricity services industry.

scale in-feeding. The current state of electricity infrastructure however does not allow optimal connection of neither medium nor large in-feeding producers (i.e. >1MW) ([Government of Curaçao, 2011b](#), p.24).

In terms of Non-Revenue Electricity (NRE)¹¹, Aqualectra has improved from 16,3% in 2004 to about 12% in 2010. This is however still significantly higher than to the comparable case of Aruba where NRE amounts to approximately 5% (Netherlands has about 4%) ([Government of Curaçao, 2011b](#), p.25-26). While these data are only indicative, they clearly demonstrate the inefficiencies within the Aqualectra network and significantly influence the prices that end-customers pay for the electricity.

However, as claimed by Aqualectra ([Tujeehut, 2012](#)), recognized by [van Weijsten \(2012\)](#) and acknowledged by [Government of Curaçao \(2011b, p.28\)](#): *‘...this situation [the obsolete and thus expensive production and network facilities] has primarily come into being through lack of supervision by an independent regulator’*. In the case of Aqualectra, past governmental decisions have had direct (in many cases potentially negative) effects on its performance.

Energy Policy

Prior to its independence, Curaçao had no policy, no long-term vision, very obsolete legislation and lacked any kind of regulatory framework (or regulator for that matter) with regards to energy ([Schotte, 2012](#)).

Until 2010, energy was not a topic on the government’s agenda ([van Weijsten, 2012](#)). After that, Curaçao set off to develop a new energy policy framework in order to realize six key policy aims for the Curaçao energy market ([Government of Curaçao, 2011b](#)):

- Realizing affordable provision of services;
- Realizing reliable provision regarding the availability of electricity for corporate and private markets;
- Structurally safeguarding the interests of the end consumers;
- Introducing more market forces;
- Realizing more sustainable energy supply;
- Introducing an independent form of market regulation.

The former Executive Council of Curaçao then appointed the Curaçao Bureau Telecommunications and Post (BT&P) to develop a policy and supervision framework. BT&P was then also elected as an independent supervisor of the sector. The fact that Curaçao actually now has an energy regulator is rather unusual in the Caribbean - the countries in the region simply do not have one ([van Weijsten, 2012](#)). On the other hand, the fact that the policy maker and regula-

¹¹Non-Revenue Electricity (NRE) - is the total loss of produced and distributed electricity that cannot be billed due to either technical or administrative reasons (e.g. due to the heat loss on the cables, in transformers, measuring issues or frauds by consumers).

tor is the same body is unusual as compared to Europe or North to America. In continental countries, independence of these organizations is essential.

The new Energy Policy was put under development in 2010 consisting of three elements: Electricity, Fuels and Water. On January 1st 2012, first significant outcomes of the governmental efforts in the energy sector were put in place - Electricity Policy. This is soon to be followed by a policy on fuels (in the draft version currently) and by a policy on water (draft version already finished) (Schotte, 2012). The new energy policy and its possible implications for OTEC are in great detail analysed in section 4.3.1.

Incumbent Technologies

Currently, vast majority of the electricity produced on the island comes from **heavy fuel oil** driven facilities. The largest production unit is in Mundo Nobo with a capacity of 84MW. The gas and steam turbines are maintained in operation, however only at about 75% of total capacity due to their obsolescence. Build-Own-Operate (BOO)¹² plant supplies with electricity mainly the ISLA refinery - its overproduction should supply a minimum of 24MW of electricity into the grid. This supply is however not being reliably delivered. There are two **diesel** generators located on the grounds of ISLA refinery that are rated as '*reasonably stable*' (Government of Curaçao, 2011b, p.21-22). According to Aqualectra (2002), the total nameplate (i.e. nominal capacity) of its facilities is about 175MW. See appendix B for a detailed list of electricity production units.

Besides the use of fossil fuelled technologies, Guda (2012) and Aqualectra (2012) argue that Curaçao can be considered a pioneer of **wind energy** in the Caribbean. Pilot project in Curaçao with one 300kW wind turbine started already in 1985. This was followed by a wind farm installed at Tera Kora (12x250kW)¹³ in 1993. The operations during the pilot project and the wind farm were used to investigate the challenges that integration of RET into the grid brings - influences of fluctuations in power outputs, on the system's voltage and frequency etc. In 2001, Playa Canoa wind farm (18x500kW)¹⁴ was constructed (Aqualectra, 2012). The Tera Kora facility was dismantled after 15 years in use (Hanst, 2006) and the Playa Canoa's operations were stopped in 2011. Some technical issues, especially in the early stages of the of Tera Kora's operations incurred due to the lack of experience with the technology. According to Tromp (2012), some administrative issues also incurred due to the bureaucratic requirements embedded within the structures of the government and Aqualectra. At this moment two wind parks, each of 15MW (5x3MW) with approximate capacity factor of around 50% (i.e. provision of about 15MW of net energy) are under construction at the same locations and were put into operation around the middle of 2012. These wind parks are neither financed nor operated by Aqualectra. The operator, NUCapital N.V. is an Independent Power Producer and supplies the energy into the grid. NUCapital was selected in a public tender and the windpark have been put into operations in a what has been defined as '*smooth*' process (in terms of financing, permit issuing, technical preparations etc.). As identified by Tromp (2012), this is due to the close cooperation among NUCapital, the utility provider and the government.

¹²BOO is a facility where a private party (in this case Curaçao Utility Company N.V.) finances, constructs, operates, and maintains a facility previously owned or operated by a public authority.

¹³Tera Kora wind farm facts: Capacity factor - 34%, Availability - 90%, Shaft height - 30m.

¹⁴Playa Canoa wind farm facts: Capacity factor - 58%, Availability - 96%, Shaft height - 47m.

Based on the measurements performed by Fundashon pa Antiyano Energia (FAPE) and Aqualectra, the wind regimes on Curaçao are highly favourable with average wind speeds of 9.5m/s at the height of 50m and wind speeds being almost constant throughout the year. Also as presented by [Hanst \(2006\)](#), the total possible penetration of wind energy under the conditions of Curaçao is 12% (which approximately corresponds to the current state). This is however not supported by any official reports or analyses. According to Aqualectra ([Tujeehut, 2012](#)), there still is 'some' potential for expanding wind energy production.

Other technologies are either being used on a small scale or are only in stage when their implementation in to the network is being planned or considered. This is further discussed in section 4.4.7.

Current technological state of the infrastructure does not to an optimum effect allow decentralized in-feeding of electricity by medium or large producers of electricity. Aqualectra is in the process of developing a masterplan to facilitate non-plant in-feeding via the transportation network. As a result, according to the interviewed experts, there is currently a high risk of infrastructure failures should the share of RET in the network significantly increase ([Guda, 2012](#)). It is recognized by Aqualectra that the level of Curaçao electricity grid's 'smartness' is one of the main challenges of future development ([Tujeehut, 2012](#)). This is mainly a potential threat to intermittent RETs that do not provide baseload electricity (i.e. not OTEC). However, cooperation between electricity producers and the only electricity distributor on the island (Aqualectra), appears to be a pre-condition for successful integration of RET into the network ([Tujeehut, 2012](#)). This was independently confirmed by several interviewees as a key factor for smooth realization of all energy related projects on the island ([Tromp, 2012](#); [Guda, 2012](#)). In order to be allowed to produce electricity in Curaçao and become an independent power producer (IPP), two things need to be put in place:

- A concession (agreement between the private company, i.e. future IPP and the government) that defines the obligations of the IPP, such as reporting, possibilities of governmental interference etc.;
- A power purchase agreement (PPA) - contract between the private company and the utility provider (Aqualectra in this case) that defines the conditions and prices of the electricity that will be produced.

This implies that the utility provider Aqualectra (which is the monopolistic distributor of electricity in Curaçao) has an important role to play in any energy related project on the island. It is so because the quality and stability of the electricity provided by any IPP can always be questioned by them.

Energy Related Legislation

Approved in November 2011 and applicable as of January 1st 2012, the Curaçao Council of Ministers has established feed-in tariffs (FITs)¹⁵ for small scale sustainable energy production

¹⁵Feed-in tariffs are legislated mandates that an electric utility provider purchases at a fixed, favourable tariff power generated by independent power producers from renewable resources. This tariff is guaranteed for a fixed time period, and varies depending upon the particular generation source (i.e. it is different for various energy

of households and small businesses. The FITs have been set to ANG0.40 (\$0.23) per kWh for households and ANG0.42 (\$0.24) per kWh for companies. ([Government of Curaçao, 2011a](#)). The FITs apply to both (and only) wind and solar energy technologies. These tariffs can be considered relatively high (especially when compared to European or American ones). However, direct comparison of FIT with other countries is not entirely possible as they are generally determined based on a large number of factors that are among others dependent on local conditions, project size, level of innovation involved (to stimulate developing technologies), availability of the RET resource as well as the actual production costs to provide reasonable ROI to the producers ([Rymer, 2008](#)). In case of Curaçao, the rates were determined based on the cost price of producing the electricity in Curaçao, the costs incurred to the distribution company and purchase costs saved by not having to purchase energy sources as a result of the feed-in supply ([Government of Curaçao, 2011d](#), p.3).

To demonstrate the difficulty of directly comparing FITs, table 4.7 shows the dispersion of tariffs across selected European countries and US. Within the Caribbean region, Curaçao appears to be the only nation with FITs. The only other country with significant developments is the Cayman Islands that are currently running a small pilot project that includes FITs of \$0.45. This pilot project is however only the initial step in developing a complete electricity policy ([Electric Regulatory Authority, 2012](#)). Haiti, Jamaica and Dominican Republic are in the process of initial explorations that would lead to an energy policy with FITs ([Worldwatch Institute, 2011](#)). Other Caribbean countries that allow connection of small scale RET installations use a net metering system¹⁶.

Table 4.7: Feed-in tariffs in selected European countries, USA, Cayman Islands and Curaçao. Prices are in US\$. The price ranges occur due to the fact that installations of different sizes apply for different FIT ([Europe Energy Portal, 2010](#); [Government of Curaçao, 2011a](#); [Hawaiian Electric Company, 2012](#)).

	Cayman Isl. ^a	Curaçao	Germany	Netherlands	Spain	Hawaii, US
Wind (on-shore)	0.45 ^a	0.23-0.24	0.07-0.11	0.16	0.1	0.14
Solar PV	0.45 ^a	0.23-0.24	0.38-0.72	0.61-0.77	0.42-0.45	0.28
Biomass	n/a	n/a	0.08-0.12	0.12	0.11-0.16	n/a

^a Only ran as a pilot project until a quota of 1 MW of capacity is filled and for installations under 20kW and 50kW for households and commercial systems respectively ([Electric Regulatory Authority, 2012](#)).

In cases where business users want to bring sustainable installations into use which are greater than 1MW (potentially the case of OTEC), the policy paper states that the supervisor (BT&P) and the distribution company (Aqualectra) will proceed on case-by-case bases. The supervisor and the distributor will impose special conditions and inspections upon the producer in order to guarantee sufficient quality and stability of the electricity supply ([Government of Curaçao, 2011c](#), p.9-10).

Energy experts, academics, business owners, environmental activists as well other actors (unannounced sources) ([Caribbean Policy Research Institute, 2009](#)) - in the Electricity Policy of Curaçao this supply is sometimes referred to as 'supply-back' electricity or 'retro-supply'.

¹⁶Net metering system deducts any energy generated from the energy consumed. The user (i.e. also producer) is not paid if the produced energy exceeds the consumed energy

imously welcome the new energy policy - ‘Even with all its flaws, Curaçao now actually has its energy policy’ (van Grieken, 2012; Brouwer, 2012). The situation is now favourable for the market and development of RET (Bulbaai, 2012; Gouverneur, 2012), for the better of consumers and the island (Marshall, 2012), and serves as a good foundation for future political decisions (Interviewee 02, 2012). While the previous governments were not necessarily hindering sustainable developments, they did not actively engage in supporting them (Casimiri, 2012).

Some flaws are however perceived by the various actors and include:

- There was insufficient involvement of the incumbent (Bulbaai, 2012);
- As a result, the policy is not fully aligned with the actual situation (infrastructure) on the island and makes for instance connection of solar panels to the grid problematic (van Grieken, 2012);
- Does not tackle issues resulting from the higher share (of higher number) of solar and wind energy facilities (Guda, 2012);
- The energy policy and the benefits resulting from the tax exemptions do not consider passive products or electronics saving energy (such devices for automation) (van Grieken, 2012);
- The new policies are focused mainly on ‘popular’ and ‘visible’ changes rather than supporting developments of the infrastructure that would have in the long term direct impact on the efficiency of the system and thus the prices (Brouwer, 2012).

While the current time is considered to be very positive towards RET, the current changes are very turbulent (especially in the political circles) making it difficult for investors to predict the future. The current government and its opposition have very contrasting views and projects strongly supported at the moment can suddenly become undesired with the change of governments. This is especially relevant for companies owned by the government (which is the case of all major companies on the island, including CAH) (Gouverneur, 2012).

4.3.2 Education

Four higher educational institutions and their affiliates are located on the island (University of Netherlands Antilles (UNA)¹⁷, Curaçao Institute for Social & Economic Studies (CURISES), University of Dutch Caribbean and Caribbean International University). CURISES implements post-graduate education activities and scientific research projects but not in the field of engineering (Curaçao Ministry of Economic Development, 2010). UNA is the only institution covering technical fields with approximately 400 students enrolled at the faculty of engineering, all on bachelor level and in a variety of fields (from information and communication technologies (ICT) to mechanical engineering) (UNA, 2012). All programmes at the UNA engineering faculty are internationally accredited and degrees gained there are accepted by universities in both Europe and North America. However, none of the engineering programmes are research

¹⁷University of Netherlands Antilles (UNA) has undergone during this project a name change to University of Curaçao - the former name (UNA) is used in this report

oriented, there is a minimum of academic papers crediting the UNA being published in recent decade in renown academic journals and there are no patents filed in any world region referring to the UNA (Bulbaai, 2012). At the 2012 Curaçao Conference and Expo on the Future of Durable Energy an agreement was signed between the UNA and the Eindhoven University of Technology (TU/e) (BT&P, 2012). This agreement enables student exchanges from Curaçao to the Netherlands under highly favourable conditions.

According to Bulbaai (2012), there is a clear change in the interests of the university students towards RET - it is however mainly in a general sense rather than that the students would have interests in specific technologies. According to Halman (2012) there are some efforts aimed towards supporting research activities at the university but those have taken no concrete steps so far.

There is currently no masters programme at the UNA engineering faculty with the exception of a 'TechnoMBA' programme that is aimed mainly (though not unconditionally) at professionals with engineering background and the interest to develop business skills. The programme was developed in cooperation with the University of Twente (UT) (UNA, 2009), it is internationally oriented, combines lectures of both local professionals and respected foreign expatriates (academics) and is heavily subsidised by the government of Curaçao in order to make it affordable to locals¹⁸ (Halman, 2012). Sustainable technologies are one of the pillars of the TechnoMBA but only within the scope of the MBA programme (i.e. mainly focused on commercial rather than technical issues).

Every three years, the university meets with representatives from local industries to discuss the needs for modifying the study programmes to fit companies' needs. In the field of engineering, this has led to adjustments of several courses but not to establishment of new study programmes or other major changes (Bulbaai, 2012). Almost 90% of students at the engineering faculty perform their bachelor theses for private companies. Yet, based on the experience of Rosheuvel (2012), a former governmental advisor in the technology commission, the standards of education in the fields of mechanical engineering and electrical engineering on the island are 'fairly poor'. The readiness of graduates on the MTS+ educational level¹⁹ for practical work in high-tech environment is questionable (Rosheuvel, 2012). This stands in contrast with relatively well qualified local graduates in the fields of civil engineering, or business and law.

While research in the engineering field is not performed in Curaçao on any significant level, marine ecosystems are. Caribbean Marine Biological Institute (CARMABI) performs scientific research on both marine and terrestrial ecological subjects, is in charge of nature management of marine and terrestrial parks, environmental education and public advisory and consultancy to third parties. CARMABI is an internationally recognized institutions with 20+ publications peer reviewed scientific journals annually and other dozens of masters or Phd theses. The institute is visited by approximately 70 scientists a year for research purposes and by various universities for courses related to coral reef ecology (Iceland Geosurvey, 2010).

¹⁸The TechnoMBA is a 1.5 years programme (90ECTS) with a tuition of 3000 ANG per year, it has been running for 3 years and about 25 students (professionals) enrol every year.

¹⁹MTS+ includes 'Middelbare and Hogere Technische School' (similar to polytechnica education) and higher education (i.e. including university)

4.3.3 Environmental organizations and NGOs

For its relatively small size, Curaçao hosts a large number of non-governmental organizations (NGOs) that oppose environmentally harmful projects and activities²⁰. Their activities range from introducing alternative solutions to the oil-refining business (GreenTown project), tackling insufficient waste management, protecting and researching marine environment to improving currently inadequate environmental education (Stokkermans, 2012; Brouwer, 2012; Casimiri, 2012).

It is however apparent that the role of consumer or environmental organizations in Curaçao is significantly weaker than the role of its European or American counterparts. Firstly, this is due to the lack of organizations specialized on specific topics (e.g. Fundashon pa Konsumido - Consumer rights organization - has no specific focus and addresses issues regarding the entire range of consumer products and services) (Marshall, 2012). Secondly, it is due to the fact that these organizations have only recently been established (e.g. Curaçao Business Council for Sustainable Development (BPM)) (Interviewee 01, 2012; Kool, 2012). However, the case of FAPE²¹, Foundation for Antillean Energy, shows that a decades ago established, highly specialized and expert organization has none to minimal influence on governmental decisions and rather focuses on educational activities and (wind) resources assessment (Guda, 2012).

However, while these organizations might not have direct influence on governmental decisions, they do shape the public opinion regarding environmental issues (Kool, 2012). By communicating via local media, they do have influence on the slow changes that are happening within the environmentally unaware society of Curaçao (Casimiri, 2012), they seem serve the role of 'watch dogs' that (negatively) publicize projects that directly harm the island. As (Brouwer, 2012) says, '*regulations, control and the actual imposing of rules on companies with regards to environmental protection are completely missing*'. However, recent case of a planned racing track on the nearby Aruba demonstrates that negative public perception can even lead to stopping a project (van den Brink, 2012).

This extends to other areas than environmental organizations. As Kloppenburg (2012) argues, Curaçao is not backed up by large professional institutions that could provide expertise within new fields (e.g. SWAC or OTEC). Any official decisions regarding these technologies might therefore take longer and may be observed as not transparent enough. And since laws and policies are much less rigid in Curaçao, project execution is a much more 'organic' process than in Europe or the USA. (Gouverneur, 2012).

4.3.4 Summary

Table 4.8 summarizes the socio-technical regime analysis. The newly introduced energy policy changes are undoubtedly positive for the development of RET on the island. The policy is considered as very progressive among a broad range of experts and presents clear tangible steps

²⁰Main environmental and conservation organizations on the island are: Curaçao Clean and Beautiful, Huntu Korsou, Green Force, SMOG, Defensa Ambiental, Amigu di Tera, CARMABI, Currassavica, Uniek Curaçao.

²¹Fundashon pa Antiyanu Energia can be viewed as a locally based counterpart of the International Energy Agency

(and not only words) that the government intends to use in order to fully support RET. What might present significant issue in the developments is the current state of the electricity infrastructure. Its improvement is a long term process and its vulnerability could force the utility provider into making conservative decisions and thus slowing down the penetration of RET.

While the universities do seem to educate students on a satisfactory level for practical work, they certainly do not ‘produce’ highly specialized experts capable of working in research environment. The case of CARMABI however proves that Curaçao can provide environment for scientific research on international level.

Environmental organizations do have influence on general public opinion, but sufficient transparency and cautiousness about environmental dangers of projects seem to offset potentially negative media attention.

Table 4.8: Summary of the socio-technical regime analysis.

Area	- Indicator
Energy	<ul style="list-style-type: none"> - Mainly use of heavy fuel oil for production, unreliable facilities - Long history of wind, currently ~10% penetration - Advanced small scale feed-in possibilities, favourable tariffs - Positively perceived and evaluated new energy policy - Political situation prone to rapid changes should the government change
NGOs	<ul style="list-style-type: none"> - Large number of environmental groups - Only indirect influence on developments (via media) - Slowly shape the public opinion towards RET
Education	<ul style="list-style-type: none"> - 4 universities, no engineering MSc program - 1 international ‘technoMBA’ programme strongly supported by the government - Poor level of engineering students on the MTS+ level - No engineering research oriented efforts on the island whatsoever - High quality research in marine and terrestrial fields

With regards to the proposed framework, the regimes have been very statistic in terms of co-operations among the various organizations (e.g. university, utility provider, policy makers). Additionally, minimal amount of cooperation with outsiders (companies) has been identified – the case of NUCapital provides a bright exception to the rule which contributed significantly to the successful implementation of wind energy. Until recent changes, the overall energy sector had been obsolete due to the lack of investments, technical expertise, and outdated legislation and regulations. Within the energy regime, new innovation systems (e.g. solar, SWAC) have had difficulties emerging. The following chapter will unveil how the recent changes imposed by the government on the energy sector influence the opportunities for new technologies.

4.4 OTEC Innovation System

This section is based on the FIS theory - seven functions inherent to technologies are used in sections 4.4.1 - 4.4.7 to analyse and reflect on the possibilities of OTEC development in Curaçao. Additionally, section 4.4.8 introduces characteristics that were found to be specific for

the environment and culture of the island and did not fit into any of the functions. Analysis of each function starts with the description of why particular indicators were used and why they are relevant.

4.4.1 Entrepreneurial Activities

This function maps out the current and past developments of OTE technologies on the island, shows their current progress and explains why these projects have been developing the way they have. For comparison, this function also outlines progress of OTE projects in the region.

The potential of OTEC development in Curaçao has been on a rather abstract scale explored already in 1970's and 1980's ([Rosheuvel, 2012](#); [Guda, 2012](#)). OTEC has however not proved technologically feasible in that time.

SWAC developments on the other hand took tangible steps in 2000. Aqualectra has together with several other parties from the USA and the Netherlands developed a project for a SWAC system with a capacity of 3,000 tons of cooling²² that would supply several commercial buildings, mainly hotels, located in the Piscadera Bay in the south west of Curaçao (thus the 'Piscadera Bay project'). The project went successfully through survey, feasibility and engineering stages. All (binding) arrangements regarding the financing and the usage of the consumers were finalized. The SWAC operator has agreements with the future users of the SWAC system. In 2008, during the tendering phase one of the main stakeholders in the project went bankrupt, which stopped the project ([Ecopower International, 2010](#)). As the owner of this project, Aqualectra restarted it in 2011.

In 2010 CAH initiated its own SWAC project. The planned SWAC system would supply its own premises as well some surrounding facilities, including the Curaçao Technology Exchange (CTEX) data centre that is currently being constructed in the airport's vicinity. Besides that, CAH intends to support operations of other technologies ('tenants') that may utilize DSW in the so called 'Curaçao Ecopark' (see section 4.1.2) ([CAH, 2010](#)). Number of experts that participated in the 'Piscadera Bay project' are involved in the current CAS SWAC project with the belief that their experience will improve the chances of success of this project ([Gouverneur, 2012](#)).

While being developed independently, CAH and Aqualectra have established a cooperation in order to support each other and (when possible) share knowledge as well as some of the incurred costs. Success of either of these projects will positively affect the other ([Tujeehut, 2012](#)).

Regional Developments

Within the region, two OTEC projects are under development. [OTE Corporation \(2011\)](#) announced a plan for two 10MW OTEC plants in the Bahamas. A French defence company DCNS is working on a project for a 10MW facility in Martinique ([DCNS Group, 2010](#)). Both of these projects are however only in the pre-engineering stages.

²²3,000 tons of cooling corresponds roughly to cooling about 2,500 hotel rooms

4.4.2 Knowledge Development

This function assess the level of knowledge about OTE technologies in Curaçao. Naturally, none of the traditional indicators (R&D investments, patents etc.) are available and this function can be considered as underdeveloped. The used indicators are of qualitative nature and include: overview of OTE engineering expertise and investments made into OTE projects.

Naturally, both ‘learning-by-doing’ and ‘learning-by-searching’ concepts introduced in section 2.3.2 can only be measured to a very limited extent as there is practically no experience with OTEC on the island. However, the suitability of using OTEC in Curaçao has been in the past evaluated by Aqualectra. Being a base-load technology, OTEC could loosen the country’s dependence on oil and potentially solve a large part of Curaçao’s energy problems (Tujeehut, 2012). High CC and associated technological uncertainties have however kept Aqualectra from further exploring OTEC.

History of SWAC on the island helped grow some engineering and financial expertise with regard to OTE technologies. Some parts of the engineering works on the past SWAC project were either directly performed by or done in cooperation with engineers based in Curaçao (Rosheuvel, 2012). Similarly, the pre-engineering part of the CAH is being performed by local project development company Ecopower (Gouverneur, 2012). The environmental assessments of the CAH SWAC project were completed by local companies (van den Brink, 2012). Additionally, the undergoing SWAC projects has already consumed 1.5 million ANG (US \$0.9 million) investments into pre-engineering works and seabed surveys. Further ~2 million ANG (US \$1.1 million) are required for engineering (decision on proceeding to the engineering phase is soon to be made). Memorandums of understanding (MOU) have been signed by future SWAC users (60% of total capacity is now allocated) Kloppenburg (2012). This demonstrates significant commitments of the customers towards CAH and significantly lowers some of the risks that have until now been present in the SWAC project.

4.4.3 Knowledge Diffusion Through Networks

This function maps out how the awareness about OTE technology diffuses among the experts and society. The indicators used include the numbers of seminars and conferences on the island, the level of cooperation between the utility provider and UNA, research and education of RET at UNA, and other cooperation related to the SWAC projects. As this function is also fairly underdeveloped with regards to OTEC, focus is put on SWAC and RET in general.

Information diffusion is guided by a variety of actors and organizations. In recent months, there has been noticeable increase in the number of seminars and conferences on the topics of sustainable development. Even more importantly, the involvement (and interest) of the governmental officials in these events demonstrate the importance that the government is attaching to sustainable development. (BPM, 2012; BT&P, 2012). At one of the conferences, OTEC was presented as a possible alternative to the current oil driven electricity production facilities. ☐

The largest organization that systematically organizes sustainably oriented seminars or workshops for corporate as well as general guests is BPM. Its main goal however is to stimulate and

support companies within the BPM council in setting and achieving sustainable targets, i.e. not highly specialized engineering or RET related seminars and conferences.

Cooperation between the utility provider (Aqualectra) and the UNA is mainly based on performing these projects of individual students. No concrete long-term cooperation on RET studies or research is established (Bulbaai, 2012). With regards to the SWAC developments, CAH and Aqualectra have established formal cooperation aimed at sharing (the 'shareable') resources, costs and expertise between their projects. Neither cooperation nor purchases of components from the local companies can be confirmed at this moment (Tujeehut, 2012; Klopburg, 2012).

4.4.4 Guidance of the Search

Guidance of the search functions evaluates the activities can positively affect the visibility and clarity of specific needs among technology users. These reflect on how well OTEC is positioned in order to be 'selected' by the socio-technical systems for further development and support. Multiple indicators are used: possible technology branches and their fit with Curaçao, awareness about OTEC among experts, number of articles in journals and media, characteristics of the applicable legislations, characteristics of the energy policy and energy targets for the future. These indicators are then briefly compared to the countries in the region.

Technology Branches

Development of on-shore, rather than off-shore facilities currently prevails worldwide. It is so because plants constructed on or near land do not require sophisticated mooring, lengthy power cables, or the more extensive maintenance associated with open-ocean environments. Additionally, small scale and research facilities can be integrated within a broad range of other technologies on-shore as explained in section 4.1.2. These trends are in exact alignment with the plans of CAH that is developing its SWAC project in Curaçao.

Technology Awareness

The relatively rich history of (planned) OTE related projects makes Curaçao a well OTEC aware island in comparison with the rest of the Caribbean. In media, OTEC has been mentioned on number of occasions within the context of the Curaçao Ecopark and the CAH's plans for exploring OTE technologies (Antilliaans Dagblad, 2011a,b). Vast majority of the interviewed experts, including the utility provider, energy policy maker, regulator as well as the minister in charge of energy are aware of OTEC technology (see interviews in Appendix C). The awareness among these actors is higher than what can generally be observed at energy related conferences and events worldwide (Blokke et al., 2012).

With regards to academic journals, publications focusing on OTEC have recently been publicized at a significantly higher rate than compared to the past 20 years (50+ articles annually over the past 5 years compared to about 10+ before). However, it has not yet reached the popularity

comparable to the era of the oil crisis in late 1970's (150+ articles on average in 1978-1981). Curaçao has not been mentioned in any of the journal articles with regards to OTEC.

The Caribbean Community Climate Change Centre (CCCCC) (2011) that provides climate change-related policy advice and guidelines to the Caribbean Community (CARICOM) has the assessment of economic viability and environmental impact of on-shore OTEC plants within its strategic framework elements and goals.

Legislation relevant to OTEC operation

With regards to relevant legislation and licensing specific to the establishment of OTE technologies there are (Delcour, 2012):

- Two legislations guiding the actions related to coastal and seabed areas;
- One regulation regarding electricity concession;
- One international convention of the United Nations (UN)²³.

