Strategies for integrated governance of the Water-Energy-Food Nexus in Bonaire

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STRATEGIES FOR INTEGRATED GOVERNANCE OF THE WATER-ENERGY-FOOD NEXUS IN BONAIRE

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EXECUTIVE SUMMARY

Small Island Developing States (SIDS) worldwide are facing numerous challenges exacerbated by climate change. Rising sea levels threatens their groundwater resources. Higher sea temperatures degrade the health of their coral reefs, which are often their most important economic asset as they attract tourists from all over the world. They are reliant on food imports and fossil fuel imports for their electricity generation and drinking water production. The dependence on imports and limited economies of scale make life expensive for their inhabitants. Furthermore SIDS often do not have the financial and institutional capacity for major change and are locked-in unsustainable practices. Bonaire is an island in the Caribbean sea and officially a special municipality of the Netherlands. It is facing many of the challenges that threaten SIDS. Its population and tourism numbers are rising, increasing the pressure on its natural resources and the security of supply of drinking water and electricity. In recognition of these challenges Bonaire has set out multiple agendas for sustainable transitions in the water, energy and food sectors. A relatively novel concept called the *water-energy-food nexus* takes an integrated approach to the three sectors and is "a systematic process for both analysis and policy-making that focuses on the linkages between water, energy, food and other linked sectors to promote sustainability, synergies and resource use efficiency." (Keskinen et al., 2016). The WEF-nexus approach still faces significant challenges in regard to practical value, governance issues and political influences in resource systems. Therefore this thesis takes a systems theory and transition management theory approach to the WEF-nexus so that the governance of the three systems can be explicitly accounted for. The goal of this thesis is to investigate if and how a water-energy-food nexus approach can be of value to guide Bonaire in their sustainability transitions. The research question to answer is: *What are the opportunities for a sustainable transition in the water-energy-food nexus in Bonaire?*. A theoretical framework was designed that is based upon the Transition Management Cycle (TMC) by Loorbach (2010). It combines systems theory and transition management theory methods to structure the problem, find shared basic principles and barriers for transitions, envision desirable futures and create transition pathways towards a shared vision.

The energy and water system are governed by a connected regime of multi-level governmental agencies. Historic investments in the water and electricity production capacity and distribution infrastructure have locked the regime in place, offering an explanation why novel technologies such as Ocean Thermal Energy Conversion (OTEC) and distributed water generation have found no support. Water and electricity prices constrain the operations of the OLB and the WEB, as this is issue is high on the political agenda in Bonaire. Stakeholders active in the governance of the water and energy sector are primarily concerned with costs, tariffs and daily operations of the

infrastructure. Security of supply is prioritised and sustainability is only a part of the mindset. The food sector is far behind the water and energy sectors in terms of professionalisation, economic opportunities, knowledge and political power. Furthermore its behaviour is complex, containing a large number of elements, multiple feedback loops and non-linear interactions. The food sector is strongly connected with the water and energy sectors and stakeholders are dependent on the stakeholders in those sectors in achieving their goals. The food sector is also strongly connected with the ecological system in Bonaire, meaning that unsustainable practices such as free-roaming goats have detrimental ecological effects. Protection of the ecosystem services is also imperative from an economical standpoint, as the value of ecosystem services will decline with 62% by 2043 if current harmful practices continue. The tourism industry has significant amounts of influence in decision-making on Bonaire and has co-initiated the 'Blue Destination' strategy to increase the economic value of tourism in Bonaire whilst focusing on protection of oceanic resources. Shared basic principles were found among stakeholders that acknowledge the value of Bonaire's natural environment and wish to conserve it.

The identified shared principles, transition barriers and opportunities led to the formulation of a shared vision for the integrated development of the water, energy and food sectors in Bonaire with five principles: 1. Sustainable resource use, 2. Effective nexus governance, 3. Environmental protection, 4. High quality of life and 5. Sustainable tourism development. Three pathways are recommended that can provide opportunities for a sustainable transition in the water-energy-food nexus: 1. Human capacity and innovation development, 2. Ecosystem management plan and 3. Sustainable tourism. A final recommendation of this research is to initiate a participatory process that continues with the Transition Management Cycle and identifies front-runners willing to engage in the transition arena and further elaborate the transition pathways with discussions on essential elements, resources and planning. The nature of the WEF-nexus implicates that a large number of stakeholders from different backgrounds are quickly involved and that stimulation of cooperation is beneficial under all circumstances.

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ACRONYMS

ACM Authority for Consumers & Markets 42
BNMP Bonaire National Marine Park 44
BONHATA Bonaire Hotel and Tourism Association 44
BOPEC Bonaire Petroleum Corporation N.V. 49
BPOA Barbados Programme of Action 1
CGB Contour Global Bonaire 53
DCNA Dutch Caribbean Nature Alliance 44
DROB Dienst Ruimtelijke Ordening Bonaire 43
EN European Netherlands 33
IAD Institutional Analysis and Development framework 20
INRM Integrated Natural Resources Management 10
IRENA International Renewable Energy Agency 51
IWRM Integrated Water Resources Management 10
MARS Managed Aquifer Recharge and Storage 42
MLP Multi-Level Perspective 18
MTF Management and Transition Framework 20
OCTA Overseas Countries and Territories of the European Union 2
OLB Openbaar Lichaam Bonaire 3
OTEC Ocean Thermal Energy Conversion v
RCN Rijksdienst Caribisch Nederland 33
RO Reverse Osmosis 41
SIDS Small Island Developing States v
TCB Tourism Corporation Bonaire 44
TEV Total Economic Value 77
TM Transition Management 16
TMC Transition Management Cycle v
TOP Talent Development Programme 73
WEB Water- en Energiebedrijf Bonaire N.V. 38
WSNP Washington Slagbaai National Park 44

1 INTRODUCTION

1.1 SMALL ISLAND DEVELOPING STATES

The United Nations recognizes 58 SIDS, worldwide. 38 of these states are UN Members, 20 are non-UN Members or Associate Members of regional commissions. Although geographically, culturally and economically widely dispersed, SIDS are facing numerous similar challenges. Their limited size, increasing population and a growing tourism industry lead to increased population pressure (UN-OHRLLS, 2013). Due to heavy reliance on fossil fuel imports and the tourism industry to GDP and employment, SIDS are vulnerable to global economic shocks (Slijkerman and van der Geest, 2019; U.N. General Assembly, 2015). As the majority of fossil fuels is imported and thus subject to international energy prices, it is virtually impossible for SIDS to control the domestic price of energy without the use of fuel subsidies (Niles and Lloyd, 2013). This use of energy subsidies further increases their public debt levels, which in turn makes SIDS less able to invest in clean and cheap renewable energy solutions that have the potential to lessen the use of fuel subsidies. This cycle increases the dependence on external sources of finance (Niles and Lloyd, 2013). Their remoteness and limited resources decouples them from larger trade networks, as well as hampering their opportunities for economies of scale (Lucas et al., 2017; UN-OHRLLS, 2015). SIDS experience significant vulnerabilities to the effects of climate change: sea level rise threatens their territory, rising sea temperatures degrade the ecosystems which provide food and attract tourists and natural disasters are occurring more frequently and with greater impact (U.N. General Assembly, 2012, 2015; Operations Policy and Country Services The World Bank, 2016). Domestic pollution factors resulting from extensive fossil fuel use and waste problems contribute to their environmental vulnerabilities (Boto and Biasca, 2012). Declining fish exports due to depleting Pacific fish populations negatively affects food security and exports of many SIDS. This in turn increases their dependence on food imports, increasing the vulnerability to variable supply and prices in the global food industry. Furthermore, access to reliable, safe, sustainable and affordable supplies of drinking water is a critical issue for SIDS, as often countries rely entirely on a single source of water supply (UNFCCC, 2005; UN-OHRLLS, 2015).

Recognition of and attention towards these adversities has grown over the past 25 years. The *1994 Barbados Programme of Action (BPOA)*, the *Mauritius Strategy for further Implementation of the BPOA* and the *Third International Conference on Small Island Developing States in Samoa* led to the *SAMOA Pathway* (UN-OHRLLS, 2015). These international proceedings recognise that poverty eradication, sustainable production and consumption patterns, and protect-

ing and managing the natural resource base are the essential requirements for achieving sustainable development in SIDS. To achieve progress towards sustainable development the mid-term review on the SAMOA Pathway recognizes that emphasis should be on analysing and enhancing existing mechanisms and institutions (ECLAC, 2018). Lacking institutional capacity is a common problem in SIDS. Henceforth the recommendation to strengthen the existing institutions is often repeated in literature (Asian Development Bank, 1998; Boto and Biasca, 2012; Niles and Lloyd, 2013).

1.2 THE ISLAND OF BONAIRE

In the Leeward Antilles, a group of islands located in the south-east region of the Caribbean sea, lies the island of Bonaire. Since 2010 its constitutional relation to the Netherlands changed to a special municipality, giving up autonomy for greater support and influence from the national level. Bonaire is therefore technically not recognised as a Small Island Developing State, but classified as an Overseas Countries and Territories of the European Union (OCTA). Despite this classification, Bonaire is facing many of the challenges described in Section 1.1. Its population has increased with 28% between 2011 and 2019 to 20.100 and is expected to increase another 23% between 2019 and 2025 (Centraal Bureau voor de Statistiek, 2019a). Fuel and food import dependency is high, exacerbated by recent turmoil in Venezuela. Consumer prices have continuously risen in the past 4 years (Centraal Bureau voor de Statistiek, 2018c). Furthermore, recent reports are critical of the quality of government in Bonaire. The *Masterplan strategic development Bonaire 2010-2025* addresses the lack of coherence in the policy planning for different sectors in Bonaire. A report by the commission led by Spies evaluating Bonaire's transition to a special municipality concluded that Bonaire's economy remained fragile due to its dependence on a limited number of sectors, high cost of living and variation of executive capacity between successive Executive Councils (Slijkerman and van der Geest, 2019; Spies et al., 2015). Bonaire is overly dependent on tourism and is heavily dependent on food and fuel imports, whilst diversification of small states' economies is critical to economic development (Operations Policy and Country Services The World Bank, 2016; Van Werven et al., 2010). The tourism sector in turn, is heavily dependent on the health of Bonaire's ecosystem and its services. Under current global and local threats, these services are expected to decrease with 62% if the current threats are unmanaged (figure 1.1) (Van Der Lely et al., 2013). Water prices have seen a 44% increase in 2018 (Centraal Bureau voor de Statistiek, 2018c). Regarding energy, the most pressing short-term problem is the availability and reliability of power. Electricity demand has increased, caused by population and economic growth. Large increases in the share of wind power and decentralised production of electricity have put pressure on the electricity grid, which has in turn seen its capacity and quality deteriorate. Recent changes in the law have enabled the growth of decentral electricity production and made formal registration of decentral installations possible (Wet elektriciteit en drinkwater BES, 2016). This has in

turn facilitated assessment where investments in the grid are most necessary.

In recognition of these challenges the Openbaar Lichaam Bonaire (OLB), Bonaire's governing body, has set multiple agendas for sustainable transitions in the water, energy and food sectors. The Masterplan strategic development 2010-2025 for instance sets CO_2 neutrality, batteries for excessive wind energy, biogas development and active water management as goals for 2025. It also addresses the lack of coherency in policy planning for the separate sectors (Van Werven et al., 2010). Bonaire has set out the 'Blue Destination' tourism program, focusing on high quality eco-tourism that is conscious of sustainable use of its ocean's resources.

Problem statement

In conclusion, a transformation towards sustainability in the water, energy and food systems in Bonaire can provide affordable and sufficient sources of water, clean and affordable electricity and healthy and sustainable food, ultimately increasing the quality of life for its residents. The reality is that rising population and tourism pressure, high consumer prices, limited knowledge and human capacity, technical difficulties and unsustainable agriculture and livestock practices limit the capacity for change. If insufficient action is taken to move towards sustainable practices, current threats to Bonaire's ecosystem will remain unsolved and greatly reduce the value the ecosystem provides to Bonaire's economy (Van Der Lely et al., 2013). Multiple technical, social and economical solutions are being considered, but from a sectoral perspective. An integrated approach to the water, energy and food nexus may provide opportunities to contribute to the transformation towards sustainability.

1.3 A SYSTEMS PERSPECTIVE TO THE WATER–ENERGY–FOOD NEXUS

Instead of tackling each sustainability transition in isolation, a relatively novel concept called the *water-energy-food nexus* may provide valuable insights for Bonaire and SIDS in general with achieving their transitions towards sustainability set out in the SAMOA Pathway by better integrating the water, energy and food sectors in ecosystem security (Slijkerman and van der Geest, 2019). The water-energy-food nexus takes an integrated approach to the three sectors and recognises that well-meaning changes in one sector can have adverse effects in others due to their interconnections. The notion of a nexus existing between water, energy and food is not a new concept however (Wichelns, 2017). Due to their small land surface and limited resource base, SIDS have long been aware of the connectedness of their resources, as many states rely increasingly on energy-intensive desalinated water as a source of potable water and irrigation, especially in fast growing areas (Bazilian et al., 2011, 2013; Bizikova et al., 2013). Their reduced size however, as their reduced complexity and remoteness may better facilitate the implementation of a nexus approach, contributing towards proof of usefulness and its practical value, which is currently contested (Leck et al.,

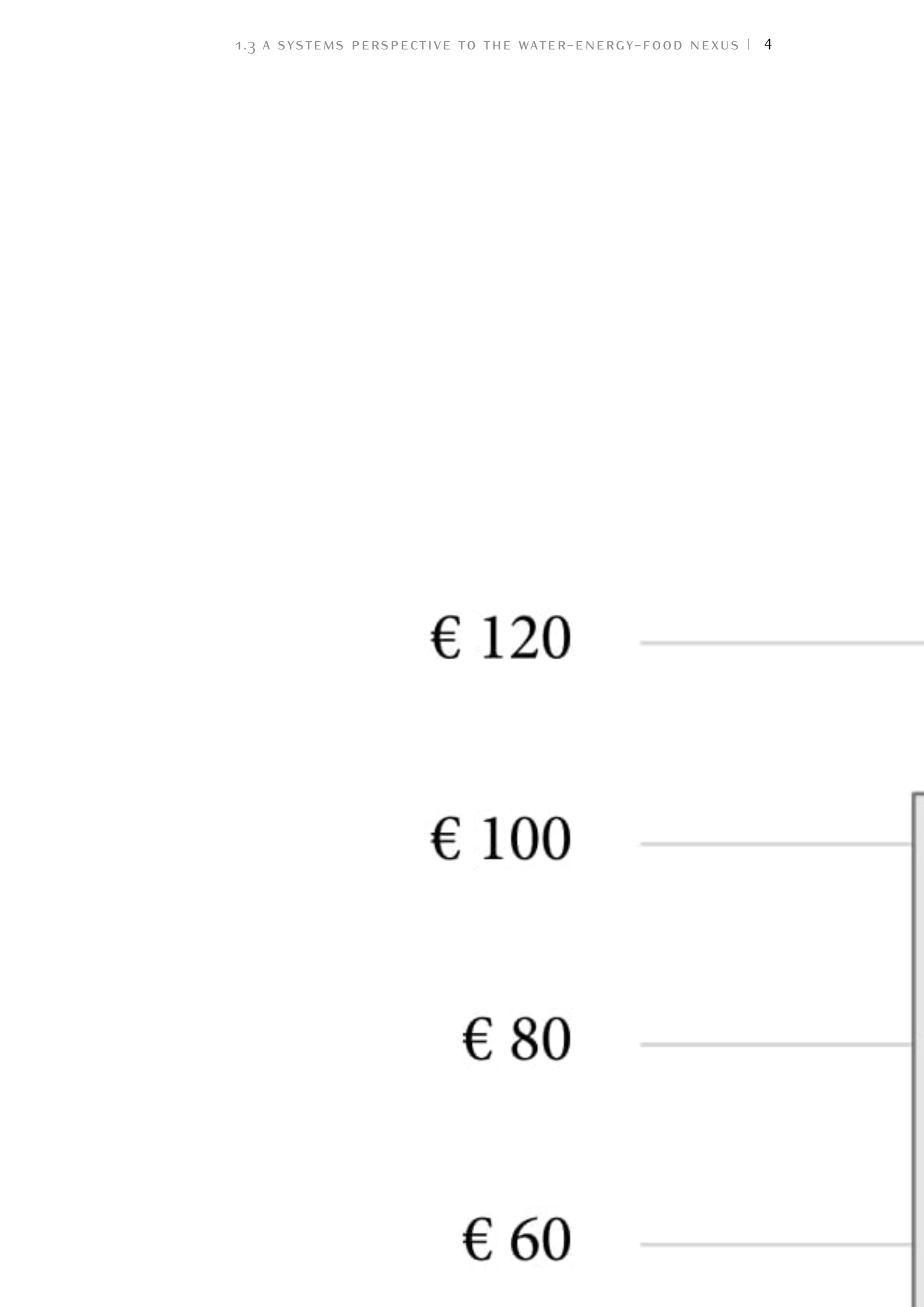
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Figure 1.2: The island Bonaire

2015; Reinhard et al., 2017; Slijkerman and van der Geest, 2019; Wichelns, 2017). There are a number of similarities between a systems perspective and the water-energy-food nexus that make it a valuable approach worth taking. The WEF-nexus emerged from the acknowledgement of multiplicity and interdependence between the water, energy and food sectors. In systems theory the belief is held that the performance of a system cannot be optimised by optimising its sub-systems in isolation from one another (Newell et al., 2011). This corresponds with the origin of nexus thinking: that water, energy and food policy can create unintended consequences when designed in silos. Furthermore, no single definition or optimal solution exists within the nexus. Rather, it is a constant interaction between stakeholders to form synergies and trade-offs between the sectors. Finally, the complex nature of the nexus and its limits in integration of multiple layers and institutions (2.1.3) warrants a systems approach that addresses these limitations.

When adopting a systems perspective, a researcher analyses a situation as a *complex system*. A complex system is constrained by certain boundaries and comprised of technical artefacts as well as institutional and social entities. Within a complex system multiple smaller subsystems exist that are connected and embedded, producing a large number of uncertainties. Its behaviour is non-linear and unpredictable (Kamensky, 2011). A lack of understanding of the properties of a complex system can prevent the design of effective cross-sector policies (Newell et al., 2011). Henceforth interventions

in complex systems can produce unintended consequences resulting from its connectedness and dynamic strategic behaviour from individual stakeholders. When designing interventions, there is no single agreed upon problem definition and no objective measurement possible of an 'optimal solution'. Therefore when a systems approach is adopted, not only a technical artefact is designed and implemented, but also the definition of roles and responsibilities, financial incentives and institutions are designed. The benefit of using a system analysis approach is that structures complex and ill-defined problems by using scientific methods (Enserink et al., 2010). In conclusion, complex systems have four properties (Brazier, 2018): 1) Multiplicity: a large number of different components are present, 2) Interdependence: connectedness between these components, 3) Diversity: a certain degree of heterogenity exists in the system, and 4) Interaction is continuous and unpredictable.

1.4 RESEARCH GOAL AND RESEARCH QUESTIONS

To confine this research to an attainable research goal, it will build upon earlier studies, in particular the *Nexus interventions for small tropical islands: Case study Bonaire* study by Wageningen Marine Research (Slijkerman and van der Geest, 2019). This research identifies the opportunities and challenges for nexus implementation in Bonaire on a strategic level. Several conclusions provide opportunities to demarcate this research effectively.

- There are benefits in using an integrated nexus approach to improve water, food, energy and ecosystems security on SIDS such as Bonaire.
- No long-term policy documents that lay out nexus plans were found, but several sectoral policy documents exist that set out goals and desirable future states for the water, energy and food sectors.
- Joint, multisectoral goal setting and proper cooperation are key to success in all sectors.

1.4.1 Research goal

The goal of this thesis is to contribute to enhancing water, energy and food security in Small Island Developing States by investigating sustainability transitions in the water-energy-food nexus. Bonaire shares many of these challenges, but has set out visions for a sustainable future and has just completed a wastewater treatment facility, showing a desire for transitions towards sustainability. An integrated nexus approach can be beneficial in Bonaire to assist in the respective sustainability transitions for the water, energy and food sectors, but a shift towards this approach has not yet occurred. By investigating the possibilities for nexus governance in Bonaire, more general lessons will be sought for the added value of the WEF-nexus in SIDS. Furthermore SIDS provide an isolated and small test chamber for developing the WEF-nexus to be of use in larger locations, such as states or nations. The water-energy-food nexus is a promising concept to analyse and

improve resource security and can be of value in Bonaire, although it still faces numerous challenges as will be demonstrated in Section 2.2. Therefore an additional goal of this research is to investigate how systems theory and transition management theory can be applied to develop the WEF-nexus research methodology. The formulated research objective and research question are:

To investigate how a water-energy-food nexus approach can be of value to guide Bonaire in their sustainability transitions.

1.4.2 Research question

What are the opportunities for a sustainability transition in the water-energy-food nexus in Bonaire?

1.4.3 Subquestions

Multiple sub-questions are drafted to assist in answering the research question. One of the critiques of the nexus is that it does not sufficiently take the political-economical environment of a target location into account (Section 2.1.3). Allouche et al. (2015) confirm that only if the political economy is more explicitly addressed within a nexus framework, it can explore alternative pathways instead of confirming the narrative for existing dominant pathways. Furthermore, Foran (2015) argues for understanding the context of social structures, as a complex systems approach may overlook the social power structures underlying nexus issues. A systems approach can be useful in analysing these issues. Additional theories exist, however, that can assist in researching the WEF-nexus. Therefore the first subquestion will address the methodological challenge in researching the WEF-nexus. It will research how systems theory and transition management theory can be of value to a nexus approach and operationalise these theories in a methodological framework.

1. *How can systems theory and transition management theory contribute to a water-energy-food nexus approach and how can these be operationalised in a methodological framework?*

The second subquestion will use the methodological framework from subquestion 1 to investigate the water, energy and food systems in Bonaire and their connections. The following sub-questions will be answered this step:

2. *What are the problems and opportunities for integrated governance of the water, energy and food systems in Bonaire?*

The third and final subquestion will use methods identified in subquestion 1 with the problems and opportunities identified in subquestion 2 to recommend future steps for implementing a nexus approach in Bonaire. The following sub-question will be answered in this step:

3. *What are possible pathways that can lead towards water-energy-food nexus governance in Bonaire?*

The following chapter will conduct a literature review into the water-energy-food nexus, complex systems and transition management literature. A theoretical framework will be presented that incorporates these theories and further demarcates this thesis in Chapter 3. Chapter 4 will present the findings of the systems analysis into the water, energy and food sectors in Bonaire, after which Chapter 5 will compare the similarities and differences between these sectors. Chapter 6 will apply the theoretical framework to identify possible pathways towards nexus governance. Section 6.4 contains recommendations for implementing and guiding these pathways. Chapter 7 will discuss the limitations of this thesis and offer recommendations for future research. Chapter 8 answers the research questions and contains the conclusions of this thesis.

2 THE WATER-ENERGY-FOOD NEXUS

As the nexus is a relatively immature and novel but promising concept (Foran, 2015; Reinhard et al., 2017), a review of the existing body of literature [1] and reports by public institutions can provide insights in the origin, current status, existing frameworks, practical application and critique. Furthermore, this literature review will identify certain knowledge gaps that currently exist within the global nexus discourse.

2.1 THE WATER–ENERGY–FOOD NEXUS

2.1.1 Origin and concept

Global demand for water, energy and food will increase with 40%, 50% and 35% respectively by 2030, as in 2030 the global population is expected to reach 8.3 billion (National Intelligence Council, 2012). Additionally, more and more people progress into the middle class, increasing the demand for middle class products (National Intelligence Council, 2012). In 2007 and 2008 the global food crises hit, where world food prices experienced significant inflation, amplifying food insecurity. The aftermath of this crisis, increasing resource demand, heightened awareness of the impact of biofuel production on water resources and inadequate attention to the complex interactions that exist between resource systems led to increasing awareness among scholars and public officials that the world's raw materials are facing significant pressure (Allouche et al., 2015; Pittock et al., 2013; Wichelns, 2017).

After the 2007-2008 global food and energy crises a business-driven perspective emerged at the 2011 World Economic Forum where large multinational companies recognised the connectedness between their primary inputs and the risks to growth of underpriced water resources and scarcity (Wales, 2011; World Economic Forum, 2011). Companies and governments alike realised

1 Scopus and Google Scholar were used to find a first set of articles, after which the references in selected articles were consulted to find a second set of articles. Search terms begun wide with "water energy food nexus" on Google Scholar yielding approximately 134.000 results. The search "TITLE-ABS-KEY(water AND energy AND food AND nexus)" on Scopus yielded 916 results. These initial searches were narrowed down with keywords like "review" to find literature reviews such as Endo et al. (2015); Leck et al. (2015); Wichelns (2017). To further delineate the results, the search queries were specified towards SIDS and transition management ("(TITLE-ABS-KEY(water AND energy AND food AND nexus)) AND (transition AND management)" and (TITLE-ABS-KEY(water AND energy AND food AND nexus)) AND (SIDS) "). From this database articles were selected that addressed the limitations of the WEF-nexus, its applicability in SIDS and its relations to envisioning and transition management methods. An initial reading of the abstract also omitted several articles from the literature review, due to limited relevance as interpreted by the researcher.

that water and energy were often not priced correctly or allocated efficiently, leading to suboptimal social gains from resource use (Wichelns, 2017). From this awareness of the connectedness of water, energy and food security emerged the *water-energy-food nexus*: a cross-sectoral perspective that seeks to explain the relationships between water, energy and food, improving the sustainable management of limited resources (FAO, 2014). After Hoff (2011), Leck et al. (2015, p.446) defines nexus thinking as being "concerned with addressing externalities across multiple sectors, with a focus on system efficiency instead on the productivity of isolated sectors.". Allouche et al. (2015) draw on the similarities of the nexus with other holistic approaches such as Integrated Natural Resources Management (INRM) and Integrated Water Resources Management (IWRM). Both have been used for several decades and emerged as approaches to manage water, land and related resources in a coordinated way. Whereas the nexus approach treats its sectors as equally important, IWRM takes a water-centric approach to all its related sectors (Benson et al., 2015). The Global Water Partnership promotes IWRM specifically as a process that can "assist countries in their endeavour to deal with water issues in a cost-effective and sustainable way" and defines it as "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (Global Water Partnership, 2000, p.6,22). Where both INRM and IWRM face difficulties is in practical implementation, particularly in developing countries (Merrey, 2008; Wichelns, 2017). It fails to sufficiently account for links between water resources and political connections, as stated by Allan (2003) and Merrey (2008) that water allocation in regions facing water-scarcity mainly occurs as a political process and is easily influenced by insufficient institutional capacity in key sectors, including agriculture and energy. In a report on IWRM in action, UNESCO recognizes that the vast amounts of electricity necessary to transport, produce, treat and apply water in many parts of the world is a growing issue. Additionally they state that "this is particularly true in situations where there is growing competition for limited water resources and/or climatic changes are altering the timing and availability of water." (Hassing et al., 2009, p.2). The nexus concept evolved from this realization of links between water, agriculture and energy, but as 2.1.3 will demonstrate, has not yet overcome the difficulties regarding practical implementation and political influences.

Pittock et al. (2013) argue that the isolated and sectoral approaches in policy making have led to resource constraints and inadequate attention to the complex interconnections between sectors and resources. The FAO (2014, p.3) argues that the implications of these propositions are that: "Nexus interactions are complex and dynamic, and sectoral issues can not be looked at in isolation from one another.". This isolated approach is often referred to as 'policy silos' within the nexus terminology. The FAO (2014, p.3) views the nexus as a "useful concept to describe and address the complex and interrelated nature of our global resource systems, on which we depend to achieve different social, economic and environmental goals", but recognizes that several concepts and frameworks exist within nexus thinking. Currently a formal

definition of the nexus as a clearly defined construct, or as an agreed and tested framework, does not exist (Endo et al., 2017; Wichelns, 2017). There is a similar lack of consensus around a 'nexus methodology' (Cairns and Krzywoszynska, 2016). Despite the lack of consensus, it will ideally be valuable in identifying potential conflicts, uncover more appropriate methods for cross-sector integration, and realize synergies and mutual benefits wherever possible (Leck et al., 2015; Pittock et al., 2013). In short, the water-energy-food nexus aims to address externalities across multiple sectors, focusing on system efficiency in a holistic manner (Hoff, 2011; Leck et al., 2015). Bazilian et al. (2011, p.7903) argue that treating water, energy and food in a holistic manner "would lead to a more optimal allocation of resources, improved economic efficiency, lower environmental and health impacts and better economic development conditions, in short, overall optimisation of welfare".

The EU H2020 SIM4NEXUS Project (Laspidou et al., 2017) defines three sources of problems that can benefit from applying a nexus approach. These are:

1. Policy incoherence: the nexus can identify siloed policies that have a beneficial effect in their respective sector, but unintended consequences in others.

2. Knowledge gaps: possible dependencies between sectors can be identified that are insufficiently researched, constraining policy-makers from a "better safe than sorry" perspective.

3. Technology lock-ins exist: this can lead to an advantage of established ideas or practices over new innovations.

2.1.2 Application of the water-energy-food nexus

A multitude of SIDS have set out ambitious renewable energy targets, motivated by a desire to reduce their dependence on expensive imported fossil fuels (Dornan, 2015). Many still face difficulty in meeting these targets however, as fiscal incentives are still necessary to make renewable energy technologies competitive with conventional technologies, diverting government budget from primary welfare such as education and healthcare. Additionally, limited opportunities for economies of scale lower the attractiveness of investing by international private parties (Timilsina and Shah, 2016). Achieving these targets requires national policies that "set out comprehensive and balanced plans to administer all energy and energy-related activities. This must include predictable and explicit frameworks within which the public and private sector can make informed planning and investment decisions." (Timilsina and Shah, 2016, p.662). Given the potential synergies these investments in renewables inhibit, it would be a lost opportunity to not connect them with advances in water and food security.

As mentioned earlier, no agreed upon framework or approach exists (Endo et al., 2017; FAO, 2014; Keskinen et al., 2016). In Figure 2.1 the initial visualization of the nexus described by Hoff (2011) shows how the available water

resources are the starting point for the security of nexus resources. Multiple studies have proposed additions to this initial schematic. Biggs et al. (2015) link the nexus to the concept of Environmental Livelihood Security (ELS) and propose that sustainable livelihoods should attain the starting point of a nexus framework. They argue that, in cases where environment-livelihood interactions are present, an ELS-nexus framework could provide a "stronger evidence base for policy-makers to ensure sustainable use of natural resources to achieve water, energy and food security for livelihoods" (Biggs et al., 2015, p.395). The International Institute for Sustainable Development analysed and improved the existing WEF-nexus frameworks and propose a conceptual framework that seeks to identify critical elements of food, water and energy security (Bizikova et al., 2013). Newell et al. (2011, p.15) propose that the "collaborative construction of simple influence diagrams can help policy makers to see and discuss possible cross-sector feedback loops that need to be taken into account". This touches upon methods used in systems theory to analyse the causal influences resulting in complex system behaviour.

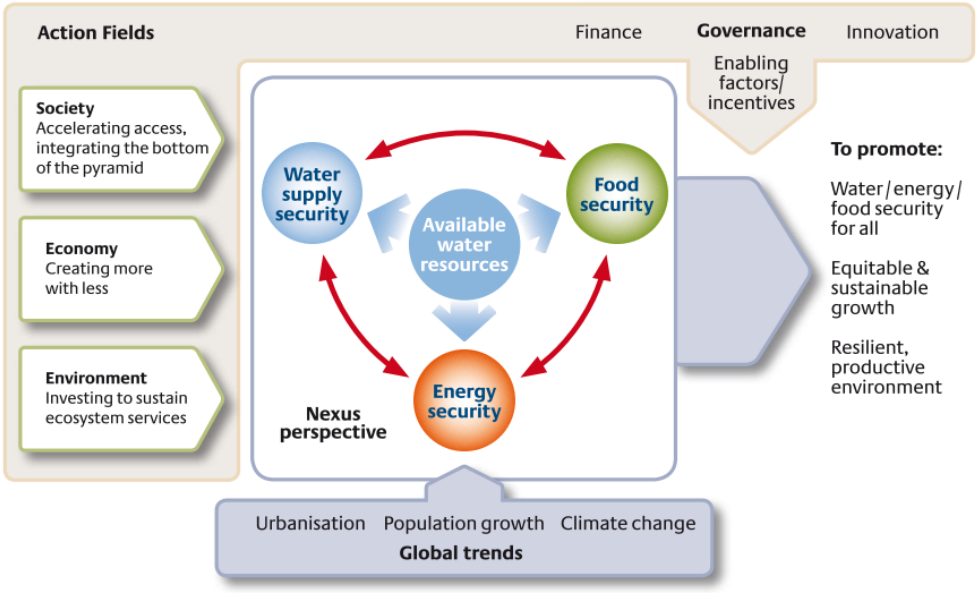


Figure 2.1: The water, energy and food security nexus (Hoff, 2011)

2.1.3 Critique

The nexus debate has mostly taken place in global circles, such as the Bonn 2011 Conference, and in papers by global institutions as the World Economic Forum (2011), the International Institute for Sustainable Development (Bizikova et al., 2013) and the FAO (2014). Despite its popularity in international visions and other policy documents, the nexus has yet to reach to the level of national and regional governments (Allouche et al., 2015). This is partly due to the complex nature of the nexus. It requires a wider view and is holistically complicated. Hence the possible configurations of solutions and policies are increased and strengthening institutional capacity is required (Lindberg and Leflaive, 2015). Furthermore decisions and actions regard-

ing natural resources are often politically charged, take place in a contested environment and create conflict through intense competition for resource access (Leck et al., 2015; Bazilian et al., 2013). As mentioned by Wichelns (2017) and Allouche et al. (2014) previous integrated approaches such as INRM and IWRM are strongly dependent on the prevalent political-economic environment. There is no reason to assume that the nexus approach will not be influenced by the vested interests in the resource systems, as Middleton and Allen (2014) caution that system approaches have widely been critiqued as under-politicised.

The FAO sees potential in the WEF-nexus in supporting food security, but states that "A recurring criticism of the water-energy-food nexus is that it adds relatively little to already existing integrated approaches to resources management, such as the integrated landscape approach (FAO, 2011) or IWRM." (FAO, 2014, p.6). A common integrative approach or framework currently does not yet exist, whilst the effectiveness of the proposed and existing frameworks to integrated policy-making beyond the existing IWRM paradigm remains to be seen (Allouche et al., 2014; Wichelns, 2017). Even when compared to siloed policies, the nexus is promising but more complex and unproven to outperform individual effective policies in the water, energy and food silos.

