uniting water energy food

NEXUS

IN THE UNITED ARAB EMIRATES

OPPORTUNITIES FOR DUTCH COOPERATION

DUTCH GULF
Dutch connection in the UAE

Holland.

NEXUS

IN THE UNITED ARAB EMIRATES

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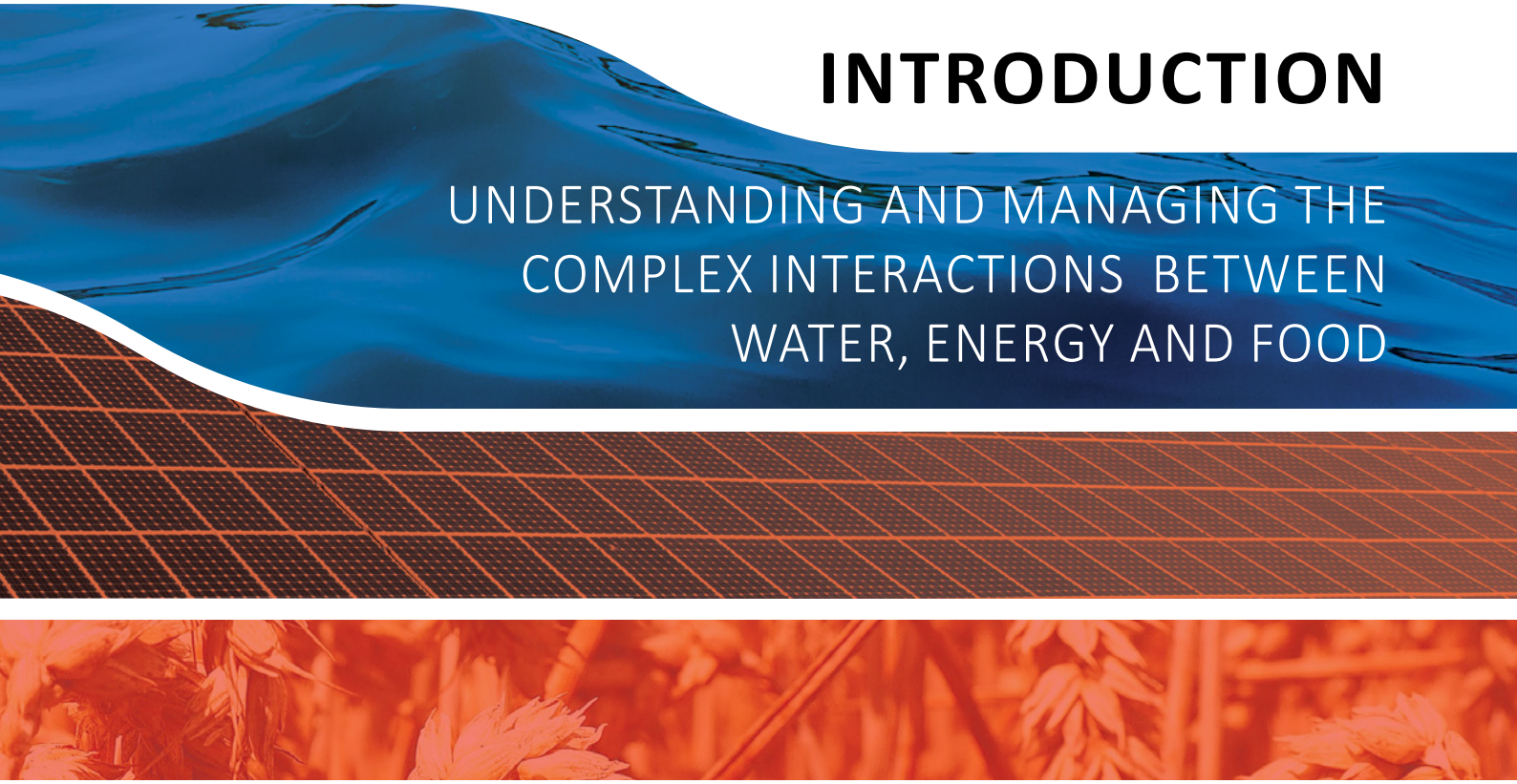


INTRODUCTION

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

Water, energy and food are the most vital resources any living organism needs to survive and thrive. Global population growth, climate change and environmental stress are but a few of the challenges to these resources, and the future demand for each of them will only increase.

The Water-Energy-Food Nexus concept looks specifically at the interrelationships between water, energy and food, and uses that knowledge to enhance the effects of looking at each resource on its own, as only an integrated approach will allow for sustainable solutions. This conceptual approach helps us to better understand, and systematically analyze, the interactions between our natural environment and human activities, and to work towards a more coordinated management and use of natural resources across sectors.

Both the United Arab Emirates and the Kingdom of the Netherlands