All other applicable laws and regulations are related to general conditions for business operations on the island (see Appendix C.6 for a complete lists of the relevant regulations). According to van den Brink (2012), experienced environmental consultant in Curaçao, the regulatory framework on the island requires companies to obtain significantly lower number of permits and comply with substantially less stringent rules than in European or North American nations. While for example environmental impact assessments are absolutely essential part of large projects in continental countries, it is not the case in Curaçao. On the island, decisions on (not) conducting these assessments is generally dependent on the project owner. Evidence shows that international corporations generally follow vigilant procedures that they apply elsewhere in the world and that are embedded within their missions and corporate social responsibility (CSR) programmes (Brouwer, 2012). Performing the (not-required) assessment studies could therefore appear as unreasonably increasing projects costs. However, it prevents conflicts with public and environmental organizations that try protect the environment of the island regardless the weaknesses of the country's regulations (van den Brink, 2012).

Due to the SWAC developments on the island, a number of environmental studies has been performed related to the impact of OTE technologies on the marine life (Gouverneur, 2012). These studies have determined that returning the DSW into the ocean at the depth greater than 50m is safe. The only potential thread is posed by the level of nutrients contained in the outflow of the cold DSW (Stokkermans, 2012). However, van den Brink (2012) who was responsible for the environmental impact study for the CAH SWAC project does not anticipate any legislation or public conflicts towards OTE technologies. And as the case of the refinery proves, the society balances the benefits (e.g. employment) against the undesired (environmental) side effects.

²³(Relevant only if the facility would be operated outside of the territorial seas of Curaçao - i.e. an off-shore OTEC facility).

Energy Policy and Relevant Political Developments

The recently introduced energy policy aims to promote development of RET in general with no specific mentioning of OTEC. [Government of Curaçao \(2011b\)](#), p.61) states that *'it is projected to produce a minimum of 50MW of wind energy and energy from waste by 2030. This corresponds to approximately 20-25% share of sustainable energy of the total energy estimated to be produced in 2030.'* At the same time, *'the energy mix of 75-25 (fossil fuels-RET) by 2015'* is mentioned in the document. The two statements are in contradiction (i.e. the later being much more ambitious).

According to [Schotte \(2012\)](#), Curaçao's prime minister and the minister in charge of energy, sustainable energy production will have a share of a minimum of 25% in 2015 and additionally there will be a (partial) switch from oil to natural gas contributing with another at least 25% of all energy produced on the island.

The role of natural gas is tackled in the energy policy only in general terms *'...production by natural gas as much as possible'* ([Government of Curaçao, 2011b](#), p.76).

These goals are not binding in any sense and it should be noted that some discrepancies occur in the set targets and the current shares of RET - e.g. in terms of years by when these targets should be achieved and in the media often quoted share of RET in production does not refer to the net energy produced but to the nominal (i.e. installed) capacity.

Foreign Developments

Within the region, according to [Energy Development in Island Nations \(EDIN\) \(2011\)](#) Bonaire and Dominica seem to have the most ambitious plan of ultimately reaching 100% share of RET. [Government of Grenada \(2011\)](#) set within its energy policy the target of at least 20% share of RET by 2020. Other islands of comparable size either have less ambitious or not specified targets.

The USA appears to be the only country where governmental institutions have actually established OTEC specific rules and guidelines. The OTEC Act of 1980, administered by [National Oceanic and Atmospheric Administration \(NOAA\) \(1980\)](#), consolidated OTEC licensing under one institution in order to simplify the process of establishing OTEC facilities and thus promote OTEC R&D. Demonstration projects (OTEC R&D) do not need NOAA's license as long as they are designated as demonstration project by the US Department of Energy (DOE). While the OTEC Act and regulations were rescinded in late 1990's ([Federal Register, 1996](#)), [Ocean & Coastal Resource Management \(OCRM\) \(2011\)](#) is currently rebuilding its licensing capacity due to the recent interests in the technology. The 'unspecific' legislation of Curaçao towards DSW related technologies therefore seems to be comparable to the legislation in other coastal nations around the world ([Crews, 1997](#)).

4.4.5 Market Formation

Market formation function maps how well can RET enter the market. The indicators used include tax exemptions and FITs for RET, market size of Curaçao, and quantitative data about

other RET on the market. Brief overview of international developments with regards to the financial support of OTEC is given.

Incentives

Opening the grid and introducing the new energy policy has unveiled a number of opportunities for the growth of niches. All foreign investors may apply for tax exemptions that were discussed in section 4.2.2. RET are specifically (planned to be) incentivized by ([Government of Curaçao, 2011b](#), p.61):

- Abolishing import duties or other levies on the import production resources (e.g. solar panels) and related electronics (e.g. invertors);
- Introducing investment allowances for RET - fiscal measure allowing creation of a tax deduction when a party purchases sustainable energy resource;
- ‘Green credits’ to enable the purchase of the necessary production resources for sustainable energy against low or none interest.

In practice, some of these incentives have already been put in place - e.g. electric vehicles are fully exempted from import duties, 10% import duty is imposed on hybrid vehicles (22% normally). Import duties were also lowered on solar panels and some of their components. OTEC components would be exempted from import duties under this policy as its purpose is to support small scale production and energy saving technologies. Specific tax conditions, import duties and other similar incentives for large projects are considered on case-by-case bases and must be negotiated with the government ([van Weijsten, 2012](#)).

The FITs described in section 4.3.1 apply to small scale RET production only. Large scale production facilities (i.e. >1MW) are obliged to receive a concession (based on the ‘National Ordinance on Electricity Concession’²⁴). As [Government of Curaçao \(2011b, p.16\)](#) states, *‘this legislation regrettably still reflects the prevailing views of another era and that therefore it should be updated as soon as possible’*.

Market Size

In the current state of OTEC development, market size (for operation) is a matter of presumptions. Should the energy market in Curaçao developed as expected, electricity demand will remain at the current 135MW ([van Weijsten, 2012](#)). Should OTEC capture about 50% of this capacity (assuming that Curaçao will desire to maintain a rich energy mix in order not to be dependent on one technology), then Curaçao’s market would be around 70-80MW.

Potentially successful integration of OTEC in Curaçao has however greater consequences for the future of the technology - prove for other nations within the region about the reliability and viability of OTEC. Similar to how the success of (back then pioneering) Danish wind industry on its own market triggered international developments. The overall electricity demand in the

²⁴Transitional National Ordinance XXVI: Electricity Concessions (P.B. 1991, no.102)

Caribbean is over 5GW (Nexant, 2010). In theory, off-shore OTEC facilities could provide the entire electricity capacity. The real share however depends on how proven OTEC technology will be but also on the desired energy mix that the island nations will want to sustain.

Other Niches

Aqualectra itself has been involved in the exploration of solar energy since 1995 focusing on exploring the impacts of the technology on the electricity grid. Currently, there are several small scale (<20kW) solar panel installations ran by Aqualectra (Aqualectra, 2012). Since January 1st 2012 and related to the new energy policy, 1MW of capacity has been connected to the grid by private individuals (and further 7MW are waiting for approval/connection) (Schotte, 2012).

Plants for WTE plant have been announced as a part of the envisioned Ecopark and for which CAH has already received concession for electricity production. The WTE would partially utilize the cold DSW of the CAH SWAC. The total capacity of the WTE plant is set to about 1MW (Kloppenburg, 2012).

As discussed in section 4.4.4, the possibilities for converting some of the Aqualectra's facilities to natural gas driven ones are being considered. There have however been no concrete steps done towards this transition and there is no indication of how this transition would influence the role of RET.

International Developments

In terms of grants and other incentives aimed specifically towards OTEC development, USA appears to be the most active nation (Department of Energy, 2010, 2009). The EU's NER300 financing instrument for subsidising installations of innovative RETs is limited to facilities built within EU (including overseas region's within EU countries, i.e. not Curaçao). The instrument is not specifically aimed at OTEC, but mentions it among the applicable technologies (European Union, 2010). Despite Curaçao's independence, its strong ties to the Netherlands still remain. Interviewed policy advisers of the Curaçao's government Interviewee 02 (2012); Jansen (2012) stated that the current situation and applicability of Curaçao based companies for various incentives, funds and subsidies from the UN, EU, IMF, the Netherlands or other organizations is unclear and should be researched by experts.

4.4.6 Resources Mobilization

Resources mobilization function is divided into three main areas. Human resources are evaluated using qualitative indicators describing the availability of technical expertise on the island, methods for gaining (and sustaining) expertise on the island, and the role of the UNA in providing technical expertise. In the financial resources area, indicators used include the possibilities for financing within the region, requirements for receiving funding, and specifics of financing local projects. Physical resources area is evaluated using indicators that focus on availability of equipment and technology, suppliers, characteristics of the harbour as well as characteristics

of the DSW. Lastly, presence of research organizations in the region is discussed. Overall, the section aims to evaluate how well could human, financial and natural resource support development of OTEC industry on the island.

Human Resources

As discussed in section 4.3.2, only research of marine organisms is performed on the island on a high scientific level. With the lack of government funded institutions or universities focused on research in the field of engineering, knowledge development in Curaçao can be found within private companies. In terms of industrial developments oil refining, logistics (harbour and airport), construction and public utilities form the strongest sectors requiring technical expertise (Curaçao Ministry of Economic Development, 2010). The local refinery, Curoil²⁵, harbour and other engineering firms have engineers with sufficient qualities across all (relevant) fields (Interviewee 03, 2012; Rosheuvel, 2012; van den Brink, 2012). Their level of expertise has however been reached only with the support of internally organized educational systems. Curoil that for example operates on highly competitive international markets with oil products spends substantial financial resources on sending its engineers to trainings or seminars abroad²⁶ (Interviewee 03, 2012). The local refinery has a very elaborated system of attracting, selecting and keeping highly qualified engineers. This system is then complemented with engineers' rotations within various departments of the refinery, high salaries (in comparison to the rest of the island), and other financial and non-financial benefits that have been adopted when Shell was operating the refinery (until 1985) (Interviewee 03, 2012; Rosheuvel, 2012; Tromp, 2012). According to Gouverneur (2012) it is challenging to work with high-tech in Curaçao as the number of experts is limited and to attract and keep them on a long term, one needs to not only provide attractive job but also attractive rewards.

With regards to RET, the Curaçao's wind park technicians and operators have been gaining expertise since the beginnings of wind energy technology on the island in early 90's (fields relevant to the operation of wind mills are to some extent also relevant to OTEC - mainly mechanical and electrical engineering). Some of the new employees that have been contracted recently are former employees of the refinery in Aruba. What is interesting is that there have recently been announcements regarding reduction of Aruban refinery's production (CBS, 2012) - this has caused uncertainty among its (well qualified) employees from whom had NUCapital subsequently received several job applications (Tromp, 2012). This is highly relevant due to the fact that this situation could repeat on a much greater scale as the Curaçao refinery is soon to face a decision for having its permit operations (not)extended (it will expire in 2019) (Ecorys, 2011).

On the basis of the above information, it can be concluded that while Curaçao does not have any research oriented facilities (neither government nor private owned), local companies that operate on internationally regulated and competitive markets do possess expertise on internationally competitive level. Competitive markets keep companies 'sharp' and compel them to engage their employees in developing expertise (Interviewee 03, 2012), which in turn keeps

²⁵Curoil is the largest provider of oil and gas related products on the island and serves all major sectors (from aviation and sea freight to individual consumers)

²⁶Curoil has established an agreement with Shell on providing regular trainings an advisory regarding the latest developments in the industry - these take place on very regular (monthly to quarterly) bases

overall level of professional competence on the island high. The high number of locally educated high school and bachelor students that successfully move to American or European universities clearly indicates that the basic education provided by local schools and university (UNA) are of sufficient quality. This is further supported by the fact that none of the large engineering oriented companies that were interviewed are concerned with the newly introduced 80/20 law enforcing preferential employment of locals (see section 4.2.2 for more details on the 80/20 law).

Financial Resources

As Vega (2010) argues, *'financing for such plants [OTEC] in general remains a daunting challenge'*. Neither research nor pre-commercial plants can produce electricity at cost competitive prices. The credit freeze introduced by the Central Bank discussed in section 4.2.4 does not have significant implications on business projects. However as Coutinho (2012) states, financing of technologies such as OTEC (little to none operational experience and the high involved risks) is generally not done by banks. Unproven technologies that bear potentially significant risks are (all over the world, not just in the Caribbean) always be financed by venture capital. As Nicastia (2012) said, *'financial projections of these technologies [OTEC] are almost irrelevant (from bank's point of view) as there are no real historical data to support them.'* Having proper testing facilities, working prototypes or more preferably operational history are the only way to get financing from banks for energy projects (Coutinho, 2012).

According to Coutinho (2012); Nicastia (2012), the following characteristics determine how easily will a given project be financed in the region:

- Whether a PPA has been awarded;
- How much the project is supported by the government;
- Future cash-flow projections;
- How caps on prices are set;
- How reliable the government's promises are in the particular country;
- How laws are being reinforced in a particular country;
- General relationships between public and private organizations.

These characteristics different significantly country by country and banks' local representation and experience is therefore of great importance. Nicastia (2012) argues that the combination of financing from local and foreign sources works best. Foreign banks can provide cheaper finances and large financing capacity, while local banks have local knowledge and experience.

Up to date the most advanced OTEC research project, that was run by Natural Energy Laboratory of Hawaii Authority (NELHA) was government funded (Daniel, 1999). The Pescadero Bay SWAC project was planned to be financed by Dutch institutions (Rosheuvel, 2012). The current CAH SWAC project which is expected to require a total investment of ~ANG50 million (US \$28.5 million). The financing model and the role of banks and/or private equity is yet to

be determined - CAH however wants to retain its major share in the project. CAH intends to finance ~30% of the SWAC project from local banks (Kloppenburger, 2012).

Physical Resources

Rosheuvel (2012) expert on Heating, Ventilation and Air-Conditioning (HVAC) who was responsible for part of the engineering works on the Piscadera bay SWAC project argues that *'the supporting technologies for OTEC are not there (in Curaçao)'*. While regular operations of OTE technologies are fairly straightforward, any unplanned maintenance or repairs could become very challenging and would require expertise and equipment from abroad.

There are currently no potential suppliers of key OTEC components (pumps, heat exchangers, DSW subsystems, turbines, generators) located on the island. As discussed in section 4.4.6, engineering expertise on the island is relatively high. However, it is to a great extent tied to the relevant companies. Some supporting services (maintenance of off-shore structures) are available due to the presence of the harbour. However as Rojer (2012) says, the dry dock and its equipment are mainly fitted for ship repair, maintenance and conversions. Operations on SPAR or oil-platform type of vessels are limited - these vessels do not fit into the channel that leads to the harbour. There are deep harbours (up to 300m) in Curaçao that are open to the sea but the equipment is not at the moment located near this area. Services on oil platforms require special skills and special equipment that Curaçao does not at the moment possess. While ship or vessel building on a large scale is according to Rojer (2012) not feasible (high labour costs, no infrastructure, no suppliers), development of specialized one time projects (i.e. not mass production) in the region would be possible as the expertise is there.

In terms of supplies, some local companies face problems with product or expertise availability. Curoil does not have sufficient supply of some quality fuels that would satisfy international standards. The company is even considering diversifying its (almost purely logistical) operations by beginning its own bio-fuel production because there are no suppliers in the region (Interviewee 03, 2012). The refinery occasionally faces delays in material and equipment supplies as they all must be shipped from (mainly) the USA (de Haset, 2012).

The suitability of Curaçao for OTE technologies has already been unveiled in section 4.1.2. The seabed profile is favourable but will require a DSW pipe of about 6km to reach the depth of 800m and temperature of about 6°C (Gouverneur, 2012). Surface water temperature measurements are not available. For comparison the DSW pipe in NELHA, Hawaii is only 1.9km long, reaches the depth of 674m, temperature of 5-8°C. The surface water temperature ranges between 24 and 28.5°C, depending on the season and weather conditions (Toyama, 2010). CAH proclaims its intentions to make the DSW available for other technologies, it is however especially important to realize that OTEC requires as cold DSW as possible. The SWAC systems in general are designed to operate at maximum capacity at all (possible) times. The question that Rosheuvel (2012) posed was *'how will the DSW for OTEC be allocated while still keeping the SWAC operation profitable?'*

Regional Development

With regards to recent regional developments, TNO²⁷ has in 2011 opened its Caribbean office in Aruba (i.e. 100km from Curaçao). As presented, the technologies that are mainly to be targeted by its researchers are solar energy, water treatment, smart grids, liquefied natural gas (LNG) and SWAC (TNO, 2011). The key driver behind TNO's operations in the Caribbean is '*is to make them fitter*' for the specific (weather) conditions of the tropics. The Caribbean office has only happened recently, there have been no concrete steps made that would indicate how SWAC technology could be explored in Aruba. Envisioned cooperation between TNO and leading western universities (as well as regional ones, including UNA) (Ebbing, 2012) does outline a potentially attractive bases for a cooperative project between Aruba and Curaçao.

4.4.7 Creation of Legitimacy, Resistance to Change

This function explores the resistance towards change from the incumbent utility provider and other institutions on the island. The indicators used map the forces that the government uses to change the status quo in the energy field, the willingness of the utility provider to allow for new market entrants and the possibilities that government provides to change or support education and research of new technologies.

The active support of RET development from the current government has been discussed throughout the entire chapter 4. The naturally monopolistic energy market is now to a much greater extent supported and regulated by the government. The introduced changes are by almost the entire list of interviewees (including the current RET project developers) considered to be highly positive for the development of RET. Recently awarded electricity production concessions for the wind-parks and the WTE support this view (see section 4.4.5).

Incumbent

Aqualectra presents itself as a utility company that is open to new projects, technologies and cooperation with external parties with regards to RET (Tujeehut, 2012). Within its 2-3 year periodic integrated resource planning the company has investigated the opportunities for utilizing wave energy, SWAC, OTEC, wind energy, solar energy, bio-diesel production, waste-to-energy (WTE), absorption cooling, organic Rankine cycle and wave energy. From these technologies solar energy, wind energy and SWAC technologies were approved as the most promising under the conditions that Aqualectra operates at the moment (Tujeehut, 2012).

However, any disruptions in the electricity production or distribution have severe and immediate consequences that cannot be fixed with the help of international partners like in continental countries. And as Halman (2012) states, the current capacity must be exploited on profitable basis as well. Despite Aqualectra's claims of openness towards RET, with the exception of wind energy their projects have never reached scales greater than on the experimental level. This is due to the limited financial possibilities (Tujeehut, 2012), but also due to the fact that utility

²⁷TNO is a Dutch independent research organisation with a turnover of over €0.5 billion

providers on the islands tend to be rather conservative in their decisions. It was only the recent changes in the electricity policy that forcibly raised Aqualectra's low risk aversion.

Others

With regards to other parts of the envisioned OTEC developments. Legislation affecting business operations is being significantly simplified at the moment (see section 4.2.2). In terms of education, the UNA's 'technoMBA' programme greatly financially supported by the government signals positive attitude towards modern, internationally oriented education. However, with the exception of CARMABI there is complete lack of research programmes on the island. Additionally, there are no clear indications from the relevant ministries on the long-term plans in the education sector. Similarly, the department of Economic Development does not at the moment have plans exceeding the horizon of several years Jansen (2012).

4.4.8 Island Specifics and Culture

Curaçao is, similar to other island nations, a small society. The relationships and other often informal interconnections among almost all organizations have significant impact on how businesses operate - *'everyone knows everyone'*. As Gouverneur (2012) states, the importance of strategic partnerships is high because sooner or later, one will have to confront everyone on the island - that goes not only for potential partners or suppliers, but also for governmental officials. And as GreenTown (2011) indicates, the relationships among the various actors on the island often reach rather controversial forms - e.g. some ministers are claimed to be on the payroll of the refinery's affiliates. This poses questions regarding the real drivers of changes on the island.

'Absolute transparency with respect to the desired goals and intentions of projects is critical' (Kloppenburger, 2012). Since change management on the island takes significantly more efforts than in Europe or USA, particularly those companies that want to innovate struggle. People are generally afraid of feedback, do not confront others and prefer to keep the same jobs, work tasks and stay comfortable (Martina, 2012). Additionally *'in general there is almost no willingness to cooperate and competitors often try to undermine ones positions'* (Vermeer, 2012). As a result, status quo is frequently the preferred option - and that is not a problem of education but of the people's mentality (Martina, 2012). And as Halman (2012) states, *'even when there are individuals that want to make a change, the organizational inertia prevents them from doing so'*.

These conditions are then complemented by the (physical) isolation of Curaçao from other countries. Islands are even more dependent on oil imports than continental countries, which makes them highly vulnerable (Interviewee 02, 2012). The island has witnessed lot of failures in the past. As Gouverneur (2012) believes, people tend to struggle to develop large ambitious projects, however once they are running, they will join and support it. Key of all projects is to find balance between the technology and local conditions (culture, infrastructure, weather conditions etc.). Kloppenburger (2012) perceives that there is disbelief in ambitious projects on which people tend to laugh at and not support it. This is frequently not understood by international companies who believe that business works the same ways on small islands as it does elsewhere. As a result, not having a sufficient number of (bindingly) committed customers and

thinking ‘too big’ leads to project failures. People do not believe in new technologies and only prove of the concept triggers further efforts and helps getting people on board. Guda (2012) demonstrates it by the example of Curaçao’s wind efforts that to a large extent triggered projects in Jamaica and Bonaire. Local representation of the technology provider helps projects and so does involvement of local parties as well renowned international partners (such as for instance TU Delft) (Gouverneur, 2012). The CAH SWAC project is performed by a large (government owned) player (CAH), which provides significant prove of commitment of a local organization.

These characteristics and other market specifics of island nations such as underdeveloped industrial sectors, brain drain or complete dependence on fossil fuels. As a result, Halman (2012) and Stokkermans (2012) argue that it is ‘*always very important to talk to everyone to see what hurdles there are*’ and *the one should always get all relevant parties ‘on board’ prior to starting (any kind of) project*. Large projects must take into account into these conditions. To apply this into the context of OTEC, energy experts on the island Gouverneur (2012); Guda (2012) agree that ‘*...with any energy production technologies, one must ensure that the project’s vision is in alignment with long-term plans of the key (future) stakeholders, such as Aqualectra*’.

A specific study or interview on local culture and mentality was not made and there is minimal amount of available literature on the topic of Curaçao and innovation. One exception is the work of Heijes (2011) who studied the power relations between the locals and the Dutch. The main conclusion can be summarized by this statement: ‘*Skin colour and relation with the former colonizer continue to play a major role in Curacaoan society...the power asymmetry and the sensitive historical relationship influenced perception between these groups*’. Additionally, the unpublished article of a UNA Phd candidate Rojer Jr (2011) does not on one hand provide sufficient scientific bases for solid conclusions. On the other hand however, the article’s quoted section (see below) very well fits the impressions about the local mentality and that were gained while conducting the interviews for this case study – from Rojer Jr (2011, p.7):

Sociologist Frank Quirindongo concluded that the society of Curaçao is quite unique, with its ‘protectorate’ status of the country; the population is very risk averse. This is also a hurdle for accepting innovations as the society is very limited towards an island way of thinking. Aside from this, resistance to change is quite high as the baby boomer generation and generation x tend to be loyal to the organization they work at and be employed there basically their entire career. Their position within the organization thus has immense value for them as they see it as a battle they have ‘won’. Whenever change is being implemented or innovations are run they resist as they see it as a threat to their position. It also makes it difficult for people to cooperate and link to each other because of the fear of losing the control on their responsibilities, and the consequences that could bring. According to Quirindongo, the culture of fear is also still present as a result of the slavery history. Many businesses with new ideas start but disappear after 2 years as they do not get a great enough basis to survive. Nevertheless, carefully marketed innovations have found their way and are quite successful.

4.4.9 Summary

In OTE related entrepreneurial activities (Function 1), Curaçao has been very active in the past decade. At the moment, there are **two separate SWAC** projects running, with one being openly proclaimed to provide **opportunities for other technologies** (including OTEC). The efforts in Curaçao are currently stimulated by the **introduced energy policy** and the lowered influence of the incumbent energy provider (F7). However, **lack of long-term academic and economic visions** on the island do not allow for participation of local companies and local educational organizations to participate within these projects. As a result, high level engineering expertise is developed strictly within private companies with **low involvement of academic institutions** and there are almost **no potential suppliers of OTE components**, equipment or engineering services. On the other hand, the past and undergoing projects on the island and increasing high oil prices support increasing (worldwide as well as regional) interest in OTE technologies. This has positive influence on the technology awareness on the island and the **ambitious governmental targets** (F4), there is however lack of OTEC specific knowledge (F2 and F3). The **progressive energy policy**, incentives and governmental targets all positively support the increasing share of RET on the island (Function 5).

It can be summarized that the **critical insufficiencies** can be found in Knowledge Development (F2), Knowledge Diffusion (F3) and Human and Technical Resource Mobilization (parts of F6). The other functions are fairly well covered and one could expect that by inducing the above mentioned functions (F2, F3 and F6) the whole FIS system would start reinforcing itself and ultimately support the Entrepreneurial Activities function (F1).

Several important cultural and island characteristics have strong influence on business operations on the island. It is particularly the **interconnections among the various actors** and organizations on the island and the necessity for creation of **strategic partnerships** and cooperation with key stakeholders. Narrow ‘island thinking’ and general resistance to accept innovations has also been observed by other researchers.

Summary of the FIS analysis is provided in table 4.10. Overview of the island and cultural characteristics are presented in table 4.9.

Table 4.9: Summary of the identified cultural and island specifics.

Culture	Indicator
	<ul style="list-style-type: none"> - Strong (in)formal links among almost all organizations - Importance of a strong network for business operations - Necessity for transparency - Challenging change management - Mentality preferring status quo - Physical isolation and vulnerability regarding oil prices - Disbelieve in ambitious projects - Importance of proof-of-concept, local involvement and renown partners - Importance of aligning long-term plans with stakeholders - ‘no way around them’ - Narrow ‘island thinking’ mentality

Table 4.10: Summary of the FIS analysis.

Function	Indicator
1. Entrepr. Activities	<ul style="list-style-type: none"> - SWAC project (2000-2008) - key stakeholder's bankruptcy in late stages - Two other SWAC projects currently undergoing - Cooperation between key stakeholders on the SWAC project - Two private OTEC projects in the region
2. Knowledge Development	<ul style="list-style-type: none"> - Minimal OTEC engineering expertise, environmental assessment available - Seabed surveys performed - Investments to pre-engineering works for DSW system made
3. Knowledge Diffusion	<ul style="list-style-type: none"> - Increasing number of RET conferences, genuine interest of the government - No OTEC/SWAC specific events - Knowledge/Resources sharing cooperation between the 2 SWAC projects - Minimal to none involvement of local suppliers in SWAC construction - Limited involvement of local engineering firms
4. Guidance of the search	<ul style="list-style-type: none"> - Current trend towards on-shore OTEC - in alignment with CAH's efforts - Expert & media awareness in Curaçao towards SWAC (to some extent OTEC) - Increasing attention about OTEC in journals - Curaçao not mentioned - OTEC among recommended technologies for the Caribbean - Undemanding legislation towards OTEC, no anticipated environmental issues - Favourable energy policy for RET, target of 75-25 energy mix by 2015 - Only Bonaire has more ambitious official plans - USA the only country with OTEC specific legislation
5. Market formation	<ul style="list-style-type: none"> - RET components investment allowances, tax exemptions - OTEC applicable - Estimated market for OTEC production 80MW max in Curaçao - 8MW small scale solar (awaiting connection), 7-10MW WTE plant 'proposed' - ~10% of energy produced from wind - limited further expansion - Unknown role of natural gas - Obsolete legislation on concession, progressive legislation being developed
6. Resource Mobilization	<ul style="list-style-type: none"> - Favourable natural resources - Limited market with engineers; guarded by large local companies - Expertise built up internally and kept mainly within private companies - Closure of Aruban and (potentially) Curaçao refinery potentially beneficial for OTEC - Education level upto bachelor level 'sufficient', utter lack of researchers - '80-20' law limiting employment of foreigners (exemptions possible) - Limited local banks' credit, previous SWAC financed from abroad/by large companies - Elsewhere, OTEC developments financed by government or large corporations - Absolute lack of equipment/technology for 'non-regular' procedures - No potential suppliers of OTEC components - TNO office in Aruba - potential SWAC research (no concrete steps yet)
7. Creation of Legitimacy	<ul style="list-style-type: none"> - Energy policy unanimously evaluated as positive for RET development - Market based energy sector - incumbent's low risk aversion raised - Limited financial possibilities of the incumbent - Business operations legislation being simplified - Highly subsidised internationally oriented 'technoMBA', non existing research - Lack of clear long term visions within education & economic development

Throughout the analysis of the niche an important notion has been brought out with regards to the proposed framework. It is related to the cooperation that should be according to the interviewed experts established between the niche itself and local stakeholders. In the case of OTEC the cooperation is emphasized for a number of reasons: to secure financing, permits, support of local experts, support of the university or support of the utility provider for future operations. Due to the smallness and remoteness nature of Curaçao, securing the support of the relevant stakeholders is not only the single most pronounced advise of the interviewed experts but it also appears to be the only possibility for integrating the innovation system into the local regimes and landscape. This support the validity of the points that have been observed already throughout the landscape and regime analyses – they emphasized the importance of only gradual growth and moderate overall size of the systems. The niche analysis confirmed this as it allows for sustainable (economically) development of the island itself. The unsuccessful development of the Piscadera SWAC project or the Texas Instruments factory clearly demonstrate these factors.

“Forget OPEC, here comes OTEC. Or does it...?”

ScienceBlog, 2008

5

OTEC in Curaçao Case Study Recommendations

Given the in-depth knowledge of OTEC technology and its potential in Curaçao, this chapter draws recommendations as to how to develop the OTEC Centre of Excellence in Curaçao as well as what the limitations of the island are. To a great extent, these recommendations are based on advices, experiences and insights of several key interviewees that were already outlined in section 1.6 and subsequently throughout chapter 4.