In a review of the current state of research on the WEF-nexus, Endo et al. (2017) show that private companies and the media are underrepresented in nexus activities, thereby concluding that the nexus is not fully acknowledged on the ground and lacks publicity. Furthermore, they find that in site-specific case studies the vertical integration of local nexus issues within national and global nexus issues was often missing (Endo et al., 2017). The concept of the nexus is not new at a local level however: farmers and fishers have long been aware of the connections in water, energy and food. The nexus, according to Allouche et al. (2014), is possibly that experts remember the connectedness of resources, and that understanding local governance in the nexus sectors is important. There is broad recognition that the interdependencies of sectors and resource systems have been inadequately acted upon. Pittock et al. (2013, p.4) attribute these shortfalls to "the inability of governments to adequately manage the complexity and uncertainty associated with environmental issues, differing values and contested methods, the challenges of working across scales and lack of clarity of rights and responsibilities". These governance issues, particularly the challenge of siloed government agencies to work beyond their sector, are fundamental to the operationalisation of nexus ideas (Leck et al., 2015). An example of the need for cross-sector governance is the need for correct resource prices across sectors. For agents to make optimal decisions in the WEF-nexus, resource prices have to correctly reflect scarcity. If resource prices are distorted, for instance through fuel subsidies, this will lead to suboptimal choices and disregard certain possible synergies between the nexus domains (Reinhard et al., 2017). The German Institute GIZ observed this in the Middle East and North Africa region, where it found that despite extreme natural resource scarcity, cross-resource use efficiencies are low due to high subsidies on re-

source use (Hoff et al., 2017).

Wichelns (2017) attributes the increasing interest in the nexus to the increasing awareness among scholars and public officials that the "processes influencing the sustainability of natural resources are dynamic, complex and uncertain.". Despite the increasing awareness, Wageningen Economic Research states that "The nexus is a promising concept to concretise food policy efficiently. However, it is not a mature concept and there is room for developing further insights." (Reinhard et al., 2017, p.5). Scholars agree that the nexus is promising but still faces significant conceptual and practical challenges (Leck et al., 2015). Agreeing upon a common definition, framework and methodology for nexus research is one of these challenges for future nexus contributions (Allouche et al., 2014; Endo et al., 2015). The need for developing a common and shared understanding of the water-energy-food nexus is repeated throughout literature (Taniguchi et al., 2017). Lucas et al. (2017, p.47) find that "There is a lack of a comprehensive approach to deploy renewables in SIDS, which would require coordination among different parties and ministries, including energy, infrastructure, education and agriculture.", addressing the need for a nexus approach that facilitates the implementation of renewables. Henry Puna, Prime Minister of the Cook Islands, also expressed this need: "To fully succeed in the energy transformation, it was strongly recommended to adopt a holistic approach, extending the focus beyond the power sector" (IRENA, 2018).

Allouche et al. (2015) and Keskinen et al. (2016) address the limits of the nexus concept in regard to political economy, politics of knowledge and politics of difference. Allouche et al. (2015) state that if the nexus is to be a useful framework for exploring alternative pathways rather than a narrative that legitimises existing dominant pathways, the political economy of the nexus must be more explicitly addressed. These limitations are a recurrent criticism in IWRM and INRM, as Allan (2003) and Merrey (2008) state that water allocation in regions facing water-scarcity mainly occurs as a political process and is easily influenced by insufficient institutional capacity in key sectors, including agriculture and energy. Efforts in policy integration might improve water, energy and food security by optimising trade-offs and increasing the overall efficiency and synergies, but it can lead to delays in the policy process, particularly in developing countries (Wichelns, 2017). Finally, little research was found on how the nexus influences decision making by stakeholders.

2.2 KNOWLEDGE GAP

In summary, changing current siloed thinking, which is incumbent in institutions, policy and discourse, to a nexus approach that accommodates sustainable transformations is a significant undertaking. Nexus thinking has previously been predominantly concerned with resource efficiency and the optimisation of resource flows between water, energy and food. As demonstrated in the literature review, this has neglected the political aspects of

resources. When attempting to implement nexus policies, governments are faced with the complexities and uncertainties the nexus inhibits, such as the challenges of working across different scales (Pittock et al., 2013), defining responsibilities amongst different governmental agencies and the increased possible configuration of solutions and policies (Lindberg and Leflaive, 2015). The problems the nexus addresses are complex and uncertain problems of unsustainability, where many stakeholders are involved with different perspectives and values (Dirven et al., 2002). As mentioned in section 2.1.3, underrepresenting the different social structures behind the water, energy and food sectors can diminish the potential of the nexus concept, or lead to misuse as a legitimisation of existing pathways. This research will focus on this knowledge gap of the missing political economical view in the water-energy-food nexus. This knowledge gap was identified in multiple literature reviews and studies on the WEF-nexus (Allouche et al., 2015; Leck et al., 2015; Matthews et al., 2015; Middleton and Allen, 2014). Two arguments speak in favour of contributing towards this knowledge gap. First, the political economical environment in SIDS and other developing countries is often a barrier towards more sustainable resource use. This implicates that accounting for these political, economical and social factors is important in a WEF-nexus approach, so that barriers for sustainability transitions can be identified and accounted for. Second, multiple suitable fields of study exist that are able to analyse socio-technical transitions towards sustainability that are influenced by political and economical pressures, adding valuable and mature research methods to the concept of the water-energy-food nexus. Systems theory offers well-established methods to analyse complex socio-technical systems and transition management theory addresses power dynamics, clusters of stakeholders influencing system behavior and the behaviour of socio-technical systems over time in a direction towards sustainability.

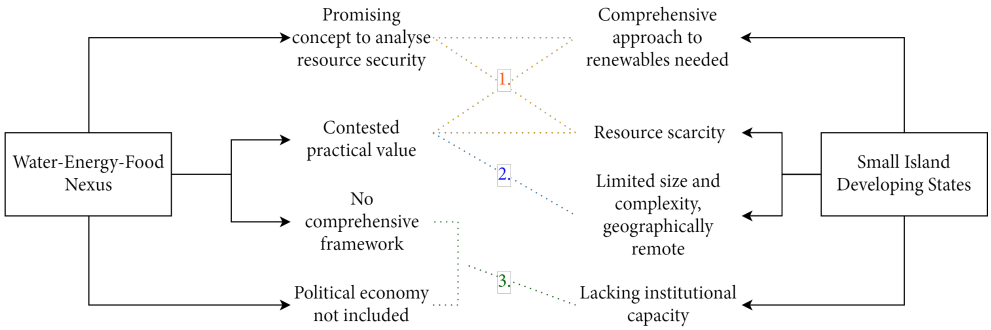


Figure 2.2: Linkages between the WEF-nexus and SIDS

Figure 2.2 identifies three connections between the benefits and knowledge gaps of the water-energy-food nexus and the characteristics of SIDS. These connections represent the perspective this thesis takes towards the water-energy-food nexus and its potential application in Bonaire. Multiple fields of study come together in such a view on the WEF-nexus and SIDS, as argued for in section 1.3.

1. SIDS experience high fuel and water prices and are reliant on food imports. A need exists for a comprehensive approach including policy and regulatory frameworks to successfully deploy clean and cheap energy on SIDS (Lucas et al., 2017). This creates a situation where a nexus approach can be valuable, both for the communities in SIDS as for the scientific understanding of how the nexus concept can be utilised.

2. As the nexus is criticised for missing the vertical integration of local nexus issues with broader national and global nexus issues (Endo et al., 2017), the limited geographical size and geographical remoteness of SIDS provide a more isolated region where a nexus approach can be applied.

3. Lacking institutional capacity is a common problem in SIDS. Strengthening existing institutions is therefore a recurring recommendation in literature (Asian Development Bank, 1998; Boto and Biasca, 2012; ECLAC, 2018; Niles and Lloyd, 2013). Furthermore, the nexus has received criticism for requiring strong institutional capacity due to its increased complexity over siloed policies (Leck et al., 2015; Lindberg and Leflaive, 2015; Hoff et al., 2017). A nexus framework and methodology that builds on the current body of work, includes a political economy perspective and yet is simple to use, may thus support policy-makers in SIDS.

2.3 SYSTEMS AND TRANSITION MANAGEMENT THEORY

This section will summarise the most relevant concepts of systems theory and transition management theory from the existing body of literature[2]. From a nexus perspective, the goal is to achieve an integrated and coordinated transition towards sustainability in the water, energy and food systems. Transitions are processes of transformation where a regime and its rules and regulations, culture and practices are undone and new regimes are created (Loorbach, 2007). Transition management theory is closely related to systems theory and is suited as a normative approach in developing governance strategies to reach desirable futures (Loorbach, 2010; Loorbach et al., 2017). Systems analysis is seen as a prerequisite for transition management. The belief is that without understanding the complexities of the socio-technical system, a desired system state offering sustainability benefits cannot be envisioned and reached through transition management (Loorbach, 2010). Examples of this are by Chappin (2011, p.46): "A system transition is substantial change in the state of a socio-technical system." and Schröder et al. (2019, p.118): "actors are embedded in multi-level systems, which can create both challenges and opportunities for institutional change". Both systems theory and Transition Management (TM) are multi-disciplinary and acknowledge that technical analysis is insufficient to address complex problems, and that

2 Scopus and Google Scholar were used to find established literature regarding these two theories. Snowballing was used as a methodology to find additional literature regarding transitions of socio-technical and socio-ecological systems. From this collection certain articles were selected or omitted based on an initial reading of the abstract.

analysing social, institutional and economic factors is imperative to decision making. As stated by Chappin (2011, p.13): "transitions emerge over time as fundamental change out of the interactions of the many stakeholders in the system that act upon or make use of elements in the physical world which also change during transition". Similar to the critique the WEF-nexus receives for being too much focused on optimisation and neglecting the social structures underlying resources, Loorbach et al. (2017, p.602) see that "From a transition perspective, sustainable development policies and programs have focused too much on reducing unsustainability through optimisation, thereby (un-willingly) adding to the lock-in of societal systems". The realisation that the WEF-nexus has to take into consideration the political-economic factors that often dominant stakeholders enforce, makes TM a suitable approach and one that is underrepresented in current literature on the WEF-nexus.

TM looks at socio-technical systems undergoing internal and external changes, often in a direction of sustainability and influenced by markets, infrastructure, rules and regulations. Two approaches to TM exist: the descriptive approach where the multi-level and multi-phase perspective is used to analyse how historical transitions emerged (Geels, 2014), and the normative approach of governing contemporary transition processes (Rotmans et al., 2000). Important is the distinction between unplanned transitions and transition management. Unplanned transitions are more related to the analysis of transitions, and focuses on an understanding of historical transitions such as the shift from horse-drawn carriages to combustion vehicles. In planned transitions TM aims to influence, facilitate, stimulate and organise transition processes and that ultimately offer sustainability benefits (Rotmans et al., 2000; Loorbach, 2007). Steering transitions has similarities to the analysis of historical transitions: both analyse a situation, historical or current, using transition theory methods. Rotmans et al. (2000) attributes the following characteristics to transition processes:

1. It concerns large scale technological, economical, ecological, socio-cultural and institutional developments that influence and reinforce each other
2. It is a long term process that covers at least one generation (25 years)
3. There are interactions between different scale levels (niche, regime, landscape)

2.3.1 Analysing transitions

Two important concepts in the analysis of transitions are 1. *phases* and 2. *niches, socio-technical regime and landscape* (Chappin, 2011). Rotmans et al. (2001) define four transition phases:

1. Predevelopment phase: a relatively stable phase where the status quo does not visibly change
2. Take-off phase: the state of the systems begins to shift and starts a process of change

3. Breakthrough phase: socio-cultural, economic, ecological and institutional changes accumulate and drive major change

4. Stabilization phase: a new status quo is reached after the speed of social change has decreased

The Multi-Level Perspective (MLP) is a popular framework to understand the dynamics of socio-technical transitions (Figure 2.3). It supposes that transitions arise from the connections between the niche, socio-technical regime and exogenous socio-technical landscape (Geels, 2014). Niches are relatively isolated and safe spaces where new technologies or social practices have developed or are developing, accumulate traction and where some eventually influence the dominant socio-technical regime. However, a local analysis of the nexus' impact is an approach that is not often adopted as a WEF-nexus research focus and can lead to different understandings of future nexus governance (Leck et al., 2015). On the regional and national level, a key barrier to successful nexus governance are the historically entrenched vertical government structures (Leck et al., 2015). Geels (2014) define these entrenched structures as a regime: a complex heterogeneous system that includes both technical artefacts and human stakeholders, is stable, resilient and capable of self-reproduction potentially leading to technological lock-ins. The technical artefacts in socio-technical systems, rules, regulations, and routines and behaviour are 'locked-in' and prevent structural change (Loorbach, 2007). Lock-in is relevant for understanding and governing transitions in the WEF-nexus (Laspidou et al., 2017). Particularly the water and energy sector are influenced by previous investments in infrastructure, generation capacity, rules and behaviour. The third and final concept is the landscape. In the socio-technical landscape global forces and paradigms develop, which in turn are able to pressure the regime. Examples of landscape pressures on the WEF-nexus are rising sea levels threatening fresh-water supplies, volatile oil prices and increasingly extreme weather influencing food production. The WEF-nexus adds another dimension to the three levels in transitions, namely that the distribution of power between different sectors can vary significantly. For instance, a well-established locked-in regime in the water sector can exert far greater amounts of influence than a still emerging regime in a developing food sector. This is often the case in SIDS, where water production and distribution organisations are predominantly public companies with large market power and close ties to the governing bodies, whilst the regime in the agriculture sector is underdeveloped. Differences in the power of regimes and niches amongst sectors has major implications and can create suboptimal and unequal solutions (Hoff, 2011).

The MLP has received critique for insufficiently accounting for politics and power (Kern, 2011; Meadowcroft, 2011). In response, Geels (2014) extended the MLP to include power and political economy by investigating relations between policymakers and incumbent firms and distinguishing four forms of power regime stakeholders can use to resist fundamental change. These forms of power are 1. instrumental strategies where resources are used to influence relations, 2. discursive strategies that can shape agendas, 3. material strategies such as technical and financial resources, and 4. broader institu-

tional power embedded in politics and governance structures (Geels, 2014). Taking these four strategies into account during the stakeholder analysis offers insight into how stakeholders can be expected to influence a sustainable transition in the WEF-nexus.

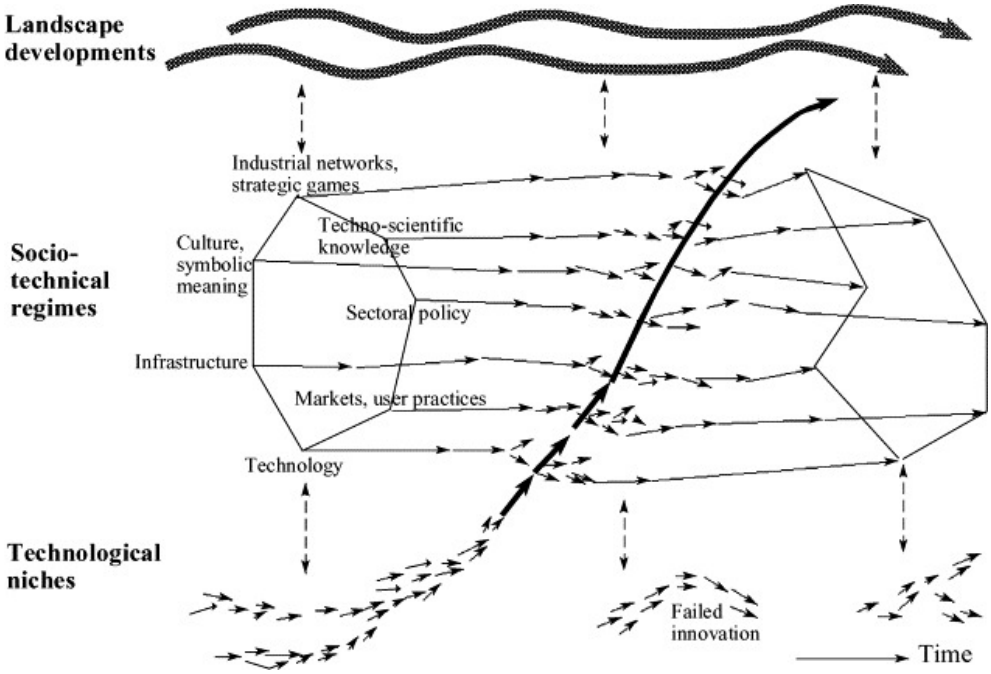


Figure 2.3: Multi-Level Perspective (Geels, 2002)

Loorbach et al. (2017) discern three research approaches to study transitions: a socio-technical approach, a socio-institutional approach and a socio-ecological approach. These three approaches differ in foci, goals, methodology and disciplines. The nexus relates to all three of these approaches: the resource-driven ecological relations of the nexus, the focus on governance of natural resource systems, technical connections between resource systems, limited institutional provisions for a nexus approach and the institutional difficulty of cooperation between different resource sectors. Specifically the socio-ecological approach to transition management focuses on interconnected planetary boundaries, interplay between ecological transitions and social context (Loorbach et al., 2017). Socio-ecological systems emphasise the interconnectedness of social and ecological systems and is challenging to govern due to the prevalence of management regimes (van der Voorn and Quist, 2018). After Smith and Stirling (2010), van der Voorn and Quist (2018) consider a management regime in socio-ecological systems to encompass multiple socio-technical systems that evolve around a socio-ecological system rooted in a spatial context. Another perspective is that of *regimes of provisioning* consisting of three dimensions: 1. a multilevel system of rules and regulations, culture and contest between incumbents and challengers 2. a level of energy and resource flows 3. the production and distribution infrastructure that supports those flows (Foran, 2015). Such a regime of provisioning contains multiple nested smaller arenas, such as the water, energy and food sectors. Methods to analyse socio-ecological systems and the rules and be-

haviours that affect it, are the Management and Transition Framework (MTF) by Pahl-Wostl et al. (2010) and the Institutional Analysis and Development framework (IAD) by Ostrom and Hess (2005). These provide methods to understand the role of institutions and communities and the effects their actions have on common pool resources in ecological systems (Ostrom and Hess, 2005). The MTF specifically aims to analyse the processes governing water management regimes. A difference between regimes of provisioning and the IAD is that provisioning regimes are constantly being contested by niche developments, instead of the rule-ordered or repetitive behaviour in communities (Foran, 2015). A second difference is that the interests and power of stakeholders can vary significantly across systems in regimes of provisioning. Because of this, the MLP is regarded as more suitable in analysing the dynamics of sustainable transformations in the water, energy and food systems in Bonaire, as it can better address the changing stakeholder positions within and between systems and the niche developments that influence them.

2.3.2 Governing transitions

When a desirable future exists transition management aims to steer a system towards this desirable future state. Transition management has been applied in the water sector, as the complexity of transitioning to an IWRM approach is often underestimated (van der Brugge and Rotmans, 2006). The strong internal connections and interwovenness of water institutions, management practices and dominant practices in water management result in a hard to change regime of different water institutions (van der Brugge and Rotmans, 2006). Similarly the energy transition (or the German Energiewende) has shown how incumbent fossil fuel regimes take action against this transition and attempt to steer it towards existing pathways, such as the clean coal discourse promoting technologies such as carbon capture and storage (CCS) (Geels, 2014). An analytic approach to governance in transitions is used to understand how the role of and interactions between stakeholders, technological artefacts, markets, infrastructures, rules and regulations lead to systemic change (Loorbach et al., 2017). From that initial analysis, multiple transition management approaches exist that have demonstrated to be able to support governance of, and for, sustainability transitions (Loorbach et al., 2017).

Transition management allows for the analysis and management of incumbent stakeholders and governance structures. The components of such an analysis are not set in stone, but a common approach often contains system theory methods and methods described in section 2.3.1. The analysis of incumbent stakeholders and governance structures is of importance in the WEF-nexus in order to successfully address inequalities in the nexus (Allouche et al., 2015) and to achieve successful cooperation and coordination between different stakeholders (Bizikova et al., 2013). Furthermore, TM allows for the multi-level analysis of the individual nexus silo's. The transdisciplinairy nature of transition management has led to the synthesis

of multiple theories to research sustainability transitions. Schröder et al. (2019) have combined the governance of pathways with co-creation, participatory visioning and learning to understand and advance sustainable consumption patterns in cities. The framework pays specific attention towards power dynamics and political economy in order to address the institutional changes necessary for transitions encompassing multiple different sectors and their resulting interactions. The concept of administrative boundaries is also relevant in the governance of transitions, as Kurian (2017) mentions that IWRM overlooks administrative boundaries in the hierarchy of authority structures, particularly in the multi-level governance (a nexus attribute) of environmental resources. Halbe and Pahl-Wostl (2019) mention that a "particular challenge of transition governance is related to the case-specific initiation and design of the transition processes.", which relates to the nexus criticism regarding its usefulness as a framework only if it explores alternative pathways instead of legitimising existing dominant pathways (Allouche et al., 2015). A broad selection of the transition team that provides a factual basis for the transition process can help with this challenge, although the risk exists that multilevel and multi-scale issues are omitted (Halbe and Pahl-Wostl, 2019; Loorbach, 2007). Support and participation of the major stakeholders is necessary to legitimise a transition process, whom itself are part and promoters of the status quo. This risks capture of the transition process by stakeholders whom can use the WEF-nexus concept to legitimise dominant pathways.

Sustainable transitions in socio-ecological systems often strive for *resilience*: the "the magnitude of change or disruption that a system can absorb before shifting to an alternative regime or state" (Cinner and Barnes, 2019, p.51). Resilience is affected by the relationship between people and the ecosystem, but dynamics between social structures and ecological systems can also lead to undesirable system states (Cinner and Barnes, 2019). Attempts to build resilience in one ecological domain may have perverse effects in others, further entrenching unsustainable behaviour (Cinner and Barnes, 2019).

Visions can create a desirable future system state for the transition process to strive towards and find common goals between different stakeholders. Shared basic principles for long-term sustainable development can form a basis for sustainability visions (Figure 2.4) (Loorbach, 2010). A clear need for change must be present to warrant visions, this need has been demonstrated by the rising water and food prices, population, poverty and the degrading capacity and quality of the current electricity network in Bonaire (Schelleman and van Weijsten, 2016). Visions are used in transformational change, to replace old structures by new ones (Van der Voorn et al., 2012). Emerging visions stem from different beliefs, values and mental frameworks typically associated with outsiders and not with larger societal groups (van der Voorn and Quist, 2018). The WEF-nexus itself can be seen as a new emerging vision that attempts to replace the old structures of governing critical resource systems and can be placed in the niche developments. Not only emerging visions in the water, energy and food sectors and the stakeholders providing agency to those visions is relevant to a transition in the WEF-nexus, but

also emerging visions regarding the WEF-nexus. In transitions the concept of sustainability (See: 1.4) makes setting goals difficult, as it is a continuous process of change and is different for each stakeholder (Loorbach, 2007). Implications are that multiple visions can be seen as sustainable or as unsustainable dependent on the level, timescale and perception by stakeholders. A categorization of visions can therefore be helpful in ordering the visions relevant to the WEF-nexus in Bonaire. Leising et al. (2018) propose a categorization of visions as follows:

- Vision image (metaphors, explicitness)
- Vision guidance (shared goals, leadership, new rule sets)
- Vision orientation (motivation, inspiration, direction)

These categories can be used to order visions found in literature interviews and to investigate the role and influence of existing visions in Bonaire. A shared vision has the strength to make stakeholders converge and commit in their actions (Van der Voorn et al., 2012). The degree in which a vision is shared between stakeholders, and where the stakeholders are placed on the MLP can provide insight in the dominance of certain visions. Another research methodology that is closely related to TM and that uses visions is backcasting (Quist et al., 2013). Instead of incremental steps towards changing policy goals, backcasting can provide a desirable future system state, or attractors of change, that supports the construction of transition pathways and a transition agenda. Both backcasting and transition management are valuable in complex problems, where there is a need for major change (*nexus: increased population and resource pressure*), dominant regimes are present and motivated to keep the status quo (*nexus: dominant infrastructure stakeholders*) and where system externalities are not adequately solved by markets (*nexus: misrepresentation of resource prices*) (Drehborg, 1996; Quist et al., 2013). In earlier research future water visions were used to discover the implications of a transitioning resource system and provided practical starting points and stakeholder roles (Halbe et al., 2015).

Transition Management Cycle

Loorbach (2010) propose using the TMC, consisting of four phase. Identifying frontrunners in society that promote sustainable development is the starting goal of TM, after which the cycle provides a learning by doing approach (Figure 2.4). As the current situation in Bonaire is still in a very exploratory phase regarding the WEF-nexus, this research will focus only on the **strategic phase** of the Transition Management Cycle. This entails: 1. Problem structuring: the analysis of current systems and the cross-case comparison of the niche developments, ST-regime and landscape between the water, energy and food sectors. This step corresponds with the methods described in section 2.3.1. 2. Envisioning: a categorisation of the visions which leads to an overview of the different (possibly shared) visions for the different sectors, and the WEF-nexus as a governance tool. 3. Establishment of the transition arena: identifying topics and possible configurations of stakeholders for the

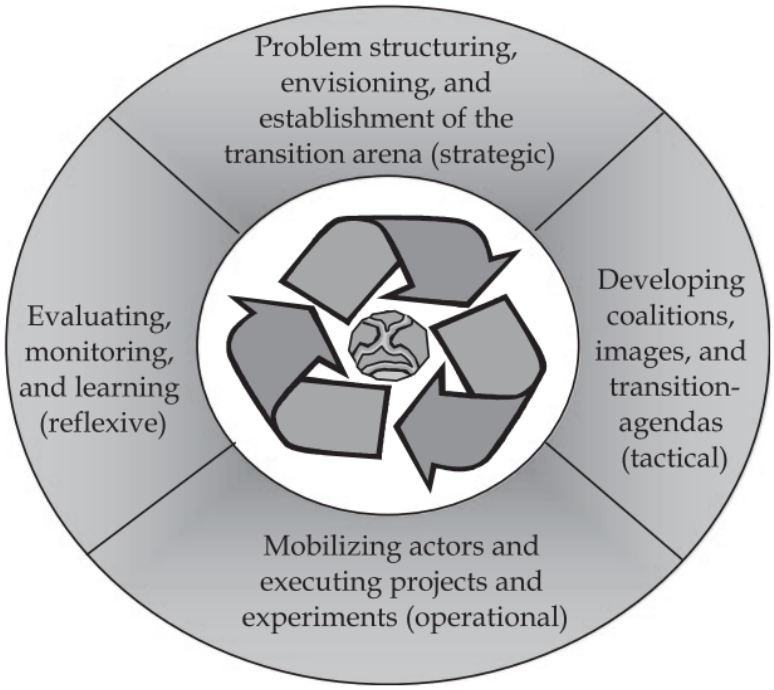


Figure 2.4: Transition Management Cycle (Loorbach, 2010)

transition arena and making recommendations for the next steps of the TMC (Figure 2.4). Section 3.1 will elaborate further on the methodology chosen for the strategic phase of the TMC.

2.4 CONCLUSION AND INTEGRATION

This section will conclude the theories described in this chapter and integrate the concepts from the WEF-nexus, systems theory and transition management theory to provide an answer to the first section of Subquestion 1: *How can systems theory and transition management theory contribute to a water-energy-food nexus approach?*. Chapter 3 will then address the second part of this Subquestion 1: *How can these be operationalised in a methodological framework?*. The water-energy-food nexus is a promising concept to tackle ecosystem and resource security issues in SIDS. It is however still a novel concept and not yet sufficiently capable of dealing with the political economical aspects of the water, energy and food systems. In order to do so, the potential of systems theory and transition management theory for implementing a nexus approach and explicitly accounting for power and political economy were discussed. Systems and transition theory provide multiple valuable concepts and methods for analysing and steering the water-energy-food nexus.

2.4.1 Systems theory and the nexus

From a systems perspective, in a specific spatial context (the island of Bonaire), the WEF-nexus consists of multiple socio-technical systems (water, energy, food) that are embedded in a larger socio-ecological system of Bonaire's environment and natural resources. The increasing pressure on ecological resources (See Section 1) drive socio-ecological systems at all levels (Hoff, 2011). This also provides a starting point for the systems analysis of the WEF-nexus: an analysis into the three respective socio-technical systems and a cross-case comparison rooted in the larger socio-ecological system. Loorbach (2010) mentions that particularly the non-linear processes of system change and emergence of system behaviour are important features in driving transitions. Causal system diagrams help understand the causal relationships between factors influencing system behaviour and the dynamic feedback loops that create non-linear behaviour (Enserink et al., 2010). Additionally the formal and informal networks of stakeholders within and between the water, energy and food systems are of use in analysing the regime and niche stakeholders and those who can and wish to engage in certain sustainability transitions. The stakeholder analysis functions as a basis on which the influences of power and politics (Geels, 2014) can be applied. Furthermore, Foran (2015) argues for understanding the context of social structures, as a complex systems approach may overlook the social power structures underlying nexus issues. Systems analysis provides multiple tools for stakeholder analysis that enable the mapping of formal relationships and stakeholder interdependencies. A cross-case comparison can then provide insight into the different socio-technical complexities between systems. Understanding these differences and similarities can thereafter show where opportunities or difficulties lie for strategies for integrated governance of the three systems. This thesis takes the definition of nexus governance to strive towards by Stein and Jaspersen (2018, p.3): *"the relational structures and processes that connect actors across sectors, governance levels, geographical boundaries and/or public, private and civic spheres, and that provide steering mechanisms for the integration of management and governance systems across different policy domains."*.

2.4.2 Transition management theory and the nexus

When applied to the WEF-nexus, analysing transitions encompasses multiple tasks after a systems analysis is performed. Finding incumbent regime stakeholders present in the water, energy and food sectors and their relationships towards infrastructure, markets and sectoral policies enables that the socio-technical regimes can be understood. In the search for sustainable processes, local level stakeholders in industry, public office and NGOs challenge the incumbent national regime stakeholders, resulting in competing institutional belief systems (Schröder et al., 2019). Rules and regulations that enforce the regime may act as barriers for niche developments and are relevant to analyse. By investigating the developments taking place in the nexus niches that have the possibility to influence the dominant regimes, possible nexus pathways can be found. Thus understanding can be created

of the landscape pressures on the water, energy and food systems, the socio-technical regimes and respective governance and finally the niche developments. Governing transitions then proposes to initiate a transition management process to reach integrated governance of the water, energy and food systems through the participatory Transition Management Cycle. Two arguments speak in favour of using transition management theory. First, it can help in achieving a coordinated and integrated sustainability transition in the water, energy and food systems by directing its socio-technical systems towards sustainable development (Halbe and Pahl-Wostl, 2019). Transition management explicitly addresses the challenges of working across scales and administrative boundaries, which is particularly relevant in coordinating the three nexus sectors. Second, it may respond to its criticism regarding lacking political-economical focus. There are multiple methodologies and focus points in TM. Both analysing and governing transitions are of value: analysis to structure the current situation in Bonaire into transition concepts; governance to guide these developments towards a sustainable future in the WEF-nexus.

2.4.3 Conclusion

In conclusion and to answer the first section of Subquestion 1[3], a socio-technical systems perspective considers not only the technical complexities of the water, energy and food systems in Bonaire, it also investigates the social, political and economical factors influencing these systems. It can be used to structure the complex problems in Bonaire's water, energy and food systems and map their interconnections. Bonaire is undertaking multiple sustainability transitions (Section 1.2) and analysing these transitions in relationship with one another and finding and steering developments towards integrated governance of the WEF-nexus is the proposed added value of combining transition management theory with the WEF-nexus. In applying these methods to the water, energy and food systems in Bonaire a novel method of looking at the WEF-nexus is conceived: one that is theoretically able to grasp the political economical environment and the incumbent regimes in the water, energy and food sectors. A selection of methods from the theories described in this chapter will be combined into a methodological framework for this thesis. The strategic phase of the Transition Management Cycle is selected as the general framework structure wherein multiple methods shall be used. Chapter 3 will describe how systems and transition theory are applied in this thesis to research governance strategies for implementing a nexus approach.

3 How can systems theory and transition management theory contribute to a water-energy-food nexus approach?

3 METHODOLOGY

This chapter will propose a theoretical framework for subquestion 1: *How can systems theory and transition management theory assist a water-energy-food nexus approach and how can these be operationalised in a methodological framework?*. This design is based on the theories described in chapter 2. This methodological framework will be applied in a case study of Bonaire. Chapter 8 and 7 will elaborate on the framework's applicability in this regard. The synthesis of multiple theories and fields of study (section 2.4) has multiple methodological implications. First, the combination of the WEF-nexus and transition management theory has implications on the scope of the research. The water, energy and food systems are not only connected with one another, multiple other pressures exist that influence these systems. Examples of these pressures are the rising resource demand from the tourism sector and the degradation of Bonaire's two natural parks. From an isolated systems perspective, these pressures might be left out of the scope, or accounted for as external pressures. Yet this risks that the political economical environment within and surrounding the WEF-nexus remains underrepresented. Furthermore, transition management theory argues that a narrow scope can create a lack of attention for important factors and alternative perspectives (Loorbach, 2007). Thus, a wide scope of this research aims to prevent overlooking key factors from the political economical environment and potential transition opportunities, but adds difficulty to the research (Hoolohan et al., 2019). Where the research boundaries are drawn is reflected upon in chapter 7. The second implication is that a selection of methods from systems theory and transition management theory has to be made that is able to address the nexus' knowledge gap and provide recommendations for Bonaire. This results in a methodological framework for subquestion 1. Third, the extensiveness of these selected methods is affected by the focus on three socio-technical systems instead of one and the wide scope. Given the time constraints of this thesis, this results in a less in-depth use of the methods. The proposed added value therefore, lies in the synthesis of multiple different methods. A theoretical framework based on the strategic phase of the TMC by Loorbach (2010) that addresses these implications is constructed in this chapter. Based on the literature review, several requirements are drafted for this framework. The theoretical framework should:

1. Conceptualize the socio-technical complexities of the water, energy and food systems
2. Compare the similarities and differences between the water, energy and food systems
3. Identify connections between the water, energy and food systems

4. Identify relevant related issues outside of the water, energy and food systems
5. Enable the identification of governance issues
6. Identify structural regime barriers and stakeholders
7. Identify niche developments related to the water-energy-food nexus
8. Compare future visions for the water-energy-food nexus
9. Construct a shared vision for Bonaire
10. Propose transition pathways towards the shared vision
11. Generate recommendations for the development of the transition arena

The strategic phase of the TMC consists of problem structuring, the envisioning of desirable futures and the initial design of the transition arena. Several methods are selected based on chapter 2. The theoretical framework is novel and useful in the sense that it takes a specific perspective to the WEF-nexus and applies the first step of the TMC towards the WEF-nexus.

