Ministry of Foreign Affairs

Nexus in Bahrein

OPPORTUNITIES FOR DUTCH COOPERATION

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IN BAHRAIN

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ACKNOWLEDGEMENTS

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INTRODUCTION

UNDERSTANDING AND MANAGING THE COMPLEX INTERACTIONS BETWEEN WATER, ENERGY AND FOOD

Water, energy and food are the most essential recourses for any society to flourish. The ever-increasing global population together with the developments related to the climate change constitute challenges to these resources that need to be addressed in order to pave the way to a sustainable future for the next generation.

Water, energy and food are the three central topics of Dutch expertise. We are world leading in these three fields, and our engineers are able to integrate them when offering our services worldwide.

The Gulf-region is preparing itself for the future. Many vision papers have been written. It is clear the role of fossil energy will come to an end, that other methods to obtain fresh water have to be developed, not only for washing and drinking but even more important for agriculture.

Bahrain and the Netherlands share quite a history of innovative operations. Most prominent of our joint achievement is the crossroad to Saudi built by the Dutch firm Ballast. But there is so much more. Apart from the cooperation in the energy field I like to mention the spectacular land reclaiming projects by our dredging companies, that give Bahrein such a pleasant outlook.

Very visible is the Dutch contribution on agriculture. It is a joy to see so much Dutch cheese, vegetables and meat in the Bahraini supermarkets. But far more important is our expertise in assisting Bahrain to set up its own agricultural production. Most of the healthy, fresh homegrown Bahraini products, eggs, dairy, veggies, have a clear link with Holland.

Bahrain is the home for quite a number of Dutchmen, active in many fields, services, in Bahrain but also in parts of Saudi Arabia. The rating for working and living brings Bahrain in the top of the Gulf-countries, in the same league as Singapore and even Holland.

The coming years the Dutch focus in the Gulf will be on water, energy and food. We hope to get active partners in Bahrein to work in this direction. The promotion of these three themes will also be central at the Dutch pavilion at the Dubai2020 World-exhibition.

I really hope many Bahraini's will join me there.

Frans Potuyt
Ambassador of the Kingdom of the Netherlands

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Citation: Embassy of the Kingdom of the Netherlands in Kuwait and Bahrain (2019) Water-Energy-Food Nexus in Kuwait.

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- This first version was produced in April 2019 -

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1. Abbreviation List

AWG	Atmospheric Water Generation
CAGR	Compounded annual growth rate
CCGT	Combined Cycle Gas Turbine
CSP	Concentrated Solar Power
ED	Electrodialysis
ESCO	Energy Servicing Company
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GMO	Genetically Modified Organism
GMOs	Genetically Modified Organisms
IoT	Internet of Things
LEED	Leadership in Energy and Environmental Design
MD	Membrane Distillation
MED	Multi-Effect Distillation
MSF	Multiple Stage Flash
MSW	Municipal Solid Waste
MVC	Mechanical Vapour Compression
NEEAP	National Energy Efficiency Action Plan
NOGA	National Oil & Gas Authority
PV	Photovoltaic
RAS	Recirculating Aquaculture System
RO	Reverse Osmosis
SCE	Supreme Council for Environment
SEU	Sustainable Energy Unit Kingdom of Bahrain
T&D	Transmission & Distribution
UNDP	United Nations Development Program
WEF	Water-Energy-Food
Voluntary National Review	VNR
WtE	Waste to Energy
WTO	World Trade Organization
WWTP	Waste Water Treatment Plant

2. Introduction

2.1 Report objective

As the WEF Nexus has risen on the agenda of various GCC countries, the Dutch government has developed partnerships with GCC governments on this strategically important topic. The Dutch government is looking to establish a bilateral cooperation on the Nexus thereby enabling business to business (B2B), knowledge to knowledge (K2K) and government to government (G2G) cooperation.

With the rising challenges to meet its nationals' demands, Bahrain published several initiatives and strategies to help meet its water, energy and food security. The objective of this report is to identify the status of Bahrain's water, energy and food security with respect to the WEF Nexus. This would be particularly in relation to the availability of primary freshwater, energy and food resources along with the challenges faced.

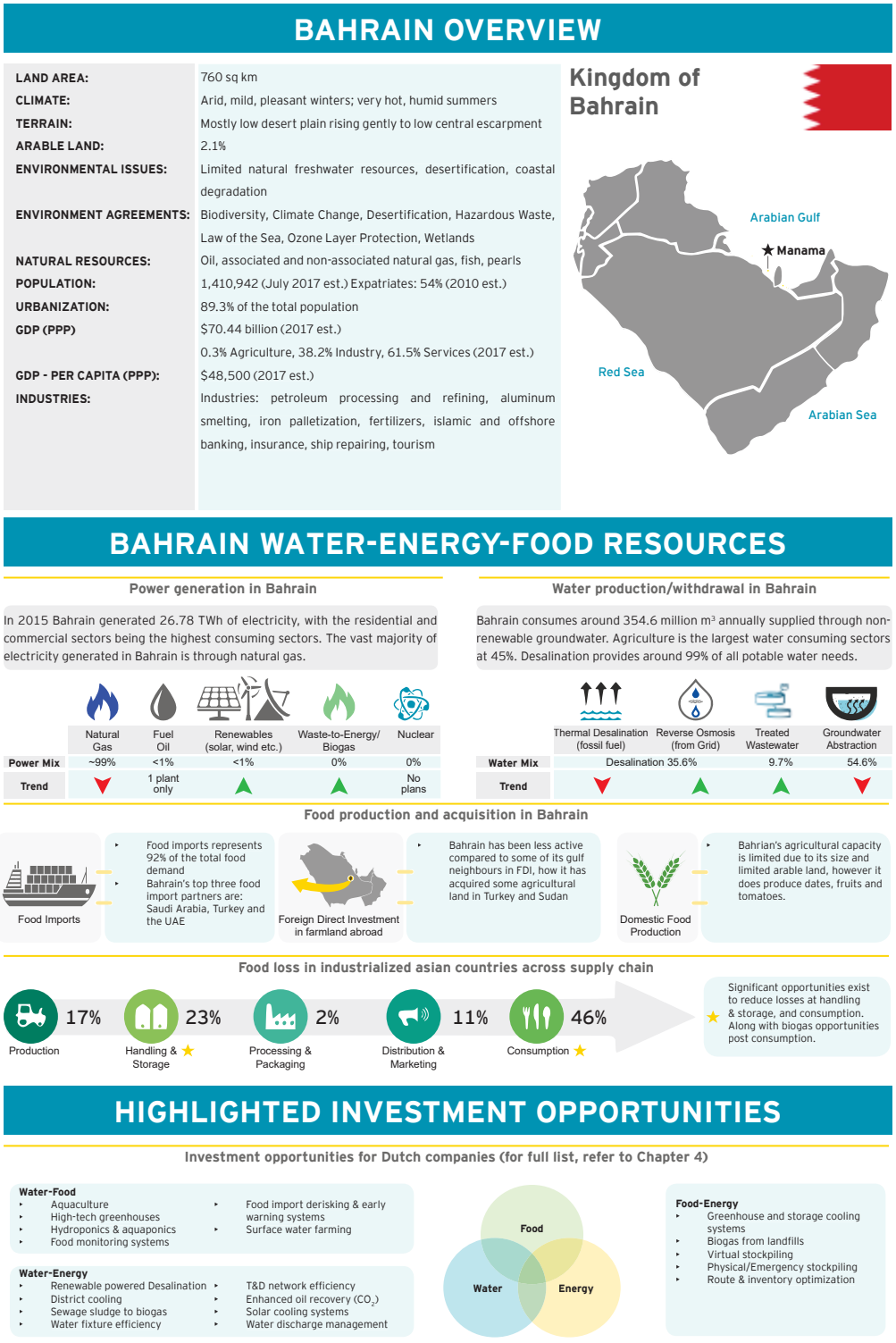
Thereafter, it provides a snapshot with respect to what national strategies are in place and what technologies/practices are implemented across each intersection of the Nexus, with a particular focus on food. The report concludes by highlighting some of the possible investment opportunities for Dutch companies in Bahrain and the engagement channels that can be utilized.

2.2 Summary

Understanding Bahrain's situation with respect to the Water-Energy-Food (WEF) Nexus helps provide insight on the type of initiatives and investment opportunities that would be applicable to the country.

Figure 1 provides a summary on Bahrain including its different resources: power and water mix, food production and acquisition. It also highlights some of the investment opportunities with respect to different aspects of the WEF Nexus: Water-Food, Water-Energy and Food-Energy. A comprehensive list of investment opportunities can be found in chapter 4.

Figure 1 Bahrain Overview



2.3 The Water-Energy-Food Nexus

The Water-Energy-Food Nexus is the inextricable link between, water, energy and food: the actions in one area often have an impact on the others. For this reason, the WEF-Nexus approach has gained significant traction over the years as a holistic method of resource management and sustainable development. Figure 2[1] and Figure 3[2] have been developed to illustrate the food security and water security tradeoffs for the GCC, respectively. Information specific to Bahrain's market and resources was presented where applicable.

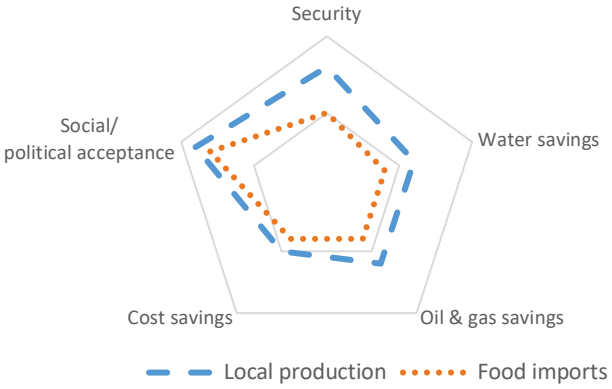
Figure 2 Food security tradeoffs in the GCC[1]

How secure are the country's food sources? Are they resilient against climate and market shocks?

- Food imports are more prone to climate and market shocks as demonstrated by the 2007/2008 Global Food Price Crisis
- Bahrain's local food production is constrained by a number of factors, including its climate conditions, limited arable land, and increasing population
- As a small country, Bahrain has relatively limited bargaining power in international food markets

Is there political and social support for the method of food production and acquisition? Is it in alignment with the strategy and vision of Bahrain?

- Support is provided to farmers through grants , and is in line with various strategies/targets, including economic diversification, and food security
- Culturally agriculture is encouraged



How water intensive is the food production/acquisition method, is the water consumed locally, or is it virtual water?

- Local food production uses non-renewable and limited groundwater aquifers

What is the food production/ acquisition method cost? Are the costs likely to fluctuate?

- Local food production is much more expensive (when all factors considered) in comparison to food imports, however, more prone to price fluctuations due to market and climate

How energy intensive is the food production/acquisition method, considering the complete value chain of a food product?

- While food imports require energy, it is not Bahrain's
- The need to desalinate local brackish aquifers makes local food production energy intensive

[1] Figure 2 is based on EY internal analysis
[2] Figure 3 is based on EY internal analysis

Figure 3 Water security tradeoffs in the GCC[3]

How secure are the country's water sources? Are they resilient against climate and market shocks?

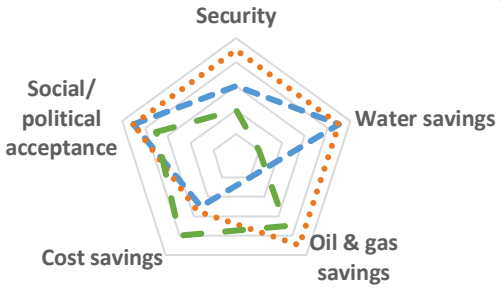
- Renewable powered desalination is more secure in the long-term, because it decouples water from natural gas
- Groundwater extraction is prevalent, however aquifers are depleting faster than their regenerative capacity

Is there political and social support for the method of water production and acquisition? Is it in alignment with the strategy and vision of Bahrain?

- Government targets to diversify Bahrain's energy mix inadvertently support non-fossil fuel desalination
- Strong government awareness on need to scale back groundwater extraction, though opposition will exist by

How does the water production/acquisition method impact domestic water resources?

- Desalination in all forms enhances water availability, while groundwater extraction depletes it



What is the water production/ acquisition method cost? Are the costs likely to fluctuate?

- Desalination is energy-intensive, and the cost will vary as energy prices fluctuate, but likely to decrease with time, as cost of renewables continues to drop, and natural gas prices go up, making renewable powered desalination more attractive

How resource intensive is the water production/acquisition method?

- Renewable powered desalination does not require natural gas, thereby presenting a large national energy saving

Fugure 2 and Figure 3 illustrate conceptual, what-if scenarios of various supply side interventions in the GCC with respect to food and water security. Due to similarities in the region, the water and food tradeoffs are quite similar. There are small differences which are dependent on the country's growth and the direction of its future strategy. If analyzing food security, Bahrain has to look at fundamental tradeoffs associated with different food security strategies. For example, a strategy of local food production relative to food importation is signficantly more water intensive and energy intensive, as local brackish aquifers require some level of desalination. Consequently, while local food production provides greater security and potential cost savings, energy and freshwater are major constraints that need to be addressed.

In the case of water security, a strategy of renewable powered desalination relative to traditional cogeneration is more expensive in the immediate term, though providing greater long term security (and potentially lower costs) as it decouples water from natural gas.

As Bahrain looks to expand its local food production capacity, it must address the associated constraints of food, water and energy. Strategies, policies, and initiatives tackling such constraints are explored in section 2.6.

2.4 Background context

A small desert island, the Kingdom of Bahrain was one of the earliest oil producers and refiners in the region. With the discovery of oil in 1932[3], Bahrain transformed from a traditional trading port island to a modern and well-developed nation. This transformation resulted in major socio-economic and environmental changes, which continue to this day. The population and economic growth that followed, depicted in Figure 4[4] and Figure 5[4] led to an increase in demand for resources that far exceeded the country's natural carrying capacity. By 2050, the population is estimated to grow by a further 56%, reaching 2.3 million[4], further straining the country's scarce natural resources.