The FIS analysis of the OTEC sector in Curaçao suggested that the most significant insufficiencies are within the functions of Knowledge Development, Knowledge Diffusion and Human and Technical Resource Mobilization. The recommendations are aimed at mainly strengthening these functions and creating links between them (e.g. not only developing educational activities, but also engaging the incumbent utility provider to strengthen the relationships among the stakeholders and improve the functioning of the innovation system). Additionally the recommendations aim to build up links among the OTEC innovation system and the island's landscape and regimes – this is in alignment with the preliminary framework in figure 2.5 as well as with what the collected data about OTEC in Curaçao indicates.

For references on facts, plans and other characteristics of Curaçao, the reader should review the related sections of the analysis. This chapter does not provide any bibliographical references and assumes that the reader is familiar with the analysis presented in chapter 4.

The four pillars of OTEC CoE (education, research, operation, advisory) outlined in chapter 1 are tackled separately in this chapter and include discussion on two key areas:

Roadmap: what steps should be taken in order to accomplish the desired ‘excellence’ in the four pillars of OTEC CoE and within the presented limitations of Curaçao.

Limitations: answering the questions on what can be accomplished within a given pillar (e.g. is OTEC educational excellence dependent on the execution of the SWAC projects?)

This chapter is concluded with the summary of key risks, preconditions and possible benefits that the OTEC CoE can bring.

5.1 Research

The goals related to the establishment of OTEC research activities can be summarized in the following points:

- Engage local students and professionals (especially the ones highly qualified and currently abroad);
- Establish physical research or testing facility on the island;
- Provide a direct link to education;
- Engage foreign institutions and develop a business plan describing how the research can be scaled up to operation.

5.1.1 Action Points

At the moment, there are no facilities or demonstration units on the island that would enable OTEC R&D. Locating physical OTEC demonstration prototypes or other research units later followed by the establishment of an actual testing or research facility are the most important and concrete steps in establishing OTEC research on the island.

Without the prospects of having access to DSW and thus scaling up OTEC use from laboratory to (pre-)commercial operation, the attractiveness of OTEC research in Curaçao diminishes. With the planned start of the SWAC system's operations in 2014, a proper business plan should be developed as early as possible - it should evaluate not only what international and local partners should be involved and how to fund the research, but also the financial terms and conditions under which the use of DSW from CAH SWAC system is acceptable. Establishment of OTEC research efforts on the island cannot be based only on pre-liminary agreements that do not provide specific prices and conditions of DSW provision. This implies that starting research without a clear prospect of gaining access to DSW and scaling up OTEC operations under favourable conditions is not desirable.

In compliance with the current governmental efforts, candidates for performing the research should be sought among the students and young professionals born in Curaçao but currently living abroad – this is important for several reasons. Firstly, it would ensure the interest of the candidates to work and live in Curaçao in the long-term (i.e. 1+ years) which was identified by the interviewees as a potential hurdle in the long-term developments. Secondly, it would be in alignment with the government's targets for reversing the brain-drain. The government provides restrictions on non-local employees and on the other provides incentives for using local labour force.

Additionally, it is essential that a very strong link between research and education is established (see section 5.2 for details). This would not only make the education highly practical, but it would also provide good opportunity to properly educate the (future) experts and researchers. Scientifically recognized institutions are involved in publicizing in academic journals. In the case of OTEC, this should serve the purpose of not only raising awareness about OTEC itself, but also establishing Curaçao as centre for OTEC developments (and a future OTEC CoE). The studies performed on the island that evaluated the environmental impact of returning DSW could be the starting point for OTEC related publications. Furthermore, societal and political challenges of integrating OTEC into the energy market presented in this thesis could be another topic. However, the actual technological challenges and technological developments should be publicized as soon the actual research on the demonstration or testing facilities begins.

Lastly, the role of foreign universities and institutions should be evaluated. With no research capabilities of the UNA, the involvement of foreign universities or organizations is inevitable – both to provide sufficiently qualified researchers and to guarantee sufficient prestige of the research efforts. Historically, politically and economically the strong link between Curaçao and the Netherlands indicates the suitability of basing the research on cooperation with (part of) the Dutch 3TU¹. Evidence from innovation systems analysed in chapter 3 showed how cooperation of islands with their former colonialist can be beneficial. While this is generally due to favourable trade agreements, there are different underlying reasons for encouraging cooperation on OTEC research and education between Curaçao and the Netherlands. Firstly, steps have already been made to establish close cooperation between the UNA and TU/e. Secondly, there is a masters programme in Sustainable Energy Technologies (SET) jointly ran and supported by the 3TU. Thirdly, specifically in the field of off-shore technologies, Dutch technical universities are generally considered as global leaders. These already existing partnerships could be utilized in favour of OTEC development with relative ease as compared to initiating completely new partnerships.

This could be supported by the cooperation with the Caribbean office of TNO that expressed interest in researching SWAC. In the long term, involvement of academic and research organizations from other continents would be highly favourable as it would increase prestige, enable cooperation with a broader range of experts and create greater awareness about the efforts in Curaçao. This could for example include researchers from Taiwan or Japan where OTEC is receiving substantial amount of attention.

Based on the above paragraphs, the following actions points are recommended:

Locate a demonstration plant/unit in Curaçao in order to start establishing the island as centre for OTEC research efforts. From early stages of OTEC activities, Curaçao should poses resources (not only DSW, but also actual prototypes and testing facilities) that distinguish it from other islands.

Develop a business plan that will clearly determine under what conditions there is a positive prospect of scaling up OTEC research. This should be followed by binding agreements regarding the provision of DSW from the CAH SWAC system or potentially deploying a DSW pipe for OTEC use only.

¹3TU - Federation of the three Dutch technical universities - TU Delft, TU Eindhoven and TU Twente

Target young professional with local roots in order to gain support of the government for reversing the brain-drain and to ensure researchers' long-term engagements.

Attract foreign universities and research organizations in order to secure high quality personnel and to ensure prestige of the research efforts. This will in turn attract other organizations.

Publicize in academic and other scientific journals and media. This will allow for raising awareness about the OTEC technologies in general as well as establishing the name for Curaçao as the centre for OTEC development.

5.1.2 Limitations

Early stages of OTEC research can be to a certain degree performed on a demonstration unit without an actual access to DSW. However, some of the main challenges of OTEC development lie in scaling up the facilities, components and equipment. As a result, a natural and inevitable next step would be using DSW for OTEC research at flows that are substantially higher than simple laboratory conditions allow. This is where the role of CAH and its SWAC project come in place.

CAH openly proclaims that it will support other technologies by providing them with DSW, land and infrastructure. The question that remains is the capacity of DSW that can be reliably and at 'acceptable' price/conditions provided by CAH. OTEC would ideally require the primary ('as cold as possible') DSW, i.e. before it enters the SWAC system. The DSW pipe is however built primarily for the SWAC system and it is generally designed to work at all possible times at its full capacity. Naturally, the provision of the primary DSW to any other technology for free or below cost price would therefore not be economically wise – the question that should be therefore posed is: Is purchasing primary DSW at the cost price actually acceptable to future operators of OTEC research? How could it be overcome? To put this into context, OTEC has much higher requirements on the volumes of DSW than SWAC - e.g. only a very small 10kW OTEC research plant would require $\sim 10\%$ (30 l/s) of the total SWAC system's DSW².

The price, availability and temperatures of the DSW that could be provided by CAH's system could therefore present a significant hurdle in establishing OTEC research on the island. Regardless any preliminary agreements between CAH and OTEC research institutions, the 'acceptable' price and conditions of DSW should be based upon a properly developed business case. Similarly, the potential deployment of a DSW pipe for the purposes of OTEC research only would have to be based on an actual business case. It is for a simple reason: *'No DSW = no advanced OTEC research'*.

Additionally, there are currently no OTEC experts on the island capable of performing research. This implies that they would have to be either trained or brought in from abroad. Keeping these experts on the long-term is then a matter of being able to provide not only sufficiently attractive working environment but also appropriate compensation.

²In 1998, the most recognized OTEC research facility in NELHA produced 250kW of gross power (Daniel, 1999) – a small 10kW facility that would consume 10% of the total DSW of the SWAC system would therefore not even come close to reaching such result.

5.2 Education

The goals related to the establishment of OTEC educational activities can be summarized in the following points:

- Provide direct link to research;
- Engage local university as well as internationally recognized institutions to gain local support and increase the prestige of the education;
- Involve local experts and students to secure the support of local stakeholders, especially of the government.

5.2.1 Action Points

Despite the fact that there are no OTEC experts on the island, Curaçao does host a number of organizations and individuals that could provide highly relevant insights into OTEC education. Once the CAH's or Aqualectra's SWAC projects are executed, a number of organizations will have significant engineering and operational experience with SWAC systems including:

- **Technical expertise** (design and operation);
- **Financial expertise** (financing and gaining commitment from customers);
- and **Legal expertise** (permitting).

In addition, SWAC **environmental impact** assessments have been performed by local companies. CARMABI is an internationally recognized organization for maritime research, i.e. this implies that number of environmental experts are present on the island. Lastly, Aqualectra has significant experience with operating on an isolated/**island energy market** and as it has been mentioned several times, OTEC is particularly suited for tropical islands that have similar electricity related issues as Curaçao. These characteristics form a rather attractive combination of expertise.

In terms of political support and involvement of foreign institutions, the current **timing** is highly favourable. The generous governmental support of the 'technoMBA' program at UNA indicates the nation's interests in developing internationally competitive educational programmes. This is supported by the TNE programme of the government of Curaçao that encourages foreign universities in establishing their affiliates on the island. Additionally, the interest of universities, including the 3TU shows that the Caribbean is economically and scientifically attractive location for educational activities. This could be supported by TNO's intentions to explore SWAC technology in the region.

UNA does not at the moment possess the qualities to provide bases for neither SWAC nor OTEC education. However, it could provide a 'home-ground' to education that is based on the expertise (and technology) already located on the island. Developing OTEC education 'from scratch' could be highly challenging, but coupling it with education on SWAC would reinsure interest of higher number of candidates. As the experience from the CoEs around the world showed, it

is important for small nations to find their niche technology that they are capable of covering and for which they have sufficient (natural or human) resources. SWAC and OTEC share many principles, components and expertise and they complement each other. Lastly as the examples from around the world showed, the involvement of local institutions (UNA in this case) is essential in order to gain support of the local stakeholders, especially the government.

Based on the above paragraphs, the following actions points are recommended:

Establish educational activities focused on OTE technologies, i.e. covering both OTEC and SWAC. An attractive option could be to establish a masters programme specifically focused on OTE (likely to be the first of its kind in the world). Such a programme would built up on already existing knowledge of DSW (SWAC) systems and extend it to the field of OTEC. This would provide scope that is manageable within the small island of Curaçao and yet attractive to a greater number of students as compared to being focused solely on either SWAC or OTEC. A possible solution could be to develop a programme focused on RET in general at a European/American/Asian university(ies) and then creating a special OTE track that would take place in Curaçao.

Involve local university in order to secure the support of local stakeholders (especially the government) and ease the establishment of a study course on the island. This could be in the form of using UNA's facilities, involving local academics, teaching basics of OTE technologies in bachelor courses or providing advantageous conditions to local applicants.

Involve renown organizations from abroad that would keep the prestige of the educational activities high, ensured engagement of high quality teachers and attract further foreign universities. Potential benefits of involving the Caribbean office of TNO should examined. Presence of OTEC components manufacturers or of leading engineering firms in the field could create a win-win situation for both the education itself (gaining up-to date knowledge) as well as the manufacturers (educating the future experts). Maintaining this cooperation and concentrating OTEC knowledge on the island can also be further utilized in the next phases of OTEC CoE development (Operation, Production & Advisory).

Involve local experts and attract local students in order to utilize the already existing knowledge on the island, further strengthen the support of local stakeholders and support the government's initiatives to attract students originally from Curaçao back to the island (to reverse the brain drain). Explore the possibilities of gaining similarly attractive governmental support as the technoMBA programme at the UNA has.

Provide a link to research by directly engaging students in OTEC research (and SWAC if desired). This could be in the form of performing theses projects, practical courses or mandatory internships. Without having access to the physical OTEC prototypes, demonstration plants, or other functioning facilities, educational activities on OTEC could in fact be given in any other country around the world.

5.2.2 Limitations

OTE related education on the island could to some extent be provided by experts that are already located on the island. However, that by no means provides sufficient bases for creating a specialized educational course.

SWAC technology is only used in several places around the world. If that could be supported by the presence of an OTEC demonstration plant or in the foreseen future with an actual testing facility, Curaçao would suddenly become a unique hub for OTE technologies. The single most important part of the education would be its link to research and practical use of the technologies. This would as a result attract attention from around the world and drive the level of prestige of the OTEC CoE. Without access to the actual DSW resource and OTE facilities, the education could be performed at any other place around the world. It is so because it is logistically much easier to send individual experts from Curaçao abroad rather than bringing groups of OTE students to Curaçao.

To conclude, without actual presence of proper research, testing or operational facilities, OTE educational activities in Curaçao would not be by any means special.

5.3 Operation

The goals related to the establishment of OTEC operational activities can be summarized in the following points:

- Gradually initiating operation based on successful research efforts;
- Utilizing earlier cooperation with local stakeholders;
- Ensuring transparency of operations to guarantee support of the government, banks and allowing for the exploitation of international subsidies and incentives.

5.3.1 Action Points

Despite the high dependence on oil (prices), island nations tend to make rather conservative decisions in the energy market. As demonstrated in the analysis in chapter 4, Curaçao is not different in this respect. As stated by the local energy market regulator, under no conditions will a technology be allowed to produce electricity in Curaçao without sufficiently supporting historical data of reliable production. The experience from operating the technology under local conditions plays a very important role in that respect as well.

It is both the government (in the form of a concession) and the electricity distributor (in the form of a PPA) that must by law give consent to anyone wishing to produce electricity in Curaçao. With an unproven technology (such as OTEC), one must anticipate disbelief and cautiousness from these stakeholders. This naturally implies that the previous two sections that discussed Research and Education would play an absolutely essential role in gaining support and trust of the local decision makers responsible for the energy market.

With regards to financing, the situation is very similar. Scaling up operations and associated deployment of a DSW pipe specifically for OTEC purposes is associated with high capital investments. Having experience with the technology under local conditions (weather, DSW parameters, permits, involvement of local stakeholders etc.) lowers to a great extent risks involved with the technology use. One can only expect banking institutions to get involved in the project if not only technological uncertainties are minimized but also local specific factors (such as support of local government) are covered. With the recent changes regarding the independence of the country, Curaçao is now not eligible for some subsidiary/incentive measures. However, the island is still considered to be a 3rd world country and a SIDS and has strong ties with the Netherlands and EU. The available incentives could therefore compensate for the higher cost of electricity production – possibilities for such funding should therefore be explored.

Based on the above paragraphs, the following actions points are recommended:

Gradually scale up production from laboratory and testing facilities to commercial production. Rapid and large scale deployment of a commercial facilities lowers the chances of gaining full governmental support (trust) and would threaten the possibilities for getting finance from banks.

Engage key local stakeholders including the government and the utility provider from the early stages of OTEC activities in order to ensure their support.

Be transparent with the results of OTEC research to ensure that the key stakeholders (government, utility provider, banks) have sufficient data in support of OTEC commercial operation.

Utilize subsidiary and incentive programs available for companies operating in Curaçao. This could provide a way of compensating for higher costs of electricity production. Additionally, other means of gaining favourable conditions for operations should be exploited (such as exemptions from import duties or income taxes – these are available in Curaçao but are determined on case-by-case bases).

5.3.2 Limitations

Gradual scaling up of operations has significant advantages for the technological development of OTEC. However, as literature review on OTEC showed, the technology only becomes profitable at a certain scale. The question therefore stands as to what extent can OTEC operations be scaled up gradually and yet become profitable within acceptable period of time (assuming that the stakeholders have profitable operation as one of the goals of using OTEC CoE in Curaçao).

The island's electricity demand and the maximum penetration of OTEC permitted by local energy market decision makers presents another natural limitation on the size of OTEC production. However, successful research and operational activities in Curaçao would open opportunities in other countries in the region that face similar challenges.

Lastly, sustaining educated experts that have been involved in education and/or research could be another challenge. Keeping experts on the island in the long-term is dependent on the ability to provide sufficiently attractive job and compensation. Parts of the analysis suggest that despite

being considered an attractive location, the culture, mentality and small size of the island might prevent foreign experts from staying on the island in the long-term. Once again, involvement of local experts and those originally from the region but currently abroad could eliminate this obstacle.

5.4 Production, Services & Advisory

The goals related to the establishment of OTEC Production & Advisory activities can be summarized in the following points:

- Utilizing the experience from Research, Education and Operation;
- Engaging OTEC components suppliers and attracting them to base parts of their operations in Curaçao;

5.4.1 Action Points

Having all the expertise (research, design, financing, permitting, construction and assembly, operation) located within the island should at this stage transform Curaçao's OTEC developments into a renown innovation system, or as the project initiators refer to it the Centre of Excellence. The aim of creating reputable academic programme(s), advanced research and actual OTEC operation is to showcase Curaçao as a complex centre or eco-system for OTEC development. Transforming this reputation into proper business operations is the last missing link in turning Curaçao into the Centre of Excellence.

It is recommended that the activities in this area focus on concentrating expertise on the island related to research, planning, design, and potentially final assembly and maintenance – i.e. not on the actual production of components (see the next section 5.4.2 for details). OTEC component and services providers should be using the OTEC Center of Excellence facilities as a home-ground for their activities.

In terms of off-shore operations, the parameters of the deep harbours in Curaçao are favourable. However, the dry-docks of Curaçao are at the moment only used for maintenance of ships (i.e. not oil-platform type of vessels). The suitability of using available equipment and expertise for off-shore OTEC vessels is therefore questionable and should be further explored.

Based on the above paragraphs, the following actions points are recommended:

Utilize the experience from research, education & operation on the island into developing a knowledge based business environment that provides OTEC related services to the region and the rest of the world.

Actively involve OTEC components manufacturers in providing some of their services from the island - their presence benefits them by having access to the state of the art research and operational facilities and Curaçao profits from the increased concentration of internationally recognized firms.

Involve the operators of the harbour in order to fully investigate the potential for development, assembly and/or maintenance of OTEC off-shore vessels.

5.4.2 Limitations

Current manufacturers of the main OTEC components (pipes, heat-exchangers, turbines, generators) are located in Europe, North America and Asia. It so for numerous reasons:

- They are located near the sources (suppliers) of sub-components and raw materials;
- They are located near their main markets;
- They are located where there is low cost of labour.

There are very little economic reasons for transferring production facilities to a small island that does not possess any of these factors. Assuming OTEC turns into a commercially viable technology, there will still remain a fairly limited market for the components in the Caribbean region. E.g. heat-exchangers are complex high-tech components used across a variety of industries and transferring their production to a technologically underdeveloped country would be very challenging (especially if it is only for the purpose of being geographically close to a market of several individual OTEC plants). For this reason, the involvement of foreign suppliers and producers of components is strongly encouraged but only to the extent of testing, customizing and showcasing the technologies (and thus supporting the idea of OTEC innovation system in Curaçao).

5.5 Preconditions and Risks

Based on the analysis in chapter 4 and recommendations presented above in sections 5.1-5.4, the areas below were identified to be areas that can potentially become sources of threats in developing OTEC CoE in Curaçao. These should be closely monitored and the risks evolving from these areas should be properly mitigated.

Execution of the CAH SWAC Project

The execution of the CAH SWAC project can be considered as a precondition for OTEC development on the island. CAH SWAC project failure would not necessarily shatter all of the favourable conditions currently present on the island (deep harbours, green energy efforts, some OTE experience etc.). However, SWAC's link to OTEC and its importance in the early stages of the OTEC developments are absolutely essential.

Favourable Conditions for Using the DSW

As discussed in section 5.1, having favourable conditions for the access to the DSW is a critical aspect in the early stages of R&D. The contrary would limit the research to laboratory scaled experiments and/or highly capital intensive deployment of a DSW only for the purposes of OTEC research. It is essential that favourable conditions for having access to DSW are negotiated.

Governmental Stability and Support

All major companies on the island, including CAH are government owned. As a result, the OTEC developments are to a certain degree dependent on a stable governmental support of the ongoing projects (again, especially of the CAH SWAC project). Similarly, FDI incentives or tax benefits for green energy projects currently available are dependent on the political developments. The current government and the opposition have very contrasting views on numbers of areas. Therefore, communication with both the current government and the opposition should be established in order to ensure that major changes will not be imposed on OTEC efforts should the government change. As stated by several interviewees, the opposing parties do not necessarily condemn their respective efforts but it is important not to become one party's 'pet project'.

Participation of Local Experts

Participation of local experts is important for two reasons. Firstly, there is a number of experts in Curaçao that already have expertise in the fields highly related to OTE development. Secondly, involvement of local experts is an important step in gaining full support from the key local stakeholders. Failure to establish a benevolent network of local stakeholders significantly threatens the chances for OTEC CoE development and was numerously emphasized by the majority of interviewed experts.

Developments in the Energy Market and the Future of the Refinery

There are certain developments in the energy sector that could have serious implications for green energy technologies. Restructuring the current production facilities for the use of natural gas could greatly influence the possibilities for the integration of other base-load technologies (such as OTEC) - since the prices of natural gas are to a great extent determined by the purchased quantities, government's maximization of the gas use could limit the entry of other technologies into the electricity production market.

On the other hand the closure of the refinery could have positive impacts on the developments of other industrial sectors as the island would have to reorient its economic activities. Additionally, the closure of the refinery would suddenly fill the market with a large number of technically experienced experts.

Minimum Standards of Each of the Four Areas

The importance of interconnections between education, research, operation and advisory has been outlined already in sections 5.1-5.4. Summarized, OTEC education loses its attractiveness without a proper link to research; advanced research is practically impossible without having access to DSW; and ability to scale up research to pre-commercial scale greatly limits the possibilities to showcase Curaçao to the future markets.

5.6 Benefits

As presented in the above sections, the benefits that the OTEC CoE would bring are twofold – benefiting OTEC related companies and organizations and benefiting the island of Curaçao.

5.6.1 OTEC Related Organizations

OTEC technology is facing a difficult challenge of advancing the current pilot stage of the development into large (pre-)commercial facilities, raising the awareness about the technology among tropical nations and creating sufficient foundations (expertise). The OTEC CoE tackles all of these challenges:

Research and Education: There are currently no specialized programmes for educating future experts. Similarly, there is no environment that would cluster scholars, researchers and prospective students in order to share and develop OTEC technology. OTEC CoE would create a platform that can be utilized by universities as well as business for OTEC education and research. This should not be understood as a mere source of revenues for private companies but rather as an investment into the technology development that is directly supported by a cluster of academic as well as private institutions and that brings long term financial and non-financial benefits.

OTEC Operation and Business: The challenges of OTEC technology that have been outlined in sections 4.1.8 and 4.1.9 can only be overcome if showcase or testing facilities exist. These facilities would bring two key benefits. Firstly, universities, research organizations and companies would get ‘hands-on’ experience with the technology. Secondly, the principle, reliability and benefits of OTEC would be demonstrated in a real working environment.

As a result, it is the technology itself and the involved organizations that benefit – OTEC is further researched and the governments and the utility providers in the tropical regions have the chance to realize the full potential and reliability of OTEC. In other words, OTEC technology that is especially suitable for tropical regions and small islands is actually tested and developed in this environment.

5.6.2 Curaçao

The benefits that the OTEC CoE brings to the island of Curaçao are directly related to the challenges that the island is facing. The key two benefits for the island are:

Brain Drain: There are no technology research oriented job positions on the island. The existing market for technical specialists is highly limited and there are no indications that this situation would change in the near future. In fact, the companies in Curaçao (including the Refinery, Curoil or the Harbour) are experiencing difficulties in attracting engineers. Young talents prefer to stay abroad for higher pay, more secure jobs and more diversity and innovativeness in their work tasks. With the OTEC CoE, Curaçao could partially provide opportunities for experts in the ‘hot’ field of green energy. Many young students from Curaçao express their desire to return to the island after their studies. However, their possibilities are limited to only several large government owned companies. Similarly, attracting students back to the island while they are still abroad increases the chances of them actually returning to Curaçao after their studies.

Economy Diversification: The continuously increasing deficit of the Curaçao’s trade balance describes very well the state of the economy. ‘Everything’ is imported from oil to food and there is a minimum number of products or services being exported. The impact of OTEC CoE can improve this situation in several ways. Firstly, the use of green energy lowers the amount of required oil imports and reduces the environmental impact of current electricity production (which ultimately also has economic benefit). Secondly, OTEC CoE triggers the so called ‘smart tourism’ – visits of foreign experts, students and companies for the purpose education, research, conferences or other business related activities (again, bringing significant benefits to the island). Thirdly, the OTEC CoE will attract FDI in the form of foreign companies locating their affiliates on the island. Lastly, the ultimate goal of OTEC CoE is to generate revenues for individual companies by providing OTE related services which supports the idea of turning Curaçao into a knowledge based rather than only tourism based economy.

Energy Independence:

Table 5.1 presents an overview of the key quantified benefits of the OTEC CoE - as estimated for the early phases of the development, i.e. first ~5 years (future revenues from electricity production and OTEC plant design are added as well). The indicated benefits are only ‘educated guesses’ or guestimates and are provided for indicative reasons. They provide ranges in which the benefits are likely to be reaped (e.g. tens, hundreds or millions). It should be noted that a large part of the value created in the CoE cannot be easily quantified – such as the actual technological progress of OTEC, prestige of the CoE, technology awareness, partnerships among OTE companies, existence of synergies with other technologies etc.

5.7 Roadmap and Summary

In alignment with the lessons learnt from other innovation systems in small islands and based on the data gathered in the analysis of Curaçao, a ‘bottom-up’ approach in developing OTEC

Table 5.1: Estimated direct benefits of the OTEC CoE for the first ~5 years.

Area	Benefit
Education	# of MSc. students: 10-30/year # of locals returning/staying on the island: 2-10/year # of employed scholars: 3-5/year
Research	# of researchers: 3-5 full time Investments into research: \$100,000s/year Performed research as part of education
Production & Advisory	Number of OTE related companies located on the island: 5-15 Full time jobs: 30-50 Revenues: Advisory on OTE related engineering \$100,000s/year Platform for FDI and subsidies from IMF, EU: \$100,000s/year Revenues: ~10-20% of revenues from each developed OTEC plant ^a Revenues from production: \$0.4/kWh

^a It is assumed that 10-20% of OTEC plant development can be served with the knowledge base available in Curaçao (project development, pre-engineering, engineering), i.e. excluding production of components. For indication, based on [The Future of Energy \(2010\)](#), 100MW plant costs ~\$500mil to be built.

CoE is being recommended. The recommendations involve building up the individual blocks/pillars of the OTEC CoE in a sequential manner in order to built-up sufficient expertise for advanced OTEC operations and to ensure broad engagement and support of local stakeholders. The diagram in figure 5.1 outlines the roadmap for establishing the individual pillars of the OTEC innovation system and their proper interconnections.

The planned deployment of the CAH DSW pipe in 2014 should also be the year of actual commencement of OTE **educational activities** (focused on both SWAC and OTEC). The early efforts should be focused on attracting the 'ABC' students, involving the UNA, local experts and students from the 3TUs. In further stages, universities from other continents should be attracted as well as private companies and research organizations focused on OTE.

The **research activities** should be initiated even prior to the moment when DSW can be used. Research should provide very strong link to the education and should even in the early stages focus on planning the scaling up of OTEC operation from laboratory to (pre-)commercial scale.

Estimating the timespan for the beginning of **operational activities** is a matter of making a large number of presumptions. The key is however to guarantee a gradual expansion of the research activities to pre- and/or fully-commercial operations (possibly with the support of various incentive and subsidiary programs). This would provide the opportunities for developing sufficient operational expertise and deployment of new OTEC facilities elsewhere in the region.

The **production, services and advisory** activities should build upon the research, education and operational efforts that will provide not only technical expertise but also the actual showcase facilities.

To summarize it, the recommendations are to:

- Engage local stakeholders to guarantee their support, specifically the government and the

utility provider;

- Engage local experts, attract students and young professionals that originally come from the region;
- Attract foreign universities, research institutions, and firms;
- Publicize and showcase local facilities.

It can be concluded that on the educational and the research levels, Curaçao can under favourable conditions become the OTEC knowledge centre with a potentially global impact. OTEC operations are only limited by the market size of Curaçao and the extent to which the local authorities will be willing to become a lead user of the technology. However, even a small scale pre-commercial operation can serve as a showcase for the rest of the region - the importance of having a reliable facility is of superior importance to its actual size (i.e. its maximum production capacity). In terms of market operations and advisory in the field of OTEC, the size of Curaçao greatly limits its ability to become the location for production of OTEC components. However, by using the insights from the analysis of Curaçao, following the given recommendations and bearing in mind the outlined risks and limitations, Curaçao can by all means become the envisioned OTEC CoE that would cluster OTEC researchers, students and firms. In addition, Curaçao's harbours and expertise in the off-shore technologies could be used to explore off-shore OTEC possibilities.