3.1 THEORETICAL FRAMEWORK

3.1.1 Problem structuring

Multiple methods will be applied in this step to structure the problems in the water, energy and food systems in Bonaire. These methods are: a systems analysis, a classification of external factors using the PESTLE framework, a stakeholder analysis, an analysis into the governance of the socio-technical system and finally a classification of published visions. Based on interviews with local stakeholders who have mentioned that more often than not, problems are viewed in connection with one another instead of in isolation, the sectors can then be compared with each other in a cross-case analysis (Interviewee #3, Interviewee #4). The discussion of this thesis will reflect on the challenge of integrally analysing the systems and the additional complexities the increased scale of the WEF-nexus brings compared with isolated systems analyses. These analyses will be constructed by researching existing literature, consisting of scientific journals, previous studies, policy documents and media and by conducting interviews with stakeholders. Section 3.1.4 will elaborate on the data collection process.

Systems analysis

First, a systems analysis is performed to investigate and structure the socio-technical systems of the water, energy and food sectors and their interconnections. This systems analysis will use multiple methods to reach the desired inputs for transition management methods described in section 2.4. From the problem statement in chapter 1 no definitive problem owner can be selected for this research. The ultimate goal of the sustainability transitions are

to improve the quality of life of Bonaire's residents, but the problem statement also take Bonaire's economic and environmental health into account. A starting point of the systems analysis is therefore to construct objective trees for the water, energy and food systems that incorporate the goals of the involved stakeholders, and not one stakeholder specifically. This "joint hierarchy of objectives" (Enserink et al., 2010, p.68) allows for the evaluation of alternatives while considering the perspectives of multiple stakeholders. From these objective trees system criteria can be extracted. These system criteria are social, economic and technical objectives for the socio-technical systems. Through a conceptual model that maps socio-technical factors influencing the system criteria the causal mechanisms in the the water, energy and food systems can be made clear. The causal mechanisms are derived from scientific and grey literature related to Bonaire. These causal mechanisms remain on a high level of abstraction due to the third implication described in 3[1]. To be clear, these steps are performed for each system in isolation to reduce the complexity of analysing the three systems in tandem. Finally the external factors influencing system behaviour are added to construct a system diagram. Here the integration of the three systems starts: factors from the one system that influence the other systems are included as external factors. Additional external factors that directly influence system behaviour are added in the system diagram. The distinction between these factors and the factors in the PESTLE analysis is as follows: factors found in literature that directly influence the causal mechanisms, such as global oil prices, are included in the system diagram and listed in the PESTLE analysis. External factors that do not directly influence the causal mechanisms, but do affect the broader socio-technical regime and its governance of the system, such as human capacity, are only included in the PESTLE analysis.

A means-end diagram is a typical element of a system analysis (Enserink et al., 2010). Means-end analysis is used to better formulate a problem owner's objectives and means in reaching those objectives. This research has chosen not to construct means-end diagrams because of the absence of a definitive problem owner. Multiple stakeholders exist within and related to the water, energy and food systems that are able to influence its trajectory. A means-end diagram containing the means of all related stakeholders can risk becoming too wide and complex to be of value. Instead TM is used to identify regime stakeholders and research their governance strategies for the WEF-nexus.

PESTLE analysis

The PESTLE classification framework allows for structuring external factors directly and indirectly influencing the system behaviour into six groups: political (P), economic (E), social (S), technological (T), legal (L), and environmental (E) (Zalengera et al., 2014). The PESTLE analysis has two uses in this methodological framework. First, the PESTLE method offers a starting point for analysing the external pressures that affect system governance.

1 The combination of multiple different methods and the nexus' implication that the analyses are performed in threefold, limits the extensiveness of individual analyses.

Political (P) factors implicate if and where political support or opposition for transition pathways can be expected. Economical (E) factors indicate where important economical developments are taking place and where financial support can be found. Both the political and economical factors specifically contribute to the nexus' knowledge gap highlighted in this thesis. Social (S) factors are relevant in the sense that they influence socio-technical system behaviour (growing population is an example presented in 1.2). By investigating the technological developments (T) taking place in the nexus niches that have the possibility to influence the dominant regimes, possible elements of nexus pathways can be found. Rules and regulations (L) that are enforced by the regime may act as barriers for niche developments and are relevant to analyse. Environmental (E) factors provide insight into the broader socio-ecological system wherein the water, energy and food systems operate. These different pressures can then be used in the Multi-Level Perspective to identify the landscape, socio-technical regime, and technological niche factors. Second, the PESTLE analysis functions as an initial delineation of the shared vision space and the possible pathways towards that shared vision. This is achieved by deducing implications for a shared vision and possible elements in the pathways from the different factors

Stakeholder analysis

The systems analysis is combined with a stakeholder analysis based on Enserink et al. (2010) to reach a socio-technical systems description. The stakeholder analysis contains six steps. This thesis will only perform the first three steps due to the third methodological implication described in 3. In the first step a problem formulation is constructed by the researcher based on the outcomes of the systems analyses, as no problem owner exists. From this problem formulation, published literature and interviews with researchers well connected in Bonaire are used to construct a stakeholder inventory. There will initially be little restrictions on which stakeholders are included in the analysis. The nature of the WEF-nexus implicates that stakeholders that are related to one or more of the water, energy and food sectors can influence other sectors. For instance, excluding stakeholders from the tourism sector, one of the largest consumers of water and food in Bonaire, will under-represent the goals and means influencing these sectors, influencing the quality of the systems analysis. Similarly the concepts of the socio-technical regime and the niche developments entails selection of stakeholders from both within and outside of the incumbent regimes, so as to not confirm the existing notions of the management regime (See 2.3); (Allouche et al., 2015; Geels, 2014; Loorbach, 2010). A broad selection is made from governmental agencies, NGOs, knowledge institutes and businesses. In this case the benefit of researching SIDS is that the isolated and small nature ensures that a wide selection of stakeholders remains comprehensible for the researcher.

In the third step of the stakeholder analysis formal relationships between stakeholders are mapped using a formal chart (Enserink et al., 2010). Formal relationships can indicate structural configurations of stakeholders and their

integration with stakeholders from other sectors (Stein and Jaspersen, 2018). A structured group of stakeholders that drive self-reinforcing governance processes is a strong indication of the regime. By combining the socio-technical system behaviour and the stakeholder analysis, the governance of the system is analysed. In this step it is described how stakeholders interact with each other and with the socio-technical system. As mentioned, this thesis will not conduct steps four to six in the stakeholder analysis by (Enserink et al., 2010). These steps are to construct stakeholder specific problem formulations (step 4), analyse interdependencies (step 5) and confront the initial problem formulation with the outcomes (step 6) (Enserink et al., 2010). This choice is reflected upon in chapter 7.

Classification of visions

Multiple visions for Bonaire drafted by a wide variety of stakeholders exist in policy documents, studies and reports. Noteworthy is that these visions are sector specific, no documents have been found that set out a vision for the WEF-nexus or an integration of multiple sectors in Bonaire. Despite growing awareness of the connections between sectors (Interviewee #4), no initiative has yet been undertaken to envision a desirable future beyond one's own sector. The WEF-nexus concept may thus be of value in linking the water, energy and food systems for the first time. The multi-level and multi-sector nature of the WEF-nexus creates competing visions and narratives for the future of Bonaire. Visions will be structured based on the three elements by Leising et al. (2018), namely 1) vision image, 2) vision guidance and 3) vision orientation. This structuring is used to create insight into how expansive and important certain visions are compared to others. Semi-structured interviews with stakeholders engaged in Bonaire are used to provide nuance and perception regarding the written visions published by stakeholders. This is useful in identifying how the individual visions are used by stakeholders to legitimise their goals and position within the socio-technical regime.

Cross-case analysis

The cross-case analysis is performed to compare the similarities and differences between the water, energy and food systems and to offer insight in cross-sector governance. The cross-case analysis has two functions: 1. To compare the similarities and differences between the water, energy and food systems and 2. To draw conclusions and implications based on that comparison to serve as input for the shared vision and transition pathways. The first step in the cross-case analysis is to compare the socio-technical complexity of the water, energy and food systems using the characteristics of complex systems by Cilliers (2000). These characteristics are: 1. number of elements 2. connections with other systems 3. dependency on other systems 4. degree of change 5. adaptivity and 6. external pressures. 'Number of elements' addresses how many system factors and connections between those factors are present. 'Connections with other systems' addresses how many connections exist between specifically the water, energy and food systems. Those three systems connect with other systems such as the tourism sector, but these connections are discussed in 'external pressures'. 'Dependency on

other systems' addresses how contingent the water, energy and food systems are on one another. Finally 'Degree of change' and 'adaptivity' are closely related: the degree of change is the gap between the current and desired system state, and adaptivity is the capacity for change of the system. Therefore these properties are discussed together. A qualitative ranking made by the researcher of the three systems is included that summarises the characteristics of the water, energy and food systems. A comparison of the similarities and differences in the PESTLE analyses of the water, energy and food systems aims to find opportunities and implications for the shared vision space and the pathways towards that vision (chapter 6). The PESTLE factors are then placed in the landscape, socio-technical regime and technological niche levels of the MLP. The stakeholder analyses are compared, primarily by comparing the formal charts and investigating the degree of connectedness and influence of certain stakeholders. This offers insight into the composition of the socio-technical regime in the MLP. The governance analyses are compared and applied to the MLP to discover how the socio-technical regime operates, how technological niches have broken/are breaking through into the regime and how landscape pressures influence the regime and niches. This provides the final input for constructing the shared vision and identifying transition pathways.

3.1.2 Envisioning desirable futures

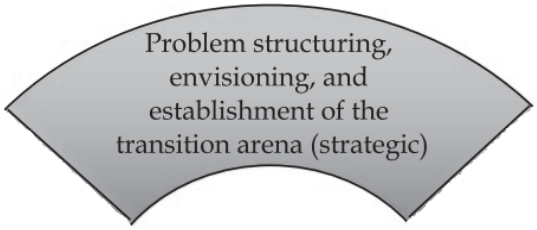
A shared vision has the strength to make stakeholders converge and commit in their actions (Van der Voorn et al., 2012). Common principles are the starting point in finding a shared vision (Loorbach, 2010). The commonalities and differences found in the previous steps serve to identify shared principles, essential elements and delineating factors for the shared vision space. The individual visions extracted from literature and interviews are combined by the researcher into a currently non-existing shared vision encompassing the water, energy and food sectors. The shared vision can also include essential elements from outside those systems, if those elements were identified earlier through for instance the analysis into the socio-technical regime in the cross-case analysis. This shared vision will serve as the input for the third step: designing the transition arena.

3.1.3 Designing the transition arena

Step 3 of the strategic phase in the TMC consists of designing the transition arena. It will apply transition management methods described in 2.3 to the results of steps 1: Problem structuring and 2: Envisioning desirable futures by constructing pathways towards a shared vision and offering recommendations for those pathways. Given the time and resource constraints in this thesis, this third step will discuss the relevant pathways that will be discussed in the first transition arena and give recommendations for stakeholders to be included. The participatory aspect of bringing together the selected stakeholders for the transition arena is excluded from this step, and is reflected upon in chapter 7. Three methods are used to reach a design of

the transition arena. First the outcomes of earlier analyses, in particular the MLP, will be used to investigate which developments towards a sustainable transition in the WEF-nexus are currently present in the niches, and what socio-technical regime and landscape opportunities and barriers are influencing these developments. These opportunities and barriers pay attention the narratives, rules and regulations that are being created by the socio-technical regime. Second, the MLP and the shared vision facilitate the construction of different pathways that lead towards a sustainable transition in the water, energy and food sectors. The niche developments found in the systems analyses and in the technological section of the PESTLE analysis will contribute to these pathways. The shared vision found in step 2 will serve as the attractor of change for these pathways. The stakeholder analysis serves to discover where support and where opposition can be expected for these pathways. Third, recommendations for the next steps in the TMC are made based on the transition pathways.

The theoretical framework



1. Problem structuring		
Step	*Inputs*	*Methods*
1.1 Systems analysis	Literature, interviews	Enserink et al. (2010)
1.2 PESTLE analysis	Literature	Rastogi and Trivedi (2016)
1.3 Stakeholder analysis	1.1, 1.2, literature, interviews	Enserink et al. (2010)
1.4 Governance	1.1-1.3, literature, interviews	
1.5 Vision classification	Published visions, interviews	Leising et al. (2018)
1.6 Cross-case analysis	1.1-1.4	Geels (2002)
2. Envisioning desirable futures		
2.1 Delineate vision space	1.1-1.4	
2.2 Construct shared vision	1.4 & 2.1	
3. Designing the transition arena		
3.1 Explore transition pathways	1.1-2.2	MLP (Geels, 2014)
3.2 Recommend transition agenda	3.1	TMC (Loorbach, 2010)

3.1.4 Data sources and interviews

Besides scientific literature discussed in chapter 2.1, two additional data sources where used in this thesis. First, 'grey'[2] literature was used for the

2 Documents published by governmental institutions, companies, NGOs, working papers, etc.

analyses in the Problem structuring step. Reports related to Bonaire were searched on stakeholder websites and archives and from news agencies such as Antilliaans Dagblad, NOS and De Volkskrant used. Additional relevant documents where found referenced in the initial search of published documents. Second, interviews with selected stakeholders were used in this thesis to contribute towards the Problem structuring step, and to gather additional relevant reports from stakeholders, such as the report on the Blue Destination strategy by Croes et al. (2017). Two initial interviews were conducted with scientific researchers active in Bonaire to gather insight into relevant stakeholders and contact information. This yielded an initial list of stakeholders that were to be contacted for interviews. This list was then cross-referenced with stakeholders who published, or were referenced, in the grey literature to make sure that no relevant stakeholders were overlooked. These stakeholders were contacted through e-mail with a description of the topic of this thesis and the interview topics. The interview topics were the perspective of the stakeholder regarding the water, energy and food systems, the published visions regarding those systems and their own vision for those systems. The interviews were conducted in a semi-structured approach, whereby a list of general and stakeholder-specific questions was used to guide the interview (Appendix D). During the interview notes were made by the researcher. Table 3.1 contains a list of interviewed stakeholders, their function, and residence: if they live and work in Bonaire or in the European Netherlands (EN). Several interviewees requested to remain anonymous. The reason for this request as explained by the interviewees was to remain impartial in their more analytic and research related role regarding Bonaire.

Table 3.1: Stakeholder interviews

	Name	Function	Residence
#1	Sid Vollebregt	Managing Director Elemental Water Makers	EN
#2	Peter Verweij	Researcher Wageningen University	EN
#3	Anonymous	Researcher	EN
#4	Yoeri de Vries	Policy Officer Agriculture, Fisheries and Economic Affairs Rijksdienst Caribisch Nederland (RCN)	Bonaire
#5	Anonymous	Ministry of Economic Affairs and Climate	Bonaire
#6	Jan-Jaap van Almenkerk	Independent consultant Wayaka Advies	Bonaire

4 PROBLEM ANALYSIS

Bonaire faces many of the common issues related to SIDS, such as high dependence on a limited natural resource base, low diversification of the economy and dependence imports (Boto and Biasca, 2012). In this chapter and in chapter 5 the problem structuring step of the theoretical framework will be applied to the water-energy-food nexus in Bonaire. The water, energy and food sectors are analysed separately, after which a cross-case analysis will compare relevant similarities and differences between the sectors. A systems analysis is applied to the three sectors that maps the socio-technical complexities of the system. External factors influencing each sector are classified using the PESTLE classification. This serves to delineate the space wherein future pathways in the WEF-nexus can take place. A stakeholder analysis is performed for each sector, providing the starting point for the elicitation of stakeholder visions and means. The systems and stakeholder analyses are combined to map the governance of the system. In the governance of the system the interactions of stakeholders with each other, the technical system and the MLP is researched. These analyses result in insight where opportunities and difficulties lie for sustainable transformations the water, energy and food systems.

Like many SIDS, the quality of Bonaire's environment is steadily decreasing. Global forces such as rising sea levels, volatile and unpredictable weather and higher temperatures affect Bonaire's ecosystem, which provides the services the water and food systems depend on. Bonaire's climate is fairly arid and only flora thrive that can survive on small quantities of water, such as dry forests. The coral reefs are the most important resource in Bonaire and its health directly affects the tourism industry (de Graaf et al., 2016). The economy is primarily based upon tourism, thus a variation in both stay-over and cruise tourist numbers has a significant effect on Bonaire's GDP. In 2017, the value added to Bonaire's economy by the tourism industry was 20% (Croes et al., 2017). GDP has seen a strong growth between 2012 and the most recent statistics of 2016 with an average of 2.3%. This can be explained by the growth in population, due to increased tourism and economic immigration, of 28% between 2010 and 2019, conversely resulting in a decrease of the GDP per capita (Centraal Bureau voor de Statistiek, 2019a). This increases the demand for water, energy and food and leads to increased pressure on Bonaire's natural resources. The costs of living, particularly rents and consumer prices, are high due to the dependence on imports and limited economies of scale (Centraal Bureau voor de Statistiek, 2018c). Poverty is is a problem in Bonaire and is particularly severe under the elderly whom are not able to meet the high food costs with a standard social pension from the state government (Drayer, 2019) (Interviewee #2 & #3). The economic be-

nefits that the growing tourism industry provides has only delivered them to a small portion of Bonaire's residents (Croes et al., 2017). That is why sustainable tourism practices are seen as an opportunity to reduce environmental pressures and increase the economic welfare of Bonaire's residents. In 2010 the Masterplan Strategic Development 2010-2025 set out the strategy to position Bonaire as a 'Sustainable Island' to increase its attractiveness (Van Werven et al., 2010). An example of this international positioning effort is the upcoming ban on disposable plastic in 2021 (Broere, 2019).

4.1 WATER

4.1.1 System analysis

Bonaire is experiencing increased pressure on its water sources from population growth, a growing tourism industry, climate change induced factors such as sea level rise and a changing hydrological cycle. Improving the quality or security of the water system often means raising water tariffs, improving the collection of unpaid bills, tackling illegal water use and reducing political influence in the investments process (Global Water Partnership, 2014). This system analysis functions to uncover the complex dynamics influencing the water system and to structure the different water flows into subsystems. Figure 4.2 conceptualises the water system in Bonaire. It uses the system criteria from the objectives tree for the water system, presented in appendix B, to construct causal relationships between factors found in literature. It is noteworthy that from an isolated view on the water system, external factors such as energy price, agricultural activity and vegetation cover are interpreted as external pressures, where in fact the goal of the WEF-nexus is to view the systems as connected. Therefore a share of the external pressures are factors in the energy and food systems. Additionally some factors are themselves external factors in the energy and food system, such as how drinking water production influences the energy demand and groundwater supply. As mentioned in chapter 3, these external factors directly influence the causal mechanisms of the system diagram; indirect factors are categorised in the PESTLE analysis.

Figure 4.1 visualises the different water streams from entrance in the system (rainfall and drinking water production) to consumption and disposal. Three observations can be made from this diagram. First, the amount of rainfall is more than sufficient to meet Bonaire's current different water demands, but the recharge of groundwater is low due to the deteriorated irrigation infrastructure and vegetation cover. Second, the amount of groundwater consumed by agriculture practices is currently unknown. Lacking information regarding the main connection between the water and food systems can implicate integrated governance of those systems, as decision making regarding investments in irrigation infrastructure and groundwater depletion rates is grounded in uncertainty. Third, there are malpractices regarding sceptic tank storage, especially in the rural areas. Some sceptic tanks are poorly maintained and overflow during heavy rainfall, leading to both onshore and

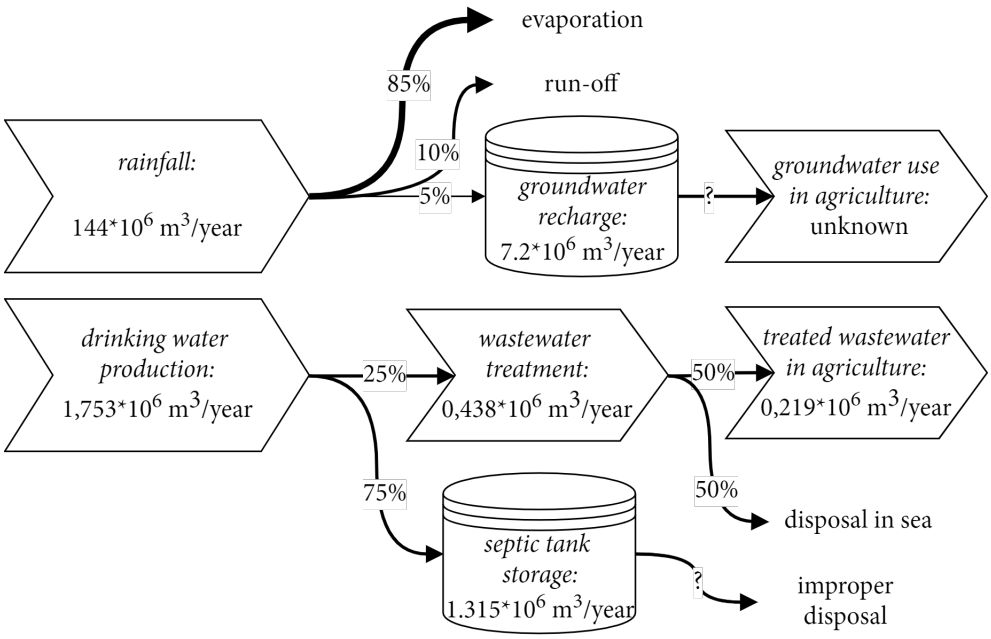


Figure 4.1: Water flows (Borst and de Haas, 2005)

offshore ecological damages (STINAPA Bonaire, 2015). Three subsystems can be identified based on the different water sources in Bonaire: rainfall & groundwater, drinking water and wastewater.

The water system diagram (figure 4.2) contains the causal relationships between the socio-technical factors related to the water system. A large number of external factors are present. Several of these originate from the energy and food systems. Energy price influences the drinking water price through the energy intensive production process. Agricultural activity increases the demand for water sources that meet the requirements of farmers and livestock herders. Farmers freely extract groundwater from wells and from scattered rainwater storage tanks to water their crops. Livestock herders also use groundwater wells to provide drinking water for their goats. Vegetation cover influences the volume of rainwater that can be harvested, but is affected by free-roaming goats. Rainfall is expected to become less intense and more frequent (Campbell et al., 2011), decreasing the volume of rainwater that can be harvested. Drinking water demand is affected by increasing population and tourists and high drinking water prices. This results in increased consumption and resulting production of drinking water, also leading to an increasing volume of wastewater. This wastewater create damages to Bonaire's environment if improperly collected, treated and disposed. Furthermore, treated wastewater has emerged as valuable new resource for farmers and livestock herders and can reduce their demand for groundwater. A self-correcting feedback loop is present when wastewater is improperly treated and is disposed in sea: coral health declines leading to a decrease in visiting tourists, reducing drinking water demand, production and wastewater production. While self-correcting, decline of coral health has major implications for Bonaire's ecosystem and the tourism industry. Improvements in irrigation infrastructure, wastewater treatment capacity and greywater transport

infrastructure have positive effects on the quality and security of groundwater. All three measures are costly and have to be financed through additional subsidies from national ministries and/or by increasing the already high water prices. From figures 4.1 and 4.2 it can be observed that the water system is quite linear from rainfall to groundwater storage and consumption, or from drinking water production to distribution, consumption and final processing. Malpractices in those linear steps however, have numerous negative consequences regarding groundwater quality and coral health.

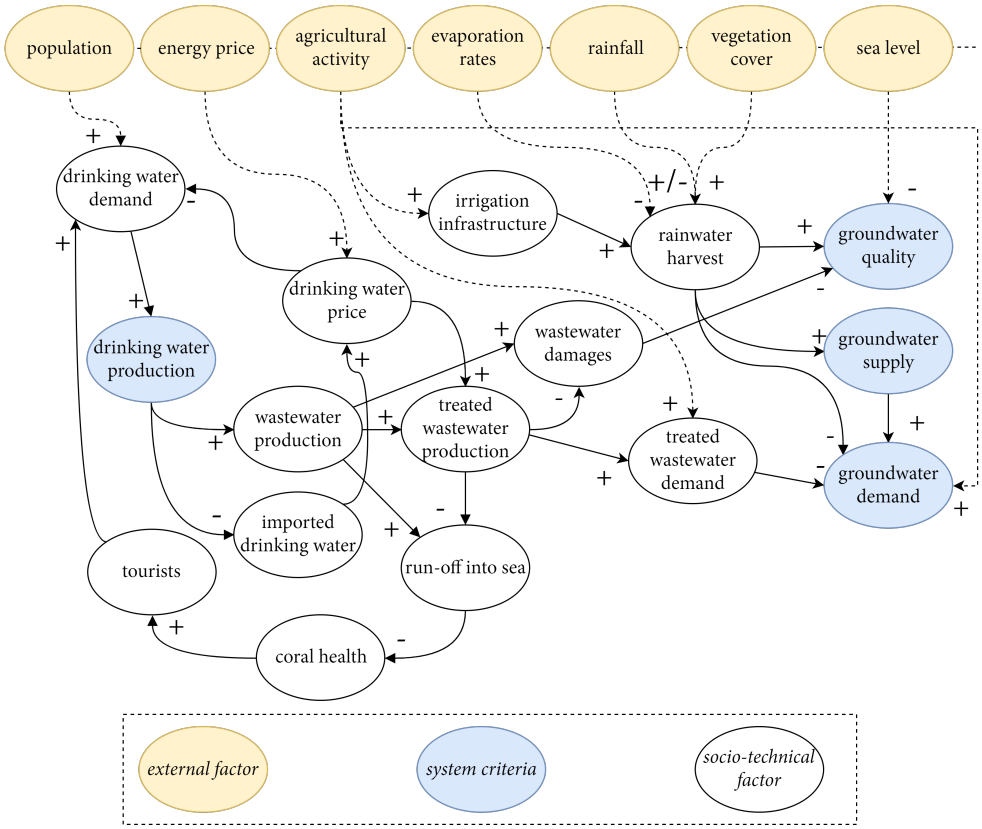


Figure 4.2: Water system diagram

Rainfall & groundwater

The main objectives for this subsystem are to reach a secure freshwater supply where rainwater is properly retained, groundwater is used in a sustainable manner and is of high quality. In Bonaire annual rainfall averages 520mm, mostly in the rainy season between October and January (Schelleman and van Weijsten, 2016). Rainfall is either retained by the soil and stored in groundwater reservoirs, or runs off towards lower ground and eventually enters the coastal waters of Bonaire. Rainwater capture has decreased as large amounts of the dry forests in Bonaire have been overgrazed and deforested for tourist facilities and agriculture (Van Der Lely et al., 2013). Multiple man-made dams and reservoirs are present that attempt to retain the rainfall during and after the rainy season. This water retaining infrastructure has deteriorated by siltation and vegetation growth. A large share of the stored water will evaporate or leak into the groundwater (Slijkerman and van der Geest, 2019). This decreases the available volume of water, as groundwater

is difficult to access, and also increases the salinity of the stored rainwater, making it less suitable for agricultural use. Recently 16 wind-powered groundwater wells were restored to provide drinking water for livestock. With ambitious plans for the development and professionalization of agriculture and animal husbandry in Bonaire (see: 4.3) and diminished groundwater regeneration, the pressure on water resources is expected to increase. If properly retained and distributed, the annual rainfall volume is sufficient to supply the drinking water needs of Bonaire, or either to significantly increase the water supply for agriculture. Additionally, better monitoring of rainfall and groundwater levels with can create a better understanding of the groundwater system and help in the spatial planning of agriculture and sustainable groundwater use (Borst and de Haas, 2005).

Drinking water

The main objectives in the drinking water subsystem are to ensure security of supply under increasing demand, whilst keeping the prices affordable. The Water- en Energiebedrijf Bonaire N.V. (WEB) is responsible for drinking water production, treatment and distribution in Bonaire and is a public company, owned by the OLB. The WEB produces drinking water by reverse osmosis, a method where seawater is pumped through a membrane under high pressure so that the water molecules pass and the salt crystals remain. This process is energy intensive and energy being import dependent and expensive, results in high water prices. The efficiency of the reverse osmosis units has major implications on the energy demand and the water price. Water prices are further increase to compensate for the loss of drinking water in the distribution process due to leaks and illegal tapping. The Ministry of Infrastructure and Water Management subsidizes the water prices in Bonaire with €925.000 per year until 2025 and with an additional €2.400.000 per year for 2018 and 2019. These are significant amounts for the small population. These subsidies serve to reduce the consumer costs for Bonaire's residents and to provide the WEB with financial means to make investments that secure drinking water production and distribution for the future. Drinking water production in 2018 was 4.800 cubic meters per day. The WEB expects this to increase to 6.400 cubic meters in 2024 and 8.800 cubic meters in 2030 (Slijkerman and van der Geest, 2019). Production can be increased to meet demand, as seawater is in abundance and installing additional reverse osmosis capacity is technically not challenging. The WEB has recently commissioned a large engineering firm to replace and expand parts of their production facilities. The WEB operates the distribution network consisting of storage tanks and pipes that supplies 95% of households with drinking water. The storage tanks are elevated so that gravity ensures sufficient water pressure. The remaining 5% of households are supplied through water trucks (Reijtenbagh, 2010). Compared to the other subsystems, the drinking water subsystem is relatively simple due to its linearity from one production facility to consumers.

Wastewater

The main objectives for this subsystem use the produced wastewater effectively. This can be reached through ensuring sufficient and stable demand and production of treated wastewater, an improved distribution infrastructure, minimal environmental impact and low costs. In 2014 Bonaire's first wastewater treatment plant was put into operation to treat grey and sewage water to be used in irrigation by hotels and agriculture. As a result of the high production costs of drinking water, recycling it after consumption to treated waste water is financially attractive. There is a profitable business case to sell the treated wastewater to hotels and farmers, who use it to irrigate their gardens and crops. This plant is a first step towards scaling up water-demanding agricultural activities (Slijkerman and van der Geest, 2019). The wastewater treatment plant produced 800 cubic meters per day in 2018. This is expected to increase to 1.200 cubic meters per day in 2019 and 1.400 cubic meters in 2021 (Slijkerman and van der Geest, 2019; Wayaka Advies and BAAB BV, 2018). The intended use of this treated greywater was to first be used by hotels to water their gardens and then for agriculture. Both uses have not yet been fully realised: the plants irrigation pipe was damaged, preventing transport to hotels, and only recently an agreement was reached between the OLB and the Ministry of Infrastructure and Water Management to provide funds for repairing the treatment plant. Additionally the hotels and farmers have different quality demands of the treated water. For hotels a third treatment step is more beneficial where nitrogen and phosphorus are removed, and thus prevented from leaking into the coast and damaging the coral reefs. For farmers the nutrients are, on the contrary, advantageous to crop production, reducing the need for imported fertilizers. 20 hectares of agricultural fields in the vicinity of the treatment plant are being irrigated with 50% of the treated water. This is expected to increase to 35 hectares irrigated by 1280 cubic meters in 2021 (Slijkerman and van der Geest, 2019). The large expected daily volume can be of great value in the food sector for the production of livestock feed. A steady acquisition of the treated water is important, as the treatment plant is currently not profitable. This is in part due to the lacking infrastructure to transport the water to the east side of the island where an additional 25 hectares could be irrigated. The Ministry of Infrastructure and Water Management therefore financially supports the plant with €1 million per year up to and including 2025 to increase its viability and create investment opportunities (Ministry of Infrastructure and Water Management, 2019). Treated water is significantly cheaper than drinking water for irrigation, but groundwater currently remains a free source of irrigation water. Correct pricing of different water sources is therefore of importance (Wales, 2011). The limited economies of scale create a conflict for the described objectives (Appendix B.1). Improved access and low costs are a prerequisite for a stable demand for treated wastewater, but require investments by the WEB in distribution infrastructure, increasing costs (Interview #6).

In conclusion, the water system is affected by multiple external factors, both from the energy and food sectors as by more generic pressures such as pop-

ulation growth and sea level rise. The emergence of treated wastewater and increasing pressures on groundwater stocks have entwined the previously more isolated subsystems in the water system. Sufficient rainwater falls in Bonaire to provide its drinking water and agricultural needs, however capturing and retaining this rainwater is difficult. Drinking water production will increase with rising population and tourism numbers, also increasing the energy demand and the volume of wastewater. If incorrectly disposed of, wastewater can have detrimental effects on the health of Bonaire's coastal ecosystem. Solving the wastewater treatment and distribution problem also ensures sufficient water supply for potential growth in agriculture and livestock herding. A distribution infrastructure to deliver the treated wastewater to farmers is currently lacking, complicating growth of demand. The growing population and tourism numbers add an extra challenge for the already sub-optimal performance of the system. The water system can create opportunities for the food system, but actions are constrained by already high and subsidised consumer prices.

4.1.2 PESTLE

The PESTLE classification serves to identify the most relevant landscape, socio-technical regime and technological niche factors for the water sector. These factors are compared and combined in the cross-case analysis, after which they are placed within the MLP and serve to delineate the shared vision space and the transition pathways.

Political

Relevant political factors are: the performance of public companies, multi-level negotiations for subsidies and living costs. The 2018-2022 administrative agreement of Bonaire's ruling government sets out plans to research the functioning of public companies such as the WEB as providers of critical services to Bonaire's residents (Openbaar Lichaam Bonaire, 2018). The aim of this plan is to improve the structure, services and financial health of public companies. This government also negotiated a financial support package with the Ministry of Infrastructure and Water Management that provides the WEB with the means to invest in the distribution system and to repair and improve the wastewater treatment plant and distribution pipelines (Ministry of Infrastructure and Water Management, 2019). The water sector benefits from multiple subsidies, but achieving these subsidies has been a challenge as negotiations between the OLB and ministries were slow. Costs of living and curtailing water prices remain high on the political agenda in Bonaire, and recently in the European Netherlands as well (Drayer, 2019). The implications of these factors are that: there is public and political attention on multiple levels for the water problems in Bonaire; public opposition can be expected for measures that further increase water prices; the WEB, OLB and the Ministry of Infrastructure and Water Management can be regarded as key stakeholders in the socio-technical regime and that although their goals are similar, cooperation and progress is sluggish.