Figure 4 Population growth in Bahrain since 1960[4]

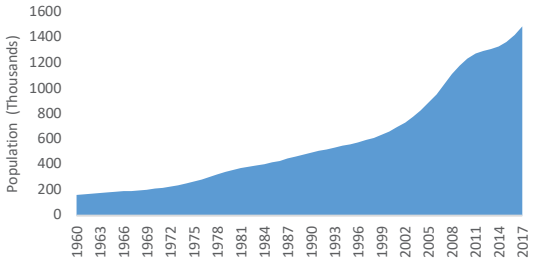
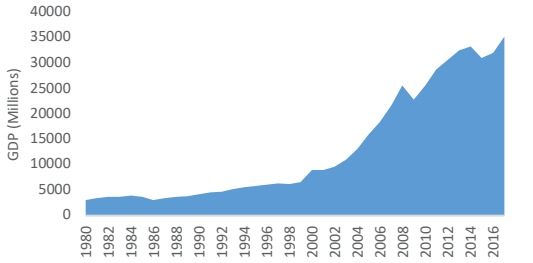


Figure 5 GDP in Bahrain since 1980 in USD current[4]



Though Bahrain began oil production and refining earlier than its Gulf neighbours, its relatively low oil and gas reserves (0.1%[5] of the world's proven natural gas reserves) indicated the need to diversify its economy early on. Nevertheless, Bahrain remains largely energy independent enabling the dry and arid country to meet its potable water needs via fossil fuel powered seawater desalination.

The result is that Bahrain is heavily reliant on its fossil fuel and fossil aquifer resources for maintaining its water and food security. This makes it vulnerable to stresses like fluctuating oil prices, population growth, increasing standards of living and climate change. Although fossil fuel and food price linkages are a global phenomenon, the interdependence of the two is even more severe and critical in Bahrain and highlights the importance of adopting a water-energy-food (WEF) nexus (the Nexus) approach when considering and addressing the country's future development.

The Kingdom of Bahrain is an archipelago of 40 islands in the Arabian Gulf, nested between the Eastern coast of Saudi Arabia, and the Qatari peninsula. Bahrain consists of five governorates: Al-Manamah (Capital), Muharraq, Al Janoubya (Southern), Al Wusta (Middle) and Ash-Shamaliyah (Northern), where each governorate is divided into constituencies[6].

[3] NOGA, Oil & Gas History
[4] The world Bank, *Population growth and GDP in the Bahrain,* 2018
[5] BP Statistical Review of the World Energy, July 2017
[6] UNDESA, Bahrain Company Profile

2.5 Bahrain resources

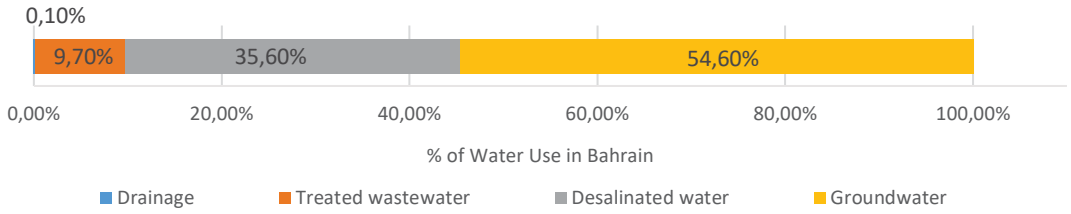
2.5.1 Freshwater

2.5.1.1 Current Outlook

The kingdom's name 'Bahrain', meaning 'the two seas' in Arabic, is believed to refer to the Arabian Gulf that surrounds the island, and the freshwater 'sea' that exists below it. Up to 1975, Bahrain's water demand was met entirely by its groundwater resources, which recharges through the lateral-underflow from the Dammam aquifer[7]. Bahrain's aquifer systems are considered to be a part of the Eastern Arabian Aquifer system, which connects between central Saudi Arabia and the Arabian Gulf waters[8].

Bahrain also used to withdraw its groundwater from a highly productive Khobar unit in Dammam and from the Umm er Radhuma Formation. Groundwater abstraction remained constant at 218 MCM until the year 2000. It began to decrease in 2010 for both the units by 56% and 75%, respectively as withdrawal for the agricultural sector decreased. This was mostly attributed to country's economic growth and the agricultural sector becoming less attractive for the nation's youth[9].In 2011, the total amount of Bahrain's water resources was 471.9 Mm^3, which met the 2011 water demand of 354.6 Mm^3. As the water demand continues to rise with the increasing population, Bahrain's water resources will not be sufficient. Figure 6 illustrates the breakdown of water distribution in Bahrain in 2013[10] in which most of Bahrain's water use (45%) is used for irrigation and livestock[11].

Figure 6: Bahrain's Water breakdown use in 2013[10]



With the increasing water demand and Bahrain's limitation of freshwater resources, Bahrain has turned to seawater desalination as a reliable source of potable water. Currently, Bahrain's municipal water supply mostly relies on desalinated water, which is either used directly or blended with groundwater. The primary desalination process used is thermal based, either MSF or MED[12]. This energy intensive process results in carbon emissions and brine discharge to the sea.

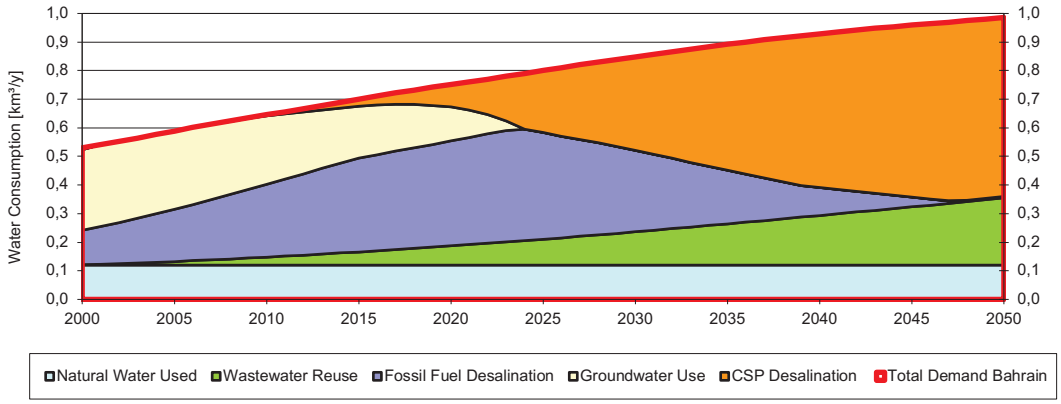
2.5.1.2 Future Outlook

Bahrain's water demand has been growing steadily and is expected to increase by 42% in 2050 from a 2010 baseline[13]. Figure 7 forecasts water demand, presenting a potential water mix that shifts away from

[7] FAO, Bahrain
[8] Ministry of Municipalities and Agriculture, Water use and management in Bahrain: An Overview
[9] UN-ESCWA and BGR, Chapter: 15 Gulf Umm er Radhuma-Dammam Aquifer System (Centre)
[10] IJEAT, The Water Demand Management in the Kingdom of Bahrain, 2013
[11] Sustainable Agriculture in the Arabian/Persian Gulf, 2018
[12] Zubari et al., Characterization of the Outfall area of MSF Desalination Plant in Bahrain, 2018
[13] Centre Energie, Water and Energy in the GCC: Securing Scarce Water in Oil Rich Countries, 2015

groundwater and fossil fuel desalination to focus more on renewable powered desalination and waste water reuse[14].

Figure 7: Projected scenario of water demand by source[14]



How will Bahrain maintain its water security in the future?

Supply: As the demand for domestic and agricultural water increases, renewable-powered desalination will begin to replace conventional fossil fuel powered technologies. In addition, the use of treated wastewater will increase to limit the depletion of groundwater.

Demand: Bahrain has implemented a number of strategies and programs that encourage and implement a greater demand side management efforts across all sectors – a trend that is expected to continue and expand. Efforts to limit the depletion of groundwater will increasingly be employed including the replacement of water intensive crops with higher value and more water efficient ones. Behavioural changes, application of new technologies (i.e. monitoring systems and increasing the efficiency of the T&D systems and solar systems in the desalination sector), removal/phasing out of subsidies and increasing tariffs will also reduce the overall demand for water.

In addition to supply and demand side initiatives, Bahrain will need to improve their response to climate risks, such as sea level rise, which the low lying country is at risk from.

2.5.2 Energy

2.5.2.1 Current Outlook

Bahrain's primary energy sources are fossil fuels based, oil and natural gas. In 2014, Bahrain's energy demand was met through its fossil fuels resources, 17% from oil and 83% from natural gas. As its energy demand continues to increase, Bahrain will also continue to rely on its hydrocarbon resources[15]. Bahrain's crude oil production comes from two fields: Bahrain field and Abu-Safa, a joint offshore field with Saudi Arabia, with a respective production of 17.6MUS Barrels and 56.2M US Barrels production and imported 76.7MUS Barrels in 2016. Bahrain also produced natural gas and associated gas with a respective production of 499,884 million ft^3 and 243,919 million ft^3 in 2016[16]. With the increase in energy demand

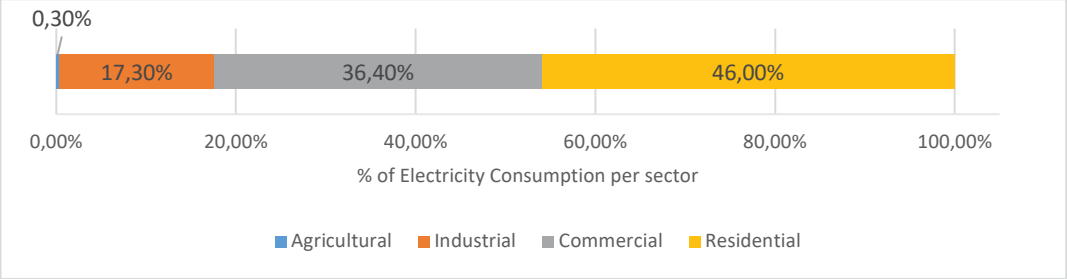
[14] Saif et al., *Water Security in the GCC Countries: Challenges and Opportunities,* 2014.
[15] SEU, National Renewable Energy Action Plan, 2017
[16] Bahrain in Figures, 2016

and Bahrain's limited fossil fuel resources in comparison to its neighbouring countries, there is a need to diversify its energy sources by including renewable energy and improving energy efficiency. Even with the recent discovery of the 80 million barrels of oil and the 13.7 trillion cubic feet of natural gas on Bahrain's west coast[17], it is unclear whether these resources are commercially recoverable. Some analysts suggest that the cost of digging up these resources may outweigh the benefit[18].

Consequently, the country's recent visions and national strategies, discussed further in Section 2.6, are centred on diversifying its national energy mix with a target of 5% renewable energy in 2025 and increasing it to 10% in 2035[15]. With KSA's recent solar plan to produce 200 GW of solar energy by 2030, the project will transform KSA into an exporter of solar energy[19] exceeding the total electricity generating demand of 66 GW approximately[20]. With the GCC interconnection completed in 2011 to integrate the electricity systems of the member states[21] and under the optimum fuel prices for both countries[22], Bahrain would be a potential candidate for solar energy import thereby helping Bahrain in achieving its national energy mix targets.

As Bahrain continues to develop its industrial and manufacturing sectors, its electricity consumption will continue to increase. It is estimated that energy demand will increase to 6.5 GW by 2030 from a 2016 summer peak of 3.42 GW[23]. Figure 8 shows Bahrain's electrical consumption by sector, with the residential and commercial sectors being the largest consumers[24]. Buildings consume most of the total generated electricity in the country, with 70%[25] going towards cooling.

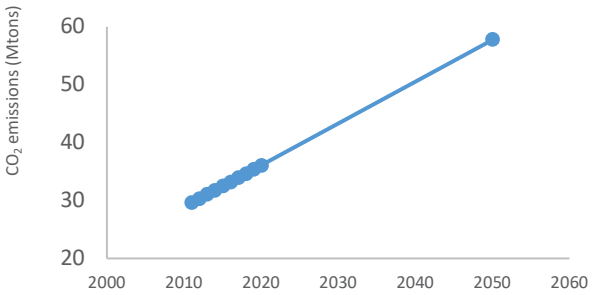
Figure 8 Bahrain Electricity Consumption by sector 2014[24]



[17] CNBC, Bahrain's Oil Discovery
[18] Forbes, Why Bahrain's Huge Oil Discovery might not provide the Windfall it was hoping for
[19] ArabNews, KSA to produce 200 GW of solar energy by 2030
[20] Atlantic Counci, Emphasis on Renewables in the National Transformation Program 2020, 2018
[21] KAPSARC, GCC Energy System Overview-2017, 2017
[22] KAPSARC, The costs and gains of coordinating electricity generation in the Gulf Cooperation Council utilizing the interconnector, 2018
[23] Renewable Energy Initiatives in Bahrain, 2018
[24] Bahrain Open Data Portal, Electricity Consumption from various sectors, 2014
[25] KAPSARC, An evaluation of High Energy Performance Residential Buildings in Bahrain, 2017

Based on the current electricity generation infrastructure, the increase in energy demand will also result in greater greenhouse gas emissions. Figure 9 displays the GHG emissions in Bahrain with a projected increase of 95% vs. the 2011 baseline[26].

Figure 9: Projected GHG Emissions until 2050 in Bahrain[26]



A significantly underutilized source of energy in Bahrain is waste to energy. There have been plans since to 2013 for the tendering of a 25 MW waste to energy facility at Askar, however the project has not been awarded to date[27]. More than 1.2 million tonnes of solid waste is generated annually and more than 4,500 tonnes of garbage is produced daily. Bahrain is considered to be one of the highest per capita municipal solid waste generators in the world with an estimate of 1.67-1.80 kg per person per day[28] with an estimate of 60%[29] of that waste being organic.

2.5.2.2 Future Outlook

As highlighted in section 2.5.2.1, due to the increasing electricity demand, it is projected that Bahrain's greenhouse gas emissions will increase by 95% vs. the 2011 baseline. For Bahrain to ensure energy security in the future, an adoption of a combination of the below measures and initiatives is proposed to overcome the existing and speculated future challenges.

How will Bahrain maintain its energy security in the future?

Supply: Renewable energy will steadily increase in contribution to Bahrain's energy mix with some projects either complete or in the pipeline. As per Bahrain's Vision 2030, the National Renewable Energy Action Plan and the National Energy Efficiency Plan, it aims to increase this share of renewable energy in the total energy mix by 5% in 2025 and 10% in 2035.

Demand: Bahrain is undergoing major revisions and changes to its tariffs, subsidies, policies and laws that will encourage greater demand side management efforts across all sectors – with private sector involvement and investment required. Initiatives will increase in the form of distributed energy resources (i.e. solar systems, electric water heaters etc.), mandatory green building codes, ESCO markets, as well as the greater adoption of energy saving smart technologies and systems across sectors. Behavioural changes, brought on by awareness and tariff reform will also reduce the overall demand for energy.