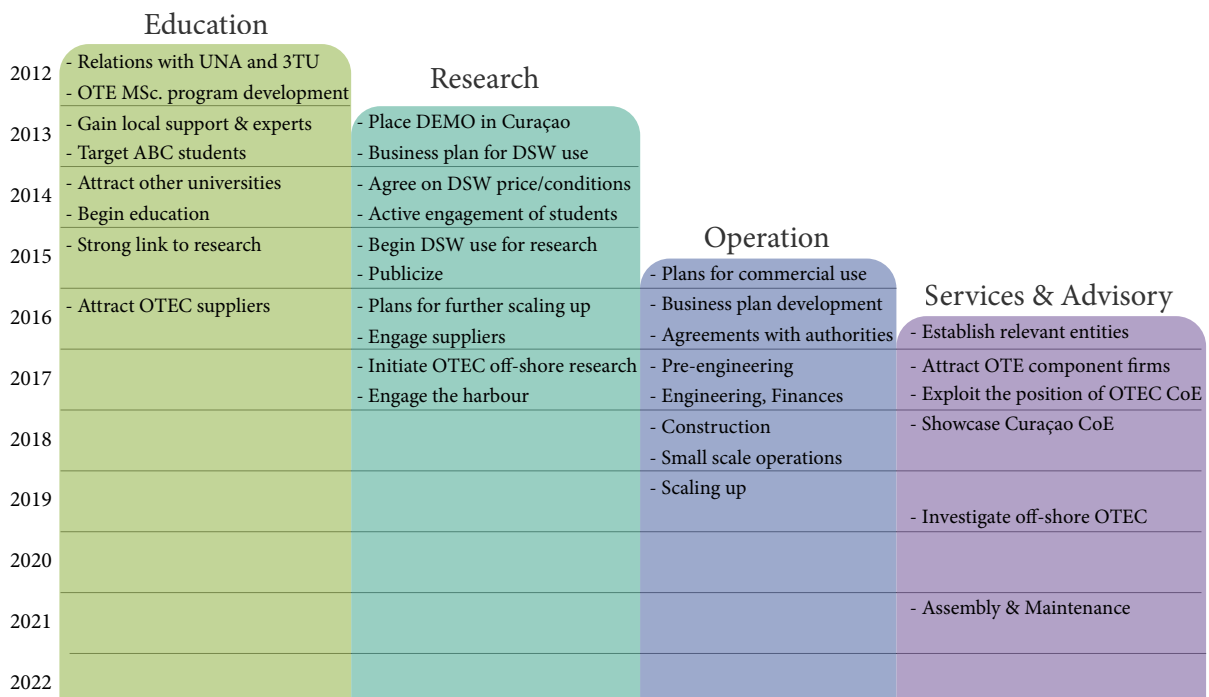


Figure 5.1: Roadmap for establishing OTEC CoE in Curaçao.

“Never before in history has innovation offered promise of so much to so many in so short a time...”

B. Gates

6

Conclusions

This chapter concludes the research by presenting the key findings. With the main objective being to *design a practically usable and generically applicable framework for guiding the development of TIS in SIDS*, a preliminary framework was proposed in section 2.4.3. Throughout chapters 3-5 this framework was tested, appropriately refined and is presented below. This chapter firstly answers the research questions. Then the scientific contribution of the thesis is presented, its generalizability and reliability, discussion and suggestions for further research are given.

1. How can the disadvantageous characteristics of SIDS be overcome when developing new technological innovation systems?

In line with the existing literature that describes the functioning of TIS in non-SIDS, it is argued that innovation systems in SIDS also need to fulfil the set of seven functions defined by the Functions of Innovations Systems (FIS) concept.

Based on the collected data, it is however concluded that in order to establish new TIS in SIDS the following two aspects need to be put in place as well: only **specific sectors** (technologies) should be targeted and their **integration into the socio-technical landscape and regimes** of the islands must be ensured.

Firstly, due the smallness and remoteness characteristics of SIDS, the targeted sectors should conform to one of the three characteristics below:

- Be either service or high-margin production rather than cost based as the islands cannot in the long term utilize scale economies, have limited markets and their operations are hindered by high transport costs;
- Utilize their location by accessing specific markets and/or;
- Utilize the specific natural resources that they have available.

Secondly, due to the vulnerabilities that SIDS face, the TIS need to be properly integrated into the socio-technical regimes and landscapes of the islands. In developed countries, the newly emerging innovation systems only gradually influence the regimes that are embedded in the stable and slow changing landscapes. In SIDS however, the impact of the TIS on the regimes and ultimately on the landscapes is much more significant and immediate. Therefore, when developing a new TIS in a SIDS, one must ensure that not only the sector prospers (companies' profits) but also that the island benefits (socio-economic growth). Since SIDS are highly vulnerable, whenever their socio-economic situation is jeopardized by the activities of the TIS, the TIS will not receive the necessary support from the key stakeholders positioned in the islands' regimes and landscapes (be it slow permit issuance, unfavourable im-/export duties, obsolete legislation etc.). As the cases of the studied TIS showed, the specific characteristics of islands make this support from the regimes and landscapes critical – this support can be seen as the TIS' 'enabler'.

It is proposed that this necessary support for the TIS' existence is reached by establishing a **strong network of local partners**. These partners will differ depending on the technology but for example in the case of energy, they would include the utility provider or the regulator. Additionally, in order to manage the impact of the sectors on the landscape the TIS should be of **moderate** sizes and should be executed **gradually** in order not to disrupt the vulnerable economies of the islands.

As a result, it is argued that TIS can only be established in SIDS when both the sectors and the islands benefit. The framework in figure 6.1 combines the FIS and the multi-level perspective and represents the above mentioned points.

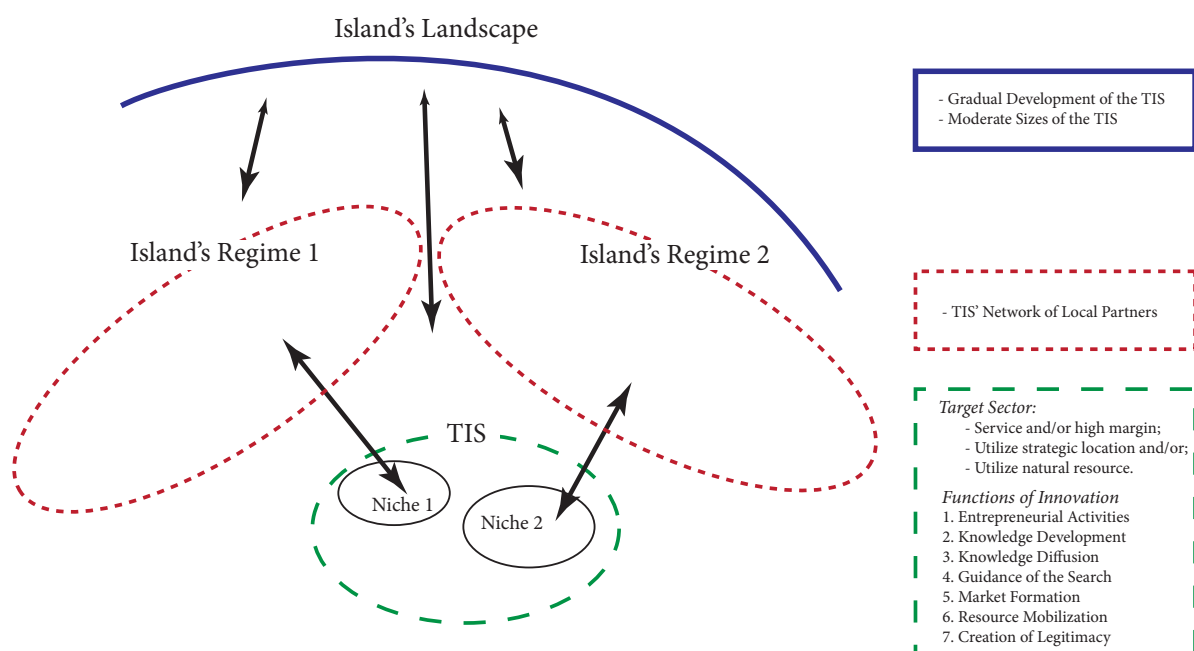


Figure 6.1: Framework for guiding the development of new innovation systems in SIDS.

A.1. What are the key characteristics of SIDS that influence the development of new technological innovation systems?

There are three major characteristics that influence the development of new TIS in SIDS – small markets, small populations (limited expertise), and the overall vulnerabilities of the SIDS.

Lack of **raw materials or components suppliers** and unavailability of **specialized machinery or equipment** are reflected in production, construction and assembly capabilities of SIDS. The limited capabilities of SIDS in this area are the main technical limitations of the islands in innovation systems' development.

Lack of technical expertise is the result of the small populations of SIDS, brain drain and the lack of quality education. Educating, attracting and sustaining technical experts and thus the overall provision of human resources on the islands is one of the main challenges in developing new TIS. The necessity to often import both human capital as well as other resources in combination with small domestic markets restricts the development of scale economies.

Conservativeness and wariness of the decision makers stem from the vulnerabilities that SIDS face. Relatively insignificant events (when looked at from the view of large or continental countries) can cause major economic or environmental setbacks in SIDS. As a result, the decision makers tend to make rather conservative decisions slowing down or hindering the development of TIS.

A.2. What methods can be used to analyse and consequently influence the development of new technological innovation systems?

In terms of the general existence of TIS, the **Evolutionary Theory** is the most recognized theory describing the complex socio-technical interactions. With its multi-level perspective, it divides societies and economies into three layers: the socio-technical landscape (the macro-level), the regimes (the meso-level) and the niches where novelties and new innovation systems (the micro-level). Innovation systems can be further be delineated by the boundaries of nations (NIS), regions (RIS) or sectors (technologies) (TIS). The **sectoral** delineation is argued to fit the purposes of this thesis the most as the boundaries of the islands are unlikely to fully enclose the boundaries of innovation systems – due to the limited size and capabilities of islands, the innovation systems are anticipated to have reach outside of them and across other regions. New innovation systems develop in niches and it was identified that for the purpose of analysing and managing a new emerging TIS applying the **functions of innovation systems** or FIS concept is highly appropriate. FIS is a set of seven functions that describe how TIS function and what their weak or strong areas are. When all functions are served, the TIS will function well. These seven functions are: Entrepreneurial activities, Knowledge development, Knowledge diffusions, Guidance of the search, Market formation, Resources mobilization and Creation of legitimacy.

A.3. Within the field of technological innovation systems in SIDS, where exactly does the existing literature fall behind?

The existing literature covers the topics of economic vulnerabilities and other specifics of SIDS very well, but fails to identify how these characteristics can be overcome when developing new innovation systems. Despite the existence of TIS in some non-SIDS islands, the literature does not address the issues of how they came to existence and how these lessons from there can be applied elsewhere. The potential benefits that these islands themselves (socio-economic growth) and the technology providers (companies' and other organizations' profits) reap from the TIS are acknowledged. Yet, the existing literature does not address strategies on how to deal with the islands' limited sizes, general lack of technical expertise or suppliers and their remoteness. Indications are given that the island states should focus on high-margin or service sectors or utilize the availability of specific natural resources. Research that focused on the development of RET in island states and on the fact that despite the abundance of RET sources islands still overwhelmingly depend on fossil fuels brought no conclusive recommendations – it is only acknowledged that the challenges are of a broad socio-technical nature.

B.1 What are the common characteristics of the existing island based technological innovation systems?

The study of five island based TIS showed some significant differences as well as important similarities among the systems. The underlying aims for initiating these systems were of various origins – government's efforts towards reversing brain drain, exploitation of a natural resource by entrepreneurs, use of cheap labour, or utilizing strategic location. The benefits that the islands or sectors reap are manifold such as economic independence or quality education, all the systems however have globally (regionally) **leading firms** in some part of the value chain and bring substantial economic benefits such profits or employment. Due to the limited size of the islands and the limited opportunities for utilizing scale economies, the island based companies generally focus on **services or small scale manufacturing**. The means that enabled the systems' existences were of a broad socio-technical nature, but they all included a strong link to **education** and cooperation with **local stakeholders**. Lastly, some specific conditions were essential for the development of the TIS and included availability of specific **natural or human resources** or **location**.

B.2. How does Curaçao currently stand with its potential to support state-of-the-art OTEC research, education, operation and advisory?

The hurdles of Curaçao's technological development are in line with the general hurdles that the literature on SIDS describes and include symptoms of brain drain or non-existent R&D sector. Specifically related to OTEC technology, there are no OTEC experts and no potential suppliers for the technology. In general, there is lack of sustainability awareness on the island, but it is a favourable location for business operations due to its **Dutch judicial system, undemanding legislation towards technology oriented projects**, favourable green energy targets, progressive energy policy and the government appears to be very supportive of initiatives that promote

smart tourism. Given the world's current economic situation, climate issues, rising oil prices, energy problems of the island, the potential regional market for OTEC and the favourable natural resources of the island, Curaçao appears to be as suitable location for OTEC developments.

The current SWAC project of the CAH is perhaps the most unique selling point that could support early OTEC developments on the island. The past and ongoing SWAC as well as windpark projects have provided large local stakeholders with important experience on how the execution of such projects should be performed. On the other hand however, the 'island mentality' and negative experience with some previous projects makes lot of stakeholders very **sceptical and unsupportive towards new technologies**. There is lack of initiative to make a major transformation from the oil-refining and tourism driven economy. The local ministries have been unable to provide long-term visions that would help diversify the island's economy in the long term. Despite these characteristics, there appear to be **no major blocking mechanisms for OTEC development**. The areas that currently lag behind related to OTEC are **knowledge development, knowledge diffusion and human and technical resource mobilization**.

B.3. What are the limitations of Curaçao in creating a technological innovation system that provides OTEC education, research, operations and advisory?

The key limitation of Curaçao is in the **production** part of the supply chain. It appears to be unfeasible to produce any major OTEC components on the island due to the complete lack of high-tech manufacturing expertise, lack of raw materials or sub-components suppliers as well as a lack of other industries besides OTEC (and possibly SWAC) that could utilize the components. With regards to off-shore OTEC, the local harbours are deep and suitable for mooring large vessels. However, the drydock is at the moment only capable of handling regular ships and not the oil platform types of (OTEC) vessels. The UNA on its own does not at the moment have the capacity to support OTEC related education on a state-of-the-art level. The ability of performing OTEC related research is to a great extent limited by the willingness and **possibilities of CAH to provide DSW** under favourable conditions. In that sense, early OTEC research is fully **dependent on CAH**. In terms of OTEC operations, the natural limit for OTEC is set by the size of the island's market but can be greatly expanded within the region.

B.4. How have the past and existing technology related projects been influenced by the SIDS characteristics of Curaçao?

Several projects can be outlined to demonstrate how their success (failure) has been accomplished. The 'Piscadera Bay' SWAC project (2000-2008) was ultimately unsuccessful due to a bankruptcy of one of the stakeholders. However, even prior to that significant delays occurred due to financing issues and disputes with the government and the utility provider. Past windpark projects ended up being a success (the windmills were operating). However, there have been some operational issues due to lack of expertise, bureaucratic issues among the utility provider, the government and the operators and financing issues that caused the windpark operations to be stopped. Lastly, a major economic disruption was caused in late 1960's when production facility of Texas Instruments employing 2000 employees was shutdown after only

a few years of operations. The facility was set up on the island mainly due to favourable tax conditions. Once the incentives were revoked, the facility was shut down.

Undergoing SWAC projects are perceived by local actors as being highly transparent and involving cooperation among various institutions. As a result, there have been no significant delays or issues with any major stakeholder. Similarly, the recently successfully commenced operations of the windpark can be observed as results of solid cooperation among the government, utility provider, technology provider and banking institutions. There is a successfully running TechnoMBA programme that involves cooperation of the UNA and TU Twente and that is receiving substantial financial support from the government. The reasons standing behind this support is a clear alignment of the TechnoMBA's purpose with the governmental efforts towards turning the island into a knowledge economy.

B.5. What steps should be followed in order to develop a state-of-the-art OTEC innovation system in Curaçao?

A **bottom-up approach** with strong **involvement of local stakeholders** specifically with the UNA, Aquallectra and CAH is recommended. The ultimate goal is to align the needs and desires of OTEC technology providers with the efforts of the government towards reversing the brain-drain and turning Curaçao into a knowledge economy. With the planned beginning of the CAH SWAC operation in 2014, efforts aimed at developing an educational programme should be initiated immediately – possibly by creating a clear blueprint that will lead to the establishment of a specialized OTE MSc. **programme** between the Dutch 3TU and the UNA. Only in the later stages should other **international institutions** be attracted. Research should be strongly and practically **linked to the education** and in the very early stages should a demonstration unit or facility be built on the island. Specific focus should be put on attracting **local students** currently studying abroad. With regards to OTEC research, conditions for the supply of DSW from CAH must be determined as soon as real working data of the CAH SWAC system are available. The OTEC related education and research should attract to Curaçao **components suppliers** and other technology providers in the field of OTEC for the purposes of component and design testing which should help establish Curaçao as the OTEC showcase in the region or globally. Scaling up the research efforts should lead to the development of a pre- and potentially also a fully-commercial facility. The ultimate goal should however not be the deployment of an as-large-as-possibility facility but rather a state-of-the-art facility that is being **showcased** around the world. By this time, OTEC researchers, component providers and other OTEC technology providers should recognize Curaçao as the centre for OTEC developments and locate their operations on the island as well.

6.1 Scientific Contribution

As already outlined in the opening chapter, this thesis contributes to the body of knowledge by:

- Providing extensive amount of data about a SIDS (Curaçao) with focus on the development of an innovation system;

- Identifying key parameters that make the development of innovation systems in SIDS challenging.

The Data

No literature, article or report was identified that would provide (anywhere near) the amount of qualitative and to some extent also quantitative data on the topic of SIDS and TIS as this thesis. The primary collected data provided unique insights for the purposes of this thesis but can ultimately serve for future research. The conclusions of this thesis are based on data from multiple sources (interviewees) that often perceive their challenges in very contradictory matters, e.g. utility vs technology provider. It is argued that these insights provide an authentic view into the challenges that the islands impose on technology development. While the 'top level' overview of the existing TIS (chapter 3) that utilized available data proved to be very useful in terms of analysing the core characteristics of the sectors, it did not provide views on the roots of how the systems really function and how they came to existence. And this in fact appears to be the main challenge in better understanding TIS in SIDS. While the basic characteristics of SIDS such as non existing R&D sectors, technological underdevelopment or lack of technical skills are clearly articulated in the literature, they tend to be presented in black or white – existent or non-existent. It is argued that the available literature and data only presents 'superficial' information on SIDS with regards to TIS.

On the other hand, referring to the performed in-depth case study, many literature sources for example mention Curaçao's Piscadera Bay SWAC project. However, neither the fact that the project was halted nor for what reasons is scrutinized. During the interviews the involved actors provided detailed overview of the project's main challenges and these often differed depending on the interviewee's role in the project. The collected data and subsequently the given recommendations are based on understanding the various viewpoints and the various hurdles that have in the past been imposed on technology developers.

This thesis therefore not only provides its own conclusions but also unlocks new opportunities for further research by providing extensive amount of qualitative data.

Understanding the Functioning of Innovation Systems in SIDS

By combining the available theories on innovation systems with the knowledge on SIDS, this research began with a hypothesis that the impact that TIS can have on the actual islands (states) is of such significance that it cannot be overlooked. In hindsight this hypothesis proved to be correct. It is argued that the links between the TIS' and the actual islands are so significant that they cannot be ignored

Given the limited number of SIDS' suppliers, service providers customers, experts, permit issuers or policy makers, technology providers and other innovation systems developers have very restricted possibilities in terms of their own development. In many ways, the island states cannot be seen as fully open economies – there are limitations in terms of their capacity to provide human capital or supplier resources and there are obstructions that can incur with the

public administration (due to the relative simplicity of the public sector and the lack of specialized departments or regulatory bodies). It appears to be inevitable that new TIS need a 'push' from the regimes and landscape that would enable their existence (as observed on the existing innovation systems, this could be in the form of lowered import or export duties, streamlined issue permitting or other incentives). The critical part is however that this 'push' becomes the 'enabler' and not the 'driver' of the TIS. It is the underlying comparative advantage (strategic location, specific resource, human capital etc.) that must drive the TIS in the first place. The islands themselves can then benefit significantly from the presence of the TIS as they allow them to socio-economically grow and ultimately reduce their vulnerabilities.

On the contrary, the sectors have immediate and potentially significant impacts on the islands. Should they be benefiting from some of the islands' comparative advantages (and the above discussed 'enablers') they naturally should conform to the needs of these islands and not jeopardize their socio-economic growth with their activities. The framework proposed in this thesis proposes to manage the impact of the sectors on the islands by monitoring the sectors gradual growths and sizes. However, the key message behind lies in ensuring that the TIS are properly integrated into the islands' economies (landscapes and regimes). Then not only do the entrepreneurs and other technology providers benefit, but also the islands themselves.

Available literature (e.g. [Chang and Chen \(2004\)](#)) state that the national and sectoral boundaries of innovation systems can provide complementary views on the development of innovation systems. The conclusions of this thesis however indicate that in the case of SIDS the two views cannot be separated in the first place and must in fact be used together as complementary.

6.2 Generalizability and Reliability

This research was centred around two terms: TIS and SIDS. While driven by the existing theories in the early phases of the research, the proposed framework is to a great extent based on the data from one island (Curaçao) and one technology (OTEC). The time constraints and the lack of data only allowed for a no more than simplistic analysis of other already existing island based TIS. However, useful insights for the framework were captured there as well.

6.2.1 Generalizability

Generalizability to Other Innovation Systems

The extent to which the proposed framework is applicable to other types of TIS than OTEC has not been verified as it was only fully applied to this one particular case study. However, in the process of arriving at the final framework the input from non-energy related fields on the island of Curaçao had been used (e.g. oil-refining or harbour services). Additionally and as mentioned above, some insights were also adopted from the review of existing island based TIS around the world. As a result, the final framework does account for the differences that occur among the different types of technologies. However, this was only achieved at the expense of

defining parts of the framework in a very broad rather than specific manner. Two particular parts of the framework share this ‘indefiniteness’.

Firstly, regarding the choice of a sector – the framework states that technologies that are not low labour cost focused or that do not require scale economies should be targeted in SIDS. This characteristic was derived from the existing literature, however it is in itself rather obscure. While its implications are apparent in extreme cases (e.g. mass car manufacturing vs yacht customization and maintenance) there are no clear definitions as to what is still suitable to be performed on a SIDS and what is not – e.g. are there any limits in the size of the production?

Secondly, regarding the adjustment to local conditions – the framework implies that close relationships with local stakeholders must be maintained. This aspect was by far the most intensively emphasized factor during the data collection and the experience from past projects on the island clearly demonstrated its importance. It is so because the close cooperation can help better manage the vulnerabilities of SIDS. However, it is very clear that different technologies will require cooperation with different stakeholders and at different strengths. For example, in the case of OTEC in Curaçao it is recommended to maintain strong relationships with local utility provider, regulator and university. It is by all means possible that other technologies would require cooperation with other institutions.

As a result it is argued that the final framework is generalizable to a very wide variety of technologies but only at the expense of being broadly defined. The framework outlines and emphasizes the key aspects for the development of TIS in SIDS but leaves it up for the potential project initiators to identify the specific requirements. Further research is suggested in section 6.4 to help reduce the generalizability issues of the framework in this particular area.

Generalizability to Other SIDS

The generalizability of the framework to other SIDS is influenced by two factors. Firstly, the main case study was only performed on one single island. Secondly, the group of SIDS is not an entirely homogeneous group with regards to sizes, cultures and locations.

It was attempted to reduce the impact of performing the study only on one island by reaching out for experts with experience from other SIDS (e.g. [Guda \(2012\)](#) or [Nicastia \(2012\)](#)). Additionally, the data collected in Curaçao indicated that the characteristics of Curaçao match the general characteristics of SIDS described in the literature almost perfectly. While none of the interviewed experts had any experience with SIDS outside of the Caribbean region, there are no indications that the specifics there would differ significantly from the specifics of Curaçao (and from the specifics described in the literature). Section 6.4 on further research discusses that applying this framework to other SIDS would be desirable in order to further study the framework’s generalizability.

The second issue is related to the group of SIDS itself. While presented by the [United Nations \(2012\)](#) as a relatively homogeneous group, it was already stated in section 2.1.1 that several islands differ in some specific characteristics (e.g. Dominican Republic with 8.5 million inhabitants). While differences among the islands do appear, they are considered by the literature as rare. This ‘weakness’ of the definition of SIDS was not tackled in this thesis. The departure

point was clearly defined by the general characteristics of SIDS described particularly in the works of Briguglio (1995, 1998); Nurse et al. (2001); Turvey (2007). The framework was developed based on the characteristics of SIDS identified by these authors and the data collected in Curaçao. Should these characteristics not be applicable to some of the SIDS, the generalizability of the framework to these states is naturally unclear. In other words, if a certain SIDS does not exhibit the characteristics of SIDS described in the literature (and that were taken as granted in this research), then the applicability of the framework to this state is unclear. No such island is explicitly mentioned in the literature to differ significantly from the others. Similarly, it is apparent that some of the characteristics of SIDS (remoteness, relatively small population etc.) are applicable to other non-SIDS states (e.g. Israel). It was not in the scope of this thesis to identify whether any of the recommendations are applicable to states outside of the SIDS group.

6.2.2 Reliability

Results are considered to be reliable if they can be achieved repeatedly. In the performed research, three particular aspects could have affected the reliability. The types of data sources that were used, the way these data sources were used and the choice of theories.

Firstly, it has been discussed several times throughout this thesis that the availability of credible data, reports or statistics is much lower in SIDS than in the developed countries. As a result data sources such as news, company websites or even promotional brochures had to be used in moments when similar information in the developed states would be easily accessible from credible sources. This was for example the case when mapping the trends in the developments of regional electricity prices. There does not appear to be any way around this drawback. It can only be hoped that with the increased attention that SIDS receive, the situation may improve with time. Despite this, it is argued that the questionable credibility of the used data had minimal impact on the overall results as the research was predominantly of qualitative nature and the less credible data sources were only used to demonstrate trends or developments rather than outline precisely certain characteristics (such as in the case of electricity price trends).

Secondly, the personal interpretation of the qualitative data may have had impact on the overall reliability of the research. In order to avoid this, several methods were used. The method of triangulation was applied whenever possible. As a result, literally all key outcomes of the case study analysis are supported by multiple interviewees. Additionally, majority of the interviewees approved the disclosure of the interview summaries in this thesis. While some interviewees will remain undisclosed, it is possible to review most of the interviews in appendix C. Also it was attempted to quote literally the interviewees whenever possible in order to explicitly show their insights. Lastly, the thesis supervisors provided important feedback to ensure independent results.

Thirdly, whether one would arrive at the same framework should this research be repeated greatly depends on the key theories that would be selected in the available literature. Throughout chapter 2 several choices were made (e.g. using the FIS instead of the SNM methodology). The motivations for making these choices are explicitly presented in the relevant sections. Should the choices be different, the research would naturally lead to the development of a framework that may visually be different than the one presented here. However, due to the approach

used in the case study it is argued that the potential framework would have similar features as the actual one presented in this thesis.

6.3 Discussion

6.3.1 The Choice of FIS over SNM

The choice of using the FIS instead of the SNM theory had significant impact on the final framework as the framework itself is based on the seven functions. The choice was made in order to better reflect on the technology that was to be studied in the in-depth case study. SNM is particularly suited for concrete technologies and artefacts that are already available and that can be tested in a pilot. While very significant overlap in the usability of these theories exists, the choice for FIS theory is being justified by the fact that it is potentially applicable to innovation systems at any stage of the development. Nevertheless, the critical question is whether the choice of theories had any significant impact on the overall conclusions of this research. It is argued that while the actual framework that was developed would naturally consist of different components, the underlying message of this thesis (the scientific contribution) would remain unchanged. The broad approach to the problem, the data sources and the methods of analysis would have not been changed. As a result, the connections between the innovation systems and the islands' landscapes and regimes would still be found.

6.3.2 The Choice of TIS for the Cross-Case Study

One very relevant objection can be made regarding the choice of TIS for analysis in chapter 3. It is only the 'success stories' and not failures that were reviewed. This is undoubtedly a weakness of the research. The reasons for only evaluating success stories are twofold: data availability and time constraints. It has been said before that the availability of data about island states is very limited. This is even more significant when it comes to failures as it is generally the success stories that receive the most attention. It was not possible within the given time constraints to identify data sources and perform data collection for other islands in the same way as it was done for the case of OTEC in Curaçao.

Secondly and also related to chapter 3 it would have been beneficial to provide direct comparisons of TIS in island states with their counterparts parts in developed countries (e.g. the textile industry in Mauritius vs textile industry in Asia). This was not performed for the same two reasons mentioned above. It would have been challenging to set up a structure for a direct comparison of the TIS given the limited data and time constraints.

It must be however concluded that tackling the two above discussed areas would improve the overall rigidity of the framework and is thus proposed for further research in section 6.4. In hindsight, more efforts should have been devoted to attempting to at least partially address the issues.

6.3.3 Practical Usability of the Theories

With regards to the practical usability of the two theories, several weaknesses have been identified. Firstly, the multi-level perspective defined by the evolutionary theory naturally has an ‘infinite reach’ – there are no boundaries as to where the analysis should end. The decision has been made in this research to collect the data until ‘saturation’ – i.e. until the moment when very little new insights come out of the data collection. This is a rather challenging process particularly when the main source of data is interviews (mainly because interviews must generally be arranged in advance which makes the entire data collection process very lengthy). This leads to the second weakness of the multi-level perspective (from the perspective of the actual data collection). The available literature does not provide a structure to the analysis of the landscape and the regimes. This makes using it in practice rather difficult – one needs to define its own structure and then seek various sources to see if all relevant factors have actually been tackled. While FIS does not provide the ultimate ‘cookbook’ for analysis, it very clearly defines the structure as well as possible indicators to be used. From that point of view, FIS is much more practically usable and ‘user friendly’ than the multilevel perspective itself.