Economical

Relevant economical factors are: low financial attractiveness of drinking water and limited wastewater demand. Fuel for the Reverse Osmosis (RO) plant is imported, resulting in high drinking water prices. The WEB is not the only drinking water producer on the island: several hotels produce their own drinking water through privately owned reverse osmosis plants due to lower costs, better quality control and security of supply. The business case for private RO installations that supply water to rural areas is slim however (Interviewee #4). This is due to the uncertain expansion plans of drinking water and greywater production and distribution capacity of the WEB. Private RO plants are unable to compete with the WEB - if it expands - due to its economies of scale and subsidies. The Ministry of Infrastructure and Water Management subsidises the water prices in Bonaire with 925.000 € per year until 2025 and with an additional 2.400.000 € per year for 2018 and 2019. Current demand for wastewater is limited due to limited agricultural activities and lacking distribution infrastructure. The implications of these factors are high risks for private investors in private RO installations and the further entrenchment of the WEB in their monopoly position and in the socio-technical regime.

Social

Relevant social factors are: rising drinking water demand and groundwater mismanagement. Population growth and rising tourism numbers increase the demand for drinking water. Population is expected to increase with 23% and drinking water demand with 33% by 2025. This subsequently leads to an increased demand for energy and supply of wastewater. Culturally, groundwater is seen as a freely accessible resource. Water from the groundwater wells is used for all different kinds of purposes, besides its intended use for livestock drinking water (Dienst Ruimtelijke Ordening Bonaire, 2019). The implications of these factors are that resources and efforts in the water system have to be diverted from any sustainability effort towards more daily operations, such as securing supply and better enforcement of certain behaviour.

Technological

Relevant technological factors are: the development of niche technologies, poorly maintained infrastructure and limited knowledge regarding Bonaire's hydrology. Efficiency rates of reverse osmosis plants keep improving and several technological innovations enable the private, small-scale RO production of drinking water with solar energy (Interviewee #1). The share of renewable electricity on Bonaire is expected to increase to 65% in 2021 (Wiebes, 2018). This increases the amount of days that there is sufficient renewable and cheap electricity that can be used to produce drinking water. Wastewater treatment has progressed as a technological niche into the socio-technical regime, being fully adopted by regime stakeholders such as the OLB and the WEB. The rainwater retainment and irrigation infrastructure is in poor condition after being neglected for several years. Water evaporates from the

storage tanks and many channels are filled up with debris. Improving the infrastructure can increase rainwater availability and groundwater replenishment, but for effective investments knowledge and data of the water dynamics is required, which is currently underdeveloped (Borst and de Haas, 2005; Openbaar Lichaam Bonaire, 2014b). In a hydrological planning study in Bonaire, Borst and de Haas (2005) recommend geospatial information systems and remote sensing tools to more carefully plan water and land use and to combine groundwater recharge with exploitation structures called Managed Aquifer Recharge and Storage (MARS). The implications of these factors are that with declining electricity prices, more investment room can appear to restore the irrigation infrastructure, but that more data and knowledge on the hydrology of Bonaire is required where to optimally direct those investments.

Legal

Relevant legal factors are: reduced regulation of monopolies and changes in multiple laws that provide a better legal framework for actions towards sustainability. The Authority for Consumers & Markets (ACM) has a legally diminished role in Bonaire when controlling competition due to the small economic scale and the isolated setting (Bogaardt et al., 2015). The WEB has a unique position in the Netherlands as solely controlling the generation, distribution and retail of water and electricity. Recent changes in the BES Electricity and Drinking Water Law enables the WEB to charge more cost-effective rates for production and distribution of drinking water to its customers. This increases the investments the WEB can make. The Island Ordinance Wastewater Bonaire adopted in 2013 mandates that residences in urban areas are connected to the sewage system that leads to the treatment plant. This ensures a steady supply of wastewater. The ordinance also mandates that producers of wastewater wishing to dispose it, do so correctly without harm to nature. Ships wishing to dispose of wastewater have to do so according to international law (Marpol) and are required to dispose it in the harbour of Bonaire. The implications of these factors are that the legal framework supporting sustainable practices has strengthened. This provides opportunities for the WEB and the OLB to better govern the water system in regard to investment planning and enforcement of rules.

Environmental

Relevant environmental factors are: global landscape pressures exacerbated by climate change and environmental damages created by bad practices with wastewater. Rainfall is expected to decrease with 5 to 6% and the southern part of the Caribbean will experience more rainy days with less intense rainfall (Campbell et al., 2011). More frequent and less intense rain is beneficial for crops, however a decrease in intense rainfall also leads to a decrease in recharge of the groundwater reservoirs. A 5% decrease in rainfall translates to a decreased water availability to the groundwater system of 360.000 m3 per year (Slijkerman and van der Geest, 2019). Rising sea levels and depleting groundwater levels lead to a higher penetration of seawater in Bonaire's groundwater reservoirs. This increases the salinity of the groundwater, mak-

ing it less suitable for irrigation and consumption by cattle. Sewage overflow has detrimental effects on Bonaire's coral reef: it contains inorganic nutrients, sediments, heavy metals and a harmful level of pathogens such as the cyanobacteria that covers coral, removing their access to sunlight (Wear and Thurber, 2015) (Interviewee #2). During and after heavy rainfall the runoff is enriched with nutrients and pollutants through overflowing poorly maintained septic tanks, fertilizers and soil (STINAPA Bonaire, 2014). The implications of the landscape factors are increased urgency and complexity in the operations of the water system. The implications of the environmental damages from wastewater are stakeholders from other sectors, in particular the tourism sector and the environmental protection sector, become engaged as their main (touristic) asset is at risk.

4.1.3 Stakeholders

The formal positions and relationships between stakeholders are mapped in a formal chart. This is then used as a starting point for an analysis into the informal relationships between actors and their interactions with the socio-technical system (4.1.4) (Enserink et al., 2010) and can lead to a better understanding of the composition of the socio-technical regime in Chapter 6.

Governmental institutions

The Dienst Ruimtelijke Ordening Bonaire (DROB) is responsible for spatial planning, including the planning of irrigation infrastructure: dams, irrigation canals, storage tanks, etc. The RCN coordinates the efforts of the ministries to align and implement their policies and to coordinate with the OLB in their water management plans. The Ministry of Infrastructure and Water Management assists the DROB in the challenge of ensuring clean soil and groundwater and constructing spatial development plans. The Ministry of Agriculture, Nature and Food Quality makes policies and management plans for Bonaire's natural resources, which in case of the water system are the groundwater reservoirs and marine ecosystems. This divided responsibility for the water system has two implications. First, as seen in the PESTLE analysis, negotiations between these Ministries, the OLB and the WEB are slow (Antilliaans Dagblad, 2019a). Second, it requires that the RCN has sufficient capacity to manage the goals of the two Ministries with the ambitions of the OLB. The ACM is responsible for supervising the WEB and regulates the maximum distribution tariffs and production costs the WEB can levy. The Chamber of Commerce advises companies active in the water sector and represents their interests with the OLB. The Chamber is well connected to multiple different stakeholders, both formally (Figure 4.3) and informally.

Businesses

The major private parties involved in the water sector are farmers and hotels. Goat farming and crop production are major consumers of groundwater and treated wastewater produced by the WEB. Several private parties fall

under the category *hotels* (4.3: 1). These are Bonaire Hotel and Tourism Association (BONHATA), officially representing the resorts, hotels, apartments, diving and water sports businesses, and Tourism Corporation Bonaire (TCB), the destination management organisation and promotion company of Bonaire. These are historically influential organisations and have significant interest in the water system as drinking and irrigation water is a major expense and it is in their interest that Bonaire's ecological assets remain undamaged. Farmers have far less influence in decision making, as their numbers are small, they are not represented by a lobby organisation or union and contribute little to Bonaire's economy. They do have the support of the Ministry of Agriculture, Nature and Food Quality who uses the treated wastewater in it's experimentation fields to produce crops for goat feed that are low in water demand. Imported drinking water is supplied by Don Andres Shipping and distributed by local SMEs and Van den Tweel Group (who operates Bonaire's supermarkets).

Non-governmental organisations and local interest groups

Bonairu Duradero is a local NGO promoting sustainable consumer practices such as efficient water use and recycling practices. STINAPA, a local NGO mandated by the government, manages Bonaire's two national parks. Its operations include park management and ecological data collection and analysis. It is not directly related to the water system, but it has strong formal and informal ties to the OLB and measures the effects of wastewater discharge on the Bonaire National Marine Park (BNMP). It also manages the Washington Slagbaai National Park (WSNP), influencing the vegetation cover of more than a tenth of Bonaire's surface.

Knowledge institutions

The Dutch Caribbean Nature Alliance (DCNA) researches multiple facets of Bonaire's ecosystem such as vegetation cover and soil composition, and publishes these to assist in policymaking and evaluation. Wageningen University has commissioned several studies into Bonaire's water system. Multiple studies exist that are commissioned by coalitions of stakeholders, including the OLB. Still no one organisation is clearly responsible for research and knowledge dissemination regarding the water system. The next section shall research how these stakeholders interact with each other and with the water system, and how their influence and actions influence a sustainable transition.

4.1.4 Governance

In the recent Administrative Agreement a research assignment is proposed into the governance and possible restructuring of public companies such as the WEB (Openbaar Lichaam Bonaire, 2018). This research assignment is initiated by the involved ministries and the OLB, and seems tied with the negotiations between the OLB and the Ministry of Infrastructure and Water Management to provide subsidies for the wastewater treatment plant to the

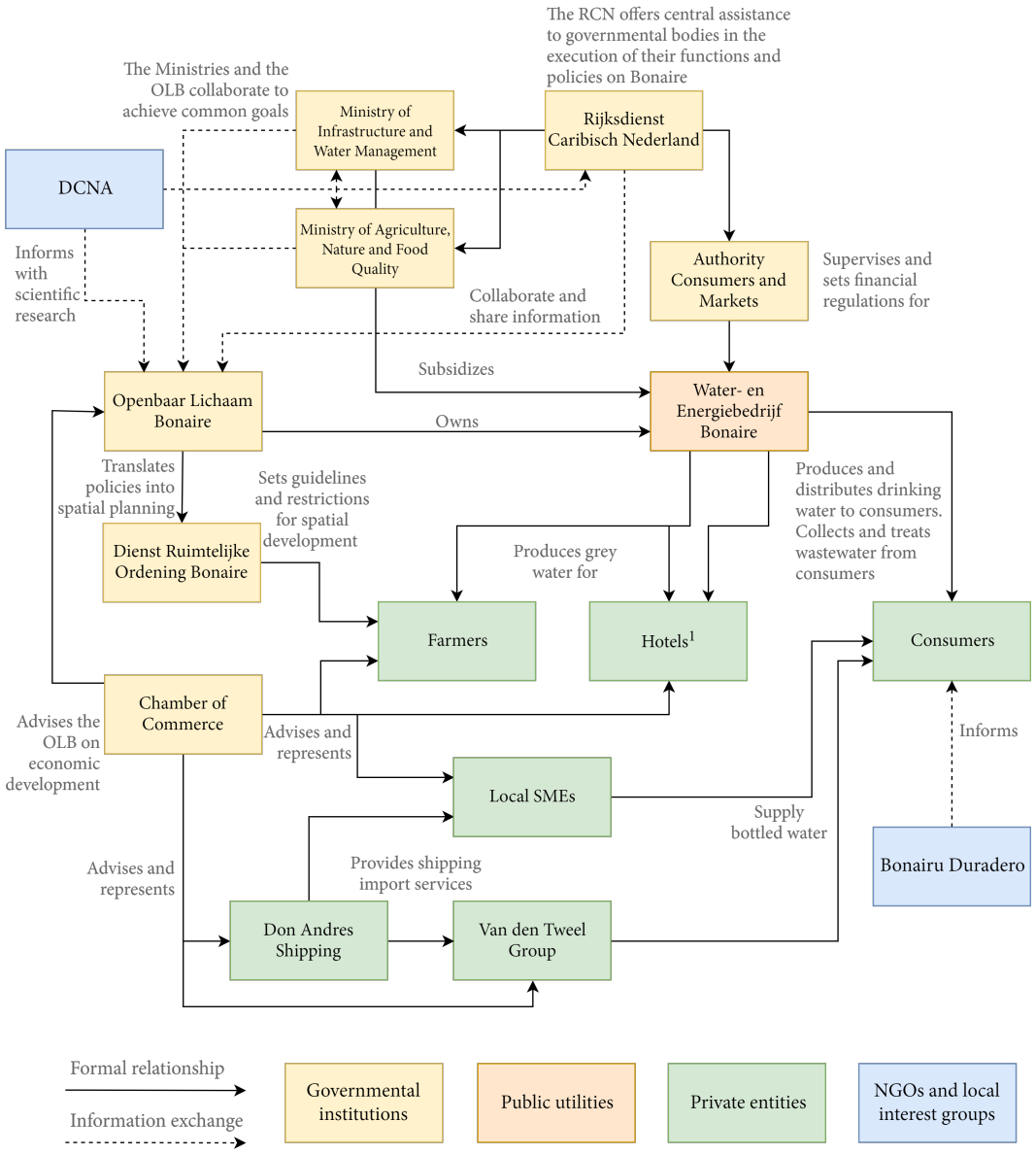


Figure 4.3: Formal chart of the water sector

WEB. The additional subsidies from the Ministry of Infrastructure and Water Management helped in getting the wastewater treatment plant fully operational and reducing the drinking water costs for the population, but took a long time to negotiate. This is indicative of the coordination challenge the OLB, WEB and Ministry of Infrastructure and Water Management have in improving the water supply, distribution and treatment, without increasing costs to unaffordable levels. Water prices have risen with 44% compared to 2018 after the ACM increased the maximum tariffs, and keeping drinking water prices to a minimum is vital for the OLB to not further contribute to the high costs of living and poverty in Bonaire (Centraal Bureau voor de Statistiek, 2019c). The subsidies the WEB received were essential in reducing the ecological damage of wastewater on the coral reefs, as the economic value of Bonaire's natural resources would have severely decreased if no financial support from the Ministry was given. The slow and uncertain investment de-

cisions resulting from this coordination process increases the risk for private entities that are considering to invest in their own water production or treatment facility, as they cannot compete with the scale effects the WEB achieves when they do decide to expand their distribution to rural areas. Thus the lack of a secure supply of treated wastewater in rural areas decreases the attractiveness and opportunities in the food sector. From a transition management perspective, the uncertain and slow actions of the regime stakeholders (WEB, OLB and Ministry of Infrastructure and Water Management) create barriers for technological niches such as private RO installations and water treatment facilities to develop in the form of uncertainty and risk.

The availability of a new and relatively cheap source of irrigation water from the wastewater treatment plant has changed the governance of the water sector, linking the goals and demands of the tourism and food sectors with the water sector. This has increased the amount of decisions that have to be made and the complexity of the trade-offs for the OLB and the WEB. A crucial decision regarding the treated wastewater is the third treatment step. Stakeholders in the food sector, particularly the Ministry of Agriculture, Nature and Food Quality and goat farmers have different requirements for the treated wastewater than the hotel industry and wish to receive the water before the third treatment step, whilst it still retains beneficial nutrients. Given the dominant position of the hotel industry and the opportunity to reduce their operation costs by using treated wastewater to irrigate their gardens instead of drinking water, it makes sense they will demand this treated wastewater (for a price). BONHATA and the TCB can use instrumental forms of power to co-fund distribution infrastructure from the treatment plant towards the hotels and discursive strategies, such as the Blue Destination strategy, to lay a claim on the treated wastewater as it benefits the sustainable tourism image the OLB wishes to create. The OLB meanwhile also wishes to increase the local production of food and livestock feed to increase economic opportunities in the food sector and reduce free-roaming goats and food imports, but this requires significant amounts of irrigation water and investments in a distribution infrastructure. Subsidies for goat feed production and goat herding are necessary to achieve profitable business cases, especially when treated wastewater prices rise, which is a possibility as the hotel industry is able to afford the treated wastewater (Wayaka Advies and BAAB BV, 2018). Rules and decisions regarding the allocation of this water are important to achieve the goals of the food sector. How the OLB will balance these trade-offs and make these decisions is not mentioned in their Administrative Agreement, but a task force electricity and water is mentioned (Openbaar Lichaam Bonaire, 2018). The OLB and the Ministry of Infrastructure and Water Management also have the opportunity to repair and improve the irrigation infrastructure and increase the capture of rainwater and groundwater recharge. A lack of data and knowledge on the water dynamics and soil composition complicates and slows down decision-making however (Borst and de Haas, 2005; Openbaar Lichaam Bonaire, 2014b).

4.1.5 Visions and goals

This section will list the different visions found in literature using the vision image, vision guidance and vision orientation concepts according to Leising et al. (2018). Outcomes from the interviews are used to add nuance and the perception of the interviewee.

Masterplan Strategic Development 2010-2025

The Masterplan vision image is sustainable well-being for every Bonairian and a focus on quality of life over quantity of economic activity (Van Werven et al., 2010). Bonaire strives for optimal happiness for the current and future generations, whereby care for the environment is essential in ensuring the well-being of future generations. Bonaire will position itself as a 'Sustainable Island' and be an example for the Caribbean region in sustainable growth and technologies. The Masterplan does not describe any desirable future states of the water sector. Vision guidance is given by the goals to recycle water used by households, and by the implementation of active water management and a rainwater plan to ensure security of supply (Van Werven et al., 2010). Vision orientation is given through a proud sketch of Bonaire's unique properties, such as its small scale, peace, and coral reefs.

2018-2022 Administrative Agreement

The Administrative Agreement does not explicitly address the water sector in vision image, guidance or orientation (Openbaar Lichaam Bonaire, 2018). The Agreement does mention that a taskforce will develop a strategic vision on particularly the affordability of electricity and drinking water. Slijkerman and van der Geest (2019) remark that without a proper vision and actions on water management, the current plans regarding the agricultural sector set out in the 2018-2022 administrative agreement will be difficult to reach.

Policy vision 2014-2029 Agriculture, Livestock and Fishery Bonaire

The Policy visions image is sustainable agriculture, livestock and fisheries sector that is self-sufficient for Bonaire's residents (Openbaar Lichaam Bonaire, 2014a). In this vision image treated wastewater is used to supply the production of fruits, vegetables and livestock feed. In its vision guidance a project will be initiated that restores the irrigation infrastructure to prevent water damages and restores groundwater levels.

2017-2027 Tourism: Synergizing people & nature for a better tomorrow

The 2017-2027 Tourism plan sketches an ambitious future where the economic significance of the tourism industry grows and provides increased well-fare to a larger share of Bonaire's residents (Croes et al., 2017). The image is of Bonaire as a 'Blue Destination': "sustainable use of ocean resources for growth, well-being, jobs and ocean ecosystem health" (Croes et al., 2017, p.7). Vision guidance is extensive with two main goals and five explicit means to reach those goals: 1. Invest $150 million 2. Generate 2.400 new jobs 3. Generate 60.000 arrivals 4. Build an additional 600 new

hotel rooms 5. Tourism grows from 20% to 45% of the total economy (Croes et al., 2017). A timeline and role recommendations for the TCB is provided as vision guidance. It's orientation is ambitious and positive, promoting the value of tourism for the majority of the population. The implications of this increased development of the tourism sector on the water system are that both demand for drinking water and wastewater production increase as the number of tourists increases. These implications are not addressed in the 112 page document.

Although Borst and de Haas stated in 2005 that better managing and planning of rainwater can increase the quality and quantity of the groundwater, this active water management plan has yet to be made (Borst and de Haas, 2005). This seems to be the main vision elicitated from literature regarding Bonaire's water sector: security of supply under growing demand from the population, the tourism sector and food sector.

4.1.6 Conclusion

The increasing technical, spatial and economical connectedness between different water flows and with the tourism and food sector increase the complexity of decision making and operations for the OLB, the WEB and the Ministry of Infrastructure and Water Management. From the perspective of this thesis, the water system is becoming increasingly entwined with the developments in the WEF-nexus. This increases the amounts of feedback loops between these systems. Whilst the water system is now being affected by the negative feedback loops of decreasing groundwater quality and damaging run-off into sea, the positive feedback loops of increasing treated wastewater production offers opportunities for sustainability in both the water and food systems. Transformative capacity is being held up by security of supply challenges and environmentally damaging practices in the wastewater subsystem. The emergence of a new resource, treated wastewater, attracts interest from influential stakeholders from the tourism industry and from stakeholders food sector. Significant investments in treated wastewater distribution infrastructure and/or irrigation are necessary to provide the water demands the food system requires in their visions. Water prices are already high, and the added costs of these investments impacts the profitability of the food system.

4.2 ENERGY

4.2.1 System analysis

Generation of electricity is the main activity in Bonaire's energy sector because of the lack of industrial activity. Yearly demand for electricity reached 113.4 GWh in 2017 and is expected to reach 121.6 GWh in 2019 (Autor-

iteit Consument en Markt, 2018a; Centraal Bureau voor de Statistiek, 2019b). Peak demand is approximately 18 MW and occurs in September, the warmest period of the year, around mid-afternoon, between 14:00 and 16:00 (Burger, 2019; Slijkerman and van der Geest, 2019). This is induced by the increased demand for cooling. The electricity demand profile in Bonaire is relatively flat: off-peak electricity demand is lowest between 05:00 and 07:00 at 12 MW. The installed generation capacity in Bonaire consists of 14.4 MW of diesel generators, 11.1 MW of wind power and 0.25 MW of solar power, which amounts to approximately 40% of renewable electricity generation on Bonaire (Schelleman and van Weijsten, 2016). Priority is given towards the security of supply, as the electricity demand has increased steadily with around 4% in the past years and is expected to continue increasing (Schelleman and van Weijsten, 2016). This short-term goal led to the lease of additional generators capable of meeting variable demand. The priority to security of supply is also necessary due to the high degree of variable wind power which intensifies the technical challenges of operating the power system (IRENA, 2018).

As with water, the WEB is responsible in delivering electricity to its consumers (Figure 4.7 2). The WEB operates the distribution grid and plans power production in coordination with Contour Global, Bonaire's independent power producer and owner of the combined 14.4 MW diesel generators and 11.1 MW wind power park. Bonaire Petroleum Corporation N.V. (BOPEC) stores and supplies the diesel to Contour Global. According to the WEB, the distribution grid is facing explosive growth owing to a large number of private solar PV projects that have initiated since the new BES Electricity and Drinking water Law permits decentralised private generation of electricity. The energy system diagram (figure 4.4) shows how high electricity prices increase both public and private investments in renewables, where particularly the growth of private renewable generation capacity increases distribution grid pressure. Subsequently, investments in the distribution grid are necessary and electricity prices increase to cover these investments. The expected grid loss percentage - the percentage of electricity lost between the production and consumption - is 11.20% in 2019, more than twice as high as the losses in the European Netherlands indicating that the distribution grid is not ready for further growth in generation (International Energy Agency, 2018). This also requires increased generation to meet electricity demand. Investing in the distribution grid requires that the already high distribution tariffs must increase, which is a socially and politically difficult decision as electricity prices are already high. The distribution of all other petroleum products for households, companies and small commercial users is operated by Curoil Bonaire (Figure 4.7 2). Additionally Curoil supplies airline fuel to Flamingo Airport Bonaire and provides bunkering services to a wide variety of ships (Curoil, 2019).

Bonaire has excellent conditions for wind power and is planning to further extend the installed capacity of wind power to 23 MW in 2021, bringing the share of renewable electricity to 65% (Wiebes, 2018). Several technologies are viable to increase the share of renewable electricity in Bonaire. An increase in the share of solar PV can lead to an increase in employment, more so than

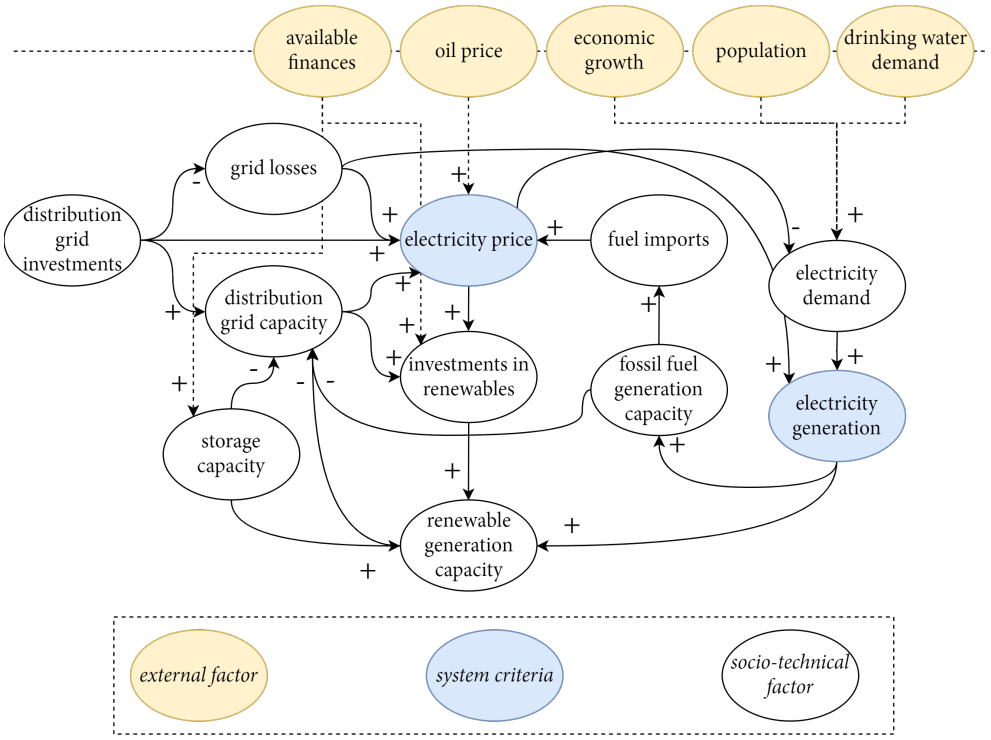


Figure 4.4: Energy system diagram

with the more capital intensive installation process of wind (Wiebes, 2018). The WEB has commissioned Countour Global to begin construction of 8 MW of solar capacity (Burger, 2019). Solar PV still faces numerous challenges in Bonaire though, namely the limited availability of capital, storage and the capacity of the distribution grid. A 3 MW battery is installed in Bonaire for backup generation in case of power outages and emergencies. A 6 MW battery is commissioned by the WEB and Countour Global, Bonaire's independent power producer, to prevent curtailment of excessive wind energy, increase reliability of supply and increase the share of renewables in the electricity mix (Burger, 2019). The battery is supplied with hardware and software for effective grid integration and power management. Wind and solar energy are currently the only two applied renewable energy sources on Bonaire. Multiple sources state that a third renewable energy production method is necessary to realistically and economically achieve a 100% renewable energy future (Ministry of Economic Affairs and Climate, 2018; Schelleman and van Weijsten, 2016; Slijkerman and van der Geest, 2019). The variability of wind and solar energy and high investment costs of storage capacity would make the energy prices unaffordable if only wind and solar energy are to be used.

4.2.2 PESTLE

The PESTLE classification serves to identify the most relevant factors in the water sector that influence system behaviour and its governance. These factors are compared and combined in the cross-case analysis, after which they serve to delineate the shared vision space and the transition pathways.

Figure 4.5: Morotin windfarm Bonaire

Political

The Energy vision Bonaire is being drafted by the OLB. In documents that reference the upcoming Energy vision no mention of an integration of visions with the water and food sectors were found. Bonaire positions itself as a role model for sustainability in the Caribbean region, with its high degree of renewable electricity and focus on ecological conservation. The political will to further increase the share of renewable electricity is present, as it can lower the costs.

Economical

The ACM regulates the maximum electricity prices and distribution tariffs that WEB can ask. In a recent evaluation the ACM allowed for an increase of these maximum prices and tariffs to account for necessary future investments in the distribution grid and in the generation of electricity (Autoriteit Consument en Markt, 2018b). Despite the allowable increase, the WEB has reduced the electricity prices in July of 2019. According to Ministry of Economic Affairs and Climate (2018) the most effective way to reduce the high prices is to replace the fossil generation capacity with renewable production, providing that affordable financing options are found. Bonaire took part in the 2016 Quickscan organised by the SIDS Lighthouses project by International Renewable Energy Agency (IRENA) and discovered through a questionnaire that 32% of the enabling conditions for renewable energy deployment were ready, 29% in progress and 39% not ready (IRENA, 2017). This indicated a significant level of readiness for a transition towards a sustainable energy sector. The conditions that scored negatively were renewable energy project financing and project deployment. This is problematic, as Schelleman and van Weijsten (2016) calculate that with a reasonably low oil price of $50 per barrel renewable electricity generation investments are only financially attractive if interest charges are low.

Social

The long-term growth of electricity demand is uncertain in Bonaire (Ministry of Economic Affairs and Climate, 2018). This is explained by the uncertain growth in tourism, agriculture production, greywater distribution, household electricity use (cooling) and water use. This in turn complicates

investment decision making in renewable energy capacity. The amount of qualified human resources in the energy sector is low, specifically regarding renewable energy and storage technologies (Slijkerman and van der Geest, 2019).

Technological

OTEC is a novel renewable energy solution for SIDS. It uses the temperature difference between surface and deep sea water to drive a heat engine and produce a steady supply of electricity. Despite its ascribed potential as a base load electricity supplier for SIDS, no support for OTEC was found in Bonaire and the planned feasibility study was not executed (Wiebes, 2018). Moreover OTEC's is early in its technological development, resulting in high investment costs compared to more conventional renewable energy solutions such as wind, solar and battery storage. Producing biofuels from algae is being researched in Bonaire, with a first experimental plant being constructed by Wageningen University and the WEB. Bonaire has good conditions for growing algae. Sufficient sunlight and seawater is present, as is the space required. Wageningen University is experimenting with producing biofuels from algae in cooperation with the WEB. These biofuels can be used in transport (cars, airplanes) and possibly in the diesel generators on Bonaire. Pumped hydro storage is considered as an alternative to the battery storage systems that are being installed (Slijkerman and van der Geest, 2019; Ministry of Economic Affairs and Climate, 2018). However according to Schelleman and van Weijsten (2016) pumped hydro is economically not viable for systems under 100 MW (Bonaire reaches only 18 MW during peak demand).

Legal

Recent changes in the BES Electricity and Drinking Water Law allow for the connection of decentralised generation units such as solar PV cells to be connected to the electricity grid. Despite being illegal before the changes, 230 households had installed solar PV cells and were profiting from the offsetting (Ministry of Economic Affairs and Climate, 2018). The updated law allows the WEB to still charge the full distribution tariffs to households and significantly reduces the compensation consumers receive for supplying excess produced power back to the electricity grid. This may reduce the attractiveness of solar PV solutions for local consumers, but ensures that the capital costs of the generation capacity and distribution grid are covered.

Environmental

Rising temperatures are expected to increase the demand for air-conditioning. The placement of renewable energy technologies has major environmental implications on Bonaire. The placement of windfarms is influenced by migratory routes of endangered and protected bat species (Interviewee #2). The placement of solar PV systems is also of consequence for the environment. Sudden clouding may greatly reduce the output of a single solar PV system (figure 4.6). Multiple solar PV systems that are spread across the island can

negate this effect, but has a greater impact on land use. The Spatial Development Plan Bonaire does not include regulations for the placement of solar PV farms. This does not hinder private solar PV growth when the panels are placed on private property or on roofs, but does create an obstacle for larger private solar PV farms, as no regulations exist that can guide placement. Large scale production of biofuels from algae requires 3% of Bonaire's surface (Slijkerman and van der Geest, 2019).

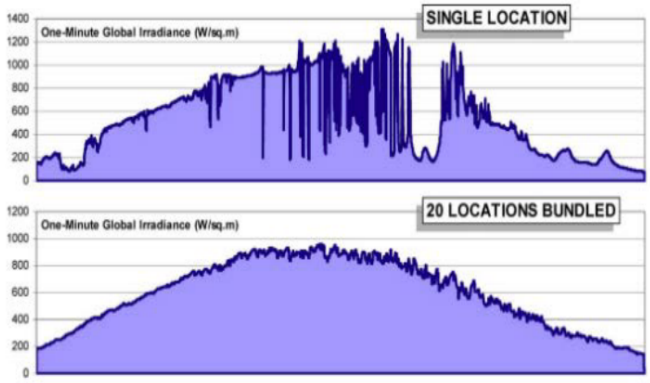


Figure 4.6: Effects of clouding on solar PV systems (Schelleman and van Weijsten, 2016)

4.2.3 Stakeholders

Governmental institutions

The Ministry of Economic Affairs and Climate works together with the RCN and the OLB to achieve reliable and affordable services in the utility sectors. The WEB is the distribution systems operator in Bonaire and supplies electricity to the island's consumers. It is a public company, owned entirely by the OLB. The ACM balances the affordability, sustainability and reliability of the electricity grid and dictates the maximum tariffs the WEB can ask for electricity production and distribution.

Businesses

Curoil distributes all petroleum products for households, companies and small commercial users. LPG for cooking is one of its major products to both households as to restaurants and hotels. Additionally Curoil supplies airline fuel to Flamingo Airport Bonaire and provides bunkering services to a wide variety of ships (Curoil, 2019). Contour Global Bonaire (CGB) is Bonaire's independent power producer. It operates the combined 14.4 MW diesel and 11.1 MW wind power generation plant and supplies the electricity to the WEB. CGB is part of Contour Global, a company that operates 101 power plants across 18 countries with a yearly revenue of $1,253 billion. The WEB and CGB collaborate closely with the OLB and the Ministry of Economic Affairs and Climate to improve daily operations and increase the share of renewable electricity on the island.

Non-governmental organisations and local interest groups

Nature conservation organisations such as STINAPA, Wild Conscience, the DCNA and Sea Turtle Conservation Bonaire influence the decision-making process regarding the construction of new renewable energy projects.

Knowledge institutions

Stedin, a distribution systems operator in the European Netherlands, supplies knowledge and capacity in managing electricity systems to the WEB. The next section shall research how these stakeholders interact with each other and with the energy system, and how their influence and actions influence a sustainable transition.