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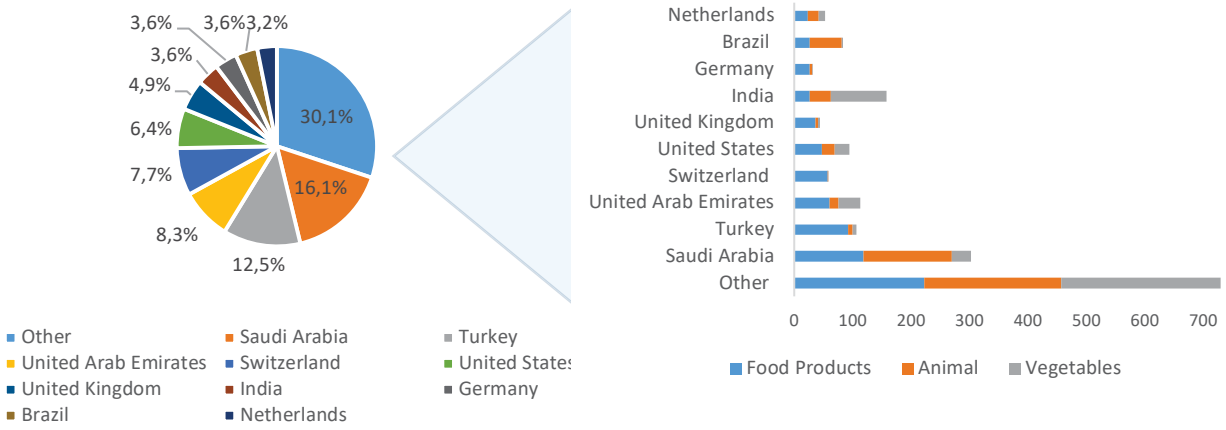
[26] Forecasting CO_2 emissions in the Persian Gulf States, 2017
[27] ECOWASTE, GCC Waste-to-energy, 2018
[28] Bioenergyconsult, MSW in Bahrain
[29] ECOMENA, Solid Waste Management in Bahrain, 2017

2.5.3 Food

2.5.3.1 Current Outlook

Bahrain's arid climate and lack of arable land prevents it from achieving food independence for its growing population. As such, the country has historically leveraged its economic stability and wealth to import the majority of its food requirements (92%)[30]. According to the Global Food Security Index (GFSI), Bahrain is ranked 37th globally with a score of 68.6%[31].

Figure 10: Bahrain's food import mix and import breakdown of the top 10 trading partners in 2016 (million USD)[32]

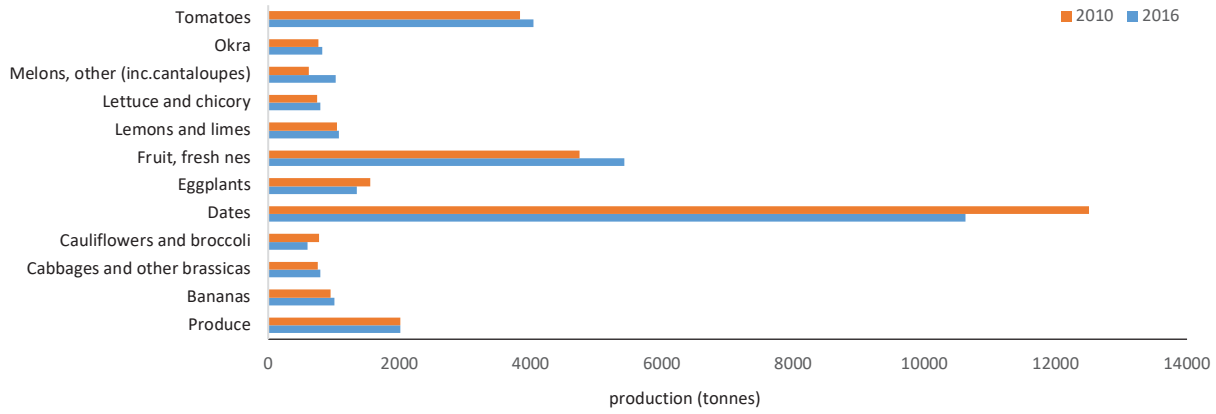


Bahrain's meets most of its food demands through food imports from various countries. Figure 10[32] highlights Bahrain's dependency on food imports with a total of USD 7.4 million in 2016, representing a compounded annual growth rate (CAGR) of 7.6% from 2010. In 2016, Bahrain imported 18% of its food from the Netherlands. These imports amounted to USD 57 million and were dominated by food products, with a smaller portion of animal, fruits and vegetables.

While Figure 10 illustrates the different food products Bahrain imports, it does produce a variety of crops within the country. Figure 11 highlights some of the fruits and vegetables Bahrain grows such as bananas, eggplants and lettuce with the bulk being the growing and harvesting of dates[33]. As Bahrain's population continues to increase, it will face the challenge of having enough arable land for growing fruits and vegetables. One of Bahrain's food security initiatives is to secure agricultural land abroad through foreign direct investment (FDI). Bahrain has done so in countries including Sudan[34] and Turkey[35].

[30] Gulf Business, Bahrain Food Imports, 2016
[31] EIU and The Economist, Global Food Security Index, 2017
[32] WTIS, Bahrain Food Imports, 2016
[33] FAO, Bahrain's Crops
[34] Bahrain News Agency, Agricultural Agreement between Sudan and Bahrain, 2015
[35] Daily Sabah Business, Foreign Agricultural Investments in Turkey

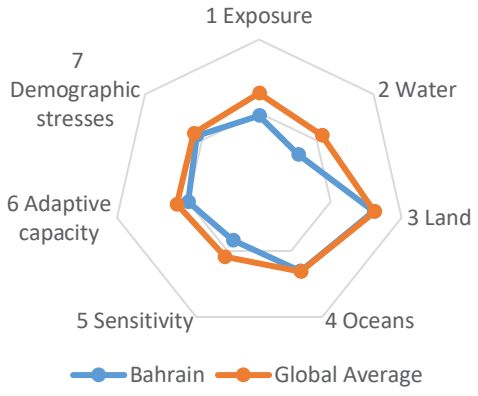
Figure 11 Comparison of Bahrain's produce production[33]



In addition to Bahrain's local food production, the kingdom has historically relied on its fisheries as a source of livelihood and food security. However, Bahrain's fish stocks have plummeted over the years, due to overfishing, unsustainable fishing practices (i.e. bottom trawling), and the destruction of reefs from dredging and other developments. Coral reefs play a pivotal role as nurseries to fish populations, and are particularly sensitive to changes in sea water such as salinity, temperature and acidity, exacerbated by climate change. As such, Bahrain initiated The Artificial Reef Project to combat biodiversity loss and improve long term fish stocks and food security. Under the project, artificially created corals were placed within key marine zones, providing habitat to nurseries, helping recover previously destroyed ecosystems[36].

Despite Bahrain's local food production, imports and foreign direct investment in, the country remains susceptible to food insecurity in the future. Its resilience to food security pressures is highlighted in Figure 12, particularly with respect to water, exposure and sensitivity.

Figure 12: Bahrain Food Security Index pressures[32]



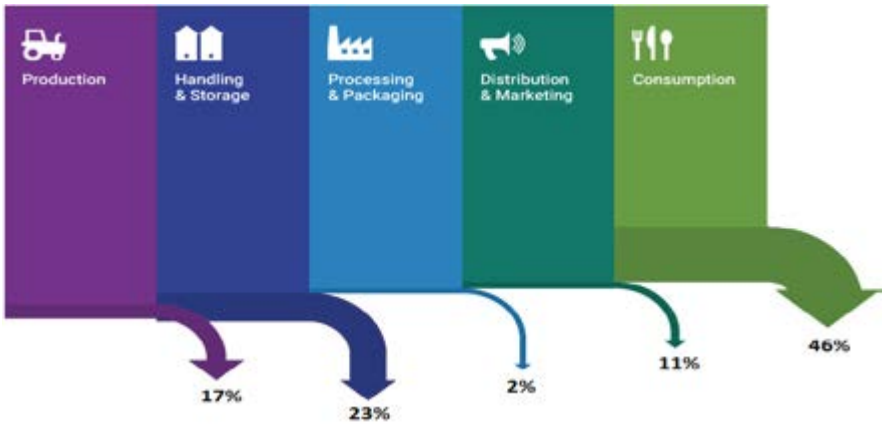
Pressure	Food Security pressure components
1. Exposure	Temperature rise, sea level rise, drought, flooding, storm severity
2. Water	Agricultural water availability, water quality
3. Land	Soil erosion, soil salinity
4. Oceans	Eutrophication/hypoxia, marine biodiversity and protected areas
5. Sensitivity	Food import dependency, disaster risk management, natural capital dependence
6. Adaptive capacity	Early warning measures, climate smart agriculture, National agricultural risk management system
7. Demographic stresses	Population growth, urbanization

[36] UNFCC, National Communication Report

2.5.3.2 Future Outlook

On the demand side, residential homes in Bahrain waste around 195,000 tonnes of food annually, 35.2% of the overall annual quantity of domestic waste in Bahrain[37]. Furthermore, as a major waste stream, food waste is an untapped resource for fertilizer and energy generation that is currently ending up in landfills with associated negative effects such as increased amounts of landfill gas. Figure 13 highlights the percentages of food lost across different stages in the supply chain. The majority of the losses lie in two stages: handling & storage, and consumption with 23% and 46% respectively[39]. To combat the increasing food waste, the Supreme Council for Environment and the local Hifzalnema Society, developed an initiative to raise awareness on the issue[38].

Figure 13 Food waste across the supply chain in industrialized Asia[39]



As Bahrain's population continues to increase, it will face a challenge in meeting growing demand in addition to the lack of sufficient arable land for growing fruits and vegetables domestically. For Bahrain to ensure food security in the future, an adoption of a combination of the below measures and initiatives is proposed to overcome the existing and speculated future challenges.

[37] Bizbahrain, Domestic waste in Bahrain, 2018
[38] GDNONLINE, Battling food waste in Bahrain, 2018
[39] M. Kummu et Al., *Lost food, waste resources: Global food supply chain losses and their impacts on freshwater, cropland and fertilizer use,* 2012

How will Bahrain maintain its food security in the future?

Supply: Food imports will remain important in Bahrain's food security strategy. Bahrain will continue to ensure its food security through food import processes as well as the further development of its agricultural industry. Bahrain will also look to consider climate and market risks more rigorously in its international food import strategy and adopt national risk management strategies such as physical stockpiling and early warning systems.

Domestic food production will also shift towards modernizing the agricultural sector across the value chain. Food production will become smarter and less resource intensive, leveraging more efficient approaches and technologies such as climate suitable crop selection, hydroponics, aeroponics, aquaponics, smart irrigation and climate control systems. All of which will be supplemented with production in the sea, through aquaculture developments.

Demand: Efforts to curb food wastage and loss will continue through better education/awareness and logistics. Storage and distribution of food will become more efficient, utilizing IoT to monitor, control and manage food quality and loss. Additionally, more food waste will be diverted from landfills to more productive uses, such as fertilizer production and waste to energy.

2.6 National strategies, visions and objectives

The run up to 2030 will witness a series of reforms and investments aimed at implementing the myriad visions and strategies of Bahrain. Although these strategies target different sectors, they all share similar overarching components: sustainable use of resources, diversification of the economy and sources of water, energy and food security, innovation, education and awareness.

National strategies, visions and objectives are detailed below, consisting of both supply side and demand side elements. WEF security is ultimately about building resilience. This requires diversifying the supply and demand strategies that complement one another and engaging the population in a meaningful way to change their current behaviours.

2.6.1 Federal Level

Figure 14 summarizes the main strategies, visions and plans within Bahrain developed to support the goals of Bahrain's Vision 2030. The country is moving towards researching and implementing initiatives to reduce its water consumption, increase its national energy mix, conserve its natural resources and continue to meet its nationals' demands currently and in the future. This strategy and direction falls in line with evaluating the water, energy and food Nexus for the country and would support initiatives that fall within it.

Figure 14: National level strategies and visions

2.6.1.1 Agenda 2030 and the SDGs[40]

The UN Agenda 2030 for Sustainable Development is the central UN action plan that embeds 17 Sustainable Development Goals and 169 targets that are critical for humanity and the planet. The successful implementation of Agenda 2030 is founded on efficient peer learning and knowledge sharing between nations.

Bahrain's Cabinet issued a resolution decree in 2015 (No.21) to establish a National Information Committee chaired by the Minister of Cabinet Affairs along with different government entities such as the Ministry of Finance, Foreign Affairs and Education in order to ensure the adoption of the Sustainable

Development Goals nationally[40]. Bahrain is one of the countries reporting their first Voluntary National Review (VNR) submission to the High-Level Political Forum. The VNRs provide a platform for partnerships and are intended to accelerate the implementation of the Agenda 2030 worldwide[41]. Bahrain's VNR report reflects on the achievements they had up to the year 2017 along with the recommendations the government of Bahrain has agreed to in alignment to the Sustainable Development Goals[42].

2.6.1.2 Paris Agreement (Intended Nationally Determined Contributions)[43]

Bahrain, among other parties to the UN Framework Convention on Climate Change (UNFCCC), have formally submitted their Intended Nationally Determined Contributions (INDCs), outlining their national circumstances and the post-2020 climate actions they intend and plan to take. Bahrain provided their plans and strategies across four categories: action with mitigation co-benefits, adaptation, adaptation action with mitigation co-benefits and the means of implementation for support contributions[43]. The INDCs came in advance of the Paris Agreement, which is a universal climate change agreement that required all parties to put forward their best efforts through nationally determined contributions and to strengthen these efforts in the coming years. The Paris Agreement's main objective is to strengthen the global response to the threat of climate change by keeping a global temperature rise for this century well below 2 degrees Celsius above pre-industrial levels, and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius.

2.6.1.3 Bahrain Economic Vision 2030[44]

Launched in 2008, Bahrain's Economic Vision 2030's main goal is to enhance the everyday life of Bahraini citizens and residents[44]. The vision revolves around having robust economic growth that benefits the country's people, an efficient and effective government and a thriving society. After the launch, the Economic Development Board, worked with the government and several entities to develop initiatives to improve national economic performance[45].

In an effort to meet the objectives set by the Economic Vision 2030 and drive the transition to a diversified economy, Bahrain's Economic Board announced that in 2017, they managed to attract 71 new companies to Bahrain with investments adding up to US $733 million. This is expected to increase job creation by 72% generating more than 2,800 local jobs in the next 3 years[46].