6.3.4 Influences on the Researched TIS

The data collection that was performed in Curaçao has in itself been an experience that clearly demonstrated the characteristics of SIDS. It was relatively easy to get access to ‘highly’ positioned managers or policy makers – there is a significantly lower number of layers in the hierarchy of organizations as compared to Europe. Similarly, everyone indeed knows everyone on the island (almost literally). This can have significant impact on the actual TIS. By performing research on a currently (or in the near future) developing TIS, one already shapes the fulfilment of the FIS. The small-scale and the small populations of SIDS have a major influence in this respect – within a few days of the data collection, *‘all people in the energy sector knew that there was a student performing research on OTEC technology that some Dutch start-up company is working on.’* Research about a newly developing technology on a small island raises a lot of attention which in turn raises the general awareness about the technology, about the involved companies and about the envisioned plans.

6.3.5 Neutrality

Performing research on a TIS that is currently under development is challenging – namely in the sense of maintaining an unbiased (neutral position). Having the status of a student or a researcher supervised by a neutral institution (Delft University of Technology in this case) increases the legitimacy of the research. However, from a subjective point of view it was observed that several interviewees still indirectly expressed some level of distrust and suspicion about the real intentions of my research (*‘why are these particular companies really sponsoring the research?’*). Not only from the researcher’s but also from the subjects’ points of views, it is difficult to maintain neutral atmosphere – in other words, it is difficult to perform research on a currently (or in the future) developing TIS, receiving funding for the research from external parties and

still maintaining a neutral position. The challenges therefore are to access funding from neutral sources, ensure proper supervision from unbiased experts and to reassure the interviewee that purely scientific research is being performed.

6.3.6 Cultural and Psychological Specifics of SIDS

The psychological or cultural aspects influencing TIS' development have only minimally been tackled in the analysis itself. From a (non-expert) subjective point of view the locals are much more open, welcoming and supportive than their European counter parts (on personal bases). On the other hand, there is a great amount scepticism, disbelief and wariness with regards to new technologies or ambitions to transform the situation on the island. The status-quo seems to be preferred both for pragmatic reasons (the islands' environments are fragile), but also for cultural reasons. These observations are therefore in alignment with the only two available sources of literature on the topic presented in section 4.4.8.

Overall, what appears to be a 'cultural' resistance towards innovation has not been tackled in any significant manner. Neither in the literature review nor in the data collection and is one of the weakness of the research. It is therefore one of the issues that further research should address.

6.3.7 Summary

In retrospect, the choice of methods and theories for this research project proved to be justified and in overall provided a comprehensive approach to solving the problem on hand. The sources of the most important weaknesses seem to stem from the vagueness (infinity) of the socio-technical landscape and the regimes. Looking back at the data collection, less landscape and regimes related data should have been collected and more focus should have been put on FIS. Not that the FIS analysis has any strong weakness, but more focus could have been put on studying several specific and important aspects: the relations between Curaçao and the Netherlands (EU) or the availability of funding from international organizations such as IMF or UN. This would mainly reflect in improving the practical recommendations related to OTEC and Curaçao. These topics will however be specific for each SIDS.

6.4 Further Research

This research has tapped on a number of issues that could be further scrutinized.

6.4.1 'Homogeneous' Group of the SIDS

United Nations assigned the status of SIDS to a variety of islands (size- as well as location- and culture-wise). While the proclaimed common characteristics of these islands were by all means

also confirmed by Curaçao, the question remains whether any major discrepancies among the SIDS exist. Curaçao has with its 150,000 inhabitants proved that it can have an internationally competitive MBA programme, it is soon to have a state of the art SWAC system and it is in advanced stages of becoming a space port. But where are the limits? Can for example an island of 50,000 people support such developments as well and can it actually have a fully functioning economy and TIS? Similar questions arise for the very large SIDS. Does the Dominican Republic with its 8.5 million inhabitants really share most of the specific characteristics of SIDS? Knowledge from these areas would allow to better (dis)approve the generalizability of the proposed framework.

6.4.2 Suitability of Technologies for SIDS

The case study used in this research was about a technology that is particularly suited for SIDS and can only to a limited extent be utilized in regular continental countries. Are these types of technologies the only ones that can be used to develop a fully functioning TIS? Or should the island become small-scale test or experimental centres? Their size makes them very suitable for testing technologies such as electric vehicles or mobile technologies. On the other hand, SIDS have very fragile economies and environments – should such environments be exploited for the purposes of technology testing and development?

6.4.3 Limits of SIDS

The case study showed that the major limitation of Curaçao lies in the production of OTEC related components. The rest of the supply chain could by all means be served within the island itself. This points relates to the points outlined in sections 6.4.1 and 6.4.2 – what are the limits of SIDS in supporting TIS? Are these limits technology specific or are the possibilities of SIDS a simple function of the SIDS' size – in terms of their production, service or import and export capabilities?

6.4.4 Motors of Innovation in the Context of SIDS

The literature review in section 2.3.3 described the self reinforcing loops in FIS and the concept of motors of innovation (when the strength of several functions drives the entire TIS. This concept was implicitly applied to the case of Curaçao (by focusing on functions 2, 3 and 6 in the recommendations). Curaçao has for example the advantage of having a freshly introduced legislation that reorganized the energy sector but this is probably not the case for the majority of other SIDS. Further research could therefore investigate what the 'baseline' or minimal requirements for each function are in order for the rest of the functions to be able to overcome it (in the case of energy the new legislation for example 'takes care' of function 7).

6.4.5 Multilevel Perspective Analysis

One of the outlined weaknesses of the used approach was related to the lack of structure in the multi-level perspective. While the analysis of the socio-technical landscape and regime proved to be very helpful for the case study, the available literature does not provide any guidance on how this analysis should be structured. Are there generic frameworks, structures or indicators that could be used to effectively perform analyses? What factors from the landscape and regimes should be addressed in order to properly support the FIS analysis?

6.4.6 Impact of Culture

Impact of the island mentality on innovation has not received much attention in this thesis as the focus was put on structural challenges related to the establishment of innovation systems. The resistance of locals towards change indicated by several interviewees could have impact on the overall success of innovative efforts on the islands.

Written Sources

- AEPC. Trade guide. Preliminary data on global trade for 2007, April 2008. URL <http://aepec.fibre2fashion.com/vol1issue29/>.
- Alkemade, F. and Suurs, R. Patterns of expectations for emerging sustainable technologies. *Technological Forecasting and Social Change*, 2011. ISSN 00401625. doi: 10.1016/j.techfore.2011.08.014.
- Amigoe. Red tape with permits is ancient history. Article Available Online, April 2012. URL <http://amigoe.com/english/107910-red-tape-with-permits-is-ancient-history->.
- Antilliaans Dagblad. Eco-industruepark bij luchthaven, July 5 2011a.
- Antilliaans Dagblad. Project oceaaenergie voor luchthave wint ontwerpwedstrijd, July 9 2011b.
- Aqualectra. Tabel Productiecapaciteit 2002. Available Online, 2002. URL http://aqbottling.com/table_022.html.
- Aqualectra. Aqualectra, the Pioneer of sustainable energy in the Caribbean. Report, Available Online, April 2012. URL <http://1657620.sites.myregisteredsite.com/images/stories/durable%20energy%20website.pdf>.
- Armstrong, H. and Read, R. Western european micro-states and eu autonomous regions: the advantages of size and sovereignty. *World Development*, 23(7):1229–1245, 1995.
- Armstrong, H. W. and Read, R. Comparing the economic performance of dependent territories and sovereign microstates. *Economic Development and Cultural Change*, 48(2):285–306, 2000.
- Armstrong, H. W. and Read, R. The determinants of economic growth in small states. *The Round Table*, 92(368):99–124, 2003.
- Avery, W. H. and Wu, C. *Renewable energy from the ocean: a guide to OTEC*. Oxford University Press, USA, 1994. ISBN 0195071999.
- Bahamas Electricity Company. Quick facts. Online, 2012. URL http://www.bahamaselectricity.com/about/quick_facts.cfm.
- Baldacchino, G. The other way round: manufacturing as an extension of services in small island states. *Asia Pacific Viewpoint*, 39(3):267–279, 1998. ISSN 1467-8373. doi: 10.1111/1467-8373.00069. URL <http://dx.doi.org/10.1111/1467-8373.00069>.
- Baldacchino, G. Successful small-scale manufacturing from small islands: Comparing firms benefiting from locally available raw material input. *Journal of Small Business and Entrepreneurship*, 18(1):21–38, 2005.
- Baldacchino, G. and Bertram, G. The beak of the finch: insights into the economic development of small economies. *The Round Table*, 98(401):141–160, 2009.

- Basu, S. R. and Das, M. Export structure and economic performance in developing countries: Evidence from nonparametric methodology. *Policy issues in international trade and commodities study series n. 48*, pages p.1–18, 2011.
- Bellinger, R. Makai Engineering: Re-Installation of a Sea Water Air Conditioning System LOL T-8. Report, 2009.
- Bergek, A., Hekkert, M., and Jacobsson, S. Functions in innovation systems: A framework for analysing energy system dynamics and identifying goals for system-building activities by entrepreneurs and policy makers. *Innovation for a low carbon economy: economic, institutional and management approaches*. Edward Elgar, Cheltenham, pages 79–111, 2008a.
- Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., and Rickne, A. Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research Policy*, 37(3):407–429, 2008b. ISSN 00487333.
- Bergman, J. Temperature of ocean water, 2011. URL <http://www.windows2universe.org/earth/Water/temp.html>.
- Berlew, D. E. and LeClere, W. E. Social intervention in curaçao: A case study. *The Journal of Applied Behavioral Science*, 10(1):29–52, 1974.
- Bluerise BV. About Bluerise BV, 2012a. URL <http://www.bluerise.nl/>.
- Bluerise BV. TU Delft team wins 2011 Design Challenge with Curaçao Ecopark, 2012b. URL <http://www.bluerise.nl/2011/07/tu-delft-team-wins-2011-design-challenge-with-curacao-ecopark/>.
- BPM. Sustainable practices among BPM members. Analysis Sustainability Questionnaire within the Curaçao Business Council for Sustainable Development, January 2011.
- BPM. Curaçao Eco-Vehicle Seminar 2012, 2012. URL http://www.bpmcuracao.com/index.php?option=com_civicrm&view=Events&Itemid=16.
- Bregman, R., Knapp, R., and Takahashi, P. Design considerations for ocean energy resource systems. *OCEANS'95. MTS/IEEE. Challenges of Our Changing Global Environment. Conference Proceedings.*, 2: 1084–1091, 1995.
- Briguglio, L. Small island developing states and their economic vulnerabilities. *World Development*, 23 (9):1615–1632, 9 1995.
- Briguglio, L. P. Small country size and returns to scale in manufacturing. *World Development*, 26(3): 507–515, 1998.
- BT&P. The 2012 Curaçao Conference and Expo on the Future of Durable Energy, 2012. URL <http://energiakonsiente.com/en/agenda/general/>.
- CAH. Curaçao Airport embracing renewable energy from the ocean. Press Release, Available Online, August 2010. URL http://www.otec.tudelft.nl/fileadmin/UD/MenC/Support/Internet/TU_Website/TU_Delft_portal/Samenwerken/Samenwerkingsmogelijkheden/Contractonderzoek/Design_Challenge/X030_OTEC-wegX/doc/Press_release_CAH-Bluerise_-_english.pdf.
- CAH. Curaçao airport holding n.v. Company profile, 2012. URL <http://www.ca-holding.com/>.
- Caniels, M. C. J. and Romijn, H. A. Strategic niche management: towards a policy tool for sustainable development. *Technology Analysis & Strategic Management*, 20(2):245–266, 2012/06/13 2008. doi: 10.1080/09537320701711264.

- Carbon Dioxide Information Analysis Center. Carbon Dioxide Emissions per Capita. Statistical Data, Available Online, 2008. URL <http://mdgs.un.org/unsd/mdg/Data.aspx>.
- Caribbean Electric Utility Service Corporation (CARILEC). Electricity Rates Across the Region. CARILEC Tariff Survey Among Member Electric Utilities, Available Online, June 2011. URL http://www.myjpsco.com/_pdfs/rates_across_the_region-June2011.pdf.
- Caribbean Policy Research Institute. Energy Diversification & the Caribbean. Policy Regulation Document available Online, 2009. URL <http://www.capricaribbean.org/research/energy-diversification-caribbean>.
- Carlsson, B. Internationalization of innovation systems: A survey of the literature. *Research Policy*, 35 (1):56–67, 2 2006.
- Carlsson, B. and Stankiewicz, R. On the nature, function and composition of technological systems. *Journal of Evolutionary Economics*, 1:93–118, 1991. ISSN 0936-9937. 10.1007/BF01224915.
- CBS. Valero to close Aruba refinery, March 2012.
- Central Bank of Malta. Malta's economy on the path to the Euro. Report, Available Online, July 2007. URL http://www.centralbankmalta.org/updates/downloads/pdfs/maltese_economy_euro.pdf.
- Centrale Bank van Curaçao en Sint Maarten. Cbcs measure. Press Release, Available Online, March 2012a. URL <http://www.centralbank.an/index.php?eid=2101>.
- Centrale Bank van Curaçao en Sint Maarten. Balance of payments: Union Curaçao and Sint Maarten. Report, Available Online, May 2012b. URL <http://www.centralbank.an/index.php?eid=1238>.
- Chang, Y. and Chen, M. Comparing approaches to systems of innovation: the knowledge perspective. *Technology in Society*, 26(1):17–37, 1 2004.
- Chen, C.-F. and Sewell, G. Strategies for technological development in south korea and taiwan: the case of semiconductors. *Research Policy*, 25(5):759–783, 8 1996.
- Chuhan-Pole, P. and Angwafo, M. *Yes Africa Can: Success Stories from a Dynamic Continent*. The World Bank, 2011.
- Commonwealth Secretariat. Small states: Meeting challenges in the global economy. *Report prepared for the Commonwealth Secretariat/World Bank Joint Task Force on Small States*. Washington, DC, April, 2000.
- Conway, G., Waage, J., and Delaney, S. *Science and Innovation for Development*. UK CDS, 2010. ISBN 978 1 84129 0829. URL http://www.ukcds.org.uk/publication-Science_and_Innovation_for_Development-172.html.
- Cooper, D., Meyer, L., and Varley, R. Otec commercialization challenges. *Offshore Technology Conference*, 2009.
- Crews, R. Otec sites. *Aquarius Rising Maldives - An Ocean Research Centre and Eco-tourist Facility*, 28, 1997.
- Curaçao Bureau of Statistics. Statistics yearbook netherlands antilles 2000. Publication, Available Online, 2009.
- Curaçao Bureau of Statistics. Statistical orientation curaçao 2010-2011. Publication, Available Online, March 2012.

- Curaçao Ministry of Economic Development. The investor's guide to the welcoming island of Curaçao - a complete guide to investing in a one of a kind island. Report, Available Online, June 2010. URL http://www.curinvest.com/files/english__1278366280.pdf.
- Curaçao Ministry of Economic Development. Curaçao Economic Outlook 2011: En route towards strengthening of the economic structure of new country Curaçao. Report, Available Online, January 2012. URL http://www.curinvest.com/downloads/curacao_economic_outlook_2011.pdf.
- Cyprus Profile. Entering a renaissance in manufacturing. Online Article, April 2012. URL <http://www.cyprusprofile.com/en/sectors/manufacturing-and-industry>.
- Daniel, T. A brief history of OTEC research at NELHA. *Kailua Kona, HI, USA: Natural Energy Laboratory of Hawaii*, 1999.
- DCNS Group. Ocean Thermal Energy. Article, Available Online, 2010. URL <http://en.dcnsgroup.com/energy/marine-renewable-energy/ocean-thermal-energy/>.
- Department of Energy. Department of Energy Awards Up to \$14.6 Million to Support Development of Advanced Water Power Technologies. Available Online, September 2009. URL <http://energy.gov/articles/doe-awards-146-million-support-development-advanced-water-power-technologies>.
- Department of Energy. Lockheed Testing the Waters for Ocean Thermal Energy System. Available Online, May 2010. URL <http://energy.gov/articles/lockheed-testing-waters-ocean-thermal-energy-system>.
- Department of Energy and Climate Change. International comparisons. Statistical Data, Available Online, March 2012. URL http://www.decc.gov.uk/en/content/cms/statistics/energy_stats/prices/prices.aspx.
- Dickson, K. and Hadjimanolis, A. Innovation and networking amongst small manufacturing firms in cyprus. *International Journal of Entrepreneurial Behaviour & Research*, 4(1):5–17, 1998.
- Dodoros, G., Kleute, B. J., Harb, Y. S., and Verpoort, J. Design a 100MW Power Plant for Curaçao - Using Ocean Thermal Energy Conversion at minimal capital cost. Technical report, Delft University of Technology, 2009.
- Duic, N. and da Graca, M. Increasing renewable energy sources in island energy supply: case study porto santo. *Renewable and Sustainable Energy Reviews*, 8(4):383–399, 8 2004.
- Dutch Caribbean Legal Portal. Agreement on consensus-statutory law Police. Article, Available Online, 2010. URL <http://www.dutchcaribbeanlegalportal.com/news/latest-news/260-agreement-on-consensus-statutory-law-police>.
- Easter, C. Small states development: a Commonwealth vulnerability index. *The Round Table, Commonwealth*, 88(351):403–422, 1999.
- Easterly, W. and Kraay, A. Small states, small problems? income, growth, and volatility in small states. *World Development*, 28(11):2013–2027, 11 2000.
- Ebbing, J. The 2012 Curaçao Conference and Expo on the Future of Durable Energy. In *Innovation fit for tropical islands - Caribbean Branch Office TNO*, 2012.
- Ecopower International. Gouverneur, g.j.m., 2010. URL http://ecopowerinternational.com/html/gilbert_gouverneur.html.

- Ecorys. A sustainable future for Curaçao - Strategic options for ISLAN and the ISLA (Phase 1, Part 1). Technical report, Ministry of Economic Development Curaçao, January 2011.
- Efstathiades, A., Tassou, S. A., Antoniou, A., and Oxinos, G. Strategic considerations in the introduction of advanced manufacturing technologies in the cypriot industry. *Technovation*, 19(2):105–115, 12 1998. URL <http://www.sciencedirect.com/science/article/pii/S0166497298000923>.
- Efstathiades, A., Tassou, S. A., Oxinos, G., and Antoniou, A. Advanced manufacturing technology transfer and implementation in developing countries: The case of the cypriot manufacturing industry. *Technovation*, 20(2):93–102, 2 2000.
- El Hakim, A. N. From the Minister of Economic Development of Curaçao, 2012. URL <http://www.rutacuracao.com/From-Minister-Economic-Development.php>.
- Electric Regulatory Authority. The Electricity Regulatory Authority of the Cayman Islands approves Renewables Feed-in Tariffs Programme. Press release, Available Online, 2012. URL <http://www.cuc-cayman.com/PDF/off%20the%20wire/fiscal%202011/era%20cuc%20feed%20in%20tariffs%20160211.pdf>.
- Elsafty, A. F. and Saeid, L. Sea Water Air Conditioning SWAC: A Cost Effective Alternative. *International Journal of Engineering (IJE)*, 3(3), 2009.
- Encontre, P. The vulnerability and resilience of small island developing states in the context of globalization. *Natural Resources Forum*, 23(3):261–270, 1999.
- Energy Development in Island Nations (EDIN). Bonaire Plans to Generate 100% Renewable Energy. Article Available Online, October 2011.
- Europe Energy Portal. Fuel prices, rates for power and natural gas. Feed-In Tariffs Overview, Available Online, April 2010. URL <http://www.energy.eu/#>.
- European Commission. The economies of Cyprus and Malta. Economies of the Member States overview, Available Online, December 2011. URL http://ec.europa.eu/economy_finance/een/001/article_3727_en.htm.
- European Union. Finance for installations of innovative renewable energy technology and CCS in the EU. Official Journal of the European Union, Available Online, November 2010. URL <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:290:0039:0048:en:PDF>.
- European Union. An overview of Malta's economy. Report, Available Online, November 2011. URL <http://www.euro-challenge.org/doc/Malta.pdf>.
- Federal Register. Federal register / vol. 61, no. 20 / tuesday, january 30, 1996 / proposed rules. Available Online, 1996. URL <http://coastalmanagement.noaa.gov/otec/docs/otecregsremoved.pdf>.
- Fleck, J. and Howells, J. Technology, the technology complex and the paradox of technological determinism. *Technology Analysis & Strategic Management*, 13(4):523–531, 2012/06/13 2001. doi: 10.1080/09537320127285.
- Forbes. Market for Deep Ocean Energy Heats Up. Windows to the universe, Online, 2012. URL <http://www.forbes.com/sites/davidferris/2012/03/31/market-for-deep-ocean-energy-starts-to-heat-up/>.
- Foreign & Commonwealth Office. Curaçao Travel Advice. Available Online, 2012. URL <http://www.fco.gov.uk/en/travel-and-living-abroad/travel-advice-by-country/north-central-america/curacao>.

- Frankel, J. A. Mauritius: African success story. Technical report, National Bureau of Economic Research: NBER Conference on African Successes, Accra, Ghana, 2010.
- Fridleifsson, I. B. Twenty five years of geothermal training in iceland. *Proceedings of the International Geothermal Conference IGC-2003 on Multiple Integrated Uses of Geothermal Resources, Reykjavik, Iceland*, 2003.
- Geels, F. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research Policy*, 31(8–9):1257–1274, 12 2002. URL <http://www.sciencedirect.com/science/article/pii/S0048733302000628>.
- Geels, F. and Raven, R. Non-linearity and expectations in niche-development trajectories: Ups and downs in dutch biogas development (1973–2003). *Technology Analysis & Strategic Management*, 18 (3–4):375–392, 2012/06/13 2006. doi: 10.1080/09537320600777143.
- Geels, F. W. Understanding system innovations: a critical literature review and a conceptual synthesis. *System Innovation and the Transition to Sustainability: Theory, evidence and policy*, pages 19–47, 2004.
- Geels, F. W. and Kemp, R. Dynamics in socio-technical systems: Typology of change processes and contrasting case studies. *Technology in Society*, 29(4):441–455, 11 2007.
- Gouverneur, G. The 2012 Curaçao Conference and Expo on the Future of Durable Energy. In *Seawater air-conditioning Airport Curaçao - Curaçao Airport Holding*, March 2012.
- Government of Curaçao. Tariff for ‘supply back’ of sustainable energy for households: 40 cents per kilowatt hours. Press Release, Available Online, November 2011a. URL <http://energiakonsiente.com/en/duurzame-energie/press/>.
- Government of Curaçao. Electricity Supply Curaçao 2011–2015. Policy Document Regulation, Available Online, February 2011b. URL <http://energiakonsiente.com/en/duurzame-energie/beleidsnota/>.
- Government of Curaçao. Small scale sustainable electricity provision - small green connectrion. Policy Paper, Available Online, November 2011c. URL <http://energiakonsiente.com/en/duurzame-energie/beleidsnota/>.
- Government of Curaçao. Small scale sustainable electricity provision. Policy Paper - Tariff Guideliness, Available Online, November 2011d. URL <http://energiakonsiente.com/en/duurzame-energie/beleidsnota/>.
- Government of Grenada. The national policy of Grenada. Policy, Available Online, November 2011.
- GreenTown. GreenTown Curaçao. Article, Available Online, 2011. URL <http://www.greentowncuracao.com/Home/Faq>.
- Greig, A., Turner, M., and D’Arcy, P. The fragility of success: Repositioning mauritian development in the twenty-first century. *Island Studies Journal*, 6(2):157–178, 2011.
- Guillaumont, P. *Assessing the economic vulnerability of small island developing states and the least developed countries*. UNU World Inst. for Development Economics Research (UNU/WIDER), 2007. ISBN 9291909831.
- Guillaumont, P. An economic vulnerability index: its design and use for international development policy. *Oxford Development Studies*, 37(3):193–228, 2009.
- Hadjimanolis, A. Barriers to innovation for smes in a small less developed country (cyprus). *Technovation*, 19(9):561–570, 9 1999.

- Hadjimanolis, A. An investigation of innovation antecedents in small firms in the context of a small developing country. *R&D Management*, 30(3):235–246, 2000.
- Hadjimanolis, A. and Dickson, K. Development of national innovation policy in small developing countries: the case of Cyprus. *Research Policy*, 30(5):805–817, 5 2001.
- Hanst, I. 21 Years of Wind Generation Experience. Presentation, Available Online, October 2006. URL <http://www.caricom.org/jsp/projects/credp/Aqualectra%20presentation.pdf>.
- Hawaiian Electric Company. HECO Feed In Tariff Program. Online, 2012. URL <http://www.heco.com/portal/site/heco/menuitem.508576f78baa14340b4c0610c510b1ca/?vgnextoid=0b0a8618ce4f7210VgnVCM1000005c011bacRCRD&vgnextfmt=default&cpsextcurrchannel=1>.
- Heijes, C. Cross-cultural perception and power dynamics across changing organizational and national contexts: Curaçao and the netherlands. *Human Relations*, 64(5):653–674, 2011.
- Hekkert, M. and Negro, S. Functions of innovation systems as a framework to understand sustainable technological change: Empirical evidence for earlier claims. *Technological Forecasting and Social Change*, 76(4):584–594, 5 2009.
- Hekkert, M. P., Suurs, R. A. A., Negro, S. O., Kuhlmann, S., and Smits, R. E. H. M. Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting and Social Change*, 74(4):413–432, 5 2007.
- Holt, C. Energy from the oceans. *Physics Education*, 42, 2007.
- Hommels, A., Peters, P., and Bijker, W. E. Techno therapy or nurtured niches? technology studies and the evaluation of radical innovations. *Research Policy*, 36(7):1088–1099, 9 2007.
- Hsiung-Shen, J. and Weng, T. S. Big country dependent economy development of taiwan—functions of japan, the us, and china in taiwan's economy development. *Advanced Management Science (ICAMS), 2010 IEEE International Conference on*, 3:138–143, 2010.
- Hurt, J., Pellen, A., and Nagurny, N. Otec power efficiency challenges. *Offshore Technology Conference*, 2010.
- Iceland Geosurvey. Annual Report 2009. Report, Available Online, March 2010. URL <http://www.carmabi.org/images/stories/file/carmabi%20annual%20report%202009%20lr.pdf>.
- Iceland Geosurvey. Annual Report. Report, Available Online, March 2012. URL <http://geothermal.is/sites/geothermal.is/files/Annual-%20Report-Iceland-GeoSurvey-2011.pdf>.
- IDABC. e-Government in Malta. Report Published by Interoperable delivery of European eGovernment Services to Administrations, Business and Citizens, 2008. URL <http://ec.europa.eu/idabc/servlets/Doc?id=31512>.
- Invest Curaçao. Investment Incentives. Overview, Available Online, 2006. URL <http://www.investcuracao.com/03d05.html>.
- Jacobsson, S. and Bergek, A. Transforming the energy sector: the evolution of technological systems in renewable energy technology. *Industrial and Corporate Change*, 13(5):815–849, 2004. doi: 10.1093/icc/dth032.
- Jacobsson, S. and Johnson, A. The diffusion of renewable energy technology: an analytical framework and key issues for research. *Energy Policy*, 28(9):625–640, 7 2000. URL <http://www.sciencedirect.com/science/article/pii/S0301421500000410>.

- Jaramillo-Nieves, L. and Del Rio, P. Contribution of renewable energy sources to the sustainable development of islands: An overview of the literature and a research agenda. *Sustainability*, 2(3):783–811, 2010. ISSN 2071-1050. doi: 10.3390/su2030783.
- Joomun, G. The textile and clothing industry in mauritius. *The Future of the Textile and Clothing Industry in Sub-Saharan Africa*, pages 193–211, 2006.
- Kelly, R. Jamaica's innovation infrastructure: A comparative analysis. *Publication. Kingston, Jamaica: Planning Institute of Jamaica*, 2008.
- Kemp, R., Schot, J., and Hoogma, R. Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management. *Technology Analysis & Strategic Management*, 10(2): 175–198, 2012/02/17 1998. doi: 10.1080/09537329808524310.
- Kemp, R., Rip, A., and Schot, J. Constructing transition paths through the management of niches. *Path dependence and creation*, pages 269–299, 2001.
- Kemp, R., Loorbach, D., and Rotmans, J. Transition management as a model for managing processes of co-evolution towards sustainable development. *International Journal of Sustainable Development & World Ecology*, 14(1):78–91, 2012/06/13 2007. doi: 10.1080/13504500709469709.
- Kern, F. and Smith, A. Restructuring energy systems for sustainability? Energy transition policy in the Netherlands. *Energy Policy*, 36(11):4093–4103, 11 2008.
- Kleute, B. OTEC Research and Initiatives, 2010. <http://www.tudelft.nl/live/pagina.jsp?id=b59be3b7-489c-4ab0-ba6e-44c8d2184b7f&lang=en>.
- Knights, M. Malta calling. *Engineering Technology*, 3(2):72–76, February 2008.
- Koomey, J. G., Belady, C., Patterson, M., A.Santos, and Lange, K. Assessing trends over time in performance, costs, and energy use for servers. *Lawrence Berkeley National Laboratory and Stanford University*, page 51, August 2009.
- Kristoferson, L., O'Keefe, P., and Soussan, J. Energy in small island economies. *Ambio*, pages 242–244, 1986.
- Lennard, D. E. The viability and best locations for ocean thermal energy conversion systems around the world. *Renewable Energy*, 6(3):359–365, 4 1995.
- Liang, C. H. J. The key factors of successful innovation for supplementary education industry in taiwan. *UNIVERSITY OF MARYLAND UNIVERSITY COLLEGE*, 2012.
- Liao, S.-H. and Hu, T.-C. Knowledge transfer and competitive advantage on environmental uncertainty: An empirical study of the taiwan semiconductor industry. *Technovation*, 27(6–7):402–411, 2007/7// 2007.
- Liu, C.-Y. Government's role in developing a high-tech industry: the case of taiwan's semiconductor industry. *Technovation*, 13(5):299–309, 7 1993. URL <http://www.sciencedirect.com/science/article/pii/S016649729390003E>.
- Magesh, R. OTEC Technology - A World of Clean Energy and Water. *Proceedings of the World Congress on Engineering*, 2(1):6, 2010.
- Malerba, F. Sectoral systems of innovation and production. *Research Policy*, 31(2):247–264, 2 2002. URL <http://www.sciencedirect.com/science/article/pii/S0048733301001391>.