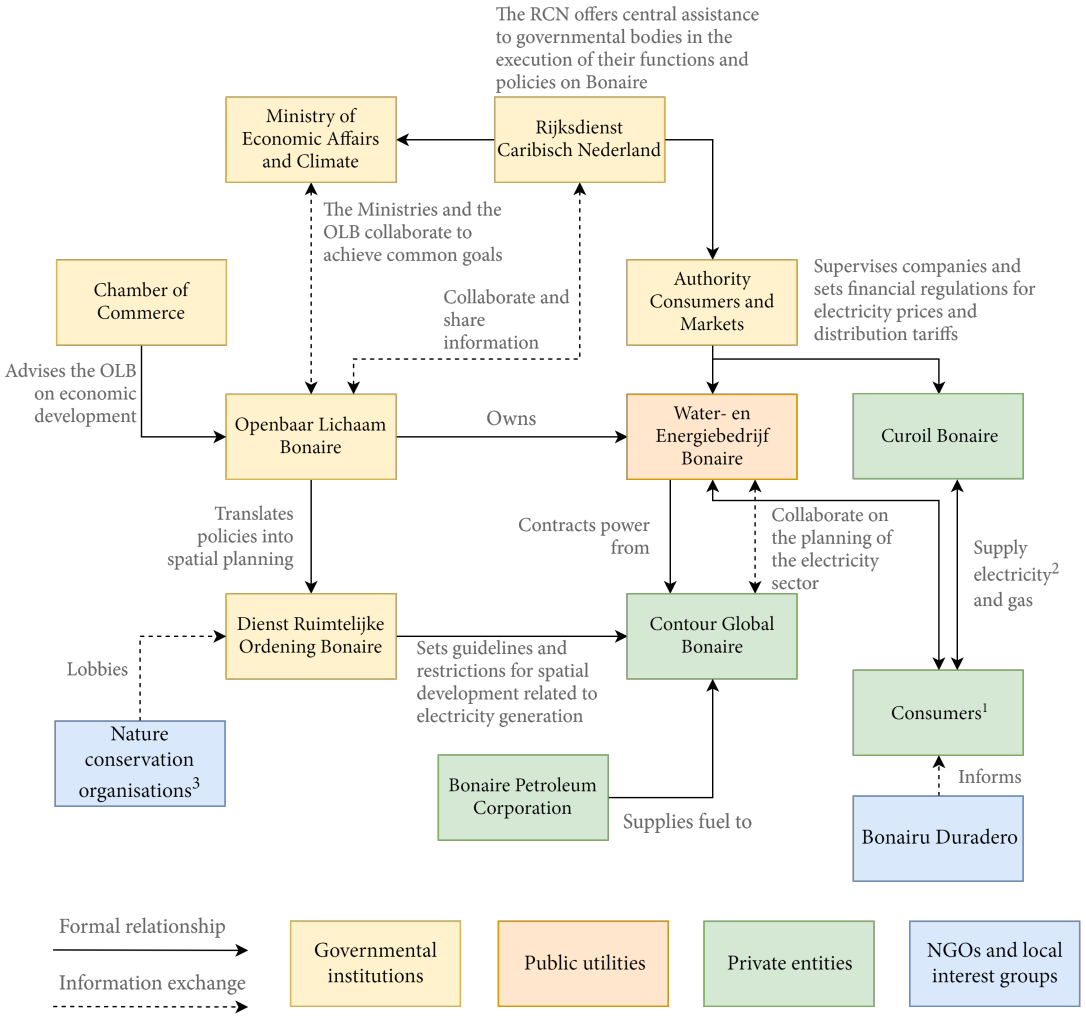


Figure 4.7: Formal chart of the energy sector

4.2.4 Governance

The Ministry of Economic Affairs and Climate and the OLB strive for affordability, availability and sustainability of the energy system and are able to advise and steer the WEB towards their goals. Increasing the share of renewables in Bonaire fits within the credibility and promotion of the OLB's Blue

Destination strategy wherein sustainable use of natural resources and environmental protection is regarded as essential for economic development. Historically there has been close cooperation between the WEB and CGB. Given that subsidies are not necessary to achieve profitability in renewable energy projects on Bonaire, the WEB commissions CGB to construct new generation capacity such as a new 8 MW solar PV park (Burger, 2019). The Power Purchase Agreement between the WEB and the CGB requires that the CGB has the initial opportunity in supplying excess demand, which is discussed with and evaluated by the WEB. If no agreement is reached the WEB is able to seek other solutions in consultation with CGB, such as constructing their own generation capacity. The WEB then coordinates with CGB how to achieve those goals within the existing infrastructure. Recent changes in the BES Electricity and Drinking Water Law provides the ACM with more insight in the generation and distribution costs of electricity. The ACM can slightly alter the maximum tariffs each year, whilst offering significant room to WEB for necessary investments in the distribution grid in view of the increasing electricity demand.

From a transition management perspective, the current infrastructure is locked-in place, creating governance issues now that decentralised generation is rising. This increases the pressure on the distribution grid and decreases the electricity demand of households that own decentralised generation capacity, changing the centralised technical infrastructure and governance by the WEB and CGB to more local practices. The transition towards a renewable energy future, where 80% is achievable with wind, solar PV and battery systems according to Schelleman and van Weijsten (2016), is complex and highly knowledge intensive. This results in a dependence on external knowledge sources such as Stedin, Contour Global and external human resources. It also impacts the OLB's capability in initiating and supervising energy projects, demonstrated in the 54% cost overrun in the new diesel and wind electricity generation plant (IRENA, 2017; Schelleman and van Weijsten, 2016). Causes of poor project planning are amongst others inefficient governmental procedures and regulations, non-realistic planning and underestimation of project complexity. Poor project culture, inadequate project organisation, poor communication and teamwork and inexperienced personnel were identified as causes of poor project execution (Schelleman and van Weijsten, 2016). This is problematic as renewable energy projects are only financially attractive if cheap financing solutions are found, which is dependent on a stable and effective political environment and good project execution.

4.2.5 Visions and goals

This section will list the different visions found in literature using the vision image, vision guidance and vision orientation concepts according to Leising et al. (2018). Outcomes from the interviews are used to add nuance and the perception of the interviewee. Multiple documents mention that an Energy

vision for Bonaire is being drafted, but this vision is currently not finished and drafts are not made public.

Masterplan Strategic Development 2010-2025

The Masterplan strategic development Bonaire 2010-2025 set the goal of reaching CO_2-neutrality for the entire energy supply in 2025 (Van Werven et al., 2010). Ambitious biogas plans were also drafted. The oil-powered electricity plant was set to only run on bio-diesel or climate-neutral fuels, an exploratory research was initiated regarding algae for biofuels and organic waste was to be fermented into biogas.

Renewable Energy Future for the Dutch Caribbean Islands Bonaire, St. Eustatius and Saba

In an exploration of sustainable energy technologies for Bonaire Schelleman and van Weijsten (2016) do not expect fuels from organic waste to be realistic for the coming 15 years. The volume of organic waste is currently too little to provide a consistent supply of biomass, importing biomass would increase electricity costs, biofuels from algae on land place a too large demand on the fresh water supply and salt-water algae would cover the coral reefs. Despite these ambitious goals, 69% of the energy supply came from fossil fuels (300 heavy oil barrels per day) in 2018 (Slijkerman and van der Geest, 2019). The diesel generators can run on biodiesel, but this is currently not available on Bonaire. Setting up algae or similar biofuel plants requires space, which will compete with the ambitions set out for agriculture development (particularly the professionalisation of the goat industry). Reaching 100% renewable electricity generation without biofuel or a similar base load generation method is technically and financially complex due to the excessive amounts of wind and solar capacity needed to meet peak demand on cloudy or windless days (Ministry of Economic Affairs and Climate, 2018). Vision guidance was presented in multiple renewable energy scenarios for Bonaire. A scenario where 80% of generation capacity consists of solar and wind is feasible, resulting in a decrease of 69% in fuel usage (Schelleman and van Weijsten, 2016). With the planned 12MW increase of wind in 2021 and the 8MW increase in solar PV, this scenario becomes a probable future.

Sustainable and affordable energy in the Caribbean Netherlands

This policy document by the Ministry of Economic Affairs and Climate sets out current challenges and short, middle and long-term solutions for Bonaire's energy sector (Ministry of Economic Affairs and Climate, 2018). It does not contain a vision image of what the energy sector should look like in the future, but does provide guidance in specifying the benefits and drawbacks of different solutions. It provides vision orientation through promoting the leading position of Bonaire in renewable electricity production and the opportunities that further increasing the share of renewables brings.

2018-2022 Administrative Agreement

The Agreement does not mentions any visions or plans regarding the energy sector in Bonaire.

4.2.6 Conclusion

The energy system is currently in transition towards a high renewable electricity percentage, with over 65% renewable electricity share being feasible in 2021. Demand for electricity is expected to grow, as Bonaire's population and tourism numbers are increasing and demand for drinking water is increasing accordingly. Combined with large growth in decentralised solar PV, the distribution grid needs significant investments to cope with the increased load and complexity. The main desirable future found in literature and interviews comprises of an affordable, secure and sustainable energy system that is capable of adequately delivering the growing demand for electricity using a high share (80% +) of renewables, whilst keeping electricity costs and distribution tariffs affordable. The WEB, ACM and OLB coordinate the necessary distribution grid investments whilst prioritising affordability and security of supply. Multiple novel renewable energy technologies exist that can provide a base load of electricity, as it was found that a 100% renewable electricity scenario based on solar PV, batteries and wind power is financially difficult to achieve. Human capacity that is able to deal with this rapidly transitioning system and implement novel technologies in large scale projects is lacking. In any case the expansion of solar PV and wind is continuing, providing large amounts of cheap and renewable electricity to Bonaire when weather conditions are favourable.

4.3 FOOD

4.3.1 System analysis

The three main production activities in Bonaire's food system are livestock herding, agriculture and fishing. The *kunuku's* are the rural areas where livestock herding and agricultural activities take place. Fishing takes place on shore, in the coastal reef waters and in deep sea waters. The food system is closely tied with the broader socio-ecological system in Bonaire. Agricultural activities and norms, such as the degree of free-roaming goats, have direct impacts on ecosystem health (figure). The production of food is reliant on the provisioning services the ecosystem provides, but the food system inhibits negative feedback loops that further degrade productivity and ecosystem health. The high theft rate for instance decreases the investments and subsequent attractiveness of agriculture, reducing the rural population density and decreasing social cohesion and control in the countryside, leading to more theft. Overgrazing by free-roaming goats decreases the vegetation cover, which exacerbates erosion and decreases the supply of livestock feed, further increasing the grazing pressure on the remaining areas where veget-

ation cover remains. The food system is hereby locked in unsustainable practices that further decrease the profitability and transformative power of the sector. Opportunities lie in the diversification of the food sector by exploring niche markets for environmentally friendly products and eco-tourism, where higher prices can be charged. An analysis into all development projects related to the food sector found that the majority of projects are related to the increase of knowledge about agriculture and to the improvement of resources and practices Bogaardt et al. (2015).

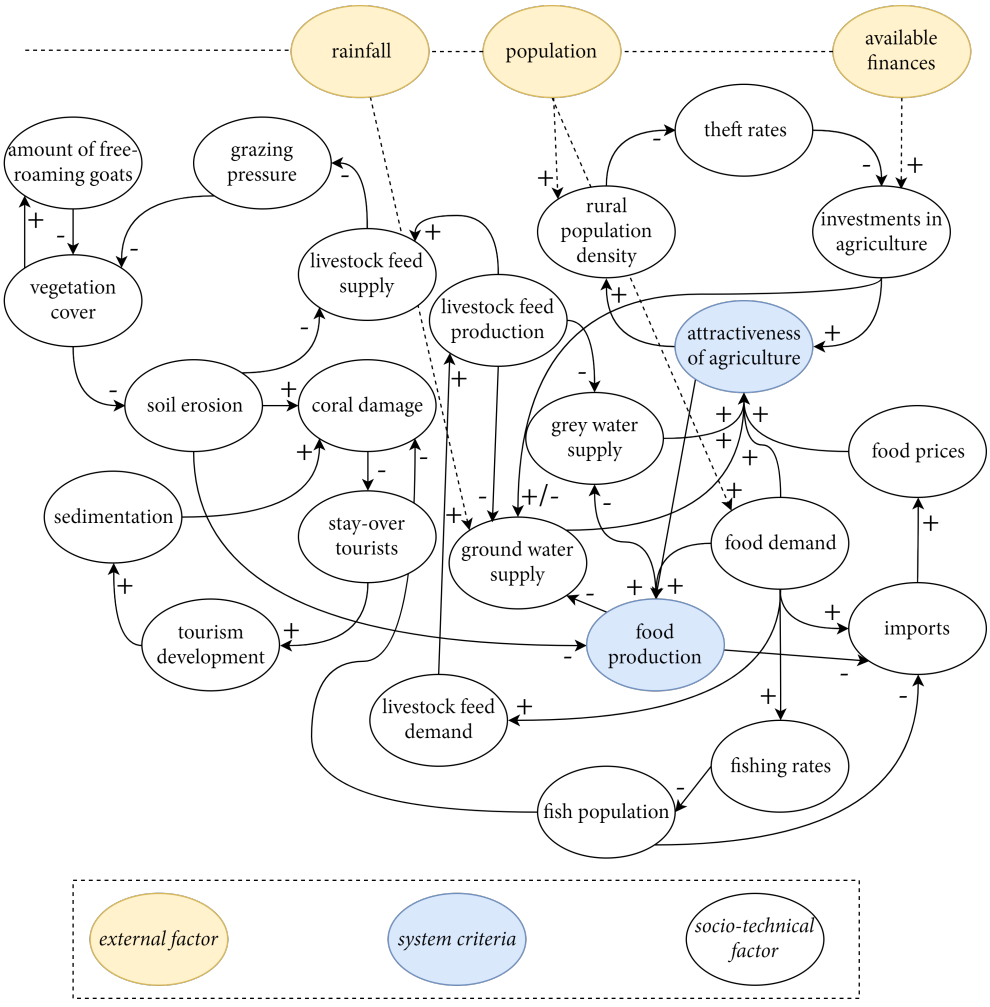


Figure 4.8: Food system diagram

Livestock

Approximately 250 farmers - of which 200 are goat farmers - are active in Bonaire according to the OLB, although Statistics Netherlands records only 40 jobs in the category agriculture, forestry and fishing (Centraal Bureau voor de Statistiek, 2018a; Openbaar Lichaam Bonaire, 2016). In a recent quantitative study, Becking et al. (2015) estimate there to be around 30.000 goats on Bonaire. The large difference in the estimates is an example of the poor data collection practices in Bonaire, which complicates decision making on ecosystem dynamics. 62% of goats are kept in fenced kunuku's. Free-roaming goats are a persistent problem in Bonaire. Land erosion arises from

overgrazing, negatively affecting the health of the coral, Bonaire's main asset. The rural development plan 2014 declares that traditional practices where goats are enclosed will be restored (Openbaar Lichaam Bonaire, 2014b). Attempts to fence in goats have not always been successful however. Nature consultancy group BonBèrdè reported on the 17th of July 2019 that special fencing designed to keep goats away from a forest conservation area was stolen. 16 recently renovated wind-powered water pumps that supply groundwater for goats have met similar problems: the faucets of two of the pumps were stolen, the pumps continue operating despite overflowing tanks and are subject to misuse by residents who use the free water to wash their cars or in concrete production (Dienst Ruimtelijke Ordening Bonaire, 2019). In interviews local goat farmers express the wish to expand their business and keep more goats, but acknowledge that if they are not always present at the farm, insufficient attention can be given to the animals and theft will become too great a problem (Rosemarijn de Jong Advies, 2015).

To reduce the dependency on free-roaming to feed goats, sufficient livestock feed must be present for farmers. This is also necessary to reduce the ecological damage the goats cause in terms of deforestation and erosion, as the current amount of goats is too high for sustainable livestock farming (Becking et al., 2015). Quality and cheap livestock feed can be produced on Bonaire provided that sufficient clean water is present (Openbaar Lichaam Bonaire, 2014b). 40 cubic meters of water a day is required to irrigate one hectare of goat feed production, on which approximately 30.000 kilograms of feed can be produced (Wayaka Advies and BAAB BV, 2018). In a professional goat farming industry, 4.000 goats are necessary to produce more high quality meat than the current situation where over 30.000 goats are farmed. This would require a location of 40 hectares to produce the required goat feed, creating a demand of 1.600 cubic meters of water a day. If this water would come from the recently installed wastewater treatment facility, a third and final purification stage would not be necessary so that nitrogen, phosphate and potassium would remain in the water and fertilise the land, also saving a large amount of money for the WEB (POP Bonaire, 2019; Wayaka Advies and BAAB BV, 2018). The wastewater treatment plant's capacity will grow to 1.400 cubic meters a day in 2021, making other water sources such as groundwater necessary to meet the demand for irrigation water. Farmers have expressed their doubts to the health hazards of the treated wastewater (Rosemarijn de Jong Advies, 2015). Furthermore the hotel industry has a claim on a portion of the treated wastewater to water their gardens and wishes to keep the third purification phase. Wayaka Advies and BAAB BV (2018) constructed a business case for sustainable goat farming which is freely available for all (potential) farmers. The document found a market for local lamb, but requires that the quality and security of supply improves (Wayaka Advies and BAAB BV, 2018). Subsidies are necessary however, to achieve a profitable professional goat business. A decisive factor in the business case is the price of water, where price ranges between $1 and $2 per cubic meter have significant effects on the feasibility of the business case. Interviews with goat farmers suggest that besides subsidies, higher prices for meat would stimulate growth, but that due to a historical regulation of price

at $7/kg (abolished in 10-10-2010) there is an "unspoken rule" that prevents farmers from raising their prices (Rosemarijn de Jong Advies, 2015).

In conclusion the ambition is present among farmers and public officials of the Ministry of Agriculture, Nature and Food Quality to professionalise the goat farming industry, yet multiple challenges need to be overcome to achieve this. Low prices and salaries limit the investment capacity, there is a lack of high quality and consistent livestock feed, theft of goats and equipment is recurring and limited financial support form a self-reinforcing set of hurdles that farmers have difficulty in overcoming. Additionally, the ecological damages that the goats cause will be severe if left untreated, damaging one of Bonaire's greatest natural, economic and cultural assets.

Agriculture

99% of agricultural products in Bonaire are imported and the domestic market for local agricultural products is small. The agricultural sector in Bonaire has prioritised increased independence from food imports to reduce food prices and increase local economic activity (Openbaar Lichaam Bonaire, 2018). One of the proposed sector developments is to cooperate with the tourism sector to position the farms as a cultural and historical attraction where high quality local products can be bought (Openbaar Lichaam Bonaire, 2014b). Significant investments are necessary to increase production of and professionalise an agricultural business. These investments can be private (greenhouses), public (improved road infrastructure) or can be shared (fresh water supply, knowledge). Farming is practiced only on a small scale and there is limited knowledge, fresh water and electricity present to expand farming practices (Slijkerman and van der Geest, 2019). Farmers living in the kunuku's are in principle not connected to the water and electricity grid, unless there are connections close by. Even then, the farmer has to pay for the costs of connecting to the grid infrastructures. If unconnected to the water distribution grid, the WEB delivers water to farmers with water trucks. The rainwater harvesting and irrigation infrastructure on Bonaire are insufficiently maintained (Openbaar Lichaam Bonaire, 2014a). This creates several problems: it increases the pressure on other water sources such as groundwater and dirt roads become inaccessible after heavy rainfall. In the drafting of the 2014 the rural development plan multiple entrepreneurs addressed the lack of financial resources to invest and an investment fund was proposed.

Consumption of fruits and vegetables is low due to high prices and a negative image stemming from cultural and historical aspects, nutrition education and the perceived quality. Despite this, there is a realistic business case for a professional agriculture operation due to the high prices of imported products. Furthermore residents are becoming more positive regarding the development of local products because they recognise the economic development and increased independence it brings to Bonaire (Rosemarijn de Jong Advies, 2015). van Almenkerk (2019) estimates that approximately 40% of fruits, vegetables and herbs can be produced locally in Bonaire. Green-

houses are essential for the production of vegetables due to the intense solar radiation year-round and grazing by parrots, insects and goats (Slijkerman and van der Geest, 2019). Fruits are mostly grown in orchards. Nevertheless, Bonaire's climate is unsuitable to produce all varieties of fruits and vegetables that are consumed. Import is expected to remain necessary to fulfill this demand.

The Ministry of Agriculture, Nature and Food Quality operates an experimentation terrain where potential crops suitable for agriculture are grown. These crops are mostly destined as feed for goats and are grown in open air. The treated wastewater from the treatment plant operated by the WEB is used to irrigate this terrain. The ambition of the Ministry is to develop the terrain to a location where innovations are developed and knowledge is shared for and between entrepreneurs. Within the terrain of this center local farmers can produce fruits, vegetables and goat feed and achieve economies of scale by sharing technological equipment, knowledge and services such as security (Openbaar Lichaam Bonaire, 2014a).

Fisheries and aquaculture

The estimated amount of coastal fishery production in Bonaire was 102 tonnes with a value of between $0.7-$1 million (de Graaf et al., 2016). Demand for fish has continually grown as the population and stay-over tourists increase (Slijkerman and van der Geest, 2019). The current local supply of fish is insufficient to meet this growing demand and as a result imported fish is common. Compared to the impacts of livestock herding and agriculture on the water and energy sectors, aquaculture and fishing requires less water and energy inputs. Instead, increased aquaculture and fishing production inhibits trade-offs with Bonaire's ecosystem. Two methods of fishing are identified: shore-based fishery and boat-based fishery. Boat-based fishery further deconstructs into shoreline fishing, coral reef fishing and pelagic water fishing. These methods vary in volume, value and ecological impact. Shore-based fishery is predominantly recreational and has a minimal impact on the benthic reef organisms such as corals. In 2014 shore-based fishery accounted for 12% of the total volume of fish caught (de Graaf et al., 2016). For coral reef and pelagic water fishing boats are used. Two types of boats are active in Bonaire: small boats that typically use handlines and large boats that use trolling lines. Overall catch rate was 7.4 kg/trip for small boats and 28.1 kg/trip for large boats, amounting to 29% and 59% of the total volume of fish for small and large boats respectively (de Graaf et al., 2016). Several global developments are present that increase fish yield, such as fish aggregating devices and improved radio sensory methods (FAO, 2018). Both methods have been effective in the Caribbean, but several species of fish appear to be maximally sustainably fished and some species of shrimps have not recovered despite reduced fishing effort (FAO, 2018). Historical data on fishing is scarce in Bonaire. This impedes the prediction future catch volumes and fish stocks. The lack of continuous monitoring of fish stocks risks overfishing going undetected if these methods where to be implemen-

ted in boat-based fishery.

Aquaculture refers to the farming of fish, shellfish, aquatic plants and algae under controlled conditions. The FAO defines aquaculture as "*...the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated*." (FAO, 2019, p.1). The annual production of aquaculture food fish in Latin America and the Caribbean has increased sixfold from 8 million tonnes in 1995 to 48 million tonnes in 2015 and the FAO expects production in the region to increase with another 49.2% by 2030 (FAO, 2018). Aquaculture has the potential to fill the gap between global aquatic food demand and supply and can be of value in Bonaire where the local supply of fish is insufficient to meet growing demand. No commercial aquaculture farm exists to date in Bonaire however. Between 2010 and 2013 Elijah Fish Farm was in business, but closed due to poor water quality, high electricity prices and insecure demand for fish (Openbaar Lichaam Bonaire, 2014a). The controlled aspect of aquaculture requires isolation and nutrients. In the case of fish and shellfish, these nutrients must be provided by the operator of the farm. The need for nutrients and the expected increase of the practice have important implications regarding the WEF-nexus. Aquaculture feed can be produced from byproducts of wild fish such as fishmeal and fish oil, or from crops such as soybeans and oilseeds such as canola and rapeseed. Currently no infrastructure or value chain exists on Bonaire that can provide for the demands of an aquaculture industry and global competition for cheap protein feeds is high (Slijkerman and van der Geest, 2019). The feed is therefore likely to come from local sources, especially if it is to be competitive with wild fish. Land-based aquaculture where fish or algae are farmed in bodies of water requires available space and, dependent on the particular species, fresh water. The spatial planning of aquaculture practices is fundamental for integrated management of land, water and other resources to minimize conflict (FAO, 2018). The effective spatial planning of aquaculture includes amongst others access to finance, improving management practices, ensuring operations stay within the ecosystem's carrying capacity, improving public perception and local demand for aquaculture and improving market linkages (FAO, 2018).

4.3.2 PESTLE

The PESTLE classification serves to identify the most relevant factors in the water sector that influence system behaviour and its governance. These factors are compared and combined in the cross-case analysis, after which they serve to delineate the shared vision space and the transition pathways.

Political

Only two civil servants are, among other responsibilities, assigned to agriculture, livestock and fisheries. This is "far too little capacity for this diverse and

complex development problem" according to the Policy Vision Agriculture, Livestock and Fisheries 2014-2029 (Openbaar Lichaam Bonaire, 2014a, p.25). The Fisheries Commission BES decided in their most recent meeting to establish a fishing license system for all fishing vessels in close involvement with Piskabon (Ministry of Agriculture Nature and Food Quality, 2018). Piskabon noted that this measure might lead to an increase of fishing as recreational fishers will become commercial once they require a license to fish and their fishing productivity might increase.

Economical

Property rights over suitable agricultural land complicates the availability of arable land. It is estimated that 3/5 of the land is privately owned and 2/5 is owned by the government. It is difficult to trace the owners of often deserted kunuku's on private land, and locals wishing to buy or lease land to start their farm have difficulty in acquiring land (Openbaar Lichaam Bonaire, 2014a). The production of raw materials or low-value agricultural produce is difficult in Bonaire (Boto and Biasca, 2012). Additionally demand for the majority of local produce is low, with concerns over the quality, security of supply and health hazards from the treated wastewater. A handful local products are popular amongst tourists, in particular the lionfish. The invasive lionfish posed a significant threat to coral health, but is being hunted by certified divers led by STINAPA. The environmental awareness and desire to protect Bonaire's coral reefs amongst tourists created a demand for the lionfish (Slijkerman and van der Geest, 2019).

Social

Population is expected to increase with 23% by 2025, with food demand likely rising with an equal degree. Poverty amongst farmers and residents in the kunuku's is high. Salaries for agriculture jobs are the lowest in Bonaire, 51% lower than the average income. Salaries also vary strongly on a yearly basis: mean yearly salary between 2011 and 2017 was $11.958 with a standard deviation of $1411 (Centraal Bureau voor de Statistiek, 2018a). Due to the low salaries the majority of people active in agriculture are either retired or employed and see agriculture as a way to earn a small amount of extra money and save on vegetables. Only 20 people work full-time in the food sector (Appendix A). The kunuku's play a strong role in the cultural identities of Bonaire's rural population (Openbaar Lichaam Bonaire, 2014a). Life on the kunuku represents freedom, closeness with nature and independence for its residents. This also increases the social appreciation of and passion for agriculture.

Technological

Rural road infrastructure is currently in a poor state, and must improve if larger volumes of raw materials and products are to be transported (Interviewee #2). Wageningen University is collaborating with the Ministry of Agriculture, Nature and Food Quality to implement new innovations at the

agricultural center, such as drip farming, a technique for growing vegetables and fruits that reduces water consumption.

Legal

The Fishing law BES (Bonaire, Sint Eustatius and Saba) requires all fishing activities in the territorial waters and fishing zone to , except when fishing in boats smaller in length than 12 meters. 76% of all boats in Bonaire are categorised as small (7 meters or smaller in length) and such at least 76% of the vessels fish without requiring a permit de Graaf et al. (2016). This is not necessarily a bad thing, although registration can be a tool used to achieve better monitoring of fish populations and catches. The Fishing Law BES grants the power to the Ministry of Economic Affairs and Climate to regulate fishing methods and fish species through statutory instruments. The Law Public Housing, Spatial Planning and Environmental Management BES 2017 provides the OLB with a legal framework to regulate the use and treatment of materials that are harmful to the environment and actions that can create erosion or salinisation of the ground (Openbaar Lichaam Bonaire, 2014a). The OLB can hereby set environmental requirements on agricultural activities. Under specific criminal law for Bonaire it is illegal to let livestock roam across agricultural property without consent. It is also illegal to let livestock roam across property where one is prohibited to enter. Nevertheless, this law still gives leeway to let livestock roam free in undesignated areas or abandoned kunuku's. Entrepreneurs wishing to start a business in farming or livestock herding need several permits and approval from the DROB, who verifies if the plans fit within Bonaire's Spatial Development Plan.

Environmental

Bonaire's soil characteristics create complicated water dynamics and strong local differences in the salinity of groundwater (Openbaar Lichaam Bonaire, 2014a). Rainfall is expected to become less intense and more frequent, benefiting crop growth but decreasing groundwater replenishment (Campbell et al., 2011). Illegal landfills and excavations have degraded the quality of the soil in the kunuku's (Openbaar Lichaam Bonaire, 2014a). Only 11% of land in Bonaire is suitable for a traditional form of agriculture and 17-20% is suitable for grazing pastures for livestock (Gewald, 1971). New technologies such as drip farming in greenhouses are less dependent on the quality of the soil, but more on a functioning logistics infrastructure.

4.3.3 Stakeholders

Governmental institutions

Figure 4.9 shows the large amount of governmental agencies active in the food sector, as stakeholders from spatial design, economic development, infrastructure, nature and regulation are all related to operations in the food sector. This requires a significant coordination effort between governmental agencies and therefore a good relationship between the OLB and the RCN

who coordinates the policies of the three active ministries. The DROB is responsible for the spatial design of Bonaire's rural areas and must coordinate between the historically influential and active nature conservation organisations such as STINAPA and other users of the countryside, such as farmers and new stakeholders wishing to develop new food technologies that require space, such as algae or aquaculture farms.

Businesses

Farmers consist of a diverse group of people whom are active in a wide variety of farming activities. The majority of farmers are retired or employed elsewhere and operate a farm to earn some extra money and save expenses on food. These farmers often also keep a few goats, either enclosed or free-roaming. Only a small degree of farmers are able to earn a living farming full-time (Appendix A). As salaries in the food sectors are low, farmers often have little financial means to invest in their business. Consumers also consist of a diverse group of private consumers (families, individuals), hotels, restaurants and other hospitality companies. This also places different requirements on food produced by farmers: hotels and restaurants prefer security of supply and safety, whereas families and individuals prefer price and familiar products (Rosemarijn de Jong Advies, 2015; Wayaka Advies and BAAB BV, 2018). Local SMEs are positioned between large and small consumers. They consist mostly of small supermarkets or cafes with little revenue and function as intermediary for local products to private consumers. In recent years the fishing community has organised themselves into a cooperation called Piskabon. This cooperation has the goal of representing fishermen in decision making processes and voicing the issues the fishing community is facing. Fishermen have noticed a decline in fish catch for years and are subject to increased legislation and restrictions (Mac Donald, 2018). Collaboration to find solutions for unsustainable fishing practices between the fishing community and RCN, OLB and STINAPA, the park management organization, has historically been unsuccessful and has sometimes led to heated discussions and resistance from the fishing community (Mac Donald, 2018).

Non-governmental organisations and local interest groups

Knowledge institutions

Wageningen University is becoming increasingly active in Bonaire to assist the development of sustainable food practices. The next section shall research how these stakeholders interact with each other and with the food system, and how their influence and actions influence a sustainable transition.

4.3.4 Governance

Although the OLB has the legal power to control free-roaming goats and other environmentally damaging aspects of agriculture, it has not been able to enforce its rules and influence the sector. There are de facto two policy

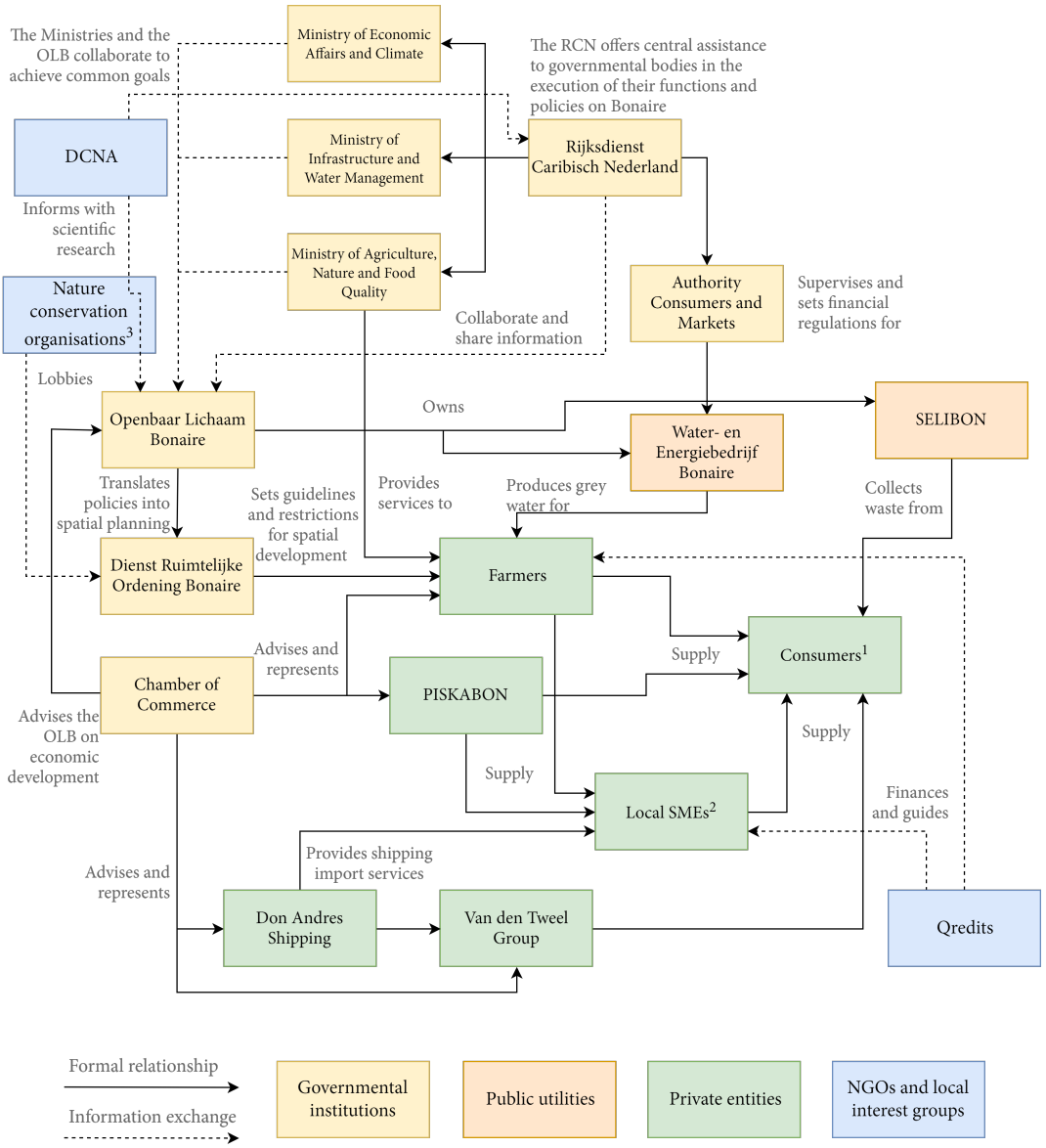


Figure 4.9: Formal chart of the food sector

officials who, in addition to other duties, are involved in agriculture, animal husbandry and fishing (Openbaar Lichaam Bonaire, 2014a). This is far too little capacity to steer the food sector, whom heavily relies on central governmental steering and assistance in knowledge provisioning, funding and water supply. The Policy vision 2014-2029 Agriculture, Livestock and Fishery Bonaire addresses the need for enforcement and strengthening of the sector by setting up regulations and increasing manpower. Training, information and guidance from the Ministry of Agriculture, Nature and Food Quality is essential in strengthening the governance of the OLB (Openbaar Lichaam Bonaire, 2014a). The Ministry of Economic Affairs and Climate has received two recommendations for their role in improving the food system: 1. stimulate entrepreneurial spirit by guiding people in the realisation of a successful project, and 2. increase the amount of internships in the agricultural sector (Bogaardt et al., 2015). This corresponds with the demand of farmers to receive more support in terms of financial aid, knowledge and

experimentation to develop their business. As the sector is still in early development, no historic regime structures have of yet formed beyond the food import chain, which is controlled by two monopolies (Don Andres shipping and Van den Tweel Group). The Minsitry of Agriculture, Nature and Food Quality is most closely involved with farmers and fishermen, and wishes to expand their experimentation terrain and play a more central steering role in developing the agriculture sector. This creates the opportunity to create new governance structures that steer towards sustainability in the food system if designed correctly.