2.6.1.4 Government Action Plan 2015-2018[47]

The Government Action Plan reflects Bahrain's priorities across the four years from 2015 to 2018. The Government Action Plan is based on the principles of sustainability, transparency, justice and competitiveness with an objective to capitalize on the kingdom's resources and capabilities to meet citizens' needs. The Government Action Plan includes six categories: sovereignty; economy and finance; human development and social services; infrastructure; environment and urban development; and

[40] Bahrain eGovernment, Sustainable Development
[41] Sustainable Development Knowledge Platform, Voluntary National Review, 2018
[42] Sustainable Development Knowledge Platform, Bahrain's VNR Report, 2018
[43] Bahrain's INDCs submission to the UNFCCC, 2016
[44] Ministry of Foreign Affairs, Bahrain 2030 Vision
[45] Economic Development Board (EDB), Bahrain
[46] Economic Development Board, Delivering Growth Year after Year, 2018

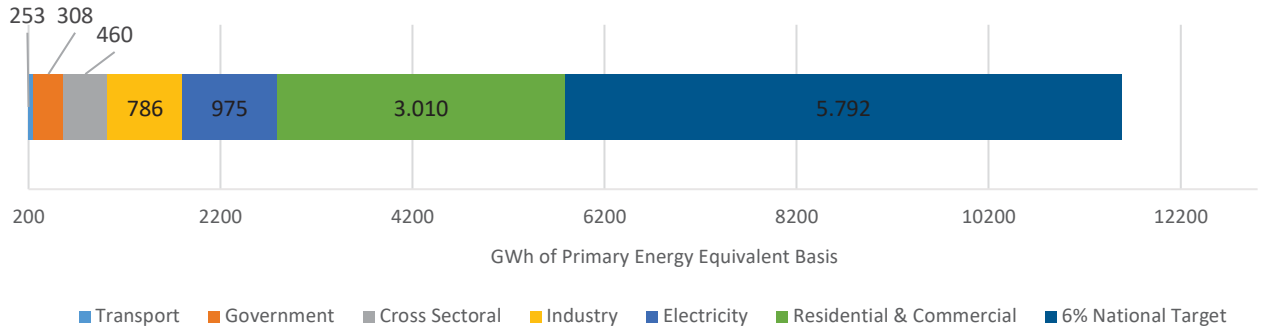
government performance[47] . After achieving 83% of the objective set out in Bahrain's Government Action Plan 2015-2018, several workshops resulted in the setting of 29 policies and 106 initiatives for the upcoming Government Action Plan from 2019 to 2022[48].

2.6.1.5 National Energy Efficiency Action Plan[49]

Launched early 2017, the NEEAP is led by the Sustainable Energy Unit and is in line with Bahrain's Vision 2030 and the Government Action Plan (2015-2018). The plan identifies specific plans and new initiatives across different sectors. It also sets national targets for energy savings and provides estimates of energy and monetary savings.

This national plan set a target of energy savings of 6% by 2025 based on technical and economic potential as well capacity to deliver energy savings. This set a reduction of energy consumption is expressed as a percentage of the average final energy consumption during the baseline period of 2009 to 2013. If the 6% national energy efficiency target is achieved, it is estimated that it will result in an energy savings of 5,800 GWh of primary energy equivalent in 2025, and a cumulative reduction in GHG emissions of 3.4 million tonnes of CO_2 [49]

Figure 15 Targeted energy savings in Bahrain by 2025 [49]



2.6.1.6 National Renewable Energy Action Plan[15]

Launched early 2017, the NREAP is led by the Sustainable Energy Unit. It supports the Vision 2030 and the Government Action Plan 2015 – 2018 and compliments Bahrain's regional and international commitments to the Paris Agreement, the UN's Sustainable Development Goals and the League of Arab States Renewable Energy Framework. The plan provides feasible renewable energy options for Bahrain, sets targets and proposes actions and policies to couple with the identified renewable energy options. Based on the current energy situation, resource potential and the economic feasibility of different renewable energy technologies, the NREAP set a national renewable energy target of 5% by 2025 and 10% by 2035[15].

2.6.1.7 Bahrain Net Metering Policy[50]

Bahrain's Net Metering Policy is one of the National Renewable Energy Action Plan's three policies, which allows individuals, companies and industries to install solar and other renewable energy systems on their

[47] Bahrain eGovernment, Government Action Plan (2015-2018)
[48] Alwatan, Update on the 2019-2022 Government Action Plan, 2018
[49] Sustainable Energy Unit, National Energy Efficiency Plan, 2017

properties [50] Approved in 2017 by Bahrain Cabinet (Resolution no. 2), Bahrain's Net Metering Policy supports the Vision 2030 goals, the Government Action Plan 2015-2018 and compliments Bahrain's international treaties such as the Paris Agreement and the UN Sustainable Development goals, specifically SDG 7 affordable and clean energy.

2.6.1.8 National Research Strategy[51]

Launched in 2014, the National Research Strategy is in line with the Vision 2030 and its objectives are to help turn Bahrain's economy into a knowledge economy, reduce Bahrain's dependence on natural resources, ensure the Kingdom's social, environmental and cultural well-being in the long term, improve the global health research's application to meet the medical needs of Bahraini citizens, advance the Kingdom's prestige regionally and globally and to provide Bahraini citizens with world-class education and research opportunities[51].

2.6.1.9 Bahrain National Environment Strategy[52]

Approved in 2006 by the Cabinet of Bahrain, the National Strategy to protect the environment was prepared by the Supreme Council for the Environment and the United National Development Programme (UNDP) in collaboration with relevant entities including research centres, universities and international experts. Different projects and initiatives were introduced for the implementation of the strategy[52].

In an effort to conserve Bahrain's Natural resources and comply with the National Environment Strategy as well as being in line with Bahrain's Vision 2030 and Government Action Plan, several committees and initiatives were set in place. These include the CFL Project to Rationalize Energy Consumption, Energy-saving LED Project, National Oil Spill Response Command Centre, Solar-powered street lighting and developing air-conditioning and refrigeration specifications[53].

2.6.1.10 National Biodiversity Strategy and Action Plan[54]

Launched in 2016, the National Biodiversity Strategy and Action Plan (NBAP) aims to improve the resilience of Bahrain's four ecosystems (marine, coastal, desert and agricultural) and to maintain the existing ecosystem services. The NBSAP shares the milestones and targets for the strategy from 2016 to 2021 such as protecting an additional 10% of Bahrain's territorial marine and coastal area and to improve seawater quality from wastewater and sewage discharge from municipal treatment plants by 50%[54].

[50] Sustainable Energy Unit, Net Metering Policy
[51] Higher Education Council, National Research Strategy, 2014
[52] Supreme Council for Environment, National Environment Strategy
[53] SCE, Our Efforts to Protect our Environment
[54] SCE & UNEP, The National Biodiversity Strategy and Action Plan

3. Bahrain WEF Nexus Snapshot

This chapter aims to provide a snapshot of the current state of the WEF Nexus within Bahrain. The chapter is structured according to the Nexus intersects of Water-Food, Water-Energy and Energy-Food. Though not exhaustive, the way in which WEF security is achieved in the country is captured through the Nexus Maps, illustrated in Figure 16, Figure 17 and Figure 18. The Nexus Maps help structure the complex interactions and interlinkages of the Nexus, providing a high level understanding of WEF dynamics and security. Meanwhile, Table 2,

Table 3 and Table 4 outline the various technologies and approaches currently utilized in Bahrain for each Nexus intersect in detail, coupled with corresponding initiatives and programmes within the past 5 years. The references for the initiatives can be found in Appendix A.

Table 1: Scoring criteria of WEF Nexus approaches/technologies

Approach/technology maturity		**Approach/technology growth potential**	
Score	**Description**	**Score**	**Description**
1	Non-existent	1	Declining growth
2	Interest/awareness present	2	No growth
3	Pilot project, investments made, or significant research on the area exists	3	Low growth
4	Emerging in the market (i.e. existing projects)	4	Medium growth
5	Well established in market	5	High growth

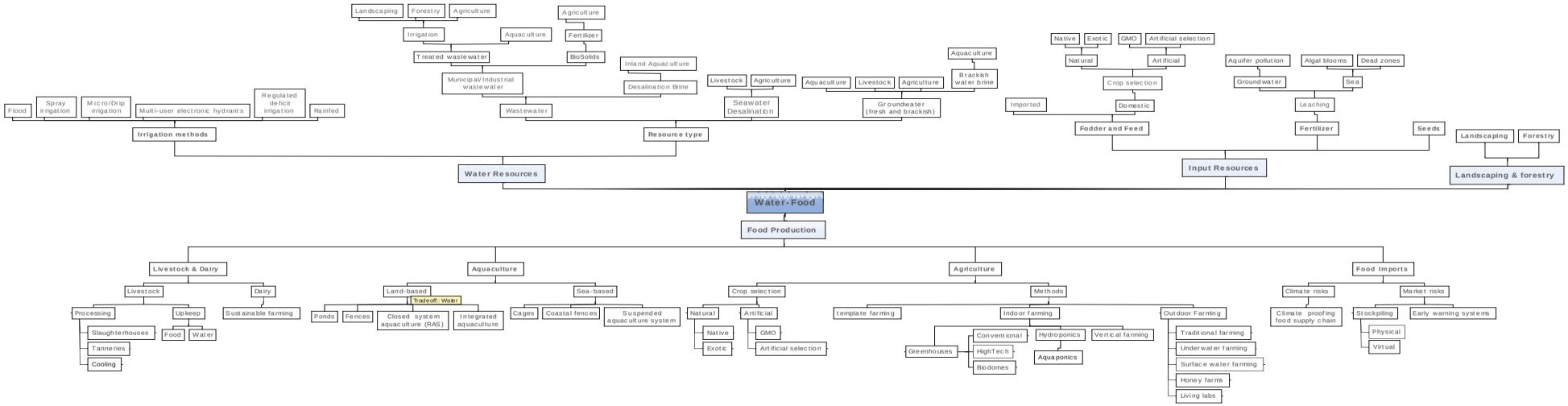
The strengths and limitations of each approach/technology are outlined and scored as per the criteria in Table 1. The criteria is based on maturity level and growth potential. Maturity level relates to how well-established a particular approach/technology is in the country while growth potential considers strengths and limitations (i.e. environment, laws and regulations, consumer preferences etc.). The scoring for each criteria were based on extensive research of the different initiatives and programs carried out across Bahrain. The scores are presented in Table 2,

Table 3 and Table 4 and were validated by expert opinion within Bahrain.

3.1 Water-Food

Figure 16 shows the GCC's Water-Food Nexus Map, which explores food production and its various inputs from the perspective of water, and Table 1 highlights Bahrain's initiatives in reference to the map. Various food production/acquisition methods are captured, including: livestock and dairy, aquaculture, agriculture and food imports. These categories are further broken down by practice of production. The required input resources includes the material used in food production such as fodder and feed, fertilizer and water. Water resources were covered in a separate section of the map due to the extensive consideration of water resources ranging from irrigation methods, wastewater, seawater desalination and groundwater.

Figure 16: GCC Water-Food Nexus Map[55]



[55] Figure 16 is based on EY's internal analysis

Table 2: Bahrain Water-Food Nexus Initiatives

SN	Category 1	Category 2	Approach/ technology	Approach strengths	Approach limitations	Maturity	Growth Opp.	Initiative(s)/Programme(s)
WF -1	Livestock, Poultry & Dairy	Livestock (cow, sheep, goat and camel)	Livestock protection & development	- Improved licensing and monitoring of veterinary products/medicine results in higher product quality, lower disease outbreaks and therefore higher yields	- No significant limitations	4	3	-Quality Standards & Exporter Supply Chain Assurance System, Bahrain Livestock Company
WF -2			Sustainable breeding	-Breed selection: particular breeds can be less resource intensive (i.e. water) and more heat tolerant --Breeding method: certain breeding methods such as artificial insemination can be more sustainable, reducing the need for livestock imports and increasing local production	- Consumers may prefer particular breeds based on quality - Farmers are inclined to raise those with the highest profit margins	3	3	- Use of artificial insemination, MUN, UN & FAO -Supporting the livestock sector, FAO
WF -3			Production systems	- The design and choice of particular production systems (meat or dairy production) can reduce costs, disease outbreaks, environmental impact and resource requirements	In Bahrain, certain production systems are constrained by: - Climate (i.e. temperature, rainfall etc.) - lack of natural shrub/vegetation for grazing	3	3	-Capacity building for emergency preparedness , FAO, 2016
WF -4			GMOs	- Opportunities to improve yields through disease resistance, saline water tolerance and heat tolerance	- Public hesitation/resistance towards GMOs	1	4	- No Initiatives
WF -5		Poultry	Farming of poultry	- Suitable for present climate conditions - Less resource intensive than livestock - Relatively low maintenance costs	- Prone to disease outbreaks due to poor ventilation - Low profit margin on poultry	5	3	- Poultry farms are widespread throughout Bahrain with various setup types (i.e. commercial farmed eggs vs. free-range organic eggs) -Goat farms, peninsula farms
WF -6	Agriculture	Crop Selection	Native and climate compatible species	- Salt and heat tolerant crops - Reduced need for freshwater - Opportunities for use as fodder, reducing irrigation requirements - Synergy with voluntary and mandatory green building standards	- Limited variety of crops - Legal challenges in registering new crop varieties	3	4	- Use of salt crops for animal feed, Desert Research Centre, 2015
WF -7			Seaweed and macro-algae farming for animal feed	- Low input requirement - High in nutrient content - Opportunities for use as fodder, reducing irrigation requirements	- Requires controlled conditions - May prove difficult to scale up	3	5	- Public perception of algal consumption as a food alternative, University of Bahrain - Research on the challenges of largescale macro-algae cultivation, Centre for Sustainable Development
WF -8			Domestic production of fodder and feed	- High demand for fodder - Reduced reliance on imports - Emergence of fodder irrigated by saline waters	- Fodder cultivation competes with other crops for water resources - Fodder crops are generally water intensive (such as Rhodes grass)	5	2	- 30,000 metric tons of forage per year, Delmon Poultry Company
WF -9			Artificial (Artificial Selection & GMOs)	Opportunities for improved yields, and disease, draught, heat and salt resistance	- Public hesitation/resistance towards GMOs	3	4	Use of GMO crops, Peninsula farms