- Markard, J. and Truffer, B. Technological innovation systems and the multi-level perspective: Towards an integrated framework. *Research Policy*, 37(4):596–615, 5 2008.
- Meyer, L., Cooper, D., and Varley, R. Are we there yet? *OCEANS 2011*, pages 1–6, 2011.
- Mitra, I., Degner, T., and Braun, M. Distributed generation and microgrids for small island electrification in developing countries: A review. *SESI Journal, Solar Energy Society of India*, 18(1):6–20, 2008.
- Monteiro Alves, L. M., Lopes Costa, A., and da Graca Carvalho, M. Analysis of potential for market penetration of renewable energy technologies in peripheral islands. *Renewable energy*, 19(1):311–317, 2000.
- Mourik, R. and Raven, R. P. J. M. *A Practitioner's View on Strategic Niche Management: Towards a Future Research Outline*. ECN, 2006.
- National Energy Authority of Iceland. Geothermal development and research in Iceland. Report, Available Online, February 2010. URL http://www.nea.is/media/utgafa/GD_loka.pdf.
- National Oceanic and Atmospheric Administration (NOAA). Ocean Thermal Energy Act of 1980 - 42 (U.S.C. S 9101 et seq.) - Congressional declaration of policy. Available Online, 1980. URL <http://coastalmanagement.noaa.gov/otec/oteka.html>.
- NEA. The National Energy Authority of Iceland. Government Agency Description, Available Online, 2012. URL <http://www.nea.is/the-national-energy-authority/>.
- Nexant. Caribbean Regional Electricity Generation, Interconnection, and Fuels Supply Strategy. Final Report of Caribbean Community and Common Market (CARICOM) for the World Bank, Available Online, March 2010. URL http://www.caricom.org/jsp/community_organs/energy_programme/electricity_gifs_strategy_final_report_summary.pdf.
- Niosi, J. and Bellon, B. The global interdependence of national innovation systems: Evidence, limits, and implications. *Technology in Society*, 16(2):173–197, 1994.
- NOS. Technical Readiness of Ocean Thermal Energy Conversion (OTEC). Technical report, National Oceanic and Atmospheric Administration, 2010a.
- NOS. Ocean Thermal Energy Conversion: Assessing Potential Physical, Chemical and Biological Impacts and Risks. Technical report, National Oceanic and Atmospheric Administration, 2010b.
- NUON. District Cooling in Amsterdam's Zuidas: Only one area can be the first. Report, October 2006.
- Nurse, L. A., Sem, G., Hay, J., Suarez, A., Wong, P. P., Briguglio, L., Ragoonaden, S., Githeko, A., Gregory, J., and Ittekkot, V. Small island states. *Climate Change 2001: Impacts, Adaptation, and Vulnerability*, pages 843–876, 2001.
- Ocean & Coastal Resource Management (OCRM). Ocean Thermal Energy Conversion. Programs of the Ocean and Coastal Resource Management available Online, July 2011. URL <http://coastalmanagement.noaa.gov/programs/otec.html>.
- OTE Corporation. Ocean Thermal Energy Corporation Reaches Written Understanding Toward Building the World's First Ocean-Powered Clean Energy Plants. Press Release, Available Online, September 2011. URL http://www.otecorporation.com/news_reader/items/ocean-thermal-energy-corporation-reaches-understanding-toward-building-otec-plants.html?utm_source=theonproject&utm_medium=op-blog&utm_campaign=op-blog-mou-announcement#.T6AEa-1-i2M.

- OTEC International LLC. OTEC International LLC moves forward on NELHA planning. Windows to the universe, Online, 2012. <http://www.windows2universe.org/earth/Water/temp.html>.
- Patel, P. Localised production of technology for global markets. *Cambridge Journal of Economics*, 19(1): 141–153, 1995.
- Pavitt, K. and Patel, P. *Global corporations and national systems of innovation: who dominates whom?* Cambridge University Press, Cambridge, p.95–119 (chapter 6) edition, 1999. URL http://books.google.nl/books?hl=en&lr=&id=QDV4sNy5rTUC&oi=fnd&pg=PA94&dq=Global+corporations+and+national+sys-+tems+of+innovation:+who+dominates+whom&ots=H80WLkcZFz&sig=3PZaVvVnBH3d8D7QsLkzj28iLpk&redir_esc=y#v=onepage&q=policy&f=false.
- Pereira, D. A. *The challenges of the small insular developing states: are the Mauritius and Seychelles examples for Cape Verde?* PhD thesis, Universidade Technica De Lisboa: Instituto Superior De Economia E Gestao, 2005.
- Pinch, T. J. and Bijker, W. E. The social construction of facts and artefacts: or how the sociology of science and the sociology of technology might benefit each other. *Social studies of Science*, pages 399–441, 1984.
- Radas, S. and Božić, L. The antecedents of sme innovativeness in an emerging transition economy. *Tech-novation*, 29(6–7):438–450, 2009/7// 2009.
- Ragnarsson, A. Utilization of geothermal energy in iceland. *Proceedings of the International Geothermal Conference IGC-2003*, pages 39–45, 2003.
- Raven, R. Niche accumulation and hybridisation strategies in transition processes towards a sustainable energy system: An assessment of differences and pitfalls. *Energy Policy*, 35(4):2390–2400, 4 2007. URL <http://www.sciencedirect.com/science/article/pii/S0301421506003351>.
- Read, R. Foreign direct investment in small island developing states. *Journal of International Development*, 20(4):502–525, 2008. ISSN 1099-1328. doi: 10.1002/jid.1477. URL <http://dx.doi.org/10.1002/jid.1477>.
- Read, R. Economic vulnerability and resilience in small island developing state. *Geneva: International Centre for Trade and Sustainable Development*, 2010.
- Rennings, K. Redefining innovation —eco-innovation research and the contribution from ecological economics. *Ecological Economics*, 32(2):319–332, 2 2000. URL <http://www.sciencedirect.com/science/article/pii/S0921800999001123>.
- Republic of Mauritius. The Mauritian Economy: 2012 Outlook. Report, Available Online, February 2012. URL <http://www.axys-group.com/photo/News/Pdf/doc24.pdf>.
- Roger Jr, G. Ki'nobo? Innovation Policy and its Economic Development Potential for Curaçao. Faculty of Social Sciences and Economics University of Curaçao, March 2011.
- Rymer, C. Feed-In Tariff: An Effective Policy To Deploy Renewable Energy Technologies. Available Online, May 2008. URL <http://www.scribd.com/doc/15438625/FeedIn-Tariff-An-Effective-Policy-to-Deploy-Renewables>.
- Schot, J. and Geels, F. W. Niches in evolutionary theories of technical change. *Journal of Evolutionary Economics*, 17(5):605–622, 2007.

- Schot, J. and Geels, F. W. Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. *Technology Analysis & Strategic Management*, 20(5):537–554, 2008.
- Schotte, G. Curaçao - from red tap to red carpet: Thinking outside the box. Interview with the prime minister Gerrit Schotte, Available Online, 2011.
- Schotte, G. The 2012 Curaçao Conference and Expo on the Future of Durable Energy. In *The Energy Policy - Involvement, Implementation, Innovation*, 2012.
- Siahaya, Y. and Salam, L. Ocean thermal energy conversion (otec) plant and its byproducts yield for small islands in indonesia sea water. *ICCHT-5th International Conference on Cooling and Heating Technologies. Bandung, Indonesia*, 2010.
- SmartCity. SmartCity business opportunities. Online Article, 2012. URL <http://www.smartcity.ae>.
- Srinivasan N., S. M. Study on the cost effective ocean thermal energy conversion power plant. *Offshore Technology Conference, Houston, Texas, USA*, page 13, May 2010.
- Straatman. Opportunities for kwh price improvement of solar thermal electricity plants. Technical report, Utrecht University, Department of Science, Technology and Society, January 2006.
- Streeten, P. The special problems of small countries. *World Development*, 21(2):197–202, 2 1993.
- Suurs, R. *Motors of sustainable innovation: Towards a theory on the dynamics of technological innovation systems*. Utrecht University, 2009.
- Taxell, C., Yellan, R., Gillespie, I., Linna, M., and Verbeek, A. Education, Research and Innovation policy: A new direction for Iceland. Report, Available Online, May 2009.
- Teal, F. Why can mauritius export manufactures and ghana not? *World Economy*, 22(7):981–993, 1999. ISSN 1467-9701. doi: 10.1111/1467-9701.00242. URL <http://dx.doi.org/10.1111/1467-9701.00242>.
- Tetiara. SWAC: Intercontinental Bora Bora Resort and Thalasso Spa. Article Available Online, 2011. URL <http://tetiaraa.pf/sustainability/swac/>.
- The Caribbean Community Climate Change Centre (CCCCC). Delivering transformational change 2011-21. Report, Available Online, June 2011. URL <http://dms.caribbeanclimate.bz/M-Files/openfile.aspx?objtype=0&docid=4665>.
- The Central Bank of Iceland. Economy of Iceland. Report, Available Online, November 2005. URL <http://sedlabanki.is/lisalib/getfile.aspx?itemid=3363>.
- The Economist. Second time around: Ocean heat may be used to generate electricity. Print Edition, 2012a. URL <http://www.economist.com/node/21542381>.
- The Economist. The Cypriot bail-out: A fifth bitter lemon. Online Article, June 2012b. URL <http://www.economist.com/node/21557762?zid=307&ah=5e80419d1bc9821ebe173f4f0f060a07>.
- The Future of Energy. The future of energy: Ocean resource. Online Article, November 2010.
- TNO. Sustainable Innovations for the Caribbean. Brochure, 2011.
- Toyama, G. Deep ocean water as a catalyst for economic development at nelha (natural energy laboratory of hawaii authority). *Deep Ocean Water Research*, 11(1):21–23, 2010.

- Transparency International. Transparency International. Press Release, Available Online, April 2012. URL http://www.transparency.org/news_room/latest_news/press_releases/2012/2012_04_05_transparency_international_to_conduct_national_integrity_system_assessment_in_curacao.
- Tung, A.-C. Taiwan's semiconductor industry: What the state did and did not. *Review of Development Economics*, 5(2):266–288, 2001. doi: 10.1111/1467-9361.00123. URL <http://dx.doi.org/10.1111/1467-9361.00123>.
- Turner, J. A. A realizable renewable energy future. *Science*, 285(5428):687–689, 1999.
- Turvey, R. Vulnerability assessment of developing countries: the case of small island developing states. *Development Policy Review*, 25(2):243–264, 2007.
- Uehara, H. The present status and future of development of otec. *Cogeneration in Japan*, 19(2):43–51, 2004.
- UN Department of Economic and Social Affairs. Small Island Developing States. Article, Available Online, June 2007. URL <http://www.un.org/esa/sustdev/sids/sidslist.htm>.
- UNA. University of Netherlands Antilles - Annual Report 2009, 2009.
- UNA. University of Netherlands Antilles - Engineering, April 16 2012. URL <http://www.una.net/>.
- United Nations. Is a special treatment of small island developing states possible? *UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT, New York and Geneva*, 2004.
- United Nations. Committee for development policy. Economic and Social Council: Report on the eighth session, 20-24 March 2006. URL <http://www.un.org/esa/analysis/devplan/e200633.pdf>.
- United Nations. About Small Island Developing States. Article Available Online, 2012. URL <http://www.unohrrls.org/en/sids/43>.
- United Nations Development Program. First Millennium Development Goals Report - Curaçao and Sint Maarten 2011. Report, 2011a.
- United Nations Development Program. Human development report. Annual Report, 2011b. URL http://hdr.undp.org/en/media/HDR_2011_EN_Complete.pdf.
- United Nations Development Program. Curaçao & Sint Maarten 2011. First Millennium Development Goals Report, Available Online, January 2011c. URL www.undp.org.tt/NA/MDGReportCURandSXM.pdf.
- United Nations FCCC. Climate Change: Small Island Developing States. Report by the United Nations Framework Convention on Climate Change, Available Online, 2005. URL http://unfccc.int/resource/docs/publications/cc_sids.pdf.
- University of the West Indies. The growing vulnerability of small island developing states. The United Nations Development Programme Capacity 21 Project, September 2002.
- US Department of Energy. 2008 Geothermal technologies market report. Report, Available Online, July 2009. URL http://www.nea.is/media/utgafa/GD_loka.pdf.
- van Alphen, K., Hekkert, M. P., and van Sark, W. G. J. H. M. Renewable energy technologies in the maldives—realizing the potential. *Renewable and Sustainable Energy Reviews*, 12(1):162–180, 1 2006.

- VanEps Kunneman VanDoorne. 80-20 regulation from a practical point of view. Available Online, 2011. URL <http://www.ekvandoorne.com/en/news/latest-news/latest-news/526-80-20-regeling-praktisch-beschouwd->.
- Vega, L. OTEC Economics. Presentation, Available Online, August 2007. URL <http://www.offinf.com/OTECeconomicsEnergyOcean2007Vega.pdf>.
- Vega, L. Economics of Ocean Thermal Energy Conversion (OTEC): An Update. *Offshore Technology Conference*, May 2010.
- Verbong, G. and Geels, F. The ongoing energy transition: Lessons from a socio-technical, multi-level analysis of the dutch electricity system (1960–2004). *Energy Policy*, 35(2):1025–1037, 2 2007.
- War, J. Seawater Air Conditioning (SWAC) a renewable energy alternative. *OCEANS 2011*, pages 1–9, 2011.
- Weisser, D. On the economics of electricity consumption in small island developing states: a role for renewable energy technologies? *Energy Policy*, 32(1):127–140, 2004a.
- Weisser, D. Power sector reform in small island developing states: what role for renewable energy technologies? *Renewable and Sustainable Energy Reviews*, 8(2):101–127, 2004b.
- Weisser, D. Costing electricity supply scenarios: A case study of promoting renewable energy technologies on rodriguez, mauritius. *Renewable energy*, 29(8):1319–1347, 2004c.
- Whitworth, B. Socio-technical systems. *Encyclopedia of human computer interaction*, pages 559–566, 2006.
- Winner, L. Do artifacts have polities? *American Academy of Arts and Sciences*, 109(1):121–136, 1980.
- World Bank. *2009 Information and communications for development: extending reach and increasing impact*. World Bank Publications, Global Information & Communication Technologies Dept. Development Data Group, 2009. ISBN 0821376055.
- Worldwatch Institute. Low-Carbon Development Strategies for the Caribbean. Online, 2011. URL <http://www.worldwatch.org/low-carbon-development-strategies-caribbean>.
- Yen-Ju, S., Shun-Chieh, C., and Tai, D. W. S. Lifelong learning in taiwan, china, korea and japan. *Advances in Computer Science and Education Applications*, pages 163–170, 2011.
- Yin, R. K. Case study research. *Design and methods*, 5 (ISBN 978-1412960991), 2008.
- Yu, X. and Taplin, R. Renewable energy and sustainable development in the pacific islands: an issue of international aid. *Natural resources forum*, 22(3):215–223, 1998.

Interview Sources

- Blokker, R., Acevedo, D., and Kleute, B. Interview by Tomas Prochazka. Bluerise B.V., February-May 2012.
- Brouwer, T. Interview by Tomas Prochazka. Director of Green Force Curaçao and board member of the Curaçao Business Council for Sustainable Development (BPM), March 28 2012.
- Bulbaai, R. R. Interview by Tomas Prochazka. Dean of Faculty of Engineering of the University of Netherlands Antilles and Associate Professor of Information Technology and Electrical Systems, March 21 2012.
- Casimiri, A. Interview by Tomas Prochazka. President of the Board of GreenTown foundation, Executive Secretary of GreenTown foundation, March 21 2012.
- Coutinho, S. Interview by Tomas Prochazka. Royal Bank of Canada (RBC), Vice President - Corporate Banking Dutch Caribbean and Suriname, May 21 2012.
- de Haseth, D. Interview by Tomas Prochazka. (Replacement) Operations Manager at Refineria ISLA, 22 May 2012.
- Delcour, I. Interview by Tomas Prochazka. Student trainee at Spigthoff Advocaten & Belastingadviseurs, Curaçao, April 14 2012.
- Gouverneur, G. Interview by Tomas Prochazka. Business Development Director/Co-Founder of Ecopower International BV, former employee at Ecofys/Econcern, March 27 2012.
- Guda, M. Interview by Tomas Prochazka. Manager and senior scientist at Fundashon Antiyano Pa Energia (FAPE) and part time lecturer at the University of Netherlands Antilles (courses on renewable energy technologies), March 27 2012.
- Halman, J. J. Interview by Tomas Prochazka. Professor in Innovation Processes at the University of Twente and a chairperson for Technology and sustainable development at the University of the Netherlands Antilles, March 13 2012.
- Hernandez, F. A. M. Interview by Tomas Prochazka. Investment Promoter at Curinde N.V. – Curaçao Industrial and International Trade Development Company, April 4 2012.
- Interviewee 01. Interview by Tomas Prochazka. Environmental Specialist based in Curaçao, March 23 2012.
- Interviewee 02. Interview by Tomas Prochazka. Policy Expert, Government of Curaçao, April 3 2012.
- Interviewee 03. Interview by Tomas Prochazka. Oil Products Expert, April 4 2012.
- Jansen, G. Interview by Tomas Prochazka. Policy Advisor at the Ministry of Economic Affairs, May 24 2012.

- Kloppenburger, S. Interview by Tomas Prochazka. Advisor: Airport Development at Curaçao Airport Holding, March 19 2012.
- Kool, A. Interview by Tomas Prochazka. Owner of and consultant in Kool Caribe Consult, secretary of Huntu Korsou organization ('Curaçao Together') and member of the Curaçao Business Council for Sustainable Development (BPM), April 2 2012.
- Marshall, M. Interview by Tomas Prochazka. Director of Fundashon pa Konsumido Curaçao, March 22 2012.
- Martina, G. Interview by Tomas Prochazka. Chief operating officer at ENNIA insurance company and Shareholder at Elijah fish farm, Bonaire, March 26 2012.
- Nicastia, J. Interview by Tomas Prochazka. Director, Corporate Finance - National Investment Bank, Curaçao (NIBanc), 25 April 2012.
- Roger, S. Interview by Tomas Prochazka. Production Manager, Curaçao Drydock company, 30 May 2012.
- Rosheuvel, F. J. Interview by Tomas Prochazka. Manager at Energy and Automation and former advisor in the Technology commission of the government, March 24 2012.
- Stokkermans, P. Interview by Tomas Prochazka. Executive director of Caribbean Research and Management of Biodiversity (CARMABI) and former employee of the ministry of Economic Affairs in Curaçao, March 23 2012.
- Tromp, J. Interview by Tomas Prochazka. Coordinator Service and Maintenance at NUCapital, Inc., April 3 2012.
- Tujeehut, K. Interview by Tomas Prochazka. Manager Corporate Strategy and Business Development of Aquallectra, March 23 2012.
- van den Brink, T. Interview by Tomas Prochazka. Managing director of EcoVision NV environmental consultancy, Member of the Curaçao Business Council for Sustainable Development, April 4 2012.
- van Grieken, C. Interview by Tomas Prochazka. Manager at Caribbean Energy Solutions (CARENSOL), March 26 2012.
- van Weijsten, B. Interview by Tomas Prochazka. Owner at Van Weijsten Management Consultancy and Advisor of the Curaçao government on energy policy issues, March 20 2012.
- Vermeer, B. Interview by Tomas Prochazka. Innovation Consultant at InnovatieCentrum Curaçao, March 22 2012.



Geothermal Research and Educational Activities in Iceland

Geothermal Research and Educational Activities in Iceland (based on [Taxell et al. \(2009, p.20-22\)\)](#)).

- The Geothermal Training Programme of the United Nations University (UNU-GTP) in which professional scientists and engineers spend six months on highly specialised studies, research, and on-the-job training in geothermal science and engineering. Iceland GeoSurvey take care of the main part of the training and education in the program ([Iceland Geosurvey, 2012](#));
- The School for Renewable Energy Science (RES) with an intensive and unique interdisciplinary research oriented one-year graduate programme in renewable energy science;
- Reykjavik Energy Graduate School of Sustainable Systems (REYST) with international graduate programmes focused on sustainable energy use, practical experience in the field and ready access to on-site work with experts on various subjects;
- University of Iceland is an active coordinative partner in the programmes of UNU-GTP, REYST, RES.

B

Electricity production facilities in Curaçao

Table B.1: Electricity production units of Aqualectra as of 2002 ([Aqualectra, 2002](#)).

Type	Max. Capacity (MW)	Act. Capacity (MW)	Boiler (Tons/hour) ^a	Fuel -	Installed -
TG1	3.5	3.5	-	-	1958
TG2	3.5	3.5	-	-	1958
K3TG3	7	6.6	110	Heavy fuel oil	1963/1998
TG4	7	6.6	45	Heavy fuel oil	1963
GT1K5	15	12	30	Gas oil	1973
GT2K7	20.8	19	55	Gas oil	1979
K8TG8	25	25	146	Heavy fuel oil	1981
K9TG9	25	25	146	Heavy fuel oil	1982
K10TG10	25	25	141	Heavy fuel oil	1989
K11TG11	25	25	141	Heavy fuel oil	1991
TG40	3.2	3.2	-	-	1988
TG50	3.2	3.2	-	-	1990
TG60	3.65	3.65	-	-	1998
DW1	6.25	6.25	-	Heavy fuel oil	1997
DW2	6.25	6.25	-	Heavy fuel oil	1997
DW3	6.25	6.25	-	Heavy fuel oil	1997
DW4	6.25	6.25	-	Heavy fuel oil	1997
DW5	6.25	6.25	-	Heavy fuel oil	2000
DW6	6.25	6.25	-	Heavy fuel oil	2000
D1	4.5	4.5	-	Gas oil	1971
D12	4.5	4.5	-	Gas oil	1968
D13	4.5	4.5	-	Gas oil	1970
D18	2.6	2.6	-	Diesel	1977
D19	2.6	2.6	-	Diesel	1977
D20	2.6	2.6	-	Diesel	1979
D21	2.6	2.6	-	Diesel	1983

^a MCR value - Maximum Continuous Rating - the maximum boiler load at which the boiler can run without any problem.



Interviews

C.1 Timo Brouwer

Interviewee: Timo Brouwer

Position: Director of Green Force Curaçao and board member of the Curaçao Business Council for Sustainable Development (BPM)

Date: March 28, 2012

Location: Salina, Curaçao

-
- After moving to Curaçao 5 years ago, Mr. Brouwer witnessed the (terrible) environmental situation and decided to set up a company that would offer solutions enabling a better future – Green Force
 - The largest waste management company on the island (Selikor) does claim that it recycles – but its methods and used technologies are not appropriate. For example, the collection of the materials for recycling is only done in one central location – people must therefore drive there and in fact cause more harm (pollution from the transport) than if they did not recycle, this due to the typical quantities a household would be able to collect.
 - Green Force therefore set up (an increasing) number of collection places with recycling bins for aluminum cans. Further it collects Low Density Polyethylen (LDPE) (plastic shrink wrap) and plans to start collection of Polyethylene Terephthalate (PET) bottles from both private and commercial parties
 - The number of organizations that are interested in his services is continuously increasing. In general, there are two reasons for that – pride (keeping the island clean, help the

environment) and money (saving costs on regular waste collection or improving image)

- Local companies generally take longer to persuade and are often not willing to pay for the service (the collection of LDPE plastics by Green Force is free, but donations to support the initiative are welcome)
- Foreigners or companies that are based abroad come to Green Force mainly from their own initiative as sustainability is an important part of their mission and their awareness of environmental issues is generally much greater than of the locals'
- Mr. Brouwer is frequently in newspapers, TV or radio – mainly in order to raise the awareness and point to the problems that are happening on the island
- Communicating via media is the most efficient way of communication as partnering up with politicians will make one vulnerable after next elections (opposing parties will see you then in negative light)
- Further, he is involved in BPM and organizes or participates in a very large number of workshops, lectures, presentations, educational activities at schools and at the university – all Green Force's activities are aimed to promote and educate locals on the issues of sustainable environment. By making such issues public, Mr. Brouwer aims to 'plant the seeds' that will eventually result into tangible changes in the society
- Mr. Brouwer sees the actions of the new government as positive ('at least something is happening'), however he points to a large number of issues that have not yet been addressed. Namely, regulations on fishing in the region, protection of ocean coast, protection of mangroves, limitation on the use of plastic bags, regular checks on car fumes etc.
- Mr. Brouwer believes that it would take a large number of unpopular decisions to make a significant change – the decision makers would then lose a larger number of votes in the elections, eventually that voters will see the benefits and give some credit back to those who saw the "light".
- The current regulations skip a large number of steps (such as recycling, reduction of energy usage etc.) and bypasses 'ordinary' people by introducing the possibilities to connect private solar panels to the grid (which require large investments). Even then, there are flaws as the current infrastructure on the island and its administration is not capable of handling requests for connection to the grid on a timeframe that makes the ROI (return on investment) interesting.
- Further, new tax reductions for 'green' products were introduced but there are for example no service centers for those products (e.g. electric vehicles)
- While there are regulations on large number of activities, no fines are being imposed as there is no authority that would do the checks or controls – this is then exploited by some local companies that do not hesitate to harm the environment
- There is a large number of similar organizations to Green Force – Huntu-Korsou, Amigu di Tera, CARMABI, Currassavica, Uniek Curaçao, SMOG, Defesa Ambiental, that somehow fight for the conservation of the environment. One big difference is that they all are

NPO (non profit Organizations) and Green Force is a company that functions as a NPO for the timebeing.

- There are 6 consecutive steps in the ladder of Landsink that should be followed in order to efficiently use resources and take care of garbage properly. Starting with the most desired one and only when it cannot be achieved, the next step is used: prevention, reduction, recycling, waste-to-energy, incineration, landfill. Curaçao is still landfilling.
- The people and companies on the island skip the initial steps and try to focus on the later ones (for various financial and political reasons) – this is also the case of the envisioned Curaçao Ecopark where waste-to-energy is discussed but not the previous steps
- Overall, the local society (and the system) lacks systematic education from which results a very low awareness about the issues of sustainability. The locals (including the government) focus on short-term gains at the expense of significantly higher long term losses
- The system dealing with permits, regulations and control is overly bureaucratic, slow, undermanned and underdeveloped

C.2 Bluerise B.V.

Interviewee: D. Acevedo, R. Blokker, B.J. Kleute

Position: Bluerise B.V.