4.3.5 Visions and goals

This section will list the different visions found in literature using the vision image, vision guidance and vision orientation concepts according to Leising et al. (2018). Outcomes from the interviews are used to add nuance and the perception of the interviewee.

Masterplan Strategic Development 2010-2025

The Masterplan's generic vision image is described in 4.1. Regarding the food sector, it describes a vision image of an increased economic independence from tourism, diversified in sectors such as the agriculture and fisheries sectors (Van Werven et al., 2010). It provides vision guidance by setting out research goals for the potential for sector growth and how to reactivate the kunuku's (rural farmlands) with for instance subsidies. A management and development plan is drawn up for the kunuku areas.

2018-2022 Administrative Agreement

The Agreements vision image contains a priority for reducing import dependence, producing healthy food and increasing employment opportunities (Openbaar Lichaam Bonaire, 2018). The Agreement sets the goal to address the overdue maintenance of road infrastructure, improving connections to the kunuku's. Vision guidance is given by explicit dates, funding and responsibilities for the maintenance plan and the incorporation of a water management plan regarding drainage of rainwater from roads. Clear responsibilities are divided between the Ministry of Agriculture, Nature and Food Quality and the OLB and a timeline is proposed for the execution of the goals. €1.6 million is made available for agricultural development, specifically the construction of a slaughterhouse for livestock and the professionalisation of the goat industry.

Policy vision 2014-2029 Agriculture, Livestock and Fishery Bonaire

The Policy vision's image is sustainable agriculture, livestock and fisheries in the broader sustainable development and protection of culture and nature in Bonaire (Openbaar Lichaam Bonaire, 2014a). The vision sets out four goals that encompass sustainable development in the food sector:

1. *Self-sufficient food production*: food prices rise, local production of food grows and stimulates the economy, providing healthy products to Bon-

airians. The self-sufficiency empowers the feeling of cultural identity and social cohesion.

2. *Good production conditions for the kunuku's*: the physical and economic infrastructure are improved by the government. Rural crime is tackled and laws and regulations regarding free-roaming cattle are enforced.

3. *A livable and attractive countryside*: Sustainable agriculture, livestock herding and new economic opportunities are stimulated and developed to increase the attractiveness and economic viability of life in the countryside.

4. *Protection of nature and the environment*: Sustainable agricultural and fishing practices bolster the biodiversity and thereby protect the environment from erosion and water issues.

One of the central actions is the development of the Center for Sustainable Agriculture run by the Ministry of Agriculture, Nature and Food Quality discussed in this section. This is also repeated in the Rural Development Plan Bonaire (Openbaar Lichaam Bonaire, 2014b). This Center will experiment with drought resistant crops for livestock feed production and provide farmers with expertise in the professionalisation of the food sector. The Policy Vision lays out a future where the Center is the test-chamber of new technologies, creating jobs and increasing local food production. Goat farming is explicitly addressed in both documents. Vision images describe a future where goat farming is professionalised and goats are enclosed in fenced-off properties where goats are selectively bred to improve yield. The Policy vision proposes to create study groups where affiliated farmers receive advice and priority when buying livestock feed.

Rural Development Plan 2014-2018

The Rural Development Plan calls for action and cooperation to engage the entrepreneurs in Playa East and Rincon (Openbaar Lichaam Bonaire, 2014b). The plan advocates for the integrated development of agriculture practices and tourism for the development of the region. In the development of the plan local entrepreneurs have indicated that they want support in learning to do business in a sustainable manner. The Rural Development Program 2014-2018 aims to develop multiple agriculture related projects related to rural tourism development, strengthening of entrepreneurship, sustainable goat husbandry and a knowledge center and receives fund from the Ministry of Agriculture, Nature and Food Quality to finance these projects

Food security on Bonaire, St. Eustatius and Saba

The Ministry of Economic Affairs and Climate commissioned Wageningen University to research where to best apply policies to ensure food security on Bonaire (Bogaardt et al., 2015). Education in agriculture was seen as the basis in accelerating local agriculture and the Ministry envisions a future where it coaches farmers in realising a successful project and provides the necessary infrastructure in coordination with the Ministry of Infrastructure and Water Management.

A vision for a sustainable fishing future can be deduced from the recommendations de Graaf et al. (2016) offers to the Ministry of Economic Affairs and Climate. In this vision the health of the coral reefs and the quantities of fish are monitored and coral is actively restored and regulated by a clear management plan with quantifiable indicators and objectives.

4.3.6 Conclusion

The food system inhibits complex relationships with the water and energy systems and the environment. It is an underdeveloped sector which provides significant economic potential to Bonaire's residents. Potential customers of agricultural and livestock produce are present but have different requirements. Catering to the demands of the tourism sector and delivering to hotels and restaurants seems a better opportunity, as prices can be higher and products are less constrained to food habits of locals. Professionalising the sector to increase security of supply, safety, quality and yield is required to provide to these customers. Lacking human capacity in key positions in the OLB and the Ministry of Agriculture, Nature and Food Quality is complicating development of the food system, as are the lack of knowledge and financial means among farmers. A large amount of ambitious visions are present. These address the opportunities to expand agricultural activities and combine them with tourism experiences. Expansion also risks in further ecological damage however, when practices are not done correctly, as the case of free-roaming goats has demonstrated.

5 CROSS-CASE COMPARISON

By using a cross-case analysis an overview of the commonalities and differences is possible, thus offering interpretations of the water-energy-food nexus in Bonaire (Cruzes et al., 2015). A comparison of the systems analyses serves to find differences in the complexity of the water, energy and food systems. This has implications on the technical, but also governance challenge in a sustainable transition for that system. A comparison of the system-specific PESTLE factors serves to find common factors that delineate the shared vision space and the pathways towards that vision (chapter 6). They also identify opportunities for the transition pathways in section 6.3.

5.1 SYSTEMS ANALYSIS

Multiple variables have been identified in the systems analysis of the water, energy and food systems, that are based on the characteristics of complex systems by Cilliers (2000). Differences in the degree of complexity, how the systems are governed and who governs the system have implications for integrated governance of the three systems. Thus the degree of heterogeneity has implications for the transitions in the water-energy-food nexus and how one transition might be more or less difficult to achieve.

	Water	**Energy**	**Food**
Number of elements	Medium	Low	High
Non-linear interactions	Medium	Medium	High
Feedback loops	High	Low	High
Connections with other systems	High	Low	High
Dependency on other systems	High	Low	High
Adaptivity	Medium	Medium	Low
Degree of change	Medium	Low	High
External pressures	High	Low	Medium

Table 5.1: Comparison of variables

Number of elements

As can be seen in the system diagrams of the water, energy and food systems (Figures 4.2, 4.4, 4.8, the food system contains the most individual elements. This can be explained by its extensive subsystems and many connections with water resources, social factors and ecological services. The water system is also divided into multiple different subsystems resulting from different water streams, increasing the number of elements. The historical

linearity of generation, distribution and consumption of electricity and the almost non-existent industrial activity explains why it has the least number of elements.

Non-linear interactions and feedback loops

The non-linear interactions and feedback loops are discussed together, as all non-linear interactions identified in the systems analyses are feedback loops. The close relationship between tourism numbers and coral health induces similar feedback loops in the water and food systems: both poorly managed wastewater and grazing pressure, which in turn decreases vegetation cover and creates soil erosion, increase coral damage which decreases the stay-over tourists. This alleviates the negative impacts of tourism development on the environment and reduces its pressure on water and food resources, but also decreases the contribution of the largest economic driver in Bonaire. The large number of elements in the food system and the dependence on ecological resources creates the most amount of interactions and feedback loops of the water, energy and food systems (figure 4.8). In contrast, the energy system contains only one stabilising feedback loops where electricity prices reduce electricity demand and one feedback loop where private consumers install more renewable generation capacity to reduce their high electricity bill, leading to more necessary investments in distribution grid capacity and further increasing electricity prices.

Connections with other systems

The energy system is the least connected of the three systems. Drinking water demand is one of the contributors to electricity demand, and electricity prices influence the drinking water price. New connections can form however, if new technologies such as biofuels from algae are developed or when small-scale reverse osmosis plants are put into use by farmers. Both the water and food systems are highly connected with one another, particularly through greywater and groundwater supply, demand and prices. Tourism and ecosystem health also connects these two systems, as do investments in irrigation infrastructure. New technologies and practices such as aquaculture will similarly increase the connections between the water and food systems as new food and feed production methods require a type of water.

Dependency on other systems

In the water value chain (figure 4.1) the dependency of one system on others can be observed. Electricity is necessary to produce drinking water and to treat wastewater. Subsequently the agriculture sector relies on grey water to irrigate their crops and on groundwater for livestock. There is a larger feedback loop where rainwater capture and groundwater levels rely on sustainable agriculture practices such as reducing free-roaming goats, increasing vegetation cover and improving the irrigation infrastructure.

Degree of change and adaptivity

The extensive physical generation and distribution infrastructure of the energy and water system lock it in place. The pressure from rising electricity demand and large growth in decentralised renewable generation steer the priorities of the WEB and the Ministry of Economic Affairs and Climate towards doing more of the same, increasing fossil fuel generation capacity and investing in grid capacity (Ministry of Economic Affairs and Climate, 2018). Transformative capacity is limited by the already high electricity prices and the burden they place on Bonaire's residents. Similarly the high water prices limit the capacity for new infrastructure investments or certain new technologies. Farmers in the kunuku's for instance, do not receive a connection to the drinking water distribution grid as this is too expensive. Instead they are delivered drinking water by truck and store wastewater in poorly maintained cisterns that overflow during heavy rainfall. Installing new distribution infrastructure for drinking water, collecting wastewater and delivering grey water to the kunuku's is beyond the WEB's financial capacity at this moment. The largest gap between the current and the desired situation however, lies in the food system. In regards to agriculture, livestock and fishing major change is necessary to reach sustainable practices that provide economic opportunities and sufficient production, whilst decreasing the environmental damage. There is almost no physical infrastructure present to limit the food systems adaptivity, rather its adaptive capacity is minimal due to the absence of financial means and a comprehensive business case.

External pressures

Global pressures such as sea level rise, oil prices and available finances have the most direct influence on the water and energy system. These pressures only reach the food system indirectly through factors from the water and energy system, such as groundwater and grey water supply. The water system is influenced by the largest number of external factors. Energy price, agricultural activity, evaporation rates and vegetation cover are all external factors influencing the water system that originate from the energy and food systems. Thereby the water system is also influenced by the most amount of external factors controlled by other systems. This can be either positive or negative, depending on the degree of influence on and collaboration with stakeholders in the energy and food sectors. Perspective also matters. The water-related factors in the food system (ground water supply and grey water supply) can be regarded as external factors and when farmers take this perspective and neglect the (in)direct influences on water resources, it has important implications on their sense of agency and can decrease the resilience of the socio-ecological system (Cinner and Barnes, 2019). Conversely different perspectives can also create agency under stakeholders whom see regard the external factors influencing their system as changeable if certain levels of influence and collaboration are met.

Conclusion

The high number of elements and non-linear interactions in particularly the food system, but also in the water system, lead to complex behavioural dynamics. While the energy system has less elements and feedback loops, it is nevertheless a highly technical system, resulting in external knowledge and capacity being necessary for its development (IRENA, 2017; Wiebes, 2018). Table 5.1 indicates that Bonaire's small scale is beneficial for the technical operations of the energy system, but the lacking economies of scale and high consumer prices constrain the water and food systems. Furthermore the water and food systems are strongly connected. Decisions made by stakeholders in one system can be expected to have consequences in the other systems and an awareness of the connections may thus help prevent unintended effects. This is particularly relevant for the food system, which is in development and has experienced bad governance in the past, particularly in the case of free-roaming goats. Knowledge of the negative feedback loops and non-linear interactions by governmental agencies and other agents, such as farmers, can help prevent negative consequences for ecological health and water resources.

5.2 PESTLE

Certain characteristics and external factors in Bonaire affect all three systems in the WEF-nexus. These factors implicate what is achievable and what is not in Bonaire's future. They serve to delineate the shared vision space and the pathways towards that vision (chapter 6). They also identify opportunities for the transition pathways, such as the current legal framework that grants the means to construct an ecosystem management plan and the TOP programme that can be expanded to improve human capacity (chapter 6.3).

Political

Relevant political factors for the integrated governance of the WEF-nexus are: lacking expertise and human capacity in the OLB and initiatives aimed at increasing human capacity. In the most recent administrative agreement of 2018-2022, the first policy objectives are to strengthen the capacity and effectiveness of the administration (OLB) and to strengthen the governance of public entities (Openbaar Lichaam Bonaire, 2018). Despite approximately 380 civil servants working for the OLB, expertise and efficiency is lacking (Openbaar Lichaam Bonaire, 2018). Improvement is beneficial, as Croes et al. (2017, p.59) reported that "a culture that is grounded in decision-making based on intuition rather than being grounded in data driven information is also hampering quick and effective decisions.". Besides high levels of bureaucracy, there is insufficient staffing and knowledge at key positions in the water, energy and food systems at the OLB (Croes et al., 2017; Openbaar Lichaam Bonaire, 2014a, 2018). In the 2018-2022 Administrative Agreement the Ministry of the Interior and Kingdom Relations will continue with the Talent Development Programme (TOP) Bonaire and TOP-Traineeship where professionals are presented with opportunities for personal development

and the exchange of knowledge and experience with peers. These initiatives are tailored towards civil servants and graduates to improve human capacity and offers intensive training courses and a network of peers. The implication of these political factors is that the increased complexity of the WEF-nexus (increased connections, feedback loops, stakeholders, decisions and solutions) in respect to a sectoral approach places a burden on the low executive capacity of the OLB.

Economical

Relevant economical factors for the integrated governance of the WEF-nexus are: a decrease in GDP per capita, prevalent poverty and high consumer prices, slim business cases in agriculture and an economic dependency on tourism. GDP has seen a strong growth between 2012 and the most recent statistics of 2016 with an average of 2.3%. This can be explained by the growth in population of 28% between 2010 and 2019, conversely resulting in a decrease of the GDP per capita. The costs of living, particularly rents and consumer prices, are high due to the dependence on imports and limited economies of scale (Centraal Bureau voor de Statistiek, 2018c). Poverty is still is a problem in Bonaire, as is rising youth unemployment (15.90% in 2016). Poverty is particularly severe under the elderly whom are not able to meet the high food costs with a standard social pension from the state government (Drayer, 2019) (Interviewee #2 & #3). Costly infrastructure with limited economies of scale result in high tariffs in the water and energy sector. The business case for agriculture practices is slim, or in some cases needs to be subsidised (Wayaka Advies and BAAB BV, 2018). High water and electricity prices increase the subsidies necessary to operate a business in agriculture or livestock.

Increasing the contribution of the tourism industry to the residents of Bonaire without infrastructure development or the degradation of the natural environment is achievable through soft tourism products (experiences) according to Croes et al. (2017). Key is the focus of Bonaire as a 'Blue destination': "sustainable use of ocean resources for economic growth, improved livelihoods and jobs, and ocean ecosystem health" (World Bank, 2017, p.1). Blue growth concerns developing more soft tourism products related to the oceanic services that the ecosystem has to offer, than on infrastructure developments (Croes et al., 2017). This entails developing high quality experiences whilst limiting tourism density. Several developments in the tourism industry focus on increasing the amount of tourists with 60.000 arrivals, reaching 200.000 in 2027 (Interviewee #2). Key in achieving greater tourism numbers and providing economic benefits to locals is the construction of 600 new boutique hotel rooms, ranging from 60-100 rooms per hotel, according to the 2017-2027 Tourism plan by Croes et al. (2017). This seems to conflict with the idea of mitigating "severe infrastructure development, the environmental consequence of which concerns many Bonairians" (page 3) mentioned in the plan. Despite noting several challenges for tourism in the 2017-2027 Tourism Master Plan Bonaire, neither water, energy or food related challenges were mentioned. Two important implications can be con-

cluded from these economic factors. First, a further increase in the cost of living, either through rising water, energy and/or food costs, will place a heavy burden on large numbers of Bonaire's population. Consumer prices are high on the political agenda in Bonaire and in the European Netherlands (Drayer, 2019). This constrains investments in critical infrastructures such as irrigation and electricity distribution grid capacity. The high water and electricity prices also decrease the attractiveness of starting a business in agriculture. Second, the Blue Destination strategy can be beneficial in improving livelihoods, but can also increase the load tourism places on Bonaire's environment.

Social

Relevant social factors for the integrated governance of the WEF-nexus are: population and tourism growth, decline in social cohesion and a conservation oriented mindset. Bonaire's population is growing rapidly due to increased tourism growth and economic immigration (table 5.2). This increases the demand for water, energy and food and leads to increased pressure on Bonaire's natural resources. The Masterplan strategic development Bonaire 2010-2025 uses a causal multiplication model to asses the impact of one additional tourism unit (touristic accommodation) on the population. The model indicates a historic growth of 75 citizens for every 10 additional tourism units (Van Werven et al., 2010). The implications of this relation is that the population of Bonaire will grow beyond 20.000 inhabitants and may even reach 30.000 inhabitants in 2025 if the primary focus is autonomous development. The economic benefits that the growing tourism industry provides has only delivered them to a small portion of Bonaire's residents (Croes et al., 2017). A symptom of the decline in social cohesion and responsibility is the increase in the illegal dumping of waste on land and sceptic tank discharge in the sea (Van Werven et al., 2010). Despite the observed decline in social cohesion a mindset seems present that recognises the value of the ecosystem and wishes to conserve it: historically Bonaire was one of the first islands in the world to create national parks.

2011	2019	2025
15.700	20.100	24.700
100%	+28%	+23%

Table 5.2: Population growth in Bonaire (Centraal Bureau voor de Statistiek, 2019a)

Technological

Relevant technological factors for the integrated governance of the WEF-nexus are: poorly maintained road and irrigation infrastructure, and the development of new promising nexus-related technologies. Insufficient maintenance and investments has led to the deterioration of Bonaire's road infrastructure. The administrative agreement 2018-2022 sets out plans to execute overdue maintenance and cooperate with the Ministry of Infrastructure and Water Management to improve road infrastructure and the drainage of rainwater on roads (Openbaar Lichaam Bonaire, 2018). Future investments in

infrastructure will increase to accommodate the increasing population and tourists, particularly with the development of more rural touristic activities (Van Werven et al., 2010). The poorly maintained irrigation infrastructure has major implications in both the water and food system, such as the decrease in the amount of available groundwater and irrigation water, the increase of run-off and the worsened soil conditions. Several new technologies are emerging that can be put to good use in Bonaire. Some of those technologies, such as algae for livestock feed and biofuels, aquaculture and small-scale solar powered reverse osmosis plants, operate in multiple nexus systems.

Legal

Relevant legal factors for the integrated governance of the WEF-nexus are: lacking oversight of public companies and legal opportunities for ecosystem planning, protection and spatial design. Oversight and financial regulation of Bonaire's public companies such as the WEB and waste management company SELIBON is not at the desired level (van Buiren and Ernst, 2019). The limited opportunities for economies of scale and the presence of dominant private entities with significant market power are aspects of Bonaire's economy that are common in SIDS. The ACM regulates market power in the Netherlands, but has a different role in Bonaire as a fair marketplace is not always realistic (Bogaardt et al., 2015). Additional legal responsibilities include supervising the electricity and drinking water production, the postal and the telecom sector (Autoriteit Consument en Markt, 2019). The BES Electricity and Drinking Water Law is particularly influential in the water and energy systems. It enables the WEB to charge more cost-effective rates to its customers for the production and distribution of drinking water and the distribution of electricity. This increases the investment room the WEB can make in the drinking water production and distribution capacity and the electricity distribution grid. According to the Law Public Housing, Spatial Planning and Environmental Management BES 2017, three ministries are required to prepare an environmental policy plan for the OLB every five years. This plan contains the starting point, goals and priorities in environmental policy, specifically for wastewater, waste and recycling. Due to administrative difficulties, the plan for 2012-2016 has not been ratified and the plan for 2003-2007 is still in force (Openbaar Lichaam Bonaire, 2017). The Law Nature Conservation and Protection BES 2019 requires the Ministry of Agriculture, Nature and Food Quality to prepare a nature policy plan that contains the goals, priorities and values for the nature and rural areas in Bonaire. The Law also created a nature conservation committee that consists of independent experienced members whom advise the OLB on environmental policy. The implications of these legal factors are that multiple laws and regulatory bodies exist that are able to coordinate and advise decision-making processes regarding the WEF-nexus in Bonaire.

Environmental

Relevant environmental factors for the integrated governance of the WEF-nexus are: loss of coral cover, degradation of ecosystem health, overfishing

and initiatives aimed at restoring ecosystem health. The 27 km2 of coral cover in Bonaire's reef ecosystem is declining consistently and has lost 50% in the last 40 years (de Graaf et al., 2016; Slijkerman and van der Geest, 2019; Van Der Lely et al., 2013). Rising sea temperatures lead to repeated coral bleaching, where coral expel the photosynthetic algae that provide their nutrients, eventually leading to their death. Overfishing threatens approximately one third of coral reefs around Bonaire, as the numbers of herbivorous fish that eat algae diminishes (Van Der Lely et al., 2013).

A quantitative evaluation estimated the Total Economic Value (TEV) of the ecosystem services at $105 million per year (Van Der Lely et al., 2013), 25% of GDP in 2016 (Centraal Bureau voor de Statistiek, 2018c). If the current threats to the ecosystem remain unchanged, the TEV is predicted to decrease to $60 million in 2022 and $40 million in 2043 (Becking et al., 2015; Van Der Lely et al., 2013). Despite the alarming decline in coral cover and health and mangrove cover, unspoiled locations remain and many damaged locations can be (partially) restored if significant efforts are made (de Bakker, 2019). The Ministry of Agriculture, Nature and Food Quality is funding the Coral Restoration Foundation Bonaire in restoring Bonaire's coral reefs. The foundation has planted over 20.000 corals in the shallow coral reefs with help of local dive operators (Virdis and Hickey, 2016). In both lionfish hunting and coral restoration volunteer divers are the main executing force of the initiatives, indicating strong engagement by regular tourists and residents with the ecosystem. In conclusion, Bonaire's ecosystem is facing multiple significant threats that, if left untreated, will diminish the value it gains from the ecosystem.

Conclusion

Development of human capacity and increasing executive power is necessary at the OLB to overcome the prevalent bureaucracy, lacking knowledge and decision-making based on intuition rather than data. Affordable consumer prices and security of supply are critical goals to fulfill in the future as population and tourism numbers grow, and constrain expensive investments in infrastructure. Subsidies remain necessary for the treatment of wastewater and the attractiveness of agriculture. Sustainable tourism development is promoted through the Blue Destination strategy, although the connections with the WEF-nexus is under-reported in literature concerning the strategy. Multiple laws and the regulations set out in the Spatial Development Plan provide the OLB with a legal framework to reduce environmentally damaging activities and better design the rural areas. The data and knowledge that can support better design regarding ecosystem dynamics such as groundwater flows, is not available however.

5.3 GOVERNANCE

Nexus governance is defined as "the relational structures and processes that connect actors across sectors, governance levels, geographical boundaries

and/or public, private and civic spheres, and that provide steering mechanisms for the integration of management and governance systems across different policy domains." (Stein and Jaspersen, 2018, p.3). Multiple socio-technical regimes are required to cooperate and different or comparable governance structures will make nexus governance easier or more difficult to achieve (Allouche et al., 2015). The WEB, the OLB and the RCN, whom coordinates the efforts of multiple ministries, are all central parties in the governance of the water, energy and food systems. These parties cooperate and communicate often as a result from Bonaire's small scale: one quickly enters the domain of other stakeholders (Interviewee #4). Stakeholders also cross system lines: the WEB is a regime actor in both the energy and water system, and has an increasingly influential role in the food system through the production of treated wastewater. The water, energy and food systems are all facing increasingly complex governance issues as new technologies and products emerge, such as private solar PV growth, aquaculture and algae. Furthermore stakeholders are increasingly aware of the existing and growing connections between the water, energy and food systems (Interviewee #4). The Administrative Agreement 2018-2022 aims to strengthen its governance, expertise and efficiency to deal with the intertwining water, energy and food systems (Openbaar Lichaam Bonaire, 2018). The biggest bottleneck to effective nexus governance is the lack of political vision and long-term commitment and stability, according to Interviewee #3. The technological solutions to problems in the WEF-nexus are available, but transforming pilot projects from technological niches into the mainstream with secure financing often fails. From this it can be concluded that the regime parties are often willing to engage in sustainability transitions, but this happens on their terms and the quality of governance is low, particularly in long-term project development.

The system analyses in the food and water industry show how system behaviour can negatively affect the number of tourists (figures 4.2 & 4.8). This can explain the push from the tourism industry towards the Blue Destination strategy, which can be regarded as the prevailing discourse in Bonaire's economic development, where sustainable transformations protect Bonaire's natural resources and enhance the competitiveness and promotability of Bonaire in the green and high quality tourism industry. The Tourism Corporation Bonaire recently hosted a conference in cooperation with the Ministry of Economic Affairs and Climate for SIDS in the Caribbean to present and promote its sustainability developments. The OLB, BONHATA, TCB, STINAPA, Chamber of Commerce and the Ministry of Economic Affairs and Climate prioritise the Blue Destination strategy to create economic growth and prioritise increased hotel construction, investments in road infrastructure to touristic sites and the development of qualitative agriculture products to sell to tourists. The tourism industry is aware of the need to understand the connections between environment, society and tourism development (Croes et al., 2017). Nevertheless, tourism representatives are disappointed in the excessively strict preservation policy, which, according to the 2017-2027 Tourism vision drafted for the tourism industry, has resulted in an airport that has not been able to make a profit and a poor condition of rural infrastructure

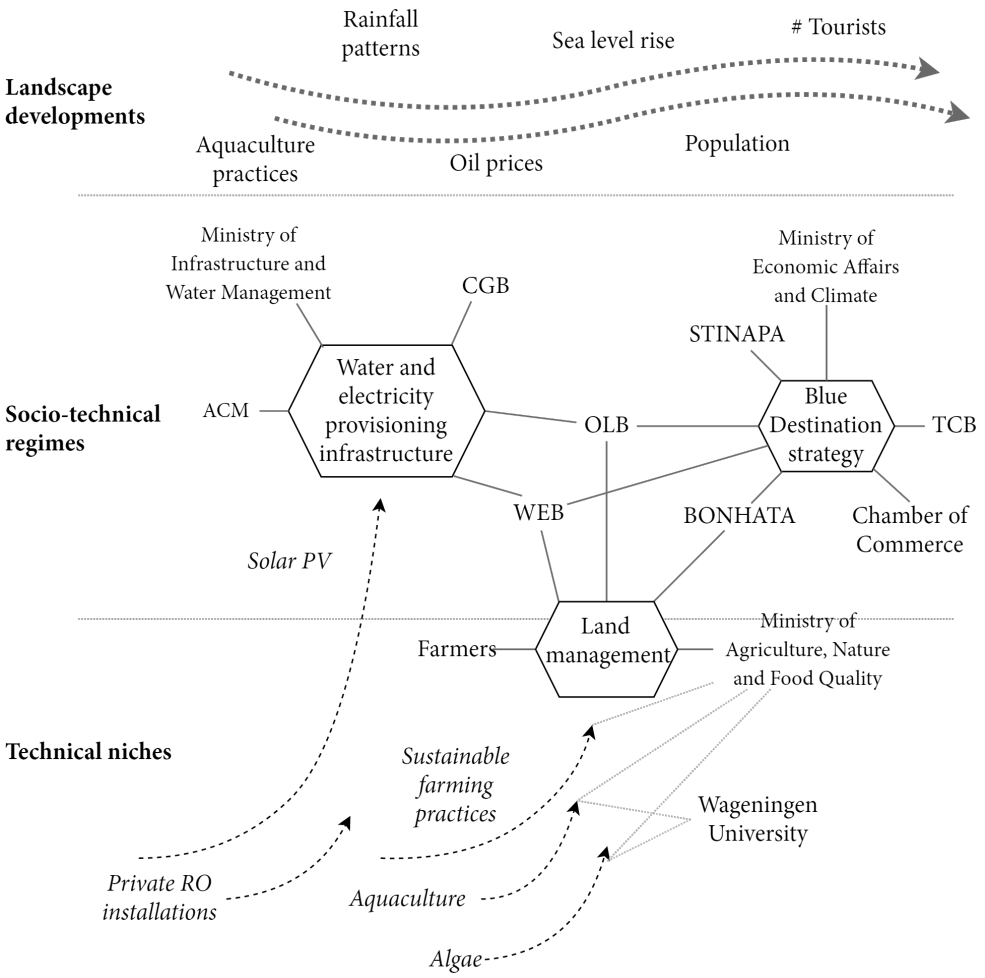


Figure 5.1: Multi-Level Perspective on Bonaire

(Croes et al., 2017). The major private parties whom have the financial means to invest in new technologies also hail from the tourism industry: several of the hotels, resorts, diving companies and other tourism related companies, represented by BONHATA, own private drinking water production capacity and solar PV installations. Historically the nature conservation organisations such as the DCNA and STINAPA have been influential and remain involved in spatial planning and promoting sustainable and environmental practices. STINAPA was one of the initiators of the Blue Destination strategy, benefiting from increased tourism numbers and improved infrastructure to facilitate access to its national parks. Two interviewees whom wish to remain anonymous critique the Blue Destination strategy as a "greenwashing" marketing strategy by disproportionately highlighting the sustainable initiatives on Bonaire to increase its sustainable image. Interviewee #4 contradicts this and mentions that a steering committee consisting of the TCB, Chamber of Commerce, BONHATA and STINAPA advise a widely shared bottom-up approach by which an objective foundation is made for the Blue Destination strategy, to prevent a greenwashing image.

The small social environment and history of cooperation has created a tightly knit group of stakeholders in the regime with representatives from govern-

ment, tourism and NGOs. Figure 5.1 visualises the historic connections that originate from an early focus on environmental conservation of touristic assets between STINAPA, the OLB, BONHATA, WEB and the resulting socio-technical regime they have formed. Solar PV demonstrates that to break into this regime has its difficulties and occurs under specific circumstances. Solar PV was adopted by a select group of hotels and residents when it was still illegal to connect the installation to the distribution grid, but the business case and financial means were both present to attract adopters. Lack of enforcement created an environment where solar PV could grow privately, eventually passing into law and being adopted by the WEB and CGB. Solar PV also fitted in the sustainability strategy and image of the OLB and several ministries, overcoming the WEB's resistance due to the increased distribution grid pressure and operation difficulties.

A new technological niche around land management practices is slowly evolving and pressuring the socio-technical regime. It is spearheaded by a small amount of farmers and the Ministry of Agriculture, Nature and Food Quality in their policy goals of professionalising the food sector and increasing local production. Wageningen University assists in maturing the agricultural practices and new technologies such as algae to be economically feasible on a larger scale. Policies regarding reforming land use and contributions to land degradation are complicated, and besides the Spatial Development plan no plan exists that addresses and combines water management, suitable locations for agriculture, renewable energy and tourism development (Global Water Partnership, 2014; Slijkerman and van der Geest, 2019). Integration as a new socio-technical regime will depend amongst others on the nature of the relationships formed with the OLB, WEB and BONHATA (figure 5.1). According to Smith and Stirling (2010), regime incumbents need to become involved in socio-technical transitions to secure their position in regime change. An example of this challenge is the treatment and distribution of wastewater, a third treatment step being beneficial for hotels but not for farmers. The question then arises whom is in a better position to "prioritise their sustainability" and incorporate the provisioning services of the socio-ecological system in their narrative and regime (Smith and Stirling, 2010). In provisioning regimes, farmers who are not able to invest in labour, inputs, land and innovations will be placed in a subordinate position to the capitalist farmers who are able to do so (Foran, 2015). This is noticeable in the preferential policy whereby farmers whom cooperate by implementing sustainable goat farming practices receive priority in buying the goat feed crops produced by the Ministry of Agriculture, Nature and Food Policy (Openbaar Lichaam Bonaire, 2014b). Where the benefits of the tourism industry has only reached a select few, agriculture is seen by policymakers as enhancing the livelihoods of a large proportion of the rural population. The explicit acknowledgement of the balancing of policies aimed at increasing the economic activity in the food system with the creation of a new regime of provisioning that creates winners and losers has not been found in literature. This risks the food sector becomes similar to the tourism industry where only a select group of farmers is able to create economies of scale and benefit from the increased growth.

Conclusion

The energy and water system are governed by a connected regime of multi-level governmental agencies such as the OLB and the Ministry of Infrastructure and Water Management, the WEB and CGB. Historic investments in the water and electricity production capacity and distribution infrastructure have locked the regime in place, offering an explanation why novel technologies such as OTEC and distributed water generation have found no support. Water and electricity prices constrain the operations of the OLB and the WEB, as this issue is high on the political agenda in Bonaire. Interviewee #3 mentioned that developments in the governance of the water and energy sector are primarily concerned with tariffs and daily operations of the infrastructure. Security of supply is prioritised and sustainability is only a part of the mindset of the WEB (Ministry of Economic Affairs and Climate, 2018). The food sector is far behind the water and energy sectors in terms of professionalisation, economic opportunities, knowledge and political power. Furthermore its behaviour is complex, containing a large number of elements, multiple feedback loops and non-linear interactions.The food sector is strongly connected with the water and energy sectors. Stakeholders in the food sector are dependent on the regime stakeholders in the water and energy sectors, such as the WEB and BONHATA, in achieving their goals (5).