SN	Category 1	Category 2	Approach/ technology	Approach strengths	Approach limitations	Maturity	Growth Opp.	Initiative(s)/Programme(s)
WF -10		Greenhouses and Hydroponics	High-tech greenhouses	- Increased crop productivity - Improved water and energy efficiency - Increased crop variety	- In extreme heat, acts as a heat trap killing crops - Does not facilitate pollination	1	5	-No initiatives
WF -11			Seawater greenhouses	- Creates ideal growing conditions for crops while producing fresh water for irrigation	- Fine tuning of complex system - Potential aquifer contamination from seawater	1	4	- No initiatives
WF -12			Bio-domes	- Energy & cost efficient - Synergies with voluntary & mandatory green buildings standards - Can serve educational purposes	- Systems need to be thoroughly designed and fine-tuned - Significant maintenance is required	1	4	- No initiatives
WF -13			Hydroponic/ Aeroponics farming	- High irrigation efficiency compared to traditional methods - Increased crop productivity - Reduced use of pesticide & fertilizer	- High CAPEX - Risk of water microorganisms contamination (hydroponics) - Does not facilitate pollination	4	5	- Use of hydroponic farming in Bahrain, Peninsula Farms - 1,000 m^2 aeroponic system for growing tomatoes, Peninsula Farms -Success of hydroponic farming in Bahrain, Ecomena
WF -14			Aquaponics	- Reduced water consumption - No addition of fertilizer required - When combined with hydroponics, reduces overall water requirements of system	- High CAPEX - Needs to be coupled with hydroponic systems, which may be difficult or not feasible at times	3	5	- Aquaponics vegetable and fish farming project worth $20 million, MUN
WF -15		Farming	Urban Farming	- Controlled growing environment - Maximize resource efficiency - Increase variety of crops - Synergies with voluntary & mandatory green building standards	- High CAPEX - Maintenance of systems may be more complicated than traditional farming	1	4	- No initiatives
WF -16			Surface Water Farming	- Extensive coastline and access to sea	- Uncontrolled conditions - Dependent on availability of salt and heat tolerant crops	1	5	- No initiatives
WF -17			Honey Farms	- Opportunities for coupling for pollination Strong cultural interest & demand	- Weather conditions, including temperatures, dust and humidity - Bahrain has limited unbuilt land that can be utilized for honey farms	1	2	- No initiatives
WF -18			Organic Fertilizers	- Reduced environmental damage caused by eutrophication and leaching into aquifers	- Potentially more expensive - Potentially more difficult to collect and process	3	4	- Recycling of agricultural waste and converting it to organic fertilizers, Ministry of Works, Municipalities Affairs & Urban Planning
WF -19			Organic Farming	- Reduced environmental damage and wide public/commercial appeal - Can be integrated with high-tech food production systems (i.e. hydroponics and aeroponic)	-Could result in reduced yields and higher disease outbreaks if not properly managed	3	4	- Jasra Organic Farm
WF -20	Aqua-culture	Integrated multi-trophic aquaculture (IMTA)	Land-based	- Usage of existing brackish water - Utilization of brine discharge from onsite brackish water reverse osmosis - Declining fish stocks	- Temperature may be too harsh for certain species - Risk of disease and contamination in closed systems, if not properly managed	3	5	-Fish Farming Project, MUN

SN	Category 1	Category 2	Approach/ technology	Approach strengths	Approach limitations	Maturity	Growth Opp.	Initiative(s)/Programme(s)
WF -21			Sea-based	- Extensive coastline available for coastal aquaculture - Declining fish stocks	- Heat and salinity threat - Risk of invasive species	4	5	- Fish Farm, GPIC -Applied research, NMC
WF -22	Land-scaping & Forestry	Landscaping & Forestry	Landscaping	- Widespread landscaping across Bahrain - Opportunities for improvements in soil, irrigation efficiency and crop selection (water, heat and salt tolerance)	- Landscaping directly competes for food production water resources unless properly managed and maintained	5	3	- Use of treated sewage water from Tubli Sewage Treatment Plant for landscaping
WF -23			Forestry	- No significant benefits	- High water use with no tangible benefit towards food security	1	1	- No forestry initiatives exist in Bahrain, only date palm plantation, such as 560 date palms at Princess Sabeeka Park developed by BAPCO, Awali
WF -24	Water Resources	Smart Irrigation	Drip irrigation	- High water efficiency - Smart monitoring and scheduling - Prevents disease and water logging	- Relatively high maintenance and replacement cost	4	5	-Widely used in landscaping across the country - Drip irrigation with timer recommendation, Electricity & Water Authority
WF -25			Spray irrigation	- Ease of installation, use and maintenance - Smart monitoring and scheduling - Prevents disease and water logging (when timed)	- Less water efficient than some other irrigation methods (high evapotranspiration)	5	3	- Widely used in landscaping across the country
WF -26		Cooling	Misting fans for animal cooling	- Easy to integrate and install within any farm	- High water use	5	3	- Commonly used on livestock farms across Bahrain
WF -27		Wastewater	Treated/ recycled wastewater	- Conservation of freshwater sources - Reduced use of synthetic fertilizer - Current policies promoting usage of treated wastewater in agriculture	- Risks of heavy metal contamination to soil, crops & groundwater - Some cultural/public backlash to practice	5	3	- Water output stream to be used for irrigation from new WWTP, 2015 -- Use of treated wastewater from Tubli sewage treatment plant for irrigation of vegetable fields, Ministry of Municipalities affairs & Urban Planning
WF -28			Aquaculture effluent	- Use effluent with salt tolerant crops - Cultivation of otherwise barren lands	- Salt tolerant crops are not widespread - Inland aquaculture farms are not widespread	1	3	-No initiatives
WF -29			Brine	- Potential for redirection towards aquaculture - Potential for mining of minerals in brine through Solar ponds, WAIV, brine concentrators, ohmic evaporators, MD & ZLD - Availability of technologies for dealing with the environmental impacts of brine discharge to sea	- Brine discharge is a by-product of the desalination process in Bahrain, which can negatively impact marine ecosystems and fisheries through thermal, chemical and saline pollution.	2	4	- Research on the use of brine from desalination plants, University of Bahrain & Aston University
WF -30		Artificial Reefs		- Attracts fish and encourages breeding - New habitats for fisheries and marine life - Replenishes depleting fish stocks - Can promote eco-tourism	-Risk of pollution from construction - Ineffective if not designed properly	4	5	- $2.7 million Bahrain Artificial Reef Project

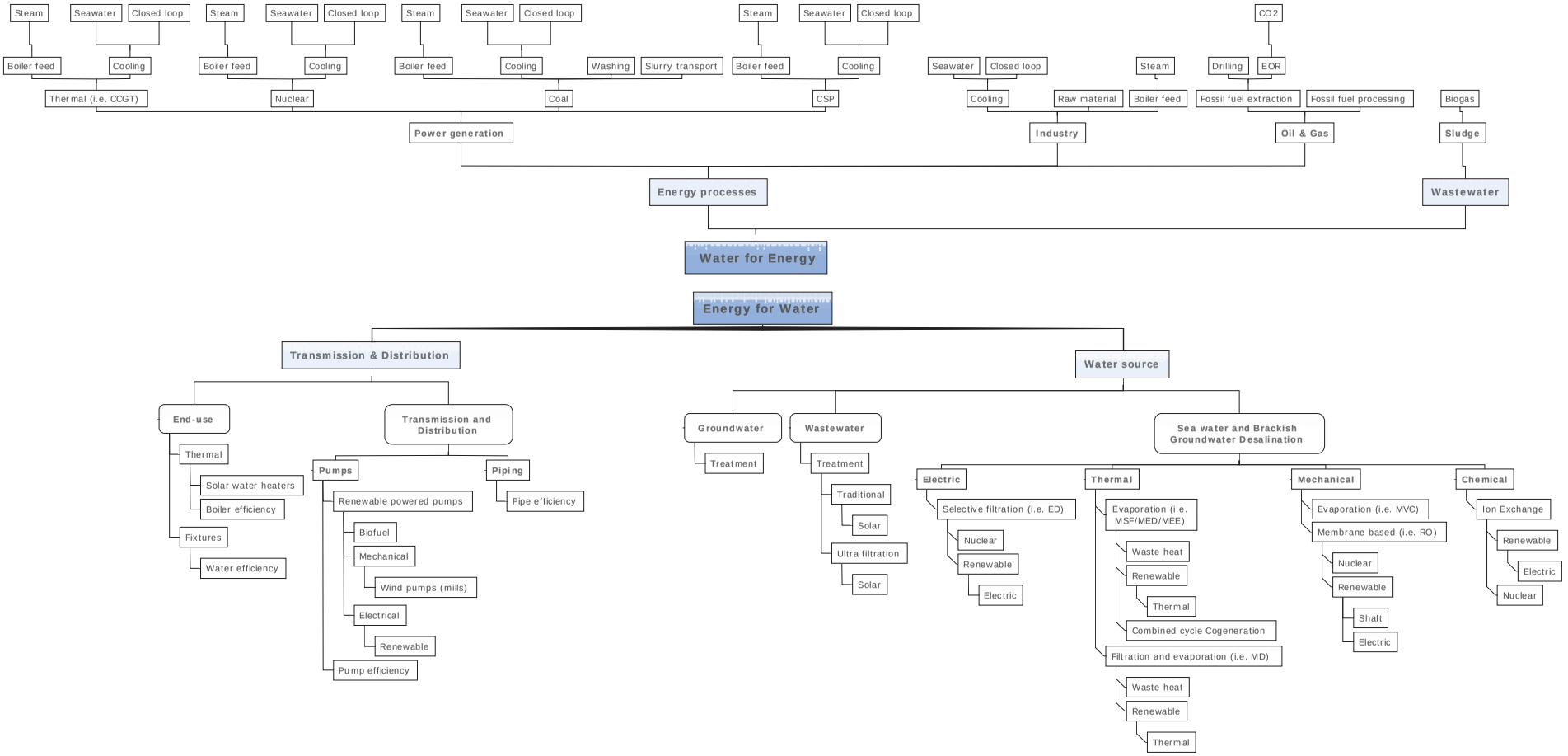
SN	Category 1	Category 2	Approach/ technology	Approach strengths	Approach limitations	Maturity	Growth Opp.	Initiative(s)/Programme(s)
WF -31	Food imports	Food import	International trade partnerships	- Ability to import food from various countries based on quality, price, availability etc. thereby constantly balancing the Bahrain's supply-demand gap	- Significant market and climate risks associated with over dependence on imports - As a small country, Bahrain's bargaining power is limited in in the international food market	5	4	- Importations for traders/businesses, Kingdom of Bahrain, Ministry of Interior Customs Affairs -Bahrain Trade Policy, WTO
WF -32		Food monitoring systems	Food safety monitoring systems	- Ability to track and monitor the value chain of food products from "farm to fork", thereby protecting public health and safety from possible foodborne disease outbreaks - Reduce food loss and wastage through monitoring	- Not well established yet, and will require significant stakeholder buy in across the food supply chain.	3	5	- Remote sensing and biotechnology used to monitor the red palm weevil, GDONLINE
WF -33			Early warning systems	- Ability to monitor and forecast market and climate related risks of major food import partners, offering resilience in case of price shocks, droughts, natural disasters etc.	- Will require government support and buy in - Requires dedicated task force to own the early warning system.	2	5	- FAO Regional Workshop on Enhancing Early Warning Capabilities and Capacities for Food Safety, FAO & WHO

3.2 Water-energy

Figure 17 shows GCC's Water-Energy Nexus Map while

Table 3 highlights Bahrain's initiatives in reference to the map. This was developed based on two main aspects: the use of energy for water production and treatment and the use of water in energy production. The use of energy in water production/treatment was classified based on two main areas of use, the transmission and distribution of water and the treatment of different sources of water. The sources included were groundwater, wastewater and desalinated water (segmented by technology type). The water used in the energy value chain was classified based on its predominant areas of consumption, namely power generation, industry/ oil and gas activities and wastewater treatment facilities. The different forms of water used are also identified, be it for steam, cooling, cleaning or as a raw material.

Figure 17: GCC Water-Energy Nexus Map[56]



[56] Figure 17 is based on EY's internal analysis

Table 3: Bahrain Water-Energy Nexus Initiatives

SN	Category 1	Approach/ technology	Approach strengths	Approach limitations	Maturity	Growth Opp.	Initiative(s)/Programme(s)
WE-1	Waste to Energy	Wastewater sludge to methane based biogas	- Significant sewage generated across Bahrain - Anaerobic digestion of sludge in the form of biogas is a net energy producing process - Recovered nutrients (phosphate and nitrogen) can be used in agriculture/industrial applications - Local climate favourable to technology	- High investment cost for anaerobic digestion tanks and system	3	5	- Construction of Sewage to energy plant in Tubli Bay in Q3 of 2018 , OAK Group Holdings
WE-2	Renewable energy powered desalination	Thermal desalination (i.e. MED/MSF/MEE) with solar thermal (i.e. CSP)	- High solar irradiance in Bahrain	- High energy requirement - Solar thermal systems (such as CSP) are yet to be integrated with desalination commercially - Higher CAPEX of systems (MSF/MED compared to RO and CSP compared to PV) - Slowing adoption of thermal desalination in Bahrain	3	4	- As Bahrain diversifies its energy mix, RO plants will be supplied more and more by renewable energy via the grid - Al-Dur 2 IWPP RO plant
WE-3		Reverse Osmosis with PV/ wind/ storage	- High solar irradiance in Bahrain - RO has lower CAPEX compared to thermal desalination and is gaining market share in total installed capacity - Combining PV directly with RO addresses the intermittency issue as it allows for addition of RE into energy mix without the associated challenges - Increasing adoption of RO in Bahrain enables the integration of renewable energy as a power source	- Reduced RO membrane lifetime due to high salinity and high temperature of Arabian gulf seawater - High OPEX (associated with membrane replacement)	4	5	
WE-4	Cogeneration	Combined cycle - MSF/MED	- Cogeneration (combined cycle with MSF/MED) is the predominant technology utilized in Bahrain - Availability of coastline makes power and water generation coupling easy - Low natural gas costs - Use of by-product steam from power generation for thermal desalination - Energy storage (i.e. batteries), can be used to optimize the cogeneration process, thereby reducing the energy requirements for thermal desalination	- Inherent risks associated with coupling water supply to natural gas - High CAPEX - Cogeneration facilities are designed for an optimal MW to MGD generation ratio, which often don't match water and electricity demand, leading to inefficient burning of natural gas	5	3	- Bahrain's Hidd Plant -Al-Dur 2 IWPP RO plant