Date: February – May, 2012

Location: Bluerise B.V. Delft, The Netherlands

-
- Required water flows for OTEC (of both warm surface water and DSW) are about 3 l/s per kW of electricity produced
 - Smaller scale off-shore OTEC plans could have a ‘SPAR’ design, larger off-shore plants (i.e. 10MW+) will resemble the shape of oil platforms. The vessels would be build in a similar way as other ships or platforms – in a dry-dock. (maybe mention possibility of using decommissioned large vessels or platforms.)
 - One of the challenges of off-shore OTEC will be attaching the pipe to the vessels – there are two possibilities:
 - Float the pipe to the site and then slowly submerge it, set it into vertical position and attach it to the vessel;
 - Or produce the pipe on site in the ‘downwards’ direction bypassing the need to reposition the pipe from horizontal to vertical position
 - The size of the DSW pipe is in the order of 3-10m for large scale (10-100MW) plants
-

- The greatest technical challenge for heat exchangers is to scale them up to the sizes required for large scale OTEC operation and to find the right materials that can resist corrosion/fouling (possibly aluminum, titanium or plastic)
- Some of the largest suppliers of OTEC components as it appears now would probably be in Europe and Asia
- The awareness about OTEC among the scientific community is much greater in the Caribbean than elsewhere. However, there is no awareness whatsoever among ordinary people

C.3 Richenel R. Bulbaai

Interviewee: Ir. Richenel R. Bulbaai MBA

Position: Dean of Faculty of Engineering of the University of Netherlands Antilles & Associate Professor of Information Technology and Electrical Systems

Date: March 21, 2012

Location: University of the Netherlands Antilles, Curaçao

-
- Mr. Bulbaai is currently working on his Phd. Thesis – its main focus is on energy saving issues of households in Curaçao
 - The areas that are covered are both technical (e.g. how are houses build, air-conditioning used, solar pannels etc.) as well behavioral (e.g. how should consumers be motivated to save energy)
 - All kinds of aspects are taken into account, such as consumers' education, salary, previous knowledge of the energy issues and how these aspects change over time
 - UNA has about 2100 students in total with about 400 studying engineering
 - There is a clear change of focus among the students over the past years and they do have interests in the 'hot' issues – such as green energy
 - There have been some changes over the past years in the curriculum to keep up with the developments – such as newly adjusted courses related to renewable technologies. However, no major changes (such entirely new programme) have been introduced
 - There is a very strong connection of companies to the university. About 90% of all students do their final theses in companies, further every 3 years, representatives of companies meet to provide opinion on the university courses and see what changes can be made to better reflect their needs – in terms energy related issues, the most discussed topic is on energy saving
 - From the neutral position that Mr. Bulbaai holds at the UNA, he sees the current developments on energy related issues in Curaçao (e.g. new electricity policy) as highly positive for the people and future of Curaçao

- The greatest downside that Mr. Bulbaai perceives is the little involvement of Aqualectra and other stakeholders in the process – the changes are very rapid and more discussions should have been held with for example Aqualectra – it should have a process rather than one huge transition
- In the past, there have been lot of parties on the island that wanted to get involved in sustainable energy technologies (mainly solar) – but until January 2012, they had no opportunity to connect to the grid
- Now, as the market opened, lot of companies can finally work in field
- Overall, the steps that have been made over the past 1 year are huge and very positive for the future of the island – it has made the gap in energy related issues between developed countries and Curaçao significantly smaller

C.4 Andres Casimiri

Interviewee: Andres Casimiri and Marijke van Rijn

Position: President of the Board of GreenTown foundation, Executive Secretary of GreenTown foundation

Date: March 21, 2012

Location: GreenTown Office, Hotel Kura Hulanda, Willemstad, Curaçao

-
- Current status of the GreenTown project - Quick scan designed to give an indication whether a project is eligible to be elevated to a next step, for example financial contributions. In fact Royal Haskoning made a “Quick scan for Development and Economic Outlook”. This has been done to evaluate the possibilities for further planning of GreenTown:
 - Punda and Otrobanda (parts of Willemstad) cannot expand any more due to the ‘monument’ status of most buildings.
 - Due to architectural and historical reasons, the current buildings cannot be replaced
 - Public and companies’ opinions were researched
 - The time and financial possibilities did not allow a full scale feasibility study – but the estimates say that are about 16000 jobs to be created in GreenTown
 - The study and report are almost finished and will be released in mid May 2012
 - The outcomes are positive and the GreenTown team hopes that it will send a clear message to the relevant stakeholders that there are alternatives to the current situation

- GreenTown is the second alternative. LightHouse projected something similar earlier (around the eighties), on which GreenTown build further. It was GreenTown's reintroduction (2011) that actually started the discussion on the island about alternative solutions to the current (oil driven) situation
- The focus of the companies located inside the GreenTown area can be divided into the following categories: marine, entertainment (with the aim of attracting 75000 tourists a week – triple of the current situation), dock, free-zone, recycling and city administration
- The government needs to decide on the future of the Isla refinery this year in fact end of May and Mr. Casimiri argued that there are no rational reasons to keep it (neither the alternative to upgrade it nor move it elsewhere is sensible) – mainly due to the costs involved and the fact that Curaçao neither has oil reserves nor is a large (oil consuming) market
- The refinery pays no taxes whatsoever and leases the refinery for 20 million USD/yearly. Considering the pollution caused and the immense area that the refinery covers, the large increase in employment from a few thousand to 16000 and a estimated income of \$300,000,000 the land could be put into much better use (GreenTown)
- The next major steps to follow are pre-feasibility study, master plan development and banking/financing plan
- Promoting the idea of GreenTown in mass media, billboards etc. is expensive and the focus has therefore been on creating the word of mouth, social media, interviews, blogging, talking to media symposium/workshops etc. The aim was to reach as many 'normal' people as possible.
- It is difficult to explain ordinary lower class workers the idea behind GreenTown – almost the entire population has some kind of a connection to the refinery and therefore does not see the reasons for shutting it down and replacing it.
- By communicating to them the change that can come with GreenTown their perceptions can be however shaped
- There is a clear change in the attitude of people towards the issue – people are aware of the pollution and of the fact that can use the area of the refinery much more efficiently
- GreenTown receives lot of attention in media especially in the Netherlands, there has not been too much attention from local media
- Lobbying is absolutely essential but must be done in a very careful manner – reaching the powerful politicians indirectly is important as it could otherwise rise questions about the ethical of supporting the project
- According to Mr. Casimiri, the current prime minister supports the idea of GreenTown and in general aims to direct the country in the right (i.e. sustainable) direction – the change between the current and the previous governments is huge (in a positive way).
- While the ultimate goal of the project is to create jobs and environment in which local people can happily and safely life, understanding of the problems of sustainability is ab-

solutely essential. At this moment, the poverty and other related issues are the cause why people do not see how badly the environment is treated and how much more efficiently it could be used.

C.5 Steven Coutinho

Interviewee: Steven Coutinho

Position: Royal Bank of Canada (RBC), Vice President - Corporate Banking Dutch Caribbean and Suriname

Date: May 18, 2012

Location: RBC, Curaçao

-
- The credit freeze of the Central Bank of Curaçao and Sint Martin does not have too many implications for larger corporate projects – especially for the long-term ones that are for the greater good of the island. And even if it was, the freeze is only for 6 months and large scale energy related projects need preparations taking at least a year
 - The advantage of having a project locally financed is in the bank's knowledge of the local environment, laws, experience from dealing with the governments etc.
 - Recent problems with a wind-park project in Bonaire shows that the projects need to be well structured and must take specific local conditions into concern or they are prone to failure
 - RBC considers projects on case-by-case bases and in the energy related projects some things are of particular importance: awarded power purchase agreement, government's support of a particular project, future cash-flow projections, how caps on prices are set, how reliable the government's promises are in a particular country in determining and regulating prices, how laws are being reinforced, general relationships between public and private organizations. With regards to these aspects, local presence and experience with similar projects is very important. Banks from the USA or EU that do not work on local projects do not have this experience
 - Financing of energy projects from banks in general is limited to proven technologies with reliable historical data. Unproven technologies that bear potentially significant risks are (all over the world, not just in the Caribbean) always be financed by venture capital
 - Testing facilities, working prototypes or more preferably operational history are the only way to get financing from banks for energy projects (assuming all the other 'local specific' conditions are met – e.g. support of the local government)
 - If there is no 'predictable model' of cash-flow available, one cannot expect banks to participate
-

- The banks' interests in the SWAC projects on Curaçao is due to the fact that it is a proven technology with operationally history and predictable returns
- For similar reasons, the waste-to-energy projects planned on the island might face some difficulties in getting finance as there have been some problems with operation of the technology around the world (e.g. the question of reliable supply of waste could be a large issue)

C.6 Isabelle Delcour

Interviewee: Isabelle Delcour

Position: Student trainee at Spigthoff Advocaten & Belastingadviseurs, Curaçao

Date: April 14, 2012

Location: Willemstad, Curaçao

★ Email communication (bold letters highlight regulations related specifically to marine and electricity generation issues)

Below is a list of regulations, which must be conformed to in relation to OTEC operations:

1. Construction and housing regulation - Bouw- en woningverordening (PB 1952, 14)
2. Nuisance Regulation (AB 1994, 40) and the general measures within Article 6 (AB 1994.43)
3. **Ordinance maritime management - Landsverordening maritiem beheer** (PB 2007, 18) (OJ 2007, 18)
4. **United Nations Sea Convention**, the Act extending territorial sea of the Kingdom, the land decision to transfer from the beaches of the sea and inland waterways with the islands therein and plates to the island territories (OJ 2005, 18).
5. **Book 5 Civil Code concerning ownership of Curaçao (territorial) seabed and beaches - Boek 5 Curaçaos Burgerlijk Wetboek inzake eigendom van (territoriale) zeebodem en stranden (Articles 25 and 26).**
6. Establishment regulations for companies - Vestigingsregeling voor bedrijven (PB 1946, 43). Follows a license requirement.
7. **Electricity concessions - Landsverordening elektriciteitsconcessies** (PB 1963, 64). Follows a license requirement.
8. Rules regarding the establishment of companies and taxation

C.7 Margo Guda

Interviewee: Margo Guda

Position: Manager and senior scientist at Fundashon Antiyano Pa Energia (FAPE) and part time teaching position at the University of Netherlands Antilles (courses on renewable energy technologies)

Date: March 27, 2012

Location: University of Netherlands Antilles, Curaçao

-
- FAPE was established in 1975 after the first oil crises happened
 - Over the time, FAPE has gained on influence, mainly due to the concentrated knowledge on energy issues that was built up within the foundation members – in the past, FAPE provided some advisory work for the government, mostly at the central (Antilles) level. At the moment, FAPE however has almost no influence on governmental actions
 - Mrs. Guda teaches majority of the courses at UNA that are focused on renewable energy technologies (but there are not very many!)
 - FAPE's largest project was on wind resource assessment on three islands (Aruba and Bonaire in addition to Curaçao) – this project was performed on a relatively low budget (with some support of Aquallectra) and with several partners (such as METEO). Update of this assessment and measurements in higher heights than the previous 10m and 21m are now on FAPE's agenda
 - FAPE/Mrs. Guda has executed an in-depth study into the benefits of a comprehensive energy policy for Curaçao. This study modeled the development of the demand for all forms of energy used on the island, based on projected demographic and economic developments. This included both the demand for potable water and the demand for fuels in the transportation sector of the island.
 - Mrs. Guda is familiar with a project in the 1980's where Curaçao was considered by a Dutch company as a location for placing an OTEC facility – the project was however never executed
 - Besides updating the wind assessment of the island, Mrs. Guda is further involved in organizing and participating in various seminars and consulting in wind related projects on other islands
 - Overall, the new government is very supportive of renewable energy technologies
 - Mrs. Guda perceives that separation of electricity production and distribution is not necessarily solving the energy issues of the island (blackouts etc.) – the policy should have better been adjusted to the actual infrastructure. The main issue of the current system according to Mrs. Guda lies in the high cost of energy of both generation and distribution. Opening up the grid might thus increase the share of renewables on the island but

will not have any effect on the end consumer and the electricity price. Large number of small scale electricity producers might even worsen the current situation unless the problems with infrastructure are tackled. This is because Aqualectra remains responsible for providing backup power while it is not clear how this extra expenditure will be financed.

- According to Mrs. Guda, the policy does not sufficiently tackle issues resulting from the higher share (of higher number) of solar and wind energy producing. The problem will be how to pay for the spinning reserve and fuel expenditure to maintain it for all the small-scale renewables expected to connect to the grid.
- The 30MW of electricity that are planned to be produced by the two wind parks on the island can be further expanded. While a study performed in the 90s (by a BSc student) suggested that maximum of 44MW can be produced from wind energy, this study is over 10 years old – the technology has made significant progress since that and the possibilities for expansion might therefore be greater. This has however not been verified
- Curaçao was the pioneer of wind energy in the region with its wind park built in 1993. According to Mrs. Guda, the wind projects in Aruba, Bonaire and Jamaica built afterwards used Curaçao as an example
- Within the region, Curaçao can be considered as a very conservative country (its policies) which explains the relatively slow development of renewables there. On the other hand, Bonaire has a very progressive energy policy with a clearly set ultimate goal of reaching 100% of its energy produced from renewables
- This clearly shows the great importance of ‘proving the concept’. There have been numerous occasions when foreign companies tried to import various technologies and making a “quick buck” (Mrs. Guda mentioned waste-to-energy project). These projects always fail as the Caribbean offers very specific conditions (e.g. expertise- or legislation-wise). Proving that for example wind energy can be done in this environment thus triggers surrounding countries in making investments and engaging in projects
- Mrs. Guda, emphasizes the importance of involvement of local people, authorities, as well as utility companies in such ambitious energy related projects. Due to the isolated character of the electricity grid, utility companies on islands are very conservative as any disruption has substantial consequences – the case of wind has proved that one needs to engage locals in the entire technology transfer and development – only selling a technology (e.g. windmill) is not sufficient. Local representation of the technology provider might significantly help as well
- Mrs. Guda sees Aqualectra, government and UNA as key stakeholders of the envisioned OTEC facility. Aqualectra due to the fact that it is the one and only utility provider – any efforts related to energy generation should thus be consulted with them in order to sufficiently adjust all the aspects to local conditions
- Involvement of UNA in research of new technologies is important in order to ensure development of proper technology expertise – in that way, the island itself will benefit. However, the pioneer wind project on the island showed, that UNA itself (its employees and students) do not take much initiative themselves – especially the young students

should thus be actively reached in order to become involved. Some students however take a more active approach than their teachers – although there is relatively few of them. Technology as a whole at the moment is not considered very ‘sexy’ in Curaçao, except for IT and computers

C.8 Fiorina A.M. Hernandez

Interviewee: Fiorina A.M. Hernandez

Position: Investment Promoter at Curinde N.V. – Curaçao Industrial and International Trade Development Company

Date: April 4, 2012

Location: Curinde N.V., Curaçao

-
- Mrs. Hernandez works in the investment promotion department. Her tasks include attracting and guiding FDI in international trade and industry. Curinde promotes Curaçao and offers establishment and guidance to FDI interested in having an operation in one of Curinde’s business park.
 - Curinde is a semi-private company, with 85% of its shares owned by the government and 15% by a local bank. It generates its own revenues by renting multi-purpose buildings and providing plots of land in long lease. Curinde does not receive any subsidies from the government
 - It operates two economic zones on the island (in the harbor and at the airport) and an industrial park. There is a total of 12 economic zones on the island – however all the ones that are out of the scope of Curinde are only allowed to have virtual trade activities
 - Before year 2000, the zones were governed by the free law and had only the 2 zones owned and managed by Curinde. Hence, the term “free zone” is frequently used
 - In year 2000, the free zone law was amended into the economic zone. Aside from the term “economic zone”, virtual trade activities were also introduced. The economic zone law grants companies complete exemption from import duty, exemption from sales tax (normally 6%) and imposes only 2% tax on profit (normally 27.5%) from export
 - The economic zone owned and managed by Curinde have numbers of multifunctional units (buildings) that are constructed to provide required facilities to the tenants, whom are allowed to adjust according to their specific needs (build refrigerator units, offices, cooking rooms etc.)
 - Within the industrial park, there are no special tax exemptions. However, companies may apply for exemptions to the government and are considered on case to case bases (any company in Curaçao, not only the ones in the industrial park can do so)
-

- There are about 140 companies in the economic zones owned and managed by Curinde – a variety of activities are being performed from storage, repackaging and relabeling, to actual production
- The harbor free zone is known as a commercial area of garments, while the airport economic zone is geared towards other activities such as trading in excise goods, pharmaceutical goods, the production of contact lenses and jewelry
- The main condition for operating within the economic zone is to have a minimum of 75% of company's revenues generated from export activities – otherwise, the regular tariffs will be imposed
- The main reasons for government to support economic zone activities is to provide employment, attract trading partners and promote transaction in foreign currencies

C.9 Johannes I. M. Halman

Interviewee: Prof.dr.ir. Johannes (Joop) I. M. Halman

Position: Professor in Innovation Processes at the University of Twente and a chairperson for Technology and sustainable development at the University of the Netherlands Antilles

Date: March 13, 2012

Location: University of Twente, the Netherlands

-
- In the 80's Prof. Halman was an advisor on various building projects in Curaçao
 - Then switched to innovation – focus on projects at TU/e, talked to R&D managers, developed a methodology for analysis risks and applied in Philips and Unilever
 - Later moved on into risks in product platforms, worked and is still working with prof. Micheal Song (famous US researcher in the field of Innovation Management) at the University of Washington in Seattle – recognized there the entrepreneurial spirit of US students
 - Then moved back to TU/e in Eindhoven and moved later to University of Twente (UT) where he focuses his research on innovation and risk management in the building industry
 - At University of Netherlands Antilles (UNA) Prof. Halman developed a Techno MBA (the first MSc. Programme at UNA developed for persons with a technical background)– aimed for bachelors in engineering and with some experience. The MBA focuses on business aspects, i.e. extending students' engineering views. Now 3rd year – about 25 students/year enroll
 - Sustainable technologies are highly relevant in the TechnoMBA
-

- There are 2 month blocks of classes and it is a mix of lectures of scholars from Antilles and expats
- Government supports it financially to make it affordable (it only costs 3000 guilders/year)
- Gerbens-Leenes Winnie, the head of 3TU SET lectures in the Sustainable block of the MBA – she will be on the island in April
- Some students of this year's MBA planned to do their masters thesis on the topic of sustainability
- One of the lecturers in the Techno MBA is Karel Tujeehut who holds a high position in Aqualactra – lectures in the sustainability
- Prof. Halman currently supervises 3 Phds in the Antilles:
 - Richenel Bulbaai– focus on reduction of electricity use
 - Rosheuvel Franklin– Has some OTE experience, studied at TU/e, focused mainly on air-co projects
 - Filomeno Marchena - Focusing on reducing water production cost, studied in Delft
- Curaçao has its specifics (island) specifics: it's a small country, very important to talk to everyone to see what the hurdles are. Individuals are often willing to make the change but organizational inertia stops it from happening
- A specific problem related to the implementation of new sustainable technology concerns the fact that current capacity of energy supply also needs to be exploited at a profitable basis. This may conflict with the introduction of new technologies. This is also the case for Aqualactra where this process goes back to the 80's
- There have been several past projects – connecting hotels to a SWAC system and later connecting it to the hospital – project was never executed though it was close to happening
- The problem is always in a mix of causes, not just one problem. The key is to find balance
- Prof. Halman also tries to promote research activities on the island – with focus on sun, ocean, water (three things that are present on the island). However, this is not his core focus of research.
- Prime minister favors RET
- Mr. Theo Lendering – did his thesis in 1970's on OTEC in Curaçao, later worked in the harbor – ships maintenance and some project in cooperation with Cuba – might still work in the field

C.10 Simon Kloppenburg

Interviewee: S. Kloppenburg

Position: Advisor Airport Development at Curaçao Airport Holding

Date: March 19 and May 15, 2012

Location: Curaçao Airport Holding, Curaçao

-
- CAH has signed MOUs with some of the key future users of the SWAC system (CTEX data center and CAP) for supplying cooling capacity. As a result, 60% of the total system's capacity is therefore already allocated.
 - Aquallectra and CAH are currently in the process of signing an agreement for formal co-operation between the two SWAC projects – this cooperation aims to increase the chances of both projects being successfully completed. The cooperation aims to:
 - To share (shareable) costs in tendering, mobilization etc. CAH has already used some seabed survey data of Aquallectra for its own use and several official meetings have already been held to formalize the cooperation agreement;
 - The parties have one 'common' consultant that facilitates and provides services for both of these parties with regards to their cooperation;
 - The two parties are currently also seeking official support from the government of Curaçao as their projects are in exact alignment with the new energy policy.
 - The final financing model is yet to be established – CAH does not at the moment have 50 mil ANG that are necessary for the full completion of the project. CAH is considering several options – involving banks and/or private equity.
 - CAH aims to have at least 30% of the project financed by local institutions so that the island itself ultimately benefits from the project
 - Willingness and interest of local financial institutions is very strong as there is 'overliquidity' in the economy. However, local banks do not have much experience with (risk) project financing.
 - CAH has almost finished its pre-engineering works and is soon to make a decision on progressing to the engineering phase – current progressive has been successful and the full engineering phase should among others quantify in detail all project risks and thus make the project more easily financeable.
 - Until now, the project has consumed about 1.5 million ANG, further ~2 million ANG are required for engineering (decision on proceeding to this phase is soon to be made). Total costs of the entire SWAC systems and the infrastructure is 50 million ANG.
 - There are some pre-conditions that Curaçao satisfies with regards to the undergoing SWAC project:

- Sea bed profile and sea water temperatures
 - Past failed projects (lessons learnt from these projects)
 - European judicial system
 - The project is backed up by a large government owned player (CAH)
- There are a few crucial aspects influencing the success of similar projects in the environment of Curaçao – due to the ‘island’ mentality:
 - Transparency – absolute transparency with respect to desired goals and intentions of projects
 - Awareness – ‘since it is a small island, people tend to have very narrow visions’. Additionally, due to the complexity of today’s technologies, people simply do not understand what these technologies are all about – ‘so why should they support or commit to them?’
 - Disbelieve – people tend to laugh at projects that aim too high or are very ambitious
- Mr. Kloppenburg believes that the previous SWAC projects on the island failed due to several reasons:
 - Scale (thinking too big) - one company cannot ‘pull-it off’ on its own with only a few committed customers and focusing purely on direct profit
 - Companies believed that business works the same way in Curaçao as in large countries
- Reasons why Mr. Kloppenburg believes that the SWAC project at the airport will succeed:
 - Pure ROI figure is not what matters;
 - CAH will only provide deep sea water pipe, but also land and infrastructure for other industries and technologies;
 - It is not just about deep sea water but about everything behind it – all the other technologies supporting each other and yet working independently
 - CAH is not only looking at the direct profit but also involving others (building knowledge center) and thus benefiting the company and the island indirectly
 - CAH does not entirely depend on the success of the project
 - ‘Start small, dream big’
- Current developments with Aqualectra and Curaçao:
 - Aqualectra used to be pure monopoly – this is slowly changing now – Aqualectra is the only distributor on the island but production is open to others;
 - There is willingness to cooperate from Aqualectra side (mainly due to the new policies);

- The volatile oil prices matter even more than elsewhere as absolutely everything on the island is dependent on it;
 - There is competition with Aruba – if they have something, we want it twice as big.
- CAH itself is making big steps to show its commitment towards sustainable development – bringing one of the first electric vehicles to the island, installing solar panels on the roof, ‘subsidizing’ solar panels for the employees.
- From Mr. Kloppenburg’s experience, corruption is not a big issue on the island – it is a matter of perception – Curaçao is a small Island and has different procedures and habits. Curaçao is not backed up by large professional institutions that could provide expertise on the topic and bases for making decisions which simply means that some procedures might take longer
- The Curaçao Ecopark of which OTEC development should be part should provide combined knowledge on renewables (wind, solar, ocean)
- There is a waste-to-energy planned that would use approximately 40 tons of waste per day and produce oil, gas, CO₂ and water – approximately 1MW of electricity could be produced from the gas

C.11 Anthony Kool

Interviewee: Ir. Anthony Kool

Position: Owner of and consultant in Kool Caribe Consult, secretary of Huntu Korsou organization (‘Curaçao Together’) and member of the Curaçao Business Council for Sustainable Development (BPM)

Date: April 2, 2012

Location: Santa Rosa, Curaçao

-
- Mr. Kool has, together with 4 other BPM members, formed a working group that performed a ‘sustainability scan’ among the BPM member companies
 - The scan was based on questionnaires distributed among the companies and aimed to investigate the views, visions, future strategy and desires of the member companies on the topic of sustainability. It was performed during the year of 2011, the report was finished at the end of the year and made public in March 2012
 - Until then, BPM was mainly focused on the issues related to working conditions and environment. Since BPM became a member of the World Business Council for Sustainable Development, it wanted to extend its operations to the field of sustainability
 - Analyzing the views of the current BPM members was aimed to set bases for the future actions of the organization
-

- The report is publically available; it was handed over to me. Mr. Kool guided me through the analysis:
 - One of main concerns (not only of Mr. Kool, but based on the report also of the BPM members), is the minimum influence of BPM on the actions and decisions of the government. One of the intentions of BPM for the future is to increase this influence – the organization has over 50 members (including the largest companies on the island) and could therefore have substantial power on political decisions. However, cooperation with the government on the island is more complicated than in the Netherlands (people rarely want to get in politics due to conflicts of interests and other issues related with living in small island community)
 - Vast majority (24 of 26 respondents) plans to invest into their future ‘sustainable’ development. The companies however seem to lack a clear direction of their future actions – Mr. Kool therefore concluded that BPM should provide some guidance
- In the near future, BPM intends to improve communication outside of the organizations with media (which it already to some extend does) and work on improving public awareness about sustainability
- Mr. Kool also suggested that BPM should improve communication within the council itself in order to better accomplish its mission

C.12 Marc Marshall

Interviewee: Marc Marshall

Position: Director of Fundashon pa Konsumido Curaçao

Date: March 22, 2012

Location: Fundashon pa Konsumido Curaçao (Consumer protection foundation)

-
- Fundashon pa Konsumido is the equivalent of Consument Board in the Netherlands
 - The organization protects the interests of consumers by:
 - Helping the consumers directly and informing them about their rights
 - Influencing the creation of new and modification of old policies and laws directly related to the interests and needs of consumers
 - In general, institutions in Curaçao are:
 - Much less specialized on particular issues (sectors) and cover much wider areas than its counterparts in Europe or USA – while developed countries usually have separate institutions for each sector (e.g. telecommunications) Fundashon pa Konsumido covers all markets and sectors
-

- Independent organizations are less established and less powerful than in Europe or USA – only recently have organizations in Curaçao such as Fundashon pa Konsumido started actively acting and influencing the market
- The foundation is 100% government funded and is now looking at other ways of financing in order to become more independent
- According to Mr. Marshall, there is almost no awareness whatsoever about ‘green’ topics and there are no complains related to the way how electricity is produced on the island at the Fundashon pa Konsumido. There are other organizations like Amigu di Tera, that do campaign against the air pollution from the refinery.
- The only energy related topic that has recently been covered in the magazine issued by the foundation was related to energy saving (energy saving light bulbs)
- In the coming months, the newly introduced energy policies will be discussed in the magazine
- Until about two years ago, there have substantial numbers of complains from the consumers on both high electricity prices and low quality of electricity supply (frequent blackouts etc.)
- Additionally, Aqualectra is among the 3 worst companies on the island with regards to number of complains and the worst company of all in reactions to these complains
- The problem appeared to be mainly in the fact that there were no sufficient competition that would force Aqualectra into changing its behavior
- Recently with the newly introduced policies by the government, the situation has significantly improved and the quality vs price ration of electricity supply has improved – this is also reflected in the number of complaints from consumers
- One of the reasons for such high complaint rate is also in poorly written (from the consumer’s perspective) general conditions of electricity use and supply
- The foundation has no actual data (e.g. from surveys) on consumer satisfaction with electricity use
- Overall, the latest developments in energy policies are undoubtedly for the better of consumers – however, the market conditions are still lagging behind Europe and USA

C.13 Gilbert Martina

Interviewee: drs. ing. Gilbert Martina MBA

Position: Chief operating officer at ENNIA insurance company and Shareholder at Elijah fish farm, Bonaire

Date: March 26, 2012

Location: ENNIA Head office, Curaçao

-
- Aquaculture is the fastest growing food sector in the world – growing 15%/year, it is a 85 billion USD industry
 - Banks seem to be still reluctant to provide finances for the business, no commercial loans are available and for financial reasons financing it by equity is more suitable
 - The problem is that to make aquaculture profitable, the business needs to be done at a relatively large scale – the fish farm in Bonaire is a 100ton/year Cobia farm - to make it financially attractive, at least 500ton/year farm would have to be set up
 - Bonaire has simply no legislation on aquaculture - Curaçao does but it is overly complicated
 - Only growing is done in the Antilles, the hatching is done in the USA – hatching is not extremely knowledge/expertise demanding but it is a very delicate process and requires highly stable conditions
 - Most of the fish on the island is imported from Venezuela, Colombia and USA – locally, only several percent are produced
 - The Bonaire fish farm started 2.5 years after the planned date due to large administrative issues (obtaining permits)
 - Mr. Martina considered setting up the fish farm in Curaçao but due to zoning restrictions, complicated regulatory system and funding issues, this idea was abandoned
 - The Elijah fish farm has now operating issues, mainly due to problems with water quality (high levels of toxic materials) and energy costs (the farm was driven by diesel generators but due to the increased costs of diesel, the profitability significantly decreased)
 - Mr. Martina has studied and worked in Europe and has been involved with foreign companies providing the fish farming technology – the slowness of administrative procedures in the Antilles judged by the European and USA standards is ‘incredible’
 - It is also difficult to come to the island with innovative ideas, as the island environment gives most stakeholders a very narrow view – people and companies tend to protect ‘their own piece of pie’ rather than cooperating and supporting the ‘growth of the pie’
 - Change management in Curaçao is extremely challenging and takes ‘10x more time than in Europe or in the USA’ – people here are afraid of giving feedback, confronting others
-

and simply are happy to keep on doing the same job forever rather than changing and moving the company or themselves forward

- The education level is not an issue, but the mentality on all levels (private, business and governmental) makes life of innovative companies very difficult – views of people are limited and institutional structure are very restricting
- With respect to education, having the experience from international projects or studying abroad significantly broadens ones horizons – a large problem is that only small proportion of people educated abroad actually return to Curaçao. One solution to this could be attracting foreign students to Curaçao (UNA)
- Potential OTEC Centre of Excellence would thus be an incredible opportunity to promote high-tech research, engage locals and yet give the opportunity to confront foreign experts and students at the same time

C.14 Joanne Nicastia

Interviewee: J. Nicastia

Position: Director, Corporate Finance, National Investment Bank (NIBanc) N.V.