6 TRANSITIONS IN THE WATER-ENERGY-FOOD NEXUS

Shared basic principles for long-term sustainable development, such as the historic protection of Bonaire's natural resources and conservation efforts, form a basis for sustainability visions (Loorbach, 2010). In this chapter the individual visions extracted from literature and interviews are combined into a currently non-existing shared vision encompassing the water, energy and food sectors. In the previous chapters the causal relationships driving system behaviour, external pressures, barriers and opportunities for change were researched. These factors delineate the space wherein a shared vision can be constructed, as do opposing visions depending on the power and influence of the respective stakeholders from whom the vision originates. Furthermore, the the cross-case analysis has shown that certain developments in Bonaire, in particular the Blue Destination strategy, are related to the technical aspects and the governance of the water, energy and food systems. This has implications on the scope of the shared vision, as certain elements are included that may at first not seem relevant to a sustainable transition in the water, energy and food systems, but are to be included if important transition barriers are to be overcome. First, a summary of relevant factors and their influence on shared vision space are listed. Second, a shared vision is outlined based on the individual stakeholder visions from chapter 4. Third, detail will be added to this vision by defining its attributes. Fourth, pathways towards this vision are constructed. Finally recommendations are proposed based on the pathways towards the shared vision.

6.1 DELINEATING THE VISION SPACE

Several conclusions from chapters 4 and 5 are relevant in defining the space wherein a shared vision can be found. These items consist of shared principles between stakeholders, essential elements that must be included, or factors that place boundaries on the shared vision space. These conclusions are listed below.

1. Shared basic principles between stakeholders are the appreciation and wish to conserve Bonaire's ecological assets, sustainability as an opportunity for growth and for reducing costs of living, and effective, stable and transparent governance enabled by a growth in human capacity and knowledge.

2. Protection of ecosystem services is an essential element to be accounted for in a shared vision, as the Total Economic Value of ecosystem services will decline from $105 million per year (25% of Bonaire's GDP) to $40 million per year in 2043 if no action is taken to reduce the dam-

aging threats (Becking et al., 2015; Van Der Lely et al., 2013). This creates a clear need for the OLB to protect its natural resources and their future contribution to the economy. It also ensures that the tourism industry, whom directly benefits from Bonaire's natural resources in attracting tourists, takes an interest in ecosystem health. Multiple initiatives work to restore parts of the ecosystem, such as the replanting of coral. These initiatives are often initiated by a coalition of businesses and NGOs, such as the Reef Renewal Foundation whom collaborates with diving companies and enlists tourists as volunteers to help replant coral. Interviewee #3 recommends to bundle visions in a nature policy plan or an environmental policy plan that finds the ecosystem limits and to use the plan to initiate nexus discussions and bring stakeholders together.

3. An essential element to be accounted for is the Blue Destination strategy. It is a focal point in Bonaire's future development, where tourism is regarded as the engine for growth. Sustainable initiatives that contribute to Bonaire as a Blue Destination are framed within this strategy by its initiators. The large amount of regime stakeholders involved in this strategy creates a strong narrative of environmental protection and economic development for disadvantaged residents. If a shared vision is to find support amongst the majority of businesses and private investors alignment with the Blue Destination vision is important.

4. The amount of residents and tourists in Bonaire is expected to grow with 25% and 43% respectively before 2030 (Centraal Bureau voor de Statistiek, 2018b; Croes et al., 2017). This increases the demand for drinking water and food which are expected to grow with 33% by 2025. Increased drinking water consumption also results in an increased production of wastewater. High consumer prices and limited benefits from the tourism sector has increased poverty and limited access to capital among Bonaire's residents (Croes et al., 2017; Drayer, 2019). This prioritises the goal of security of supply under affordable costs for the water and energy provisioning regime. Its implications are that pathways must account for the security of supply and affordability of water, energy and food.

5. The energy and water system are governed by a connected regime of multi-level governmental agencies such as the OLB and the Ministry of Infrastructure and Water Management, the WEB and CGB. Historic investments in the water and electricity production capacity and distribution infrastructure have locked the regime in place, offering an explanation why novel technologies such as OTEC and distributed water generation have found no support. Water and electricity prices constrain the operations of the OLB and the WEB, as this is issue is high on the political agenda in Bonaire. Interviewee #3 mentioned that developments in the governance of the water and energy sector are primarily concerned with tariffs and daily operations of the infrastructure. Sustainability is only a part of the mindset of the WEB. The food sector is far behind the water and energy sectors in terms of profes-

sionalisation, economic opportunities, knowledge and political power. Furthermore its behaviour is complex, containing a large number of elements, multiple feedback loops and non-linear interactions. The food sector is strongly connected with the water and energy sectors and stakeholders are dependent on the regime stakeholders in those sectors, such as the WEB and BONHATA, in achieving their goals (5). The implication of these differences in regime strength across sectors is that explicit attention must be given to the needs of the food sector to realise the ambitious plans and prevent further ecological damage from bad practices. The emergence of the fishing cooperation PISKABON is an example of niche stakeholders organising and advocating for themselves after underrepresentation.

6. A 100% renewable electricity scenario is difficult to achieve due to the connections with other domains, security of supply, high costs resulting from necessary excess generation capacity and storage, limited distribution grid capacity, absence of skilled human resources, and the lack of support for OTEC (Schelleman and van Weijsten, 2016; Wiebes, 2018). A 60% renewable electricity scenario is highly likely to be achieved before 2021 (Burger, 2019). A 80% renewable electricity scenario is feasible in a centralised generation capacity configuration, but requires cheap financing and medium to high oil prices ($90-$130 per barrel). decentralised generation still faces significant barriers from the distribution grid and reduced feed-in tariffs resulting from the updated BES Electricity and Drinking Water Law. The implications of this growth in renewable electricity production is that during favourable conditions, large amounts of renewable and cheap electricity will become available. Investments in the distribution grid are necessary to cope with this load and with the expansion of decentralised generation.

7. Road and irrigation infrastructure are in poor condition. During heavy rainfall run-off and sedimentation to sea damage the coral, sceptic tanks in rural areas overflow and dirt roads without proper irrigation become impassable. The water retaining infrastructure is overgrown and poorly maintained. This decreases the groundwater recharge and the amount of rainwater that can be stored for agricultural purposes.

6.2 A SHARED VISION

Based on the visions researched in sections 4.1, 4.2 and 4.3, a shared vision is constructed for Bonaire. The shared vision is developed by combining multiple broad vision images into a set of non-excluding and interdependent principles. For the shared vision to create converging and committing power, the degree in which its principles are non-exclusive for the majority of stakeholders is imperative. Principles are chosen that are widely shared, but are thereby inherently broad and can be interpreted differently by different stakeholders. For instance, environmental protection can mean something different for PISKABON, the cooperative fishing organisation, than

to the Dutch Caribbean Nature Alliance. The implications of the multi-interpretation of principles shall be discussed in section 6.3. The shared vision (figure 6.1) represents a future where a sustainable transformation of the water, energy and food sectors is achieved. In this future Bonaire is able to effectively govern the relationships between the water, energy and food systems, the tourism industry and its environment to provide a high quality of life for its residents. As mentioned in the introduction of this chapter, the explicit inclusion of the tourism industry and high quality of life (amongst others: affordable costs of living) is a result of the governance and transition management analyses in chapters 4 and 5. Timelines in the researched documents reach up to the year 2029. To match their scale, the timeline of the shared vision is set for 2030.

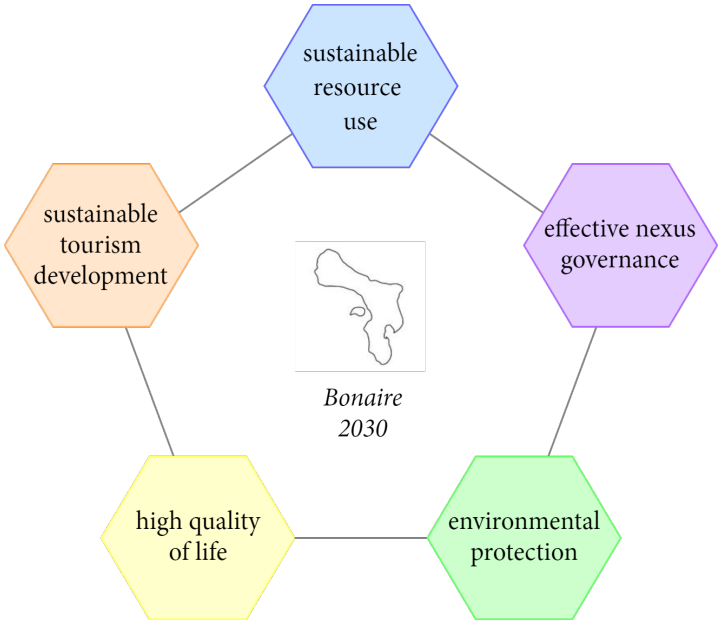


Figure 6.1: A shared vision for Bonaire's future

6.2.1 Sustainable resource use

This principle envisions a future where water, energy and food resources are produced and consumed in a sustainable and optimal manner.

6.2.2 Effective nexus governance

In effective nexus governance the synergies between the water, energy and food systems are identified and taken advantage of through a combination of technical solutions, rules and regulations, stakeholder collaboration and knowledge dissemination. The OLB has sufficient human capacity to govern the water, energy and food systems and their interconnections. The negative consequences of actions in one system on the other systems are known and corrected for. Decision-making is fact-based, consistent and transparent. The OLB, RCN and involved ministries collaborate efficiently and project management capacity is high. The public companies responsible for provid-

ing critical services such as the WEB and SELIBON work efficiently and are successfully directed by the OLB.

6.2.3 Environmental protection

Bonaire's natural assets are monitored, protected and resilient in response to global pressures. Groundwater levels and salinity are monitored and sedimentation and run-off are reduced through increased vegetation cover and irrigation infrastructure. An ecological management plan guides the spatial design of renewable energy generation capacity, tourism development and agricultural activity. The plan clearly delineates what areas of Bonaire are destined for economic activities, residential areas and nature reserves. Residents of Bonaire are aware of the value of the environment and the harmful effects of pollution on their livelihoods. Rules combating illegal landfills and wastewater dumping are enforced by the OLB.

6.2.4 High quality of life

The Masterplan Strategic Development 2010-2025 envisions sustainable prosperity development for its residents as the main focus for Bonaire's future development (Van Werven et al., 2010). Bonaire's population is healthy: there is a secure supply of affordable and healthy food. Conflict with high food prices in attractiveness of agriculture (figure B.3), distinction necessary for everyday produce such as vegetables and fruits, and high quality artisanal produce focused on tourists. The residents are economically prosperous: there are ample economic opportunities in the tourism, agriculture and service sector and the electricity and water bills are reasonable. The residents are innovative and entrepreneurial: sufficient and affordable financing options are available, solar PV installations are accessible and knowledge and support is easy to access.

6.2.5 Sustainable tourism development

Stakeholders share a vision where Bonaire is the preferred destination in the Caribbean for high quality touristic experiences, where it contributes 50% to GDP and where the economic benefits of tourism reach a large share of the population (Croes et al., 2017; Openbaar Lichaam Bonaire, 2018; Van Werven et al., 2010). Road infrastructure to rural areas, tourism destinations and WSNP is kept in good condition. An integrated destination management plan is developed and executed by a strong and professional Tourism Corporation Bonaire. Common objectives and partnerships between the TCB, governmental agencies and parties active in environmental protection are found and initiated. Room taxes are strictly enforced by the OLB.

6.3 PATHWAYS

Three pathways sketch different trajectories that strive towards the shared vision. First, the origin of the pathways is discussed. Second the contents and strategy of the pathway is elaborated upon. Interdependency of principles implies cooperation between stakeholders to achieve their goals within the shared vision. Therefore as a third step the involved stakeholders, their roles, configurations and their means are discussed. This will provide a starting point for recommendations regarding the next steps of the Transition Management Cycle. Finally the merits and risks of the pathway are discussed.

6.3.1 Human capacity and innovation development

Origin

This pathway originates from multiple policy documents, visions and interviews that mention increasing human capacity in a wide variety of organisations. The first two policy objectives of the OLB in their recent Administrative Agreement 2018-2022 concern strengthening executive power and improving governance (Openbaar Lichaam Bonaire, 2018). The Agreement plans to research the structure and operations of public companies such as the WEB to secure the critical services they provide. Farmers have indicated a need for a supportive organisation that provides entrepreneurial and technical knowledge. The Ministry of Agriculture, Nature and Food Quality is reorganising their operations on Bonaire to better facilitate this demand (Openbaar Lichaam Bonaire, 2014b). One of the pillars of the 2017-2027 Tourism vision for Bonaire is a strong and professional TCB (Croes et al., 2017). In her project of setting up a cooperative fishing organisation in Bonaire, Mac Donald (2018, p.9) recommends that PISKABON "board members must receive support and coaching so that they can excel in their role". Interviewee #4 mentions that the small scale of the island and the amount of involved governmental agencies makes the distribution of roles ambiguous, slowing down decision-making processes. Furthermore a lack of innovation management and project execution capacity is observed, creating additional barriers for stakeholders whom wish to develop emerging technologies beyond a pilot project (Interviewee #3).

Strategy

This pathway will focus on increasing human capacity in Bonaire in regards to project planning and execution, innovation management and knowledge dissemination. The individual stakeholder commitments to human capacity development described in the section above are connected to incorporate cross-sectoral communication and collaboration. An existing example of this is the Talent Development Programme Bonaire (TOP Bonaire) where new civil servants and employees of governmental agencies such as the OLB, Chamber of Commerce, WEB and RCN receive coaching and training to improve their skills and knowledge. In the Human capacity development

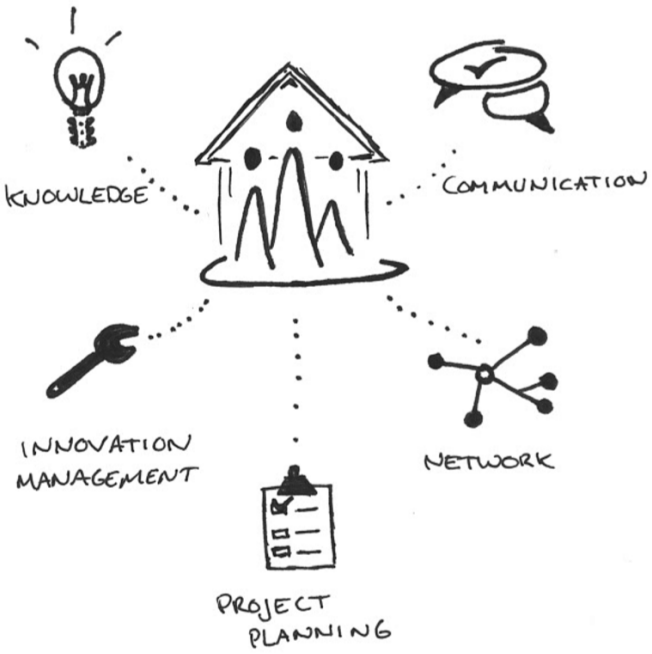


Figure 6.2: Human capacity and Innovation Development Pathway elements

pathway this programme is continued and augmented with water-energy-food nexus principles to teach the interconnectedness of the three sectors to the trainees and to improve later decision-making. TOP alumni are able to enter the TOP Think tank to further grow their network. Within the think tank alumni are engaged in cross-boundary projects. By focusing on cross-sectoral projects in the water-energy-food nexus, alumni can use their existing network from the TOP to find effective collaboration structures and better define roles. As stated by Reinhard et al. (2017), when the synergies and trade-offs between the nexus sectors are identified in the design and implementation of policies, plans and investments, policy coherence is increased. Linking human capacity development to a public investment programme, such as the investment fund created by the Ministry of Agriculture, Nature and Food Quality, or a private investment fund such as the microfinancing programme run by the NGO Qredits (C), can encourage learning by doing, an established practice within transition management (Halbe and Pahl-Wostl, 2019; Reinhard et al., 2017). Farmers have expressed a need for financial aid and knowledge in growing their tourism services, presenting opportunities for a combined investment and human capacity programme. Stimulating and facilitating innovation management through developing human capacity can help promising technologies such as biofuels and high-tech vegetable and fruit production break through into the socio-technical regime in Bonaire.

Stakeholders

Stakeholders that play a crucial role in this pathway are those with human capacity development plans (see: ***origin***), the Ministry of the Interior and Kingdom Relations whom manages TOP Bonaire and the Chamber of Commerce in connecting government officials with entrepreneurs. Qredits can

play a role in contributing to a learning by doing programme within the human capacity development pathway. Furthermore they operate an established training program to the entrepreneurs that they finance, which can also be helpful in this pathway. Given that the majority of stakeholders with human capacity plans are active in either the water and energy provisioning regime and/or the Blue Destination strategy, central steering of the human capacity development programmes risks capture by the socio-technical regime. Capture could steer learning away from nexus governance and innovation management towards conventional thinking and the continuation of regime practices. To connect all the capacity programmes and implement a WEF-nexus perspective, an independent process facilitator is recommended.

Merits and risks

The merits of this pathway are first the scale benefits in and integration of capacity development for Bonaire. Second new trainees and existing employees enlarge their network from the programme if attention is paid to group coherence and a common goal. Third the development of project management capacity can help explore and mature promising technological niches.

The risks of this pathway are first capture of the learning programme by conventional thinking, thereby continuing regime practices. Second an integrated capacity building programme risks becoming too complex and not providing sufficient practical decision making tools for the involved stakeholders.

6.3.2 Ecosystem management plan

Origin

A large loss of the value of ecosystem services is expected if no actions are taken to protect Bonaire's environment (Van Der Lely et al., 2013). Multiple sectoral reports advocate better practices that limit the negative ecological and economical consequences for the socio-ecological system (Becking et al., 2015). Furthermore Slijkerman and van der Geest (2019) recommend developing an integrated water management plan and address the lack of an ecosystem management plan. There is a lack of data on ecosystem components such as groundwater dynamics, fish stocks, habitats, biodiversity and coastal erosion. Additionally there is a beginning insight into the connectedness of resource systems, but not yet the data to visualise and quantify these connections (Interviewee #4).

Strategy

The first step in this pathway is to gather knowledge on the functioning and connections of the ecosystem and its resource systems. Shared fact finding is recommended as a process by Slijkerman and van der Geest (2019) to increase the acceptance and objectiveness of the gathered data and to reduce the risk of multi-interpretation of principles by stakeholders from

different backgrounds. Fish stocks, the volume and salinity of water reservoirs, rainfall, sedimentation, ground composition and cover, biodiversity and ecosystem threats are all relevant factors to the WEF-nexus wherefore data collection is useful. Second, a participatory process is developed to construct the ecosystem management plan where sustainable ecosystem use is the main goal. Topics included in the ecosystem management plan are spatial design for the optimal planning of activities within the ecosystem limits and the rules and regulations necessary to achieve and enforce the desired behaviour. Third the restoration of beneficial infrastructure such as irrigation infrastructure, rural sceptic tanks and the replanting vegetation and coral is undertaken. Continuous ecosystem governance and enforcement of rules and regulations by the OLB is necessary, as the problem with free-roaming goats demonstrates that despite laws regulating free-roaming livestock, lack of enforcement leads to harmful consequences for ecosystem health (Debrot et al., 2018). Financing structures for data gathering and infrastructure improvement is going to be key in the support for this pathway and needs to be included in the next transition steps. Three laws have to be fully utilised by the OLB in this pathway: the Fishing law BES, the Law Public Housing, Spatial Planning and Environmental Management BES 2017 and the Law Nature Conservation and Protection BES 2019. These laws provide the legal framework wherein the ecosystem management plan can be drafted, enforced and updated every five years.

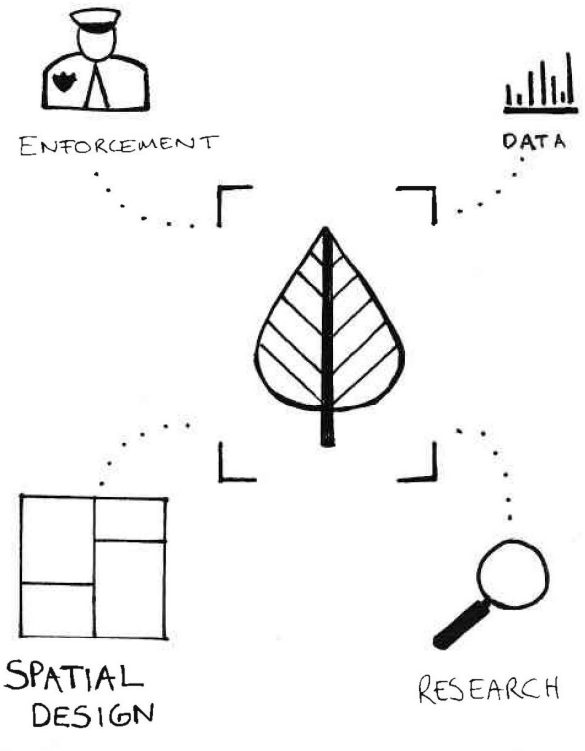


Figure 6.3: Ecosystem Management Pathway elements

Stakeholders

Essential governmental stakeholders are the OLB, the Ministry of Infrastructure and Water management and the Ministry of Agriculture, Nature and Food Quality. The ministries are necessary stakeholders in drafting the ecosystem management plan through the activities these ministries must perform under the Law Public Housing, Spatial Planning and Environmental Management BES 2017 and the Law Nature Conservation and Protection BES 2019. Close coordination between these ministries, the OLB and knowledge institutions responsible for data collection is necessary to draft a comprehensive and correct ecosystem management plan. Knowledge institutions responsible for data collection can be Wageningen University, the TU Delft and/or the DCNA. PISKABON and farmers must be included in the drafting process to account for their operations regarding the ecosystem, as bad practices in fishing, agriculture and livestock can negate the good intent of the ecosystem management plan. Including BONHATA and the TCB can result in agreements where new infrastructure and hotels can be developed, but can also steer the pathway more towards extracting the most tourism benefits from the ecosystem, as the tourism community feels that the historical conservation focus has had negative consequences on the growth of the tourism sector (Croes et al., 2017).

Merits and risks

Knowledge on ecosystem dynamics and data collection can provide a factual basis for research and the evaluation of policies. Furthermore if clearly published, it can create transparency amongst stakeholders for the decision-making processes related to the spatial design of ecosystem activities.

Data must guide decision-making to be useful, no-regret solutions can be overlooked by increasingly complex decision-making processes. Additionally to interpret data and convert this into policies sufficient human capacity and knowledge is required at decision-making stakeholders such as the OLB and DROB. The OLB must be independent and capable enough to enforce rules and regulations set out by the ecosystem management plan and to implement recommendations from research. Historically multiple illegal activities have not been strictly enforced, such as the collection of hotel room tax, overflowing sceptic tanks and free-roaming goats.

6.3.3 Sustainable tourism

Origin

Bonaire has a history of environmental protection which results in healthy and high quality natural assets that attract tourists. Tourism has been a major part of Bonaire's economy for decades. Cruise tourist numbers are high, but deliver little economic benefits compared with the environmental and logistical issues they bring (Interviewee #2). Global pressures such as rising sea temperatures and local pressures from increasing tourism numbers are threatening Bonaire's natural assets, which are the main tourist attraction.

As early as 1992 the OLB chose to move away from mass tourism towards qualitative tourism with a high contribution to the local economy (Van Werven et al., 2010). The Blue Destination strategy is the initiative that responds to this long existing wish to transform the tourism industry, increase the value of tourism to the local population and protect Bonaire's natural assets.

Strategy

In this pathway sustainable tourism is used as an engine for growth. More soft tourism experiences are developed that are less dependent on the environment, require less investments in infrastructure and provide economic opportunities to the residents of rural areas. An example of this are the clearly indicated routes in rural areas where tourists can learn about the natural environment, culture and history of the area (Openbaar Lichaam Bonaire, 2014b). When combined with a professional agriculture sector, these routs lead tourists to farms that offer small shops or restaurants selling local high quality produce. The existing hotel room inventory is upgraded and "eco-hotels" are constructed in the rural areas. The 2017-2027 Tourism report lists a capital requirement of $ 150 million to develop and upgrade the existing hotel room inventory to the desired quality. Initiatives already exist that combine tourism with environmental engagement, such as diving schools offering coral replanting excursions and restaurants promoting recipes containing the invasive lionfish species. The development and promotion of these initiatives increases Bonaire's image and attractiveness as a sustainable destination. An integrated destination management plan is developed by the community and executed by the TCB. The destination management plan sets out how and by whom tourism is developed and how it synchronises with other economic sectors in Bonaire. The guidelines set out in the Spatial Development Plan for eco-tourism development in the kunuku's are enforced by the OLB.

Stakeholders

Multiple established stakeholders have been engaged in the development of Bonaire's tourism sector and have initiated the Blue Destination strategy. These are the OLB, the Chamber of Commerce, BONHATA, TCB, and STINAPA. In the pathway towards more sustainable and economically beneficial tourism, the TCB is expected to play a central role in connecting and mediating between stakeholders from different backgrounds. The TCB currently lacks the capacities to execute the responsibilities of a professional destination management organisation (DMO) (Croes et al., 2017). To ensure that the TCB has the necessary capabilities to coordinate the complex multi-stakeholder challenge of increasing the economic benefits from sustainable tourism, guidance from an experienced institution and the strengthening of their capabilities is recommended. Other relevant stakeholders are related to infrastructure development and touristic activities, such as farmers, the Ministry of Agriculture, Nature and Food Quality, the Ministry of Economic Affairs and Climate, the Ministry of Infrastructure and Water Management and the RCN.

Figure 6.4: Sustainable Tourism Pathway elements

Merits and risks

The sustainable tourism strategy is oldest and most established pathway, its potential being recognised and discussed for more than 25 years. Sustainable transitions in the water, energy and food sectors can benefit from the attention and private investments sustainable tourism generates if the transition's sustainability opportunities are beneficial to and framed within sustainable tourism. For instance professionalising goat farming helps reduce free-roaming goats and the resulting run-off and coral degradation, increasing the ecosystem value for tourism.

The sustainable tourism pathway risks the further increase of resource demand from construction activities and increased tourism numbers, also in rural areas for "eco-hotels" and rural tourism activities. This also increases the distribution efforts the WEB must make to provide drinking water and electricity to the rural areas and collect the increased volume of wastewater. The lack of economies of scale in distribution to secluded eco-hotels in turn increases the distribution tariffs. The ACM has just increased the maximum distribution tariffs the WEB can levy and new discussions can be expected regarding if and how the tariffs differ for private consumers and rural businesses. The Blue Destination branding risks legitimising existing unsustainable regime practices through greenwashing and suppressing technologies and practices in the technological niche that can offer benefits to Bonaire. An example of this is the recent article in the Antilliaans Dagblad, wherein a property developer of eco-hostels in a rural area of Bonaire facing criticism for the ecological damages resulting from the proposed plan (An-

tilliaans Dagblad, 2019b). It also risks conflicting with the desire to become less dependent on tourism in the future, expressed Masterplan Strategic Development 2010-2025, whilst the Blue Destination strategy aims to increase the contribution of tourism to the economy from 20% to 45% (Croes et al., 2017; Van Werven et al., 2010).

6.4 TRANSITION MANAGEMENT PROPOSAL

This section will lay out recommendations and a proposal for the transition processes that can be initiated based on the transition pathways. The next steps in the TMC are to select frontrunners with different backgrounds and perceptions of the WEF-nexus issues to come together in a transition arena. These frontrunners should be individuals whom wish to participate on a personal basis and have affinity with and passion for innovation and the long-term development of Bonaire. It is advised in literature that these frontrunners should come from the "societal pentagon" of government, companies, NGOs, knowledge institutes and intermediaries (Loorbach, 2010; Quist et al., 2013). The nature of the WEF-nexus places an additional requirement on the selection of frontrunners, namely that the water, energy and food sectors are all represented. In the transition arena the shared principles and vision from 6.1 will be discussed and augmented where relevant. The second step is the further identification of regime barriers. Chapter 5 has provided insight into how technical infrastructures, governance practices and (lack of) certain rules and regulations have created regime barriers in the past for solar PV. Some of these barriers also apply to new technologies and practices, such as the poor project management capacity at the OLB, low enforcement of rules and uncertain long-term policy of the WEB, which create barriers for private parties wishing to invest in reverse osmosis drinking water production or rural wastewater treatment facilities. Nevertheless these barriers were identified through literature research and a select number of interviews. The further identification of barriers through stakeholder discussion can uncover additional regime barriers relevant to the sustainability transitions. The three transition pathways are recommendations in themselves; they are the proposed pathways to overcome the identified barriers to sustainability transitions in the water, energy and food sectors. The pathways and the means to achieve these pathways are the object of discussion by the stakeholders in the transition arena. The outcome of the transition arena negotiations can be a selection of one or more elements of the transition pathways, a process describing the steps how to achieve that pathway, which stakeholders are to be included and the means stakeholders will commit to the process.

Certain no-regret measures independent of the pathways and barriers are recommended. It can be observed that a large degree of cooperation will be necessary in all three pathways. Initiatives that make stakeholders aware of the need to cooperate and help improve cooperation will be beneficial in the next steps of the transition process, independent of the pathway(s) chosen. Inclusivity is particularly important in the food system, as the influence

of farmers and fishermen on the water and energy provisioning regime is low, but dependence is high. Furthermore their practices can either harm or benefit Bonaire's environment. Creating a farmers cooperative similar to the fishing cooperative PISKABON is recommended to better represent their voices and increase social cohesion and benefiting knowledge exchange among farmers.

7 DISCUSSION

The discussion of this thesis will reflect on two topics: the scientific value and the societal value. The reflection on the scientific value will discuss the methodology used in this thesis, its merits and novelty. It will also discuss the limitations of this research and the implications on the results. The reflection on societal value will discuss how this thesis and its recommendations can be interpreted by the community in Bonaire, the societal value of the WEF-nexus and how it contributes to the challenges facing SIDS worldwide.

7.1 SCIENTIFIC VALUE

According to Keskinen et al. (2016, p.3): "An ideal nexus approach therefore consists of a systematic process for both analysis and policy-making that focuses on the linkages between water, energy, food and other linked sectors to promote sustainability, synergies and resource use efficiency.". A nexus approach to governance would be "one that explicitly focuses on linkages between water, energy, food and linked sectors as well as their related actors in order to enhance cross-sectoral collaboration and policy coherence and ultimately promote sustainability, win-win solutions and resource use efficiency." (Keskinen et al., 2016, p.3). The approach taken in this thesis consisted of a combination of systems analysis and transition management. As discussed in 2.4, these two methods are closely related to one another. This ensured that concepts were comparable between the two methods and that the outcomes of the systems analysis were of value when used as input in the Transition Management Cycle. An example of this were the negative feedback loops affecting coral health and tourism numbers in the water and food system, as this contributed to the understanding of the tourism sector's influence in Bonaire and led to the inclusion of regime stakeholders from the tourism industry. A PESTLE analysis was added to the systems analysis and helped in structuring the external factors influencing system behaviour and future systems states. The governance of the system was investigated by researching the interactions of stakeholders with the technical system and with each other. Thereafter the visions found in literature were categorised and augmented with the perception of interviewees. These actions, steps 1 and 2 of the theoretical framework (section 3.1), led to the understanding of the technical complexities of the water, energy and food systems, their governance, their barriers and opportunities for change, shared principles and their envisioned desirable states. From the understanding of the water, energy and food systems a shared vision was constructed for Bonaire. Three transition pathways were recommended that provide a starting point for discussion in the next steps of the Transition Management Cycle. When

evaluating this theoretical approach taken in this thesis to the definitions by Keskinen et al. (2016), the combination of systems analysis and transition management offers qualitative methods to analyse the linkages between the WEF-nexus sectors and other sectors. It also offers methods to analyse their related stakeholders and policy-making processes, namely the stakeholder and governance analyses and the Multi-Level Perspective.

7.1.1 Novelty

Using systems analyses, the PESTLE classification framework and transition management in a WEF-nexus setting allowed for the structured comparison of the technical complexity, external factors, transition barriers and transition opportunities of three individual systems. By taking the WEF-nexus perspective, the systems analyses provided insights that would otherwise not be found if sectoral systems analyses would be conducted. An example is the interactions between irrigation water availability, livestock feed production, the degree of free-roaming goats, vegetation cover and groundwater replenishment. Regarding the knowledge gap of the political economical context of the WEF-nexus, the combination of systems analysis and transition management principles such as governance, regime constellations and rules and regulations contributed to understanding this context in the WEF-nexus and related sectors in Bonaire. In this regard this thesis contributes to the development of the WEF-nexus concept by explicitly accounting for governance structures and their implications on the water, energy and food sectors.

This thesis also looked at the applicability of the WEF-nexus in SIDS. In agreement with the initial assumption, the WEF-nexus perspective is very suitable in understanding the complex challenges facing SIDS and the difficulties in solving those challenges in a sustainable manner. It is able to provide recommended pathways to integrate the water, energy and food systems from a technical and governance perspective, instead of sectoral recommendations that neglect the negative feedback loops and synergies between the systems. Sufficient attention must be given to the specific political, economical and institutional barriers that are unique to SIDS, such as lacking economies of scale, high consumer prices and lacking human capacity. To the question if the WEF-nexus can outperform effective sectoral policies in SIDS (section 2.1.3), I would respond that this depends on the approach taken. Yes, the WEF-nexus can identify synergies and negative feedback loops across the water, energy and food systems. It can also make the integrated analyses of those systems unnecessarily complex and politically contested, hampering quick and effective decision-making and creating complicated regulations requiring high levels of human capacity. It is therefore recommended that a WEF-nexus approach looks at the main outlines of the technical and governance aspects of the water, energy and food systems and their similarities and differences.

In regard to the novelty of the theoretical framework it is a specification of the strategic phase of the Transition Management Cycle by Loorbach (2010) towards the WEF-nexus. The TMC and the analyses performed are well-established, but executing them in threefold and comparing them using a cross-case analysis is novel in regard to the WEF-nexus. The theoretical framework has similarities to the community arena methodology by Quist et al. (2013). The community arena methodology is however more focused on local communities and consumers for addressing sustainability issues, whereas the framework developed in this thesis aims to achieve more government driven transitions, and has less of a focus on reflexive learning within communities.

Where to draw the line?