SN	Category 1	Approach/ technology	Approach strengths	Approach limitations	Maturity	Growth Opp.	Initiative(s)/Programme(s)
WE-5	Water Production	Atmospheric Water Generation (AWG)	- While water scarce, Bahrain is hot and humid many parts of the year, ideal conditions for AWG - AWG can occur passively, or with an energy input (such as solar) for higher production	- Challenges in scaling up (ideal for low to medium capacity usage) - Can be an expensive investment for non-passive systems (depends largely on the cost of other alternatives) - Bahrain's population is entirely urbanized with access to T&D system	3	2	Study conducted by the University of Bahrain on the extraction of water from air humidity
WE-6	Industrial water discharge	Water discharge management	- Availability of technologies for managing the environmental impacts (i.e. chemical, thermal and saline pollution) associated with water use for industrial, power and desalination processes	- Current regulations on discharge (Resolution 3 2001 – Air and Water standards) may not be conducive to technology/solution adoption - Cost of systems - Technical challenges related to the Arabian Gulf (depth, high temperature and salinity)	1	5	- All industries, power plants and desalination plants on the coast that discharge cooling water, treated wastewater or brine into the sea are regulated by the Supreme Council for Environment - No initiatives on zero-liquid discharge for brine
WE-7	RE powered WWTP	Wind powered WWTP	- Some wind sources available within Bahrain	- High CAPEX - Intermittency, unless a hybrid system - Currently, higher cost than grid	3	4	- As the national energy mix is diversified, the share of renewables used in WWTP will naturally increase
WE-8		Solar powered WWTP	- High solar irradiance in Bahrain	- Intermittency, unless a hybrid system - Currently, higher cost than grid connection	4	4	- As the national energy mix is diversified, the share of renewables used in WWTP will naturally increase - Solar drying technique used at Tubli Sewage Treatment Plant, Tubli
WE-9	Water pumping and transport	Solar water pumps	- High solar irradiance in Bahrain - Off-grid usage makes system mobile, and avoids electrification costs	- Intermittency, unless a hybrid system	4	4	- Solar pumps, Nexcel - Solar water pumping company, Jyoty Solar Power
WE-10		Biofuel water pump	- Various native bio-matter available in Bahrain including algae and seaweed that can be used for biofuel production - Carbon neutral, and renewable source of energy - No issues with intermittency	- Dependent on maturity of biofuel technology - Costlier than conventional fuel options	1	4	- No initiatives
WE-11		Piping efficiency and T&D monitoring	- Water system savings - Identification of system nodes requiring maintenance and/or replacement through monitoring system (i.e. SCADA) - High room for network efficiency improvement, with current system loss of around 30%	- Pipe replacement and/or maintenance can be costly and disruptive	3	5	- Sewage network project, Ministry of Works
WE-12	Water heating & cooling	Solar-water heaters	- High solar irradiance in Bahrain is well suited for technology - High cost savings and quick ROI - Emerging supporting regulations at national level - High growth market	- Higher installation costs than conventional water heating systems - High requirement for proper insulation	3	4	- The use of solar-powered heaters for the green building initiative, Ministry of Works, Municipalities Affairs and Urban Planning

SN	Category 1	Approach/ technology	Approach strengths	Approach limitations	Maturity	Growth Opp.	Initiative(s)/Programme(s)
WE-13		Solar-Cooling systems	- High solar irradiance in Bahrain - High cooling load in Bahrain - Dropping PV and other solar technology costs - Lower OPEX compared to traditional system	- Intermittency, unless a hybrid system	2	5	- Assessment on Solar Cooling Technologies & Applications, UNDP & RCREEE
WE-14	Cooling	District Cooling	- District cooling reduces energy consumption to about 40% compared to traditional cooling - Strong market growth and interest, with well-established regional players	- Highly linked to booms and busts of real-estate sector	5	4	- Tabreed, Manama - Bahrain Bay, North of Manama - SE4All District Cooling Regulations, UNDP and the Ministry of Electricity & Water Affairs
WE-15	Water fixtures	Water fixture efficiency	- Market adoption of existing voluntary green building codes such as LEED - Rising water tariffs among all Emirates and sectors	- No significant constraints	5	5	- 40 green building projects implementing green building regulations, Manama - Energy Efficiency Implementation Program (KEEP), The Government of Bahrain and the World Bank
WE-16	Water use in Oil & Gas	Fossil fuel extraction	- Water steam savings from EOR process by CO_2 injection substitution - Reduced aquifer pollution compared to using produced water - Form of carbon sequestering	- Risk of CO_2 contamination into aquifers	4	4	- BAPCO carbon recovery plan - Gulf Petrochemical Industries Company Carbon recovery project
WE-17		Monitoring systems	- Ability to monitor and analyse water and energy consumption and losses across Oil & Gas value chain	- Challenges in data collection and integration of assets across value chain	1	4	- No initiatives

3.3 Energy-Food

Figure 18 shows GCC's Energy-Food Nexus Map and Table 4 highlights Bahrain's initiatives in reference to the map. This was developed based on two main aspects: the use of energy for food production and the use of organic material in the production of energy. The use of energy in food production was categorized based on inputs of energy and resources required for production. The energy inputs were categorized based on the energy used to operate water treatment and irrigation systems, machinery, cooling systems as well as the transport and distribution of the energy for the production of food. The organic material used in energy production was classified into two types: organic waste and grown food. For the organic waste, the map presents the different sources of waste, i.e. food-waste, agricultural waste, animal waste and waste from landfills. On the other hand, grown food was grouped based on method of production (i.e. seawater grown or freshwater irrigated). Seawater grown includes microalgae and seagrass production while irrigated includes the cultivation of date palms and mangroves for the production of bioethanol.

Figure 18: GCC Energy-Food Nexus Map[57]

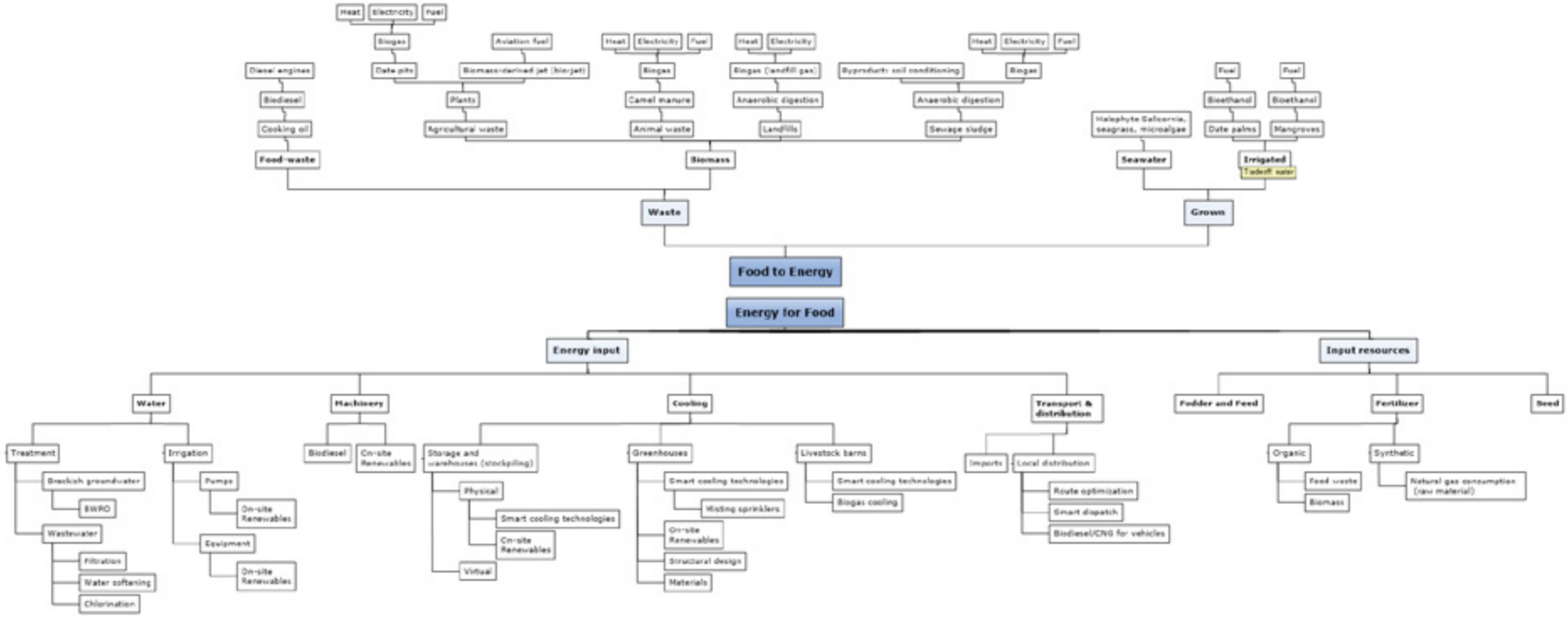


Table 4: Bahrain Food-Energy Nexus Initiatives

SN	Category 1	Category 2	Approach/ technology	Approach strengths	Approach limitations	Maturity	Growth Opp.	Initiative(s)/Programme(s)
FE-1	Biofuels	Grown biofuels	Biomass from halophytes	- Salt tolerant (use of Salicornia Halophyte) - Wide availability of seawater and avoided use of freshwater - Strong demand and support by local airlines for green/renewable jet fuel	- Commercialization and scaling up - More expensive than conventional fuels	3	4	- Research on Halophytes in Bahrain, Royal Botanic Gardens
FE-2			Bioethanol	- Strong market interest in sustainable fuels	- Unless resulting from a waste stream or introduction of speciality plants (i.e.	1	4	- No initiatives

[57] Figure 18 is based on EY internal analysis

SN	Category 1	Category 2	Approach/ technology	Approach strengths	Approach limitations	Maturity	Growth Opp.	Initiative(s)/Programme(s)
					Jatropha), the process will be water intensive - Limited number of native species that can be used at commercial scale - More expensive than conventional fuels			
FE-3		Biofuels from Waste	Biogas from animal waste	- Animal waste is a significant and un-utilized waste stream in Bahrain	- Biomass yield is dependent on the kind of bio-waste (e.g. cattle or camel manure, chicken droppings etc.) and whether animals are held in stables or not - Not feasible for all farms given size	1	4	-No initiatives
WE-1			Biogas from sewage sludge	Please refer to WE-1 for the details of this approach as it is categorized under Water-Energy as well as Food-Energy				
FE-4			Biogas from Landfills	- Large potential of landfill gas in Bahrain - Organic fraction of MSW may provide a source for organic fertilizer/soil improver depending on waste stream purity	- Depending on the conditions of the landfill (sanitary landfill vs. unregulated landfill) Large infrastructural investments may be required	3	5	- 25MW Askar Waste-to-Energy Project in Manama, Bahrain Ministry of Municipalities Affairs & Urban Planning - Assessing Bahrain's Energy from Waste Resource, Loughborough University
FE-5			Biodiesel from food waste	- There is significant food waste in Bahrain, such as waste cooking oil - Hotels are a major source of food waste in the country, offering potential food waste collection partnerships	- Limited by ability to collect food waste at commercial scale - More expensive than conventional fuels	3	4	- Research on Biodiesel production from spent palm cooking oil, University of Bahrain
FE-6	Onsite energy inputs for food production	Smart Cooling Technologies	Cooling of animal farms	- Large number of farms (cow, camel, goat, sheep) in the country - High energy requirement for cooling to maintain optimal range for animals - Opportunities exist for more energy efficient cooling technologies, coupled with smart systems for monitoring and process optimization	- Lack of proper cooling can result in loss of livestock, disease or decreased output	2	4	- No initiatives
FE-7			Cooling of greenhouses	- Large consumers of energy for cooling Opportunities exist for more energy efficient cooling technologies, coupled with smart systems for monitoring and process optimization	- Cooling systems may present high initial investment cost with a long ROI - Inherent trade-offs of some cooling systems (i.e. high water efficiency but high energy or vice versa)	4	4	- Pad & Cooling System commonly used, Peninsula Farms - Fan & Pad Cooling, Fogger Cooling System, BK Greenhouses - Application of an environmental control system for a greenhouse prototype- Bahrain Polytechnic
FE-8			Cooling of storage			3	4	- No initiatives
FE-9		Greenhouses	Reducing cooling load through	- Greenhouses are widespread in Bahrain and the main viable method of non-animal food production in the country	- Materials must be tolerant to harsh Bahrain - Potentially higher cost	3	4	- No initiatives

SN	Category 1	Category 2	Approach/ technology	Approach strengths	Approach limitations	Maturity	Growth Opp.	Initiative(s)/Programme(s)
			design and materials	- Greenhouses consume significant amounts of energy for cooling - Opportunities for synergies with other technologies and setups (i.e. aquaculture)				
FE-10		Fertilizer	Synthetic fertilizer production	- Improves crop yields - Haber process is net CO2 consuming	- Can result in eutrophication of water bodies - Haber process is natural gas consuming	5	2	- Urea Fertilizer, GPIC
FE-11		Onsite renewables	PV for irrigation & pumps	- Off-grid solution for water pumps, reducing maintenance and electrical connection	- Low electricity tariffs for agricultural sector - Intermittency, unless a hybrid system	4	5	- Solar Irrigation Systems, Nexcel Bahrain
FE-12			PV for water treatment	- Off-grid solution for water treatment and onsite brackish water RO	- Low electricity tariffs for agricultural sector - Intermittency, unless a hybrid system	1	4	- No initiatives
FE-13			Biodiesel for equipment	- Renewable source of fuel that can be generated from onsite agricultural waste streams and by-products	- More expensive than conventional fuels if purchased	2	4	- Biodiesel equipment companies presented in Bahrain's Gulf Industry Fair, Globecore
FE-14	Energy inputs for transport & distribution of food	Stockpiling	Virtual Stockpiling	- Utilization of warehouses abroad avoid infrastructure investment domestically - Enhanced energy saving initiative for reduced cooling requirements - Cost saving (buying during low prices) - Added food security (emergency preparedness)	- Cost of storage/stockpiling abroad	1	5	- No initiatives
FE-15			Physical/ emergency stockpiling	- Strategic storage reserves allow for release of stockpiles during emergencies or price hikes	- Investment cost and maintenance - Cooling and humidity control	1	5	- No initiatives
FE-16		Local distribution	Route & inventory optimization	- Route optimization can reduce energy cost of transport and lengthen freshness and lifetime of food products - Reduced inventory time can reduce food wastage and costs for businesses - Emerging technology (i.e. IoT) can enable the above solutions in a cost effective and integrated way	- No significant constraints	3	4	- May exist with private sector companies. However, no initiatives disclosed on the matter

4. Investment and Engagement Opportunities

Investment/engagement opportunities in Bahrain were identified for Dutch companies based on the technologies and approaches outlined in Table 2,

Table 3 and Table 4 of the previous chapter. The maturity and growth opportunity scoring of each technology/approach was used to identify the most suitable opportunities.

Table 5: Investment/engagement opportunity type for Dutch companies

Opportunity Category	Category description	Maturity	Growth opportunity
Category 1	High growth potential and mature market, ready for entry	> 3	≥4
Category 2	High growth potential market, but requires knowledge partner(s)	≤ 3	5

The technologies/approaches identified in the previous chapter are categorized into two opportunities; Category 1 or Category 2 as per Table 5. Category 1 represents well established technologies/approaches with good growth potential, as such Dutch companies can engage with those markets directly as technology/solution providers.