Date: May 25, 2012

Location: NIBanc, Willemstad, Curaçao

-
- NIBanc's main focus is syndicating loans for large infrastructural projects, i.e. advisory on structuring the financing aspects of projects – finding the right balance among various banks (local and/or international) as well as private equity
 - There is money available for green projects, but there is lack of good enough projects (this is applicable around the world but specifically also in the region)
 - There is a general trend among investors in switching from traditional to emerging markets (including green energy), but there is lack of knowledge about how risks in these projects can be assessed. There are number of aspects that should be considered prior to financing green projects within the region – governmental support, permit and power purchase agreements awarded, financial projections...
 - The single most challenging issue in financing green energy projects on small islands is the scale – impact of any green energy project on the island is tremendous. E.g. a 30MW wind-park is 'nothing' in the Netherlands, but integrating it into the infrastructure of the island has major implications (both technologically and financially)
 - The impacts of oil prices on islands' economies are significant – not only the direct ones (higher fuel prices for transport) but also the indirect ones (higher island's imports and negative effects on the tourism on which most islands depend on) – the switch to green energy is therefore inevitable

- With new technologies (such as OTEC), financial projections are almost irrelevant (from bank's point of view) as there are no real historical data to support them – this makes financing of unproven or pre-commercial technologies difficult
- The solution to this problem is pilot projects. Mrs. Nicastia demonstrates this on the example of waste-to-energy plant. To reach profitable operations, one needs to have a plant of a certain scale, which requires substantial supplies of waste (that small islands generally cannot provide). Operating a smaller/pilot/pre-commercial sized plant on the island that proves the concept and demonstrates the impacts on the grid, economy, waste quantities etc. can showcase to the world that the technology works and is viable
- These pilot projects can then provide the necessary data for successful rollout of the technology on larger scale and in other countries around the world. It also helps the island itself in becoming a knowledge economy. Additionally, it is also the only way to get finances from banking institutions
- Starting a knowledge/research centre that covers a broader range of technologies (SWAC, OTEC, sustainable housing etc.) however requires a great degree of coordination: 'Bunch of loose cannons will not make it, one needs to coordinate them, pull them together and build an industry around it'
- Such large-scale projects should have local representation: local institutions such as the university, government and banks (so it is also the island itself that benefits). But they should also include foreign institutions: banks, research institutions and renown universities that guarantee prestige and a good name – these institutions should be from multiple continents to attract interest from broad range of potential partners (e.g. from Europe, USA, Asia...) and diversify the focus across the world
- The research should be focused on applicable/practical parts of technology, rather than fundamental research that can be better performed at large research institutions in the USA or Europe
- Partners should be sought on the other two of the ABC islands and should therefore include the Caribbean office of TNO – the islands themselves are already small and together they can achieve much more and create a global showcase
- It is at the moment cheaper to get finances from Europe, but the banks there do not have proper knowledge of the Caribbean/small islands region – this is why financing projects both locally and from abroad is beneficial
- One of the main reasons why the current wind-park project in Bonaire has problems is in its poor financing structure – the project was to a great extent dependent on green funds that were suddenly not available after Econcern's bankruptcy and crisis in 2008
- One of the main challenges of financing green energy on the island is 'translating' the projects into the 'language' of foreign investors – so they can understanding all the underlying issues – this is the most important part of NIBanc's (and Mrs. Nicastias') work
- Perhaps the most important unique selling point (USP) of the island is the Dutch legislation that forms the bases for local legislation – it is a guarantee for investors that they can

(if necessary) take local authorities to the International Court of Justice in The Hague. This is why many companies from abroad base their operations in Curaçao

C.15 Surlidric F. Rojer

Interviewee: Ing. Surlidric F. Rojer

Position: Production Manager at Curaçao Drydock Company Inc.

Date: May 31, 2012

Location: Curaçao Drydock, Curaçao

-
- Curaçao Drydock Company is only one of the companies operating in the harbor (besides the cargo handling, tourism cruises service etc.). The harbor is being managed by the Curaçao Port Authority
 - The Drydock Company is involved mainly in ship repair, maintenance and conversions, it has international base of customers and is considered to have good reputation for services in the region
 - The company has about 5% of the Caribbean ship repairing market. Other regional harbors with large market shares are in Cuba, Bahamas, Mexico, Panama and Caramor. The company has the intentions to grow and increase the number of docks for repairs from the current two to four
 - The advantage that Curaçao has are the deep harbors, the fact that it is outside of the hurricane belt and that is strategically well positioned (close to South America, close to the Panama channel).
 - There are two limitations of Curaçao in terms of handling large ships: the width of the channel when entering the harbor and the height of the ships. As a result, the harbor can handle ships of up to 270m long and 47m wide. The average depth of the harbor is 12m
 - Since shipbuilding is highly labor-intensive work, ships are generally built in places with low costs of labor and with sufficient number of suppliers (and the appropriate infrastructure). In more developed countries (e.g. in western Europe) it is the high-end works that are performed. Within the region, only smaller scale or specialized projects can be run as there is no infrastructure to efficiently support production of large vessels or ships
 - The Drydock Company does not work with oil platform types of vessels – firstly, the parameters of the harbor limit their entry and secondly, only specialized companies are involved in repairs and maintenance of oil platforms. These are generally located close to the market, i.e. in the Central American regions, these are mainly located in the Gulf of Mexico
 - Due to the strategic location of Curaçao, the island is often used as a temporary stop for the platforms to exchange crews

- With the expansion of the Panama channel, there will be more and more very large ships in the region – to handle those, Curaçao would need a new dock at the open sea
- Projects such as maintenance or assembly of off-shore OTEC vessels are essentially possible, but would require changes to the existing infrastructure of the harbor and would be dependent on the ability of getting the vessels into the harbor

C.16 Franklin J. Rosheuvel

Interviewee: Franklin J. Rosheuvel

Position: Manager at Energy and Automation and former advisor in the Technology commission of the government

Date: March 24, 2012

Location: Oud Hato, Energy and Automation office, Curaçao

-
- Mr. Rosheuvel was looking at the possibilities of OTEC and SWAC development in Curaçao already 25 years ago – over time, even experts from NELHA were involved. Various possible locations for SWAC were identified.
 - Later, Mr. Rosheuvel became involved in the SWAC project in the Piscadera bay – he worked on both the engineering and economic aspects of the project in cooperation with Makai engineering (Hawaii based ocean energy company focused on oceans and related technologies – e.g. besides SWAC and OTEC, also pipes, underwater cables etc.)
 - The Piscadera bay project started as a project of Aqualectra, but for financial reasons, other institutions became involved as well. Firstly, a power company (banking institution) from Zeeland (Netherlands) and later Econcern (Dutch consulting company focused on renewable technologies)
 - The project progressed successfully to the tendering phase but in 2008, with the beginning of the economic recession, Econcern went bankrupt
 - Since Econcern and Aqualectra were the owners of the project, Aqualectra has now 100
 - Mr. Rosheuvel as an expert on HVAC systems and among others on SWAC, perceives it as absolutely essential to have the capacity of the SWAC system well design(at)ed – the enormous investments associated with laying down a deep sea water pipe imply that the SWAC system should run at all possible moments at maximum capacity (otherwise the system is losing money)
 - Finding the right (and sufficient amount of) committed customers on the island is challenging, and involvement of the large potential consumer – e.g. the planned ‘CTEX’ data center – is very important for the airport SWAC.

- Mr. Rosheuvel is skeptical about OTEC (especially in Curaçao) – the economic feasibility predetermines it to be suitable for 100+MW plants while the current technologies only allow building plants below 100MW. And since Curaçao is 120-130MW island, it is simply not suitable
- Another major issue with such undiscovered technology is the resources needed for actual research, maintenance and operation of the OTEC plant:
- As a former advisor of the government on educational issues on the island, he stated that within the fields of mechanical and electrical engineering the level of education is fairly poor (namely on the MTS+ (higher university) level)
- The supporting technology is not here – e.g. heavy machinery for manipulating the pipes
- While operation of the plant itself would be relatively simple, any non-expected and unconventional operations would require equipment and expertise from abroad
- Mr. Rosheuvel further questioned the economic feasibility of running even a small sized OTEC plant – e.g. 100kW – the volumes of water that would be required should rather be used by the SWAC system in order to pay off the investment for the deep-sea water pipe. The aim of designing the deep-sea water pipe in the first place is to make it as small as possible, in order to satisfy the required capacity and keep the costs down.
- Overall, what matters in such project is not just the technical aspects but (perhaps even more importantly) the ‘financial engineering’ – e.g. how will one utilize the deep sea water pipe to its fullest? Who are the committed consumers? etc.
- With regards to OTEC, one needs to answer the questions such as: who will benefit from the OTEC research? Who will provide the technical and financial support to the facility? And if it doesn’t workout who will pay to clean-up the rubbish.
- There is technical expertise on the island, however it is mainly due to the fact that the all the major companies (refinery, harbor, Aqualectra etc.) have their own educational systems. These employees are then relatively strongly tied to these companies

C.17 Paul Stokkermans

Interviewee: Paul Stokkermans

Position: Executive director of the Caribbean Research & Management of Biodiversity (CARMABI) and former employee of the ministry of Economic Affairs in Curaçao

Date: March 23, 2012

Location: CARMABI, Curaçao

-
- Carmabi focuses on the green part of the environment (everything living - e.g. marine life etc.) rather than the gray part (how electricity is produced or garbage processed etc.)

- As a former employee of the ministry for Economic affairs, Mr. Stokkermans was in charge of managing and appraising development projects in Curaçao – he was to a small extent familiar with the SWAC projects that started about 15 years ago
- Mr. Stokkermans is aware that some of the issues related to SWAC projects included financing and cooperation with key stakeholders (at that time Aqualectra and the potential customers)
- From this, Mr. Stokkermans concluded that getting all relevant stakeholders ‘on board’ prior starting (any kind of) project on the island is very important
- Mr. Stokkermans also perceives some traits of island mentality in Curaçao – since the island is isolated from other countries, the views of people on different topics are fairly narrow. Projects in Curaçao take often long time (due to administrative procedures etc.) but they eventually happen.
- CARMABI as an organization has no political power and its main source of influencing developments on the island is publicity – both in local media (newspapers, radio, TV) but also on academic level by publicizing journal articles (around 20-25/year articles in respected journals)
- On some particular projects (e.g. regarding ‘no-fishing’ zones or wetlands of Curaçao), CARMABI cooperates directly with the government
- With respect to the environmental impacts of SWAC and deep sea water pipe, he is not an expert but is aware that the main potential issues lie in the amount of nutrients that will be brought up from the sea bottom and that can negatively affect the coral reef. The coral reef is of immense economic and environmental importance to Curaçao (due to fishing and tourism industries)
- The focus of education that CARMABI provides to school children is now changing from being mainly focused on land (e.g. plants) to some marine education (coral reefs and their importance)
- With respect to the work of CARMABI, no significant changes from the previous government can be observed
- However, Mr. Stokkermans does perceive the government as clearly in favor of green technologies

C.18 Julissa Tromp

Interviewee: Julissa Tromp

Position: Coordinator Service and Maintenance at NUCapital, Inc.

Date: April 4, 2012

Location: NuCapital office, Willemstad, Curaçao

-
- NUCapital has been redeveloping the two wind parks Playa Kanoa and Tera Kora (2x15 MW). These wind parks are currently being finalized and are to be operational by July of this year. NUCapital is an independent power producer and has a agreement with Aqualectra – i.e. it will be NUCapital who will be operating the wind parks
 - Major advantage of wind energy that Curaçao has nowadays over other locations in the region is the experience from past projects:
 - Pilot project was already running in 1985, by utility company
 - In 1993 Windfarm Tera Kora of 3MW was grid connected to the utility; operational from 1993 to 2008) – this results not only in operational experience, grid-interconnection experience and also regarding zoning issues. The current projects had therefore much easier path towards completion:
 - In 2000 Windpar Playa Kanoa, 9MW windfarm operational till 2011; also grid connected.
 - Amigo di Tera (Friends of Earth) organization opposed the wind park plans due to potentially negative effects on bats & birds, but time has shown that it was not the case at all Studies regarding the aviation traffic also had to be made but presented no problem at all
 - The project significantly benefited from the very good cooperation between NUCapital and Aqualectra (who initiated the project in the first place back in 1985).. Aqualectra would have to be involved in any project that refers to energy supply to 3rd parties. Considering it is always them who can argue the reliability and quality of the provided electricity, . And since Aqualectra will have to bear the consequences of any disruptions, their approval for providing electricity to grid is essential
 - The project was financed from multiple foreign sources (UK, EU and USA)
 - Some expertise regarding operations has already built up since 1993 during the first wind project at Tera Kora. For a technician ‘MBO’ education in electrical or mechanical engineering could be sufficient, supervisor needs have a ‘HBO’ education also majoring in Electrical or Mechanical engineering.
 - Finding new employees is a relatively complicated process, and the ad was placed in local papers that can also be read/purchased in Aruba, Bonaire and Curaçao. (In the last re-

cruiting process, candidates from Aruba's refinery applied) There were some candidates of refinery because:

- There was a decision made in Aruba that refinery's operations will be cut back
- This has triggered 'insecurity' (uncertainty) among the local employee's who therefore started searching for other opportunities
- The candidates have sufficient expertise (mechanical engineering is the core area)
- What is often strongly underestimated is the role of culture and distance from Europe. In the area (Caribbean) an 8-5 mentality is often present. NUCapital uses technical support of technicians from the European, the wind turbine manufacturer. Good communication is essential considering remote accessibility to a system - all actions of the operators (both in Curaçao and in Europe) must be communicated properly. Further, the culture and environment of Curaçao make the transitions for expats challenging – the rigid, responsible attitude towards work in Europe is not present in Curaçao
- Mrs. Tromp does not perceive the job market for technicians to be highly competitive (unlike in the financial or IT sectors), but it is very difficult to beat the secondary conditions that the local refinery provides to its employees (generous benefits and salaries, pension funds, access to medical facilities etc.) – these benefits have been kept since the time Shell was operating the refinery and they are not common in other companies on the island
- New government that came to power in 2010 did not present struggles for the project – the project only needed to be updated to the new government with exact plans of the wind park
- The first project at Tera Kora that started in 1993 had some operational issues. These were caused partially by lack of technical expertise and technology within the company (formerly KODELA, nowadays Aqualectra) but also by the bureaucratic procedures embedded

C.19 Karel Tujeehut

Interviewee: Karel Tujeehut

Position: Manager Corporate Strategy & Business Development of Aqualectra

Date: March 23, 2012

Location: Mundu Nobo Aqualectra production plant, Curaçao

-
- Mr. Tujeehut's main focus is on Client Relations, New Developments and Economic Development within Aqualectra. Further, he is responsible for managing several other areas such multi-utility NV and Aqualectra Bottling Company NV.
-

- Mr. Tujeehut has been involved in all major renewable energy related projects on the island since 1990's
- The relatively negative evaluation of BTP that states that some of Aqualectra's machinery is inefficient and obsolete is to some extent correct – however, within the context that Aqualectra is operating (isolated market, dependence on oil prices, limited finances, underdeveloped regulatory system etc.) the actual output (electricity and water) of Aqualectra is of high quality
- Especially over the past couple of years, Aqualectra has been actively involved in increasing consumer satisfaction and based on assessments of independent parties the service has clearly improved. However, within the conditions that Aqualectra is operating, it is almost impossible to reach to total satisfaction. There are some areas that Aqualectra knows should be addressed such as timely connecting new clients to the grid
- Other issues (such replacement of old machinery) is strongly dependent on finances and governmental willingness to adapt tariff according to market prices.
- Majority of complains are related to pricing that is influenced mainly by factors that are not in the hands of Aqualectra and that are dependent on machinery that is available
- It is absolutely necessary to compare Aqualectra and situation in Curaçao with similar environments (countries with similar resources and size) – otherwise it is impossible to make any conclusions
- The latest changes in the electricity policy create a very challenging situation for Aqualectra, both with respect to the technological and management problems associated with opening up the grid. Making the current grid 'smarter' is an important step. If too many people or companies connect their solar panels (or other means of electricity generation) to the grid, there will be a problem
- Every 2-3 years, Aqualectra performs integrated resource planning where various technologies are evaluated for their suitability in Curaçao. Besides wind and solar energies other technologies have been considered: organic Rankin cycle, absorption technologies for cooling, smart wind turbines, OTEC, SWAC, wave energy, biodiesel, waste to energy...
- The most promising at this moment appear to be wind, solar energy and solar street lighting, SWAC, organic Rankin cycle
- Currently there are 2 wind parks in the process of completion (2x15MW) replacing the existing windpark capacity– there still is some potential for further expansion of wind energy use
- Aqualectra is also involved with the SWAC project that started in early 2000 – the project's success was however dependent on Econcern's ability to get funding. Econcern's bankruptcy in 2008 thus stalled the project. The project was in the tendering phase. Efforts are being done at this moment in time to proceed with the project.
- The main challenges that the project faced were financing and convincing consumers to commit to the project

- Currently, Aqualectra has a SWAC project under development While Curaçao Airport Holding has its own SWAC project, cooperation between the two parties was started (formal status of this cooperation is yet to be finalized). The cooperation is there to guarantee information sharing as well as utilizing synergies (e.g. sharing some costs for surveys or material purchases)
- These two projects are independent but yet in many ways complementary. Mr. Tujeehut perceives it important to successfully finalize at least one of these projects as its success will trigger other projects and will eventually benefit the island
- Besides financing, Mr. Tujeehut does not perceive other steps in the projects as highly problematic In general, the key aspects that Mr. Tujeehut considers important in performing similar projects are cooperation (with all other relevant stakeholders) and stability of the government (that the governments decisions and views on topics do not change). Creating a win-win situation for all involved parties is essential and is also what Aqualectra attempts to achieve with all its projects

C.20 Tim van den Brink

Interviewee: Tim van den Brink

Position: Managing director of EcoVision NV environmental consultancy, Member of the Curaçao Business Council for Sustainable Development

Date: April 4, 2012

Location: EcoVision, Curaçao

-
- EcoVision is involved in four main areas – Environmental Management Systems, Energy and Water Management, Environmental Planning and Policy, and Environmental Studies and Permit Applications
 - Among others, EcoVision has been advising the government of Curaçao on several environmentally related issues, performed environmental impact assessment for the envisioned waste to energy plant or assessed the waste amounts and recycling opportunities on the island
 - Further, EcoVision wrote a draft of legislation that would modernize the current regulatory framework ('filled the missing gaps') regarding permits, fines, impact assessments etc. environmentally related projects
 - EcoVision was also involved in performing impact assessment of the SWAC project – checking relevant legislation and if all requirements are met and assessing the risks of returning the deep-sea water back into the ocean
 - Based on the study no significant issue were found. The water can be safely returned at the depth of about 50m. The greatest concern was about the nutrient levels of the deep-

sea water and its influence on the coral reef because the corals have a very narrow range of tolerance for their living conditions

- What could potentially be a source of environmental problems is the ‘branched’ water that is planned to be used by other technologies than SWAC (Aquaculture, Agriculture etc.)
- All legislation regarding the project has until now been met but ‘regular’ procedures for subtle re-movement of the corals, abiding the noise level regulations or construction periods will have to be followed
- In theory, the current regulatory framework of Curaçao requires companies to obtain a very low number of permits as compared to Europe or USA where for example environmental impact assessments are essential parts of large projects (not in Curaçao)
- In Curaçao, the project approach greatly depends on the project owner – large international companies generally follow the procedures (impact assessments etc.) that they apply in all other locations around the world
- On the other hand, example of a recent hotel construction in Curaçao shows that some project developers only strictly follow the regulations (get the necessary permits and nothing more) – these projects then risk negative public attention that can hinder project progress. Mr. van den Brink showed the dangers of negative public perception on an example of a Race Track project in Aruba.
- Proper environmental assessment also greatly reduces the resistance of environmental organizations. These organizations (that are plentiful on the island) play the role of ‘watch dogs’ as they point to projects and activities that are harming the island. They either make such activities public (via media) or in some cases get involved in law suits
- Community does however not look only at the environmental impacts but also considers the positive socio-economic impacts of projects. This is for example the case of refinery – while people to some extent perceive the environmental issues those are balanced by the employment and economic benefits it brings (check sentence)
- Regarding expertise required for EcoVision’s work, Mr. van den Brink does not see significant issues in availability on the island. EcoVision consists of a core team that occasionally hires experts or even students for specific tasks such as visualizations or modeling

C.21 Chris van Grieken

Interviewee: Chris van Grieken

Position: Manager at Caribbean Energy Solutions (CARENSOL)

Date: March 26, 2012

Location: CARENSOL office, Curaçao

- While also selling and installing solar panels, CARENSOL focuses mainly on decreasing the energy consumption of households – in the forms of insulation, automation etc.
- Mr. van Grieken perceives energy saving as the first step in transforming towards sustainable living. Sustainable energy generation is only the second step (energy saving is the 1st step in sustainable energy. As for sustainable living the 1st step is personal habits and patterns)
- Energy saving has much more favorable (shorter) return on investment than often more promoted renewable technologies (solar)
- Overall on the island, there seems to be very level of awareness about energy related issues (among both the public and businesses)
- Nowadays, especially large companies are trying to identify ways of saving on energy cost
- Mr. van Grieken tries to be engaged in variety of workshops, talks and seminars that would help direct the island in a more sustainable direction
- Even the simple rules such as turning off lights or computers are difficult to enforce on people. According to Mr. van Grieken smart use of modern technologies such as sensors or other means of automation therefore are the most suitable solutions to the basics of energy saving
- The newly introduced energy policy is definitely a very positive step for the island. However, Mr. van Grieken sees several opportunities for further improvements – namely in precisely adapting the policy to the specific characteristics of Curaçao and its technical infrastructure.
- Mr. van Grieken is aware of some technical issues of opening up the grid such as problematic connection of solar panels to the grid and unavailability of meters
- Other introduced change – low taxes on environmentally friendly products (PV panels etc.) is another very positive step for the island. Mr. van Grieken however suggests, that the low import tax should also be extended to the ‘passive’ products such as insulation or energy saving electronics
- The new government has made some impact on the public and ‘got people talking about the issues’ however further improvements must be put in place in order to sufficiently promote sustainable development – the perceived gaps in the system are mainly in the actual enforcement the introduced policies (‘setting up the exact rules’), aligning the policies with the actual state of the electricity infrastructure and expanding the tax benefits to the area of energy saving (classifications of house appliances etc.)
- In general, Curaçao has not yet reached a stage where ‘green labels’ and other similar certificates would be attractive to companies (i.e. also to their customers) - the public is not aware what ‘green labels’, that they are legitimate and are not just marketing
- Mr. van Grieken believes that direct change of prices (such as for example significant increase in fuel prices) would have immediate effect on the behavior of people – unless

people are directly confronted with incentives/higher markups they will not change their behavior

C.22 Bertine Vermeer

Interviewee: Bertine Vermeer

Position: Innovation Consultant at InnovatieCentrum Curaçao

Date: March 22, 2012

Location: InnovatieCentrum Curaçao

-
- InnovatieCentrum was setup and is funded by the government to promote development of SMEs on the island
 - The center receives a list with numerous topics/areas from the government every year that should be addressed – InnovatieCentrum then proposes different projects (e.g. set of workshops and informative lectures for companies) to be executed
 - Government then revises the proposed projects and approves (rejects) them and provides the necessary funds
 - Since the new government came to power (this is its 2nd year), the topic of sustainability is the main interest of the government and all project related to the subjects so far have been approved
 - One area that is also of particular focus of the InnovatieCentrum is tourism
 - The center is involved in developing a 'quality standard' that will be awarded to dive centers, restaurants and other tourist services as recognition by Curaçao Tourist Board
 - Further, one of the center's main activities at the moment is supporting companies in receiving certifications (e.g. ISO) and getting the companies in touch with the appropriate departments at the ministries etc.
 - There is relatively strong interest of some companies to tackle energy issues and they are willing to make the investments. However, receiving (any kind of) permits is often a very lengthy procedure and as the time goes, the interest of companies just fades away
 - Events organized for general public and broad range of companies have not received much interests – it is individual companies that are usually interested in the issue of sustainability
 - While the application procedures on the island (e.g. for solar panels and connection to grid) are simple on paper, in reality it is a long process that often requires connections' to the right people

- It is difficult to tackle environment related problems on the island – the refinery as well as the oil driven technologies for electricity production or excessive use of air-conditioning ‘have always been here’. Many people are in one way or another connected to the refinery, including the people in the government - and changing ones behavior or perceptions is very difficult
- The latest developments however show some progress (e.g. there was a protest against the refinery earlier this week)
- Aquallectra has been involved in some initiatives supporting sustainable development, but it is the government who should make the efforts to change people’s behavior and perceptions
- The greatest challenge in establishing a business on the island is having the right network of ‘friendly’ parties – there is almost no willingness to collaborate and competitors (or companies that do not profit from ones activities) often try undermine your position
- Since Curaçao is a small community and market, having the right network and not having enemies is a prerequisite for successful business
- Another significant problem about starting a business on the island is definitely the complicated procedures for obtaining permits allowing legal establishment of companies – connections may be helpful in this matter as well.

C.23 Bart van Weijsten

Interviewee: Bart van Weijsten

Position: Principal Consultant at Oxperts Consultancy - in charge of defining and implementing a new regulatory framework for energy, water and fuels on Curaçao

Date: March 20 and May 21, 2012

Location: Bureau Telecommunications and Post (BT&P), Curaçao

-
- Mr. van Weijsten was as a consultant (Oxperts Consultancy) hired by the government of Curaçao to redesign energy policies and regulations on the island
 - The reasons why an outsider party was brought in is manifold:
 - Since Curaçao is a small island, many governmental functions and department have never existed – there is lack of experience and expertise in many (‘progressive’) fields such as energy
 - There is lack of expertise in general – young generation goes to study abroad and does not return which creates a great generation gap (there is outflow of knowledge and intelligence)
-

- Mr. van Weijsten was hired to design both policies and regulations for the energy sector – no particular requirements were defined by the government – ‘the knowledge was not there, they simply had no idea what to do’
- The current prime minister and minister for energy G. Schotte is very strongly in favor of green energy (and so is his government)
- The specifics of islands make it a very different task than in most larger (continental) countries. As identified by Mr. van Weijsten:
 - The island is too small to have a department/function for every specific task – as a result, organizations in small islands are often in charge of multiple tasks that are elsewhere performed by legally separated and independent organizations. As for energy related topics, major difference between Curaçao and countries like Germany or the Netherlands is that the laws and regulations (setting maximum tariffs, overseeing the market etc.) are done by the same body (BTP)
 - One gets a very narrow perspective from living on an island as it is not exposed to neighboring countries, the market is isolated etc.
 - There is absolute dependence on oil and separation from other countries.
- BT&P is probably the only regulator in the Caribbean
- While there is lot of poverty in Curaçao, it is still a wealthy and advanced nation as compared to the rest of the Caribbean
- Past governments did not have energy issues on the agenda at all which created bad situation from both consumer and environmental views – not only expensive electricity but also frequent blackouts
- Mr. van Weijsten has also been involved in telecommunications in the past and the main challenge of the energy sector is the fact that the transitions take decades as opposed to e.g. mobile phone networks – where within 6 months one can have a state of the art network
- Mr. van Weijsten’s and his colleague’s tasks consisted of two steps: analysis of the current situation and design of new policies and regulations:
 - The essential problem was that energy was considered to be one homogenous thing – the first step was to divide it into production, distribution and supply.
 - While Aqualetra used to behave in a monopolistic matter, the key problem was the government and the (non-existing) policies
 - Electricity tariffs were too high – not only compared to continental nations but also to neighboring islands.
- Creation of new policies:
 - The first step after the analysis was identifications of ways to reduce energy consumption. By Mr. van Weijsten’s estimate, about 50

- There was a campaign organized by the government for promoting energy saving measures
- The new policies were created in several steps – firstly they were drafted and then in several rounds discussed with relevant stakeholders (about 20-30 stakeholders in total) ranging from relevant industry representatives, large companies (e.g. Aqualec-tra, the airport etc.) and representatives of smaller companies and other organizations (e.g. foundation for protection of consumer rights)
- The policies were then adjusted based on the stakeholders' insights (a balance had to be found which is the most challenging part as views of very different actors must be taken into consideration)
- Creation and definition of incentives (such as subsidies, feed-in tariffs etc.) must then be 'correctly' determined
- The first major step was opening up the grid to small producers (below 1MW) from January 1, 2012 – approximately 8MW of small scale (mainly solar) energy is being produced (or awaiting to be connected to the grid)
- There will be another large conference in either 2013 or 2014
- Under current conditions and as long as the number of small scale residential producers does not significantly increase, the influence of the small scale production on the price of the electricity (that has to be paid by ordinary consumers) is negligible
- The cap of 1MW production for businesses was set in order to prevent any significant influence on the price that is being paid by other end consumers
- Under current conditions, many business owners with diesel generators switch to solar panels (some business still use diesel generator as cheaper replacements of the electricity from the grid)
- Change in the electricity price structure is being considered. There should be a variable part corresponding to the cost of production (e.g. cost of fuel and machinery) and a fixed part corresponding to all the other incurred costs (e.g. maintaining or upgrading infrastructure, losses in the grid etc.). This will allow for prompt (possibly monthly) changes in the variable part of the electricity price that truly correspond to the changes in oil prices.
- The import duty exemptions on certain products (e.g. inverter air-conditioners) were put in place specifically to support energy saving and electricity production on small scale. Exemptions of specific components of renewable energy technologies (e.g. heat exchangers for the SWAC system) are not included in the policy. It is a matter of agreements between the project owners and the government to determine any kind of incentives or favorable tax regimes for their projects
- To operate as an independent power producer (IPP), a private company needs to have two things in place:
 - A concession (agreement between the private company and the government) that defines the obligations of the IPP, such as reporting, possibilities of governmental

interference etc.

- and a power purchase agreement (PPA) - contract between the private company and the utility provider that defines the conditions and prices of the electricity that will be produced
- WTE plant is being considered to be set up on the island – several companies have already showed their interest – their involvement would be similar to the one of NUCapital and its windpark (i.e. based on a tender)
- The role of gas in the electricity production is very unclear. To a large extent, the suitability of integrating gas into the local infrastructure is dependent on the future of the refinery as the volumes at which the gas is being purchased greatly influences its price. If gas could be used for electricity generation, cars and refinery operations, then it would be a very attractive option. The transition towards gas is expensive (due to the need for storage and regasification facilities and other infrastructure). If on the other hand the refinery was completely shut down, the suitability of using gas would be much lower
- The problem is that Curaçao (and other islands) are too small to have all the technologies – e.g. the government needs to decide whether to aim for supporting the use of vehicles that run on gas, electricity, fuel cells etc. Unlike in Europe or the USA, Curaçao cannot support all of these technologies. The ‘path dependence’ is much stronger in island nations
- The expected electricity demand of 200MW in 2020 mentioned in the electricity policy is not accurate and based on old assumptions of 2% annual growth. In fact, the demand might stay (or even decrease) from the current 135MW due to the increasing
- There are two key elements in determining whether a certain technology will be awarded a PPA – reliability and costs. Integrating new and unproven technologies into the network is very risky. While the current government favors the entrance of new technologies, the only way these technologies can get support is to gradually prove step-by-step reliability of the technology (from experimental to small and large scale production). The island’s production and distribution network are highly sensitive and one cannot afford to be dependent on an unproven technology