Section 2.1.2 mentions that no agreed upon framework or approach exists for the WEF-nexus. Multiple additions have been made, such as including Environmental Livelihood Security, industry, logistics, households and ecosystems. A similar observation was made whilst researching the WEF-nexus in Bonaire. The water and food systems were not only strongly connected with Bonaire's ecosystem, but indirectly with its tourism industry. This not only presents scoping challenges for the researcher, but also for the transition process where unclear system boundaries can be used to a stakeholders advantage by including or excluding their interests and means when it suits them. The tourism industry could for example say "The problems in the water, energy and food sectors are not our problem, we are merely a consumer, just like households are.", or take the opposite approach observed in Bonaire where they use the high degree of renewable electricity on Bonaire to promote their sustainable practices to tourists. The broad nature of the transition management approach has therein been useful in identifying influential stakeholders (in)directly related to the WEF-nexus. Nevertheless it can complicate the transition process by risking capture by influential regime stakeholders whom would have otherwise not been included. From a transition management perspective, the tourism stakeholders are essential to include in a sustainable transition in the WEF-nexus as they are regime actors through the Blue Destination strategy. In response to Reinhard et al. (2017, p.5), who states that the nexus methodology should include an "Identification of issues that have to be handled with the nexus approach", the theoretical framework in this thesis did identify issues that have to be included in sustainable transitions in the WEF-nexus.

7.2 LIMITATIONS

The main limitation of this thesis is the reliance on policy documents, written visions and plans for the governance and visioning analyses. No field trip was conducted to the island of Bonaire, which would have been beneficial in increasing the number of interviews with stakeholders. Only the published visions regarding the development of Bonaire could be used to find common shared principles and construct a shared vision. Stakeholder interviews

provided some nuance to these visions, but still it remains unclear what the relative importance of certain documents is compared to others. This risks that alternative visions that contest the status quo are not included in this research and that the shared vision is a confirmation of the goals held by the socio-technical regime. It also assumes equal importance of the visions, whereas the local influence of certain documents might be greater than others. Section 5.3 confirms this risk by observing that no documents have been found that explicitly acknowledge the creation of new regimes with new winners and losers when the food sector develops, indicating the lack of alternative visions in published documents. During the interviews the question "What is/are elements of your vision on the sustainable future of the water, energy and food sectors?" was useful in extracting nuance and perception of local stakeholders regarding the published visions, but it did not sufficiently provide the alternative visions that could have been of value in this thesis. A possible explanation can be the inexperience of the researcher in interviewing, and an improvement can be a participatory workshop wherein alternative visions are constructed in a more structured process.

Regarding the governance of the systems, additional interviews with stakeholders would have been beneficial in uncovering informal governance issues such as hidden relationships and unclear boundaries and responsibilities of stakeholders. The current perspective on the WEF-nexus systems and their governance also resulted in a high level view on stakeholder responsibilities and means. This has largely overlooked the role households and individuals play in their decision-making, consumption patterns and possible production (solar PV, local agriculture). Multiple unscientific sources were consulted regularly to gauge public perception regarding the socio-technical regime, such as the Antilliaans Dagblad (online newspaper) and the Facebook group "DurftevragenBonaire" (Dare to ask Bonaire) where over 10.000 individuals notify each other and ask questions on topics such as WEB services, tourism expansion plans, beach pollution and wild dogs.

Recommendations for future research are first and foremost to increase the participatory nature of the transition management process to find alternative visions and transition pathways to the ones in this thesis. Parts of the methodological framework for participatory backcasting developed by Quist and Vergragt (2006) are valuable and applicable in committing stakeholders behind a shared vision, improving the transition pathways and engaging them in the transition management process through participatory tools. Another recommendation would be to include household behaviour into the WEF-nexus on Bonaire, to better understand the decision-making of individuals regarding their high water, electricity and food bills and their means and willingness to change their lifestyle and invest in novel solutions such as solar PV, wastewater treatment and small-scale drip-farming. The integrated model by Hussien et al. (2017) evaluates the WEF-nexus on a household scale.

Qualitative or quantitative?

An argument for the use of qualitative visioning instead of quantitative models for Bonaire is presented in Van der Voorn et al. (2012), whom argue that the explanatory capacity of model-based impact assessment studies is limited due to the generation of simplified projections of future climate change, a restricted subset of potential future conditions, linear development and model uncertainties. The complex adaptive nature of socio-ecological systems is difficult to capture in model-based studies, whereas scenario-based exploration of desirable futures has proved useful for transition research. This argument is noticeable in this thesis, where the qualitative approach allowed for the construction of a shared vision and transition pathways within certain identified boundaries. This does not exclude the value of quantitative studies in the WEF-nexus however. A quantitative approach such as System Dynamics can provide better insight than this thesis in the strength of non-linear interactions and the importance of certain connections in and between the water, energy and food systems. The results of such a study might yield recommendations for the OLB or certain ministries to design and prioritise policies influencing specific (un)desirable practices. Such a study would be particularly challenging to conduct for the WEF-nexus however, as three socio-technical systems and their placement within the larger socio-ecological system would have to be modelled altogether to fully include the complex dynamics between the systems. Scoping would become difficult, as the system diagrams for the water and food systems show that tourism and social cohesion quickly become part of the problem (figures 4.2 & 4.8). Additionally accounting for the political nature of resource flows would have been difficult in a purely qualitative study as power and political economy are not easily quantifiable and stakeholder roles and positions can change in transitions. It would also not adjust recommendations from the model to the challenges for governments to work across scales and unclear responsibilities (Leck et al., 2015), something that was explicitly attempted in this research by including transition management. To conclude the qualitative/quantitative question, both can support each other if designed correctly. A quantitative study based on independent data and participatory modelling can provide both insight into the complex dynamics of the WEF-nexus and legitimise certain actions. A qualitative study based on transition management and systems analysis can then investigate the differences in the power of regimes and niches amongst sectors, explore desirable futures, bring stakeholders together and analyse how the recommendations from the quantitative study can best be implemented.

7.3 SOCIETAL VALUE

First and foremost the societal value of this thesis is to analyse the water, energy and food systems integrally to discover the challenges facing the three systems as whole, instead of individually. Furthermore this thesis recommends integrated transition pathways for Bonaire in the governance of their sustainability challenges and transitions in the water, energy and food sys-

tems. It can facilitate discussion between stakeholders from different sectors and bring a different perspective to problems (Interviewee #4). The WEF-nexus as a governance tool can increase in societal value by developing a simple yet comprehensive and freely accessible toolbox for SIDS that assist decision-making processes, similar to the IWRM toolbox developed by the Global Water Partnership.

This thesis also contributes to the development of the WEF-nexus as a governance tool for steering sustainability transitions in SIDS. It should be noted that this thesis has one case study: the island of Bonaire. Due to its formal ties with the Netherlands as a special municipality, Bonaire has a different institutional arrangement and resulting financial and institutional capacity than most SIDS. This has implications in the degree of generality in the results of the case study towards SIDS. In most respects, Bonaire can draw on more resources and human capacity than SIDS from national subsidies, national level governmental agencies, a strong legal framework and national institutions and consumer protection. For instance, the ACM and multiple national ministries are active in Bonaire and have access to resources that governmental agencies of almost all SIDS do not have. On the other hand, Bonaire is less independent than other SIDS as it still falls within the administrative boundaries of a municipality within the Netherlands. The implications of this difference is that sufficient attention must be given to the quality and comprehensiveness of the governance analyses (stakeholders, rules and regulations, relationships with the socio-technical systems). This ensures that common SIDS issues such as low human capacity, limited access to capital, bureaucracy and poor project planning and execution are sufficiently accounted for in the WEF-nexus.

8 CONCLUSIONS

In concluding this thesis, the answers to subquestions 1, 2 and 3 will be presented, after which the main research question will be answered the research goal reflected upon. The first subquestion concerned the methodological aspect of this thesis.

1. How can systems theory and transition management theory assist a water-energy-food nexus approach and how can these be operationalised in a methodological framework?

The first section of this subquestion asks how systems theory and transition management theory can assist a WEF-nexus approach. Systems theory can assist a WEF-nexus approach by creating an understanding of the complex dynamics of the three socio-technical systems and their connections. The stakeholder analysis that is part of systems theory helps uncovering the formal and informal ties between stakeholders and their relationships to the socio-technical system. This is valuable in understanding the governance challenges of the WEF-nexus, particularly the challenges of working across scales and levels and unclear boundaries. Transition management theory can assist a WEF-nexus approach by using the analytical outcomes of the systems analysis to coordinate an integrated sustainability transition in the water, energy and food systems. It also provides the tools to explicitly focus on power and politics in the sustainable transitions of the water, energy and food sectors.

The theoretical framework presented in section 3.1 is an elaboration and specification of the strategic phase of the Transition Management Cycle by Loorbach (2010) to the WEF-nexus. The strategic phase consists of three steps: problem structuring, envisioning and the establishment of the transition arena. In this thesis problem structuring entailed performing a systems and stakeholder analysis for the water, energy and food systems, classifying influential factors using the PESTLE framework, investigating the socio-technical system governance and comparing the water, energy and food analyses in a cross-case analysis. Envisioning desirable futures was conducted by structuring visions found in published documents and through stakeholder interviews to add nuance and perception on these visions. By combining the outcomes of the systems analysis with the stakeholder visions a shared vision for Bonaire was developed. The third step - designing the transition arena - was conducted by first identifying transition opportunities and barriers from the systems analyses. Through use of the MLP by Geels (2014) the characteristics of the socio-technical regime and niche developments were explored. This enabled the construction of three transition pathways for Bonaire to reach the shared vision within the transition

boundaries and regime dynamics. Finally recommendations where made for further steps in the TMC. In conclusion, systems theory and transition management theory proved useful for an integrated analysis of the technical complexities, governance challenges and sustainability transitions of the water, energy and food systems.

2. What are the problems and opportunities for integrating the water, energy and food systems in Bonaire?

Problems for integrating the water, energy and food systems are:

1. The lack of sufficient and qualified human capacity at the OLB and the Ministry of Agriculture, Nature and Food Quality. This diminishes project planning and execution, effective governance and the design of comprehensive WEF-nexus policies.

2. The lack of monitoring and knowledge regarding key ecosystem dynamics, such as groundwater levels, salinity, fish stocks, sedimentation and rainwater capture. This makes the design of spatial policies and activities connected to the water and food sectors difficult.

3. The low enforcement rates of rules and regulations, most importantly on free-roaming goats, rural wastewater storage, hotel room tax and spatial development. This also has enabled the increase of rural theft rates, whereby for instance faucets of groundwater pumps and fencing that was supposed to enclose goats were stolen.

4. The limited economies of scale and high production and distribution costs for water and energy. This limits the investment capacity in beneficial nexus infrastructure, such as treated wastewater distribution to the kunuku's.

5. Regime barriers from the WEB and OLB, discouraging investments in private nexus technologies such as decentral reverse osmosis drinking water production and wastewater treatment plants.

6. The low access to knowledge, capital and irrigation infrastructure of farmers. These barriers complicate the professionalisation of the food system and reducing its ecological impact.

7. The expected growth in population and tourism numbers. This prioritises daily security of supply and limits the long-term sustainability focus of the water and energy provisioning regime.

8. The poor state of road infrastructure, particularly in rural areas. This constrains the growth of rural areas, particularly agriculture and potential aquaculture farms.

Opportunities for integrating the water, energy and food systems are:

1. The increasing and secure supply of treated wastewater from the WEB. This can provide a valuable source of irrigation water to farmers.

2. The increasing share of renewable and cheap electricity as the capacity of renewable generation and battery storage is expected to reach 80% in 2021.

3. Shared basic principles between stakeholders, such as the appreciation and wish to conserve Bonaire's ecological assets, sustainability as an opportunity for growth and reducing costs of living, and effective, stable and transparent governance enabled by a growth in human capacity and knowledge. Furthermore there is an increasing awareness of the connectedness of the water, energy and food systems among stakeholders.

4. New opportunities for decentralised solar PV growth and the more equal regulation of water and electricity generation and distribution tariffs by the ACM after changes in the BES Electricity and Drinking Water Law. Furthermore promising new WEF-nexus technologies are developing such as algae and biofuels.

3. What are recommendations for possible pathways that can lead towards water-energy-food nexus governance?

Three transition pathways have been proposed in section 6.3: 1. Human capacity and innovation development, 2. Ecosystem management plan and 3. Sustainable tourism. These pathways lay out different ways of reaching the shared vision for Bonaire and achieving WEF-nexus governance. Particularly the first two pathways can be recommended to reach WEF-nexus governance. The demand for human capacity and knowledge development is present with many nexus stakeholders. Integration of the human capacity development programmes is recommended to achieve scale benefits, increasing professional networks and to experience participation with other sectors early on through collaborative learning. The development of project management capacity can help explore and mature promising technological niches for the WEF-nexus. The ecosystem management plan can provide knowledge on ecosystem dynamics, guide spatial design and identify the ecological system boundaries wherein WEF-nexus practices can be developed. Data collection can provide a factual basis for research and the evaluation of cross-sectoral policies.

What are the opportunities for a sustainable transition in the water-energy-food nexus in Bonaire?

The opportunities for a sustainable transition in the water-energy-food nexus in Bonaire are as follows. First, the three recommended transition pathways are ways of contributing to a sustainable transition in the WEF-nexus. Integrated human capacity and innovation development can provide decision-makers and other stakeholders in the WEF-nexus with the knowledge, means and network to steer and connect sustainable transitions. An ecosystem management plan can be constructed within an existing legal framework and if properly enforced, lay out integrated spatial development of Bonaire's natural resource use. Sustainable tourism can provide capital, awareness, improvements in infrastructure and an increased demand for high-quality local

produce if done properly. Second, the continuation of the Transition Management Cycle with a participatory approach can identify and engage frontrunners willing to engage in the sustainable transition of the WEF-nexus.

The research goal of this thesis was: **To investigate if and how a water-energy-food nexus approach can be of value to guide Bonaire in their sustainability transitions**. As argued in chapter 7, the WEF-nexus approach can be of value to guide Bonaire in their sustainability transitions. The WEF-nexus approach taken in this thesis combined systems theory and transition management theory to analyse the socio-technical water, energy and food systems, their relationships, their connection with the larger socio-ecological system, barriers for change, opportunities, envisioned future and possible transition pathways. It enabled a view on the main outlines of differences and similarities for integration in regard to technical complexity and governance. Being aware of these differences and similarities can provide guidance in Bonaire's sustainability transitions, as it allows for the identification of barriers and opportunities for change present in the WEF-nexus.

A CONTEXT FOR THE WATER-ENERGY-FOOD NEXUS IN BONAIRE

Tourism is the largest private provider of jobs, as seen in table A.1. This table contains a list of job categories relevant to the WEF-nexus.

Public administration and government services	1610
Tourism	1320
Healthcare	1250
Construction and industry	1120
Trade	1010
Transport and storage	700
Education	600
Industry	580
Water companies and waste management	30
Energy supply	30
Agriculture, forestry and fishing	20

Table A.1: Amount of jobs per category 2018 (Centraal Bureau voor de Statistiek, 2018a)

The small size of Bonaire (20.100 residents) has created a culture where quickly one knows another. As shown in table A.2, the origin of Bonaire's residents is quite different (Centraal Bureau voor de Statistiek, 2018b). This is changing rapidly due to the continuing immigration resulting from the growing tourism industry.

Bonaire	39%
Dutch Antilles and Aruba	21%
South- and Middle America	19%
European Netherlands	14%
Other	5%
United Stated and Canada	2%

Table A.2: Country of birth 01-01-2017

B OBJECTIVE TREES

Figure B.1 contains an objectives tree of the water system comprised of the different goals elicitated in literature, whereby a sustainable water system is the main goal. The supply of drinking water is secure and meets the increased demand. The hydrological characteristics of Bonaire are understood and measured. This knowledge and data is used to guide spatial planning for irrigation infrastructure and agricultural practices. Irrigation infrastructure is properly maintained and is able to capture sufficient rainwater to recharge groundwater levels and provide water for agricultural purposes. Wastewater is properly collected, treated and consistently available to customers for a fair price. Clear and fair rules are made on the distribution of treated wastewater between hotels and farmers.

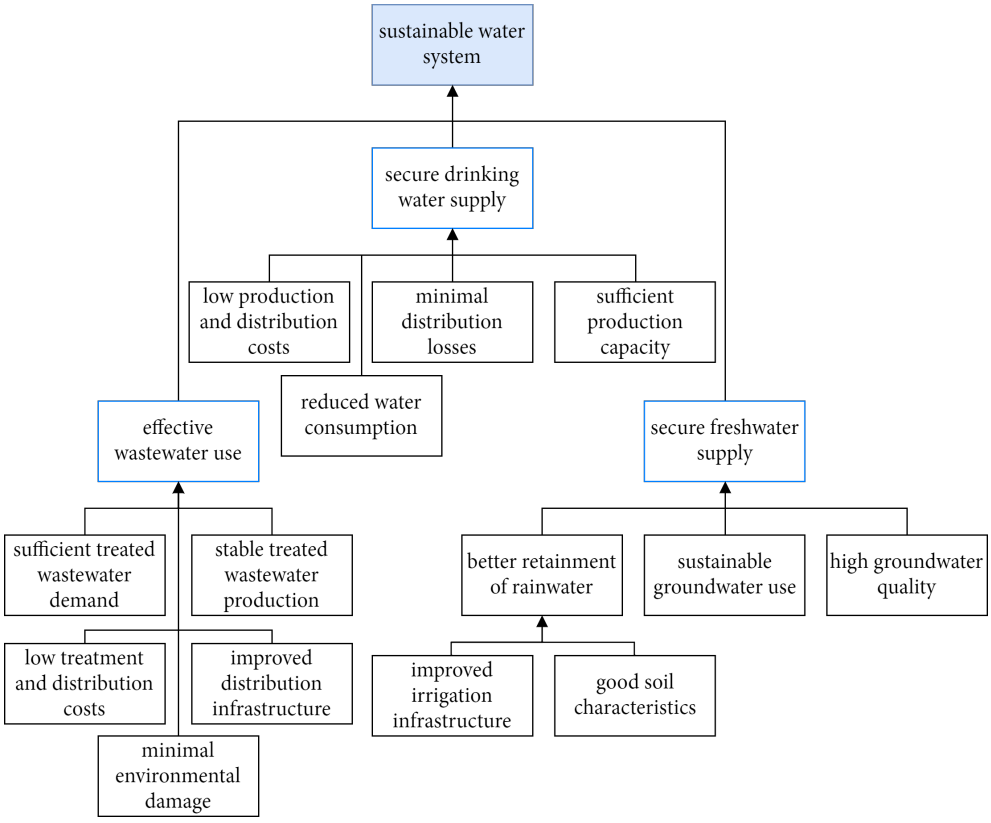


Figure B.1: Shared objectives tree water system

Figure B.2 contains an objectives tree of the energy system comprised of the different goals elicitated in literature, whereby a sustainable energy system is the main goal. Future electricity supply is able to meet the increased demand and operate under affordable costs for consumers. The distribution grid has sufficient capacity to facilitate an 80% share of renewables consist-

ing of wind power, solar PV and battery storage facilities. Distribution losses are reduced by at least 50% to meet the current levels as in European Netherlands. Sustainable alternatives to fossil fuels are being produced locally in coordination with the water and food sectors.

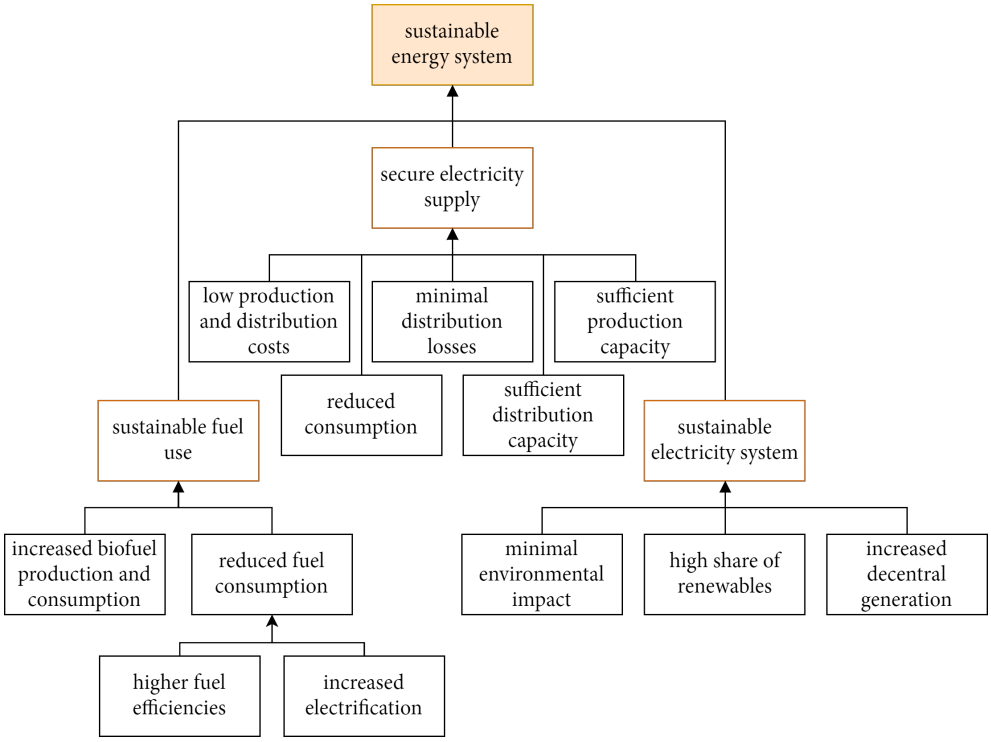


Figure B.2: Shared objectives tree energy system

Figure B.3 contains an objectives tree of the food system comprised of the different goals elicitated in literature, whereby a sustainable food system is the main goal. Local production of food and fish is increased and operated in a sustainable manner in regards to ecosystem health and water resources. All goats are enclosed in professional livestock farms with a secure livestock feed supply. There is a stable and financially feasible demand for high quality local products from the population, tourists and restaurants. Agriculture is a financially attractive way of life, with sufficient irrigation water, high quality infrastructure, good business conditions and a socially coherent and secure countryside. Fishing practices are professionalised with improved on-land infrastructure and the impact on the aquatic ecological resources is kept at a minimum through population and catch monitoring and through safe fishing practices.

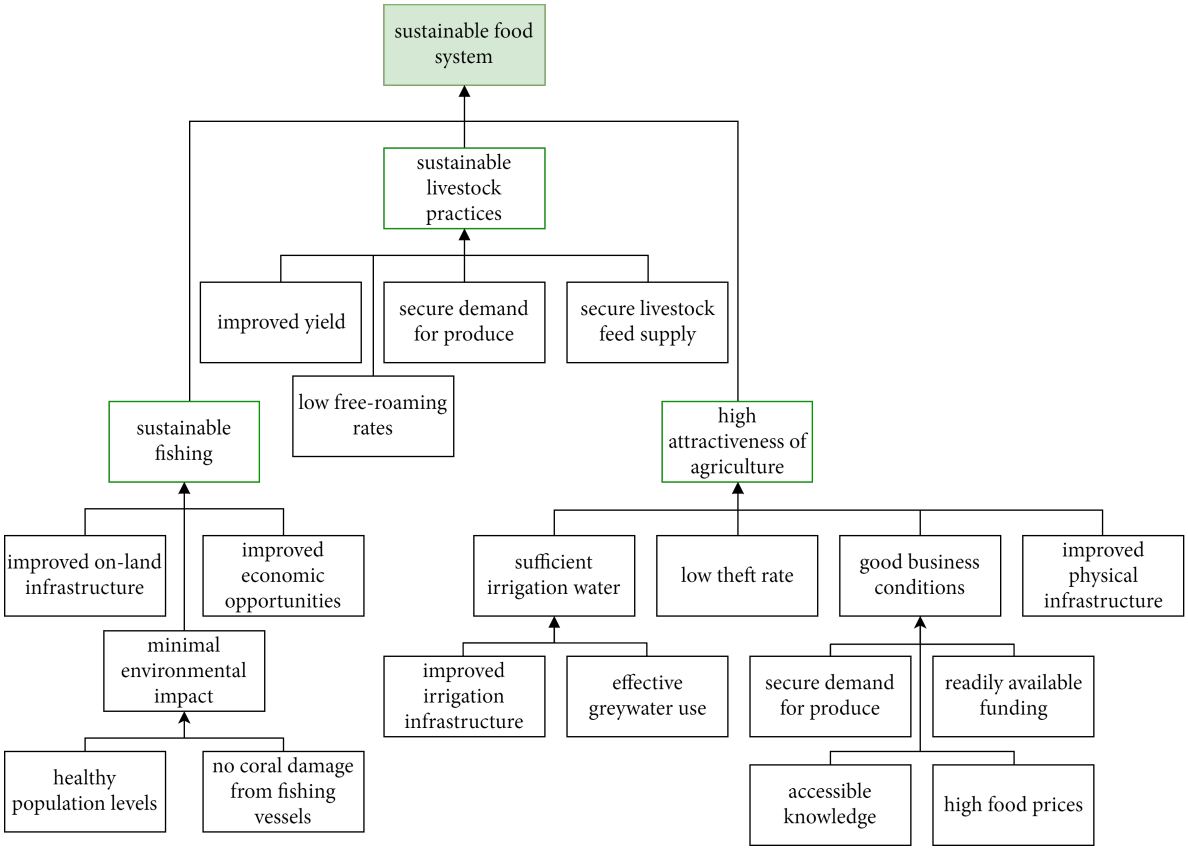


Figure B.3: Shared objectives tree food system

C STAKEHOLDER ANALYSIS

C.1 STAKEHOLDER INVENTORY

C.1.1 Governmental institutions

- Openbaar Lichaam Bonaire (OLB)
- Dienst Ruimtelijke Ordening Bonaire (DROB)
- Rijksdienst Caribisch Nederland (RCN)
- Ministry of Agriculture, Nature and Food Quality
- Ministry of Economic Affairs and Climate
- Ministry of Infrastructure and Water Management
- Authority for Consumers and Markets (ACM)
- Chamber of Commerce (KvK)

The **Openbaar Lichaam Bonaire** is the governing body of Bonaire, consisting of elected officials and public servants. A relevant department of the OLB is the DROB. This department is responsible for all topics concerning spatial planning, such as land permits, writing spatial development policy and monitoring buildings and building sites. The **Rijksdienst Caribisch Nederland** is a special department of the Ministry of the Interior and Kingdom Relations and is responsible for police, education, healthcare and social welfare in Bonaire. Multiple ministries work together in the RCN to implement their respective policies, such as the **Ministry of Agriculture, Nature and Food Quality** and the **Ministry of Economic Affairs and Climate** (de Vries, 2019). The **Authority for Consumers and Markets** is a public body responsible for supervision of competition law and consumer protection in the Netherlands. In the Caribbean Netherlands the ACM has a different role, as the small scale means that a fair marketplace where European competition policy is not always realistic (Bogaardt et al., 2015). Additional legal responsibilities include supervising the electricity and drinking water production, the postal and the telecom sector (Autoriteit Consument en Markt, 2019). The ACM balances the affordability, sustainability and reliability of the electricity grid and dictates the maximum tariffs the WEB can ask for electricity production and distribution. It slightly alters the maximum tariffs each year, whilst offering significant room to WEB for necessary investments in the distribution grid in view of the increasing electricity demand. The **Chamber of Commerce** is primarily focused on tourism in Bonaire, as it is the main economic driver of Bonaire and a major provider of jobs (Centraal Bureau voor de Statistiek,

2018a). Its two other economic focal points are the service sector and agriculture. Through the BES Chambers of Commerce and Industry Law the Chamber legally represents all businesses on Bonaire and advises the local government on economic development. The Chamber advises future entrepreneurs to know the characteristics of Bonaire when starting a business: "Because of the challenges of an island, a small community, the weather and the circumstances the utmost will be asked of an entrepreneur. The entrepreneur who wishes to begin and succeed needs to think innovatively, be creative with the circumstances and adjust to the Caribbean market.", whilst also recognising the opportunities of a emerging market (Chamber of Commerce, 2019, p.1). The Ondernemershuis (entrepreneur house) - a "one-stop-shop" for entrepreneurs operated by the Chamber - permits, information and advice is provided for starting and operating a business.

C.1.2 Businesses

- Bonaire Petroleum Corporation (BOPEC)
- Bonaire Hotel and Tourism Association (BONHATA)
- Cargill Bonaire
- Curoil Bonaire
- Contour Global Bonaire (CGB)
- Don Andres shipping
- Local SMEs
- PISKABON
- SELIBON
- Tourism Corporation Bonaire (TCB)
- Van den Tweel Group
- Water- en Energiebedrijf Bonaire (WEB)
- Wayaka advies
- Wolfs company

This list of businesses comprises the most relevant companies and organisations related to the WEF-nexus in Bonaire, and as a result of the strong connections of the tourism industry with the WEF-nexus, lists a significant portion of companies active in Bonaire. The **Bonaire Petroleum Corporation** supplies the diesel used in the diesel generators used for electricity production. BOPEC had serious operational and safety issues in 2018 due to severely overdue maintenance issues, endangering the generation of electricity in Bonaire. The storage tanks received last-minute repairs as they were in danger of leaking or breaking and severely damaging Bonaire's environment (Antilliaans Dagblad, 2019c). This led to the formulation of plans

by the Ministries of Infrastructure and Water Management, Economic Affairs and Climate and Interior and Kingdom Relations to construct a new storage tank park. **Bonaire Hotel and Tourism Association** is the official hotel and tourism association representing almost 100 resorts, hotels, apartments, diving businesses, restaurants and other tourism-related companies. Its objectives are to provide a sustainable quality tourism products and to function as a lobbying voice in the tourism sector. **Cargill** leases around 13% of Bonaire's surface area to produce salt for chemical purposes by evaporating sea water with sunlight (Figure 1.2). The salt flats are a major touristic attraction, as is the flamingo sanctuary located partially on their property. As it conducts its business on a significant portion of Bonaire, Cargill has a history of partnership with STINAPA and Sea Turtle Conservation Bonaire to protect nesting sites of flamingos and sea turtles. **Curoil** distributes all petroleum products for households, companies and small commercial users. LPG for cooking is one of its major products to both households as to restaurants and hotels. Additionally Curoil supplies airline fuel to Flamingo Airport Bonaire and provides bunkering services to a wide variety of ships (Curoil, 2019). **Contour Global Bonaire** is Bonaire's independent power producer. It operates a combined 14.4 MW diesel and 11.1 MW wind power generation plant and supplies the electricity to the WEB. CGB is part of Contour Global, a company that operates 101 power plants across 18 countries with a yearly revenue of $1,253 billion. **Don Andres** shipping is the sole shipping import company active in Bonaire, transporting everything apart from oil or goods transported by airplanes. **PISKABON** is the cooperative association of fishermen (and women). This cooperation has the goal of representing fishermen in decision making processes and voicing the issues the fishing community is facing. In recent years the institutional capacity and the status of PISKABON under individual fishermen has improved. This has in turn led to a more active and established role of PISKABON in decision making processes. **Local small and medium-sized enterprises** are mostly active in the service sector, often focused on tourism and sustainability (Chamber of Commerce, 2019). **SELIBON** is a public company responsible for waste management and cleaning public spaces on Bonaire. In 2010 the Masterplan Strategic Development set out ambitious goals to combat the increasing amounts of waste that were being dumped and strive towards maximum recycling of waste streams (Van Werven et al., 2010). Opportunities lie in the gasification of organic waste into biogas, bio-oil and compost, but realisation of these opportunities is still far away (Schelleman and van Weijsten, 2016). SELIBON has not yet achieved their ambitious recycling goals: burying waste in landfills remains the prevalent disposal method (Debrot et al., 2018). The **Tourism Corporation Bonaire** is the tourism management and promotion company for Bonaire and sets out tourism related goals and policies, provides information and collects data. The TCB is one of the driving organisations behind the 'Blue Destination' vision of Bonaire, together with STINAPA, BONHATA and the Chamber of Commerce.

C.1.3 Non-governmental organisations and local interest groups

- Boneiru Duradero
- Dutch Caribbean Nature Alliance (DCNA)
- Sea Turtle Conservation Bonaire (STCB)
- STINAPA (Stichting Nationale Parken Bonaire)
- Qredits
- Wild Conscience

Bonaire's history of conservation efforts correlates with the amount and the level of engagement of local NGOs and interest groups. **Bonairu Duradero** (Sustainable Bonaire) is a local advocacy group funded by the WWF that aims to raise awareness under Bonaire's residents for waste management, reducing energy and water use, local food production and sustainable entrepreneurship. It organises multiple initiatives each year, the most well known being the Clean Coast Bonaire initiative where volunteers take part in a large cleanup of marine litter. The DCNA is a nonprofit organisation that protects the natural environment and promotes sustainable use of natural resources on the Dutch Caribbean Islands. It supports the conservation organisations, in Bonaire that being STINAPA, in attracting funding, building institutional capacity, promoting nature conservation and provides an information database regarding those topics (DCNA, 2014). The DCNA manages a long-term trust fund initiated to secure funding for nature conservation, containing approximately $15 million (DCNA, 2014). **STINAPA**, a local NGO mandated by the government, manages Bonaire's two national parks: WSNP and BNMP. It operations include park management and ecological data collection and analysis. It organises several initiatives such as the Junior Ranger Program and it leads 300 certified lionfish hunters to protect the coral reefs in BNMP. **Qredits** is a micro-financing foundation active on Bonaire that supplies credit up to $50.000 to local entrepreneurs and provides personal coaching lessons to help entrepreneurs succeed in their mission. Since its establishment in 2015, Qredits has supplied over 100 micro-credits to local businesses. Finally, **Wild Conscience** supports governments and NGOs with nature conservation projects through environmental research and education. It's work together with the OLB, DROB and the Ministry of Economic Affairs and Climate into protected bat populations in Bonaire's caves has important implications in locations unsuitable for windmills due to the migration routes.

C.1.4 Knowledge institutions

- Stedin
- TU Delft
- Wageningen University

Finally several knowledge institutions are active in Bonaire. Again the history of conservation efforts and a gradual decline in ecosystem health grants plenty of opportunities to research changes in ecological systems and biodiversity. Furthermore there are clear needs for improvements in many aspects of the residents' livelihoods, such as high consumer prices, poverty and increased demand for electricity and water. Stedin is a distribution system operator in the Netherlands, but functions in Bonaire as a supplier of knowledge and capacity in managing electricity systems to the WEB. Wageningen University conducts research into amongst others: biodiversity, coral reef ecosystems, turtle populations, chemical pollutants, coastal management, mangroves and monitoring programs for fisheries. Wageningen University and the DCNA manage the Dutch Caribbean Biodiversity Database: the central repository of all biodiversity related research and data. Research from the TU Delft has primarily focused on coastal management and protection.

D STAKEHOLDER INTERVIEWS

This chapter will elaborate on the interviewees, interview questions and the answers received. Due to multiple reasons, such as the desire to remain an independent observer and given the small community on Bonaire, three interviewees wished to remain anonymous. Table 3.1 lists the interviewees consulted for this thesis. Semi-structured interviewing was the approach taken, therefore certain questions were not asked to all interviewees, and some were asked unique questions if the interview enabled that.

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