Category 2 technologies/approaches demonstrate high growth potential but are considered less mature commercially (still in research/ testing phase within Bahrain). For Dutch companies, Category 2 presents good growth potential, but will require knowledge partner(s) (Dutch and/or local) to further develop such markets within Bahrain. Knowledge partnerships can include more than one local or Dutch partner. The WEF stakeholder groups in Bahrain identified in Table 8Table 8: Engagement strategy of WEF stakeholder groups in Bahrain are to be considered for these potential partnerships.

Applying the criteria in Table 5 to the technologies/approaches in the previous chapter yields a prioritized list of investment opportunities for Dutch companies presented in Table 6 and Table 7. It is worth noting that such opportunities often comprise of two parts which Dutch companies can contribute towards. Such opportunities consist of technical solutions and complimentary knowledge sharing/expertise. Taking hydroponics as an example, Dutch companies can deliver technical solutions with respect to irrigation, cooling, system automation etc., while also providing knowledge sharing and expertise on the most suitable choice of crops, best practices in system maintenance and analysis of data. The latter can be delivered via training, consulting, joint research projects etc.

Table 6: Category 1 Identified opportunities for direct investment

Nexus	Category	Approach/ technology	Scoring	
			Maturity	Growth Opportunity
WF-13	Agriculture	Hydroponic/Aeroponic farming	4	5
WF-21	Aquaculture	Sea-based Aquaculture	4	5
WF-24	Water resources	Drip irrigation	4	5
WF-30	Artificial reefs	Artificial reefs	4	5
WE-3	Renewable energy powered desalination	Reverse osmosis with PV/nuclear/storage	4	5
WE-15	Water fixtures	Water fixture efficiency	5	5
FE-7	Onsite energy inputs for food production	Cooling for greenhouses	4	5
FE-11	Onsite energy inputs for food production	PV for irrigation pumps	4	5

Table 7: Category 2 Identified technologies and approaches for partnership opportunities

Nexus	Category	Approach/ technology	Scoring	
			Maturity	Growth Opportunity
WF-7	Agriculture	Seaweed and macro-algae farming for animal feed	3	5
WF-10	Agriculture	High tech greenhouses	1	5
WF-14	Agriculture	Aquaponics	3	5
WF-16	Agriculture	Surface water farming	1	5
WF-20	Aquaculture	Land-based aquaculture	3	5
WF-32	Food imports	Food safety monitoring systems	3	5
WF-33	Food imports	Early warning systems	2	5
WE-1	Waste to energy	Wastewater sludge to methane based biogas	3	5
WE-6	Industrial water discharge	Water discharge management	1	5
WE-11	Water pumping and transport	Piping efficiency and T&D monitoring	3	5
WE-13	Water heating & cooling	Solar cooling systems	2	5
FE-4	Biofuels	Biogas from landfills	3	5
FE-14	Stockpiling	Virtual Stockpiling	1	5
FE-15	Stockpiling	Physical/Emergency Stockpiling	1	5

The success of the Netherlands in the area of food production has placed them as the second largest global exporter of food in terms of dollar value after the United States. With the Netherlands being 3rd in the Global Innovation Index 2017 and Bahrain at 66[58], many opportunities exist for the Netherlands to share their technical expertise and knowledge with Bahrain.

Furthermore, Bahrain plans to become the data hub of the GCC[59]. Although it may be small in size in comparison to its neighbouring countries, Bahrain has many opportunities for business. It was ranked 66th out of 190 in the World Bank's Ease of Doing Business report[60].Its strategic location with having Saudi Arabia close by and it being an easy access to the Middle Eastern market, make it's a market hub for the region. Bahrain also allows for a 100% foreign ownership in most sectors[61].

In line with the government plan 2015-2018 and Vision 2030, Bahrain has an opportunity to grow and develop its agricultural sector. Technological advancements in modern technologies and approaches for the agricultural sector is an essential aspect of the country's strategy towards its future water and food security. The country can benefit from its human and financial capital to drive innovative research and development in addition to attracting foreign investments. Bahrain can focus on creating an environment for achieving food security through technology innovation.

One of the main areas Bahrain can adopt from the Netherlands is their Dutch Triple Helix approach that strengthens synergies between government, industry, academia and society.

[58] WIPO, Global Innovation Index 2017 rankings, 2017
[59] MEED, Bahrain: Data Hub of the GCC
[60] The World Bank, Ease of Doing Business: Bahrain
[61] Economic Development Board Bahrain, Ease of Set Up

5. Success through Engagement

For Dutch companies looking to enter Bahrain's WEF market, engaging with the right stakeholders is pivotal. Doing business in Bahrain and wider region requires a certain level of adaptiveness and fluidity – brought on by sharp climatic, regulatory and cultural contrasts when compared to Europe and other regions. In Bahrain, the ministries are driving the strategies on resource conservation and diversification linked to the WEF Nexus. Although Bahrain has a liberal economy and provides foreign companies with relatively east processes within the country, Dutch companies will also need to showcase their best practices, solutions and expertise – by actively engaging with local entities and cultivating those relationships in the long term.

5.1 Direct engagement with local entities

Though by no means exhaustive, Figure 19 and Table 8 illustrates some of the key WEF stakeholders in Bahrain. Briefs about the entities and website links can be found in Appendix B. The level to which they should be engaged will vary dramatically from company to company, based on the support required, value proposition etc. Nonetheless, a qualitative prioritization was conducted to showcase the stakeholders whom Dutch companies might find the most relevant. Additionally, Table 8 identifies high level engagement strategies by stakeholder group.

Figure 19 Bahrain Water Energy Food Nexus Map

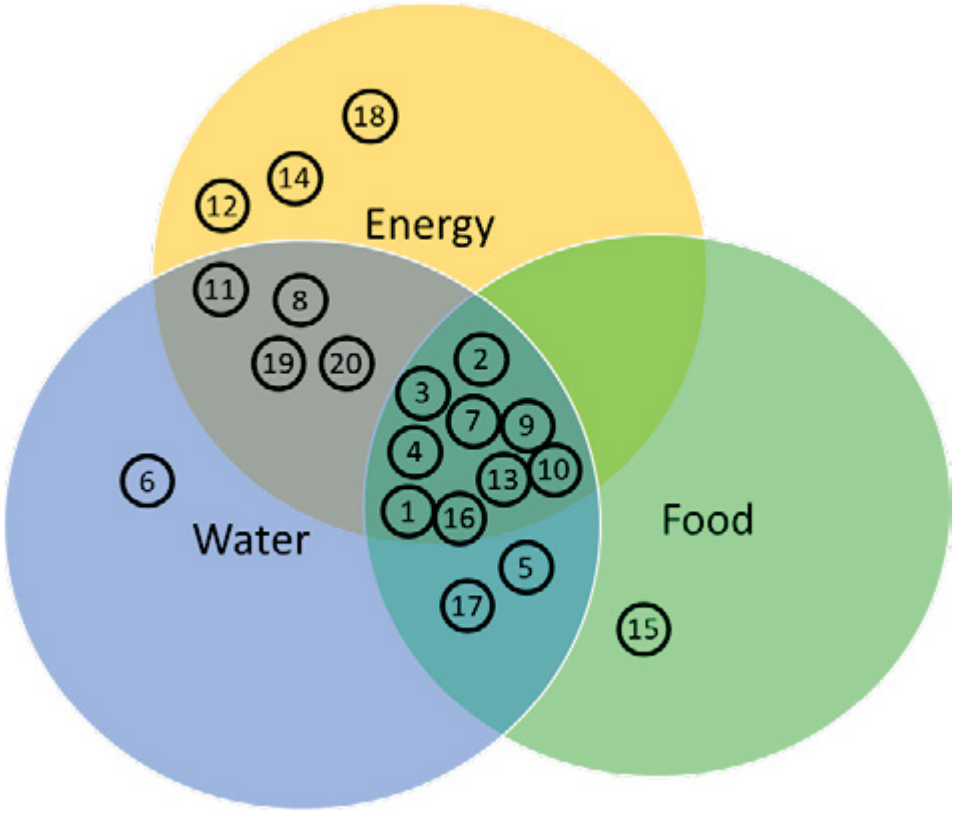


Table 8: Engagement strategy of WEF stakeholder groups in Bahrain

Entity Type	Engagement Strategy
Government operator entities 1. Bahrain Chamber of Commerce and Industry 2. Sustainable Energy Unit 3. Economic Development Board 4. Ministry of Works, Municipality Affairs and Urban Planning 5. The National Initiative for Agricultural Development 6. Electricity & Water Authority	1. Information collection: Dutch Companies need to form a solid understanding of the strategies, objectives and operations of the various government operators in Bahrain if they wish to collaborate successfully 2. Involve senior management: Dutch companies need to utilize the information collected in their research to connect with government operators based on their most pressing issues. Dutch companies should employ their senior management to connect with government operators and capitalize on the Bahraini-Dutch diplomatic channels (i.e. the Dutch embassy, Majlis) for introductions where relevant/possible. 3. Share insights: Dutch Companies need to share their insights and experiences with government operators. This is best done in an interactive manner that emphasizes demonstration. This may include: meetings, conferences, workshops and invitations to see leading best practices abroad etc.
Government regulator entities 7. Ministry of Foreign Affairs 8. National Oil & Gas Authority 9. Ministry of Industry, Commerce and Tourism 10. Supreme Council for Environment	1. Establish focal point: Dutch companies need to establish a key focal point within their organization that will regularly engage with the Bahraini government regulator entities to improve communications and access to information. This can be complemented with meetings in person to establish key contact points within priority departments in Bahrain government entities to build a trust-based relationship. Dutch companies can capitalize on Bahrain-Dutch diplomatic channels (i.e. the Dutch embassy) for introductions where relevant/possible. 2. Consult regularly: Regular consultations are important and should be followed up at regular intervals to help Bahrain government regulators familiarize themselves with new information. As Bahrain is a dynamic environment in which regulations are regularly updated, Dutch companies can benefit from regular consultations to remain up to date with regulatory changes. 3. Share insights: Dutch entities can share their experience and insights with Bahrain regulators with respect to which regulatory enablers would support agricultural sector growth and innovation in Bahrain. This is best done in an interactive manner that emphasizes demonstration. This may include: meetings, conferences, workshops and particularly invitations to see leading best practices abroad etc. 4. Awareness building: As Dutch companies look to introduce novel ideas and solutions to Bahrain, awareness building will play a key part of any engagement strategy. Developing promotional material for regulators is key to refresh memories of officials who are aware of on-going discussions and provide introductory information to those who are not.

Entity Type	Engagement Strategy
Industry 11. The Bahrain Petroleum Company, BAPCO 12. Bahrain National Gas Company (BANAGAS) 13. Agribusinesses 14. Bahrain Solar Industry Association	1. Identify industry drivers: Dutch Companies should research and understand the scope and operations of the industries they wish to engage with to identify the key challenges and drivers before engaging. 2. Establish focal point: Companies should nominate a focal point to directly engage with key industry personnel in order to establish a trust based relationship and maintain an open line of communication. 3. Share insight: Dutch Companies should focus on personalizing all pitches to Bahrain's industry leaders to increase their chances of success. Sharing new insight might be challenging as Bahrain's companies might initially resist change. However, interactive strategies that emphasize demonstration often work well. This may include: meetings, conferences, workshops and particularly invitations to see leading best practices abroad. Additionally, pilot projects and key collaborations opens the way for greater market acceptance/adoption of new technologies and practices.
International organizations and NGOs 15. Arab Authority for Agricultural Investment & Development 16. IRENA 17. Food and Agriculture Organization 18. Regional centre for renewable energy and energy efficiency	1. Signing a MoU: Companies can establish effective partnerships with international organizations by signing a Memorandum of Understanding (MoU) to develop further cooperation in different areas. For instance, companies can share their know-how but also improve oversight of the Bahrain market which could support companies in their engagement with government operators/regulators.
Universities and Research Institutes 19. Bahrain Polytechnic University 20. University of Bahrain	1. Building local relationships: Dutch companies may want to engage with local universities and research institutes to gain country/region specific context, which will help them tailor their solutions when engaging with stakeholders such as government regulators/operators and local companies etc. This can be achieved through direct partnership, or by bringing in Dutch universities as well. 2. Nominate a key contact: Companies should ensure there is a champion within the university/research institute who understands the importance of the collaboration to guarantee endorsement for the project and help in securing legitimacy and access to resources

5.2 Dutch Economic Network in the Gulf

The Netherlands Embassy in Kuwait is the official representation of the Netherlands in both Kuwait and Bahrain. The Dutch Economic Network in the Gulf Region, including Bahrain, is a useful diplomatic channel of entry for Dutch companies looking to enter Bahrain's WEF market. It is established to help Dutch businesses in identifying business opportunities within the Gulf Countries.[62] The aim of this network is to provide advice to Dutch businesses in terms of setting up a business in the Gulf where they advise based on the market as well as potential partners. The 5 Embassies and 1 Consulate-General in the Gulf Region each have one or more Economic and Trade Affairs Officers, in addition to a regionally operating Agricultural Office in Riyadh, Saudi Arabia[6263,] and a newly appointed regionally operating Nexus expert in Abu Dhabi, UAE, to support or advice Dutch companies that want to do business in Bahrain.

For more information on the Dutch Economic network in the Gulf region kindly visit our website www.dutchgulf.com or https://www.netherlandsworldwide.nl/doing-business-in-the-gulf-region.

Another entry channel for Dutch companies is Bahrain's Chamber of Commerce and Industry[64] as it provides support to national products, advocates members' interests and the private sector towards the

[62] Kingdom of the Netherlands, Dutch Economic Network in the GCC, 2018.
[63] Kingdom of the Netherlands, Agricultural Department for the GCC-countries
[64] Bahrain Chamber of Commerce and Industry

competent authorities and also represents them in local, regional and international committees, bodies, and institutions and defends their interest and Bahrain's Tender board[65], which announces the tenders for upcoming projects.

[65] Bahrain Tender Board

6. Appendix A

The tables below include the sources of all the initiatives cited in chapter 3, and are listed by initiative number, mirroring Tables 2, 3 and 4.

SN	Initiative(s)/Programme(s)	Links
WF-1	- Quality Standards & Exporter Supply Chain Assurance System, Bahrain Livestock Company	https://www.bahrainlivestock.com/quality-assurance
WF-2	- Use of artificial insemination, MUN, UN & FAO --Supporting the livestock sector, FAO	http://www.tradearabia.com/news/MISC_268838.html http://www.fao.org/3/a-az569e.pdf
WF-3	-Capacity building for emergency preparedness , FAO, 2016	http://www.fao.org/3/a-az569e.pdf
WF-4	- No initiatives	Not applicable
WF-5	-Poultry farms are widespread throughout Bahrain with various setup types (i.e. commercial farmed eggs vs. free-range organic eggs) -Goat farms, peninsula farms	https://www.peninsulafarms.com/about-us/
WF-6	- Use of salt crops for animal feed, Desert Research Centre, 2015	https://www.researchgate.net/publication/286755979_Mineral_Balance_in_Animals_as_Affected_by_Halophyte_and_Salt_Tolerant_Plant_Feeding
WF-7	- Public perception of algal consumption as a food alternative, University of Bahrain - Research on the challenges of largescale macro-algae cultivation, Centre for Sustainable Development	https://www.researchgate.net/publication/324596002_Public_perception_of_algal_consumption_as_an_alternative_food_in_the_Kingdom_of_Bahrain www.mdpi.com/2071-1050/10/5/1364/pdf
WF-8	- 30,000 metric tons of forage per year, Delmon Poultry Company	http://www.dawajen.bh/en/content/feedmill-factory
WF-9	- Use of GMO crops, Peninsula farms	https://www.peninsulafarms.com/product-category/vegetables-fruits/
WF-10	- No initiatives	Not applicable
WF-11	- No initiatives	Not applicable
WF-12	- No Initiatives	Not applicable
WF-13	- Use of hydroponic farming in Bahrain, Peninsula Farms - 1,000 m^2 aeroponic system for growing tomatoes, Peninsula Farms -Success of hydroponic farming in Bahrain, Ecomena	https://www.peninsulafarms.com/technology/ http://www.hortidaily.com/article/14220/Bahrain-Peninsula-Farms-upgrades-greenhouse-technology https://www.ecomena.org/hydroponic-farming-bahrain/
WF-14	-Aquaponics vegetable and fish farming project worth $20 million, MUN	http://www.bna.bh/portal/en/news/713128
WF-15	- No Initiatives	Not applicable
WF-16	- No initiatives	Not applicable
WF-17	- No initiatives	Not applicable
WF-18	- Recycling of agricultural waste and converting it to organic fertilizers, Ministry of Works, Municipalities Affairs & Urban Planning	http://www.bna.bh/portal/en/news/711974
WF-19	- Jasra Organic Farm	http://womanthismonth.com/born-with-a-green-thumb/
WF-20	--Fish Farming Projects, MUN	http://www.bna.bh/portal/en/news/713128
WF-21	- Fish Farm, GPIC -Applied Research, NMC	http://www.gpic.com/responcibility/EnvironmentalProjects/40.aspx http://www.fao.org/3/a-az569e.pdf
WF-22	- Use of treated sewage water from Tubli Sewage Treatment Plant for landscaping	http://bna.bh/portal/en/news/799247
WF-23	- No forestry initiatives exist in Bahrain, only date palm plantations such as 560 date palms at Princess Sabeeka Park developed by BAPCO, Awali	https://www.researchgate.net/publication/283735466_Date_Palm_Status_and_Perspective_in_Bahrain

SN	Initiative(s)/Programme(s)	Links
WF-24	- Widely used in landscaping across the country -Drip irrigation with timer recommendation, Electricity & Water Authority	http://www.ewa.bh/en/Conservation/Water/water-conservation-tips
WF-25	- Widely used in landscaping across the country	Not applicable
WF-26	- Commonly used on livestock farms across Bahrain	Not applicable
WF-27	- Water output stream to be used for irrigation from new WWTP, 2015 - Use of treated wastewater from Tubli sewage treatment plant for irrigation of vegetable fields, Ministry of Municipalities affairs & Urban Planning	https://www.water-technology.net/uncategorised/newsbahrain-gives-green-light-to-new-wastewater-treatment-project-4753441/ www.ijias.issr-journals.org/abstract.php?article=IJIAS-15-107-03
WF-28	- No initiatives	Not applicable
WF-29	- Research on the use of brine from desalination plants, University of Bahrain & Aston University	http://wesii.uob.edu.bh/images/Presentations/ManagementandvalorizationofbrinesfromdesalinationplantsintheGulf.pdf
WF-30	- $2.7 million Bahrain Artificial Reef Project	https://www.ecomagazine.com/featured-stories/reef-arabia-s-game-changing-reef-modules-majfara-units-durable-solutions-that-blend-with-the-environment
WF-31	- Importations for traders/businesses, Kingdom of Bahrain, Ministry of Interior Customs Affairs -Bahrain Trade Policy, WTO	http://www.bahraincustoms.gov.bh/page.php?SID=WTBkR2JscFVNREJOZVZwMFVGUlpiV015TURsT1JFazk%253D -https://www.wto.org/english/tratop_e/tpr_e/s294_e.pdf
WF-32	- Remote sensing and biotechnology used to monitor the red palm weevil, GDONLINE	http://www.gdnonline.com/Details/194296/Protecting-date-palm-trees-discussed
WF-33	FAO regional workshop on Enhancing Early Warning Capabilities and Capacities for Food Safety, FAO & WHO	http://www.fao.org/fao-who-codexalimentarius/sh-proxy/fr/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FMeetings%252FCX-701-39%252FWD%252Fcac39_18e.pdf

SN	Initiative(s)/Programme(s)	Links
WE-1	- Construction of Sewage to energy plant in Tubli Bay in Q3 of 2018 , OAK Group Holdings	https://www.meedprojects.com/Projects/bahrain-min.-of-mun.-affairs-urban-planning-askar-waste-to-energy-plant-10491.aspx
WE-2	- Al-Dur 2 IWPP RO plant	https://www.internationalwatersummit.com/__media/Energy-Efficient-Desalination-2018.pdf
WE-3		
WE-4	Bahrain's Hidd Plant (Characterization of the outfall area of a MSF desalination plant in Bahrain), 2018 - Al-Dur 2 IWPP RO plant	https://file.scirp.org/pdf/JWARP_2018031615305720.pdf https://www.internationalwatersummit.com/__media/Energy-Efficient-Desalination-2018.pdf
WE-5	- Study conducted by the University of Bahrain on the extraction of water from air humidity	https://www.e3s-conferences.org/articles/e3sconf/pdf/2017/11/e3sconf_wrec2017_03001.pdf
WE-6	- All industries, power plants and desalination plants on the coast that discharge cooling water, treated wastewater or brine into the sea are regulated by the Supreme Council for Environment - No initiatives on zero-liquid discharge for brine	Not applicable
WE-7	- As the national energy mix is diversified, the share of renewables used in the WWTP will naturally increase	Not applicable
WE-8	- Solar drying technique used at Tubli Sewage Treatment Plant, Tubli	http://www.tradearabia.com/news/OGN_280581.html
WE-9	-Solar pumps, Nexcel -Solar water pumping company, Jyoty Solar Power	http://nexcelbahrain.com/BahrainSolarNexcel/solar-water-pump-systems.html http://www.jyotysolarpower.com/solarwaterpump/solar-water-pump-dealers-in-bahrain
WE-10	No Initiatives	Not Applicable
WE-11	-Sewage Network Project, Ministry of Works	https://www.works.gov.bh/English/Projects/sanitary-projects/Pages/SEWERAGE-NETWORK-PROJECT-IN-NASFA-733.aspx
WE-12	- The use of solar-powered heaters for the green building initiative, Ministry of Works, Municipalities Affairs and Urban Planning	http://www.tradearabia.com/news/CONS_306664.html
WE-13	- Assessment on Solar Cooling Technologies & Applications, UNDP & RCREEE	https://www.solarthermalworld.org/sites/gstec/files/news/file/2016-04-30/solar_cooling_roadmap_arab_states_march_2016.pdf
WE-14	- Tabreed, Manama - Bahrain Bay, North of Manama - SE4All District Cooling Regulations, UNDP and the Ministry of Electricity & Water Affairs	http://www.binhindi.com/webfiles/gd_binhindi.aspx?wpid=w022&wptype=profile&pagetype=partnership&pagetypeheader=partnerships&lcl=0&ccl=0&or=0&display_category_logo=0 http://www.constructionweekonline.com/article-27495-site-visit-bahrain-bay-district-cooling-plant https://info.undp.org/docs/pdc/Documents/BHR/Progress%20Report%20Q4.pdf
WE-15	- 40 green building projects implementing green building regulations, Manama - Energy Efficiency Implementation Program (KEEP), The Government of Bahrain and the World Bank	http://www.tradearabia.com/news/CONS_306664.html http://www.worldbank.org/en/news/press-release/2013/09/23/world-bank-supports-kingdom-of-bahrain-energy-efficiency-program
WE-16	- BAPCO carbon recovery plan - Gulf Petrochemical Industries Company Carbon recovery project	https://www.pik-potsdam.de/paris-reality-check/indcs-carbon-capture-and-storage/
WE-17	- No initiatives	Not applicable

SN	Initiative(s)/Programme(s)	Links
FE-1	- Research on Halophytes in Bahrain, Royal Botanic Gardens (Halophytes of Southeast Asia)	https://www.researchgate.net/publication/300706672_Halophytes_of_Southwest_Asia
FE-2	- No initiatives	Not applicable
FE-3	- No initiatives	Not applicable
WE-1	Please refer to WE-1	
FE-4	- 25MW Askar Waste-to-Energy Project in Manama, Bahrain Ministry of Municipalities Affairs & Urban Planning -Assessing Bahrain's Energy from Waste Resource, Loughborough University	https://www.meedprojects.com/Projects/bahrain-min.-of-mun.-affairs-urban-planning-askar-waste-to-energy-plant-10491.aspx http://wesii.uob.edu.bh/images/Presentations/WastewaterImpactsofAdvancedEnergyfromwasteTechnologies.pdf
FE-5	- Research on Biodiesel production from spent palm cooking oil, University of Bahrain	http://thescipub.com/pdf/10.3844/ajassp.2016.1255.1263
FE-6	- No initiatives	Not applicable
FE-7	- Pad & Cooling System commonly used, Peninsula Farms - Fan & Pad Cooling, Fogger Cooling System, BK Greenhouses -Application of an environmental control system for a greenhouse prototype- Bahrain Polytechnic	http://www.hortidaily.com/article/6825/Bahrain-Big-potential-for-horticulture,-but-you-will-need-the-right-people-and-the-best-technology http://www.bkgreenhouses.com/main/commercial-systems/ https://pdfs.semanticscholar.org/5253/7a76940c200b7f4415e854059e6aef61d320.pdf
FE-8	- No initiatives	Not applicable
FE-9	- No initiatives	Not applicable
FE-10	- Urea Fertilizer, GPIC	http://www.gpic.com/products/Urea/
FE-11	- Solar Irrigation Systems, Nexcel Bahrain	http://nexcelbahrain.com/BahrainSolarNexcel/solar-water-pump-systems.html
FE-12	- No initiatives	Not applicable
FE-13	- Biodiesel equipment companies presented in Bahrain's Gulf Industry Fair, Globecore	https://biodiesel.globecore.com/globecore-presented-equipment-gulf-industry-fair-bahrain
FE-14	- No initiatives	Not applicable
FE-15	- No initiatives	Not applicable
FE-16	- May exist with private sector companies. However, no initiatives disclosed on the matter	Not applicable

7. Appendix B

The table below elaborates on the stakeholder entities identified in Chapter 5, providing entity descriptions and links.

Entity type		Entity Responsibility	Link
Government operator entities			
1	Supreme Council for Environment	Working towards integrated management of ecosystems and natural resources for sustainable development Services include waste management, management of hazardous chemicals and industrial and service projects	http://www.sce.gov.bh/en/
2	Sustainable Energy Unit	Develop cohesive and sustainable energy policy and to promote renewable energy and energy efficiency in Bahrain	http://www.seu.gov.bh/
3	Economic Development Board	Works with the government and investors to support initiatives, which will enhance Bahrain's economy	http://bahrainedb.com
4	Bahrain Solar Industry Association	This organization is to create solar energy business and employment opportunities in Bahrain and to enable collaboration opportunities through the region	http://www.solargcc.com/bahrain-solar/
5	The National Initiative for Agricultural Development	To have an effective agricultural sector in Bahrain that contributes to the country's social, environmental and economic development	http://www.niadbh.com/en/
6	Electricity & Water Authority	Provide electricity and water resources to all sectors of Bahrain	http://www.ewa.bh/en/Pages/default.aspx
Government regulator entities			
7	Ministry of Foreign Affairs	Builds relationships and frameworks that protect the rights of the people of Bahrain Provides information about the country's law, vision 2030 and relationships with international organizations	https://www.mofa.gov.bh
8	National Oil & Gas Authority	Regulate, oversee and develop the oil and gas and related industries within Bahrain	http://www.noga.gov.bh
9	Ministry of Industry, Commerce and Tourism	Aims to make Bahrain a distinct commercial location and gateway for free trade and re-export operations. Its services include foreign trade relations services, industrial development services, industrial area development services and operations services	http://www.moic.gov.bh
10	Bahrain Chamber of Commerce and Industry	Provides information about business and investment opportunities, statistics, reports and research in different sectors	https://www.bcci.bh/en
11	Ministry of Works, Municipality Affairs and Urban Planning	Development of policies, application of development plans and the provision of municipal services	https://www.mun.gov.bh/mun/index_en.html

		Also serves as the umbrella for ministry of agriculture and marine wealth	
Industry			
12	The Bahrain Petroleum Company, BAPCO	Provide energy to increase Bahrain's prosperity and also carries out studies to obtain accurate data on existing oil and gas reserves	http://www.bapco.net/en-us
13	Bahrain National Gas Company (BANAGAS)	Process associated gas into marketable products, supply residue gas for local industrial use	http://www.banagas.com/
14	Agribusinesses	To provide world-class agricultural products It also includes various businesses as well as up and coming start ups	
International organizations and NGOs			
15	Arab Authority for Agricultural Investment & Development	To invest in agricultural activities for food security in the Arab World	https://www.aaaid.org/en/aaaid-glance
16	IRENA	To provide data on renewable energy and promote economic, social and environmental benefits of renewables	http://www.irena.org/
17	Food and Agriculture Organization	To contribute to the sustainable production of agriculture and fisheries to combat poverty	http://www.fao.org/countryprofiles/index/en/?iso3=ARE
18	Regional centre for renewable energy and energy efficiency	To be a strategic partner for Arab countries and help them drive energy transition for the country's prosperity	http://www.rcreee.org/
Universities and Research Institutes			
19	Bahrain Polytechnic University	Supporting the economic growth and diversification Programs are developed in consultation with business, industries, professions, international education and training institutions	http://www.polytechnic.bh
20	University of Bahrain	Contribute directly to Bahrain's economic growth and development through by the support of a leading edge in teaching, technology and research with a regional impact	http://www.uob.edu.bh/en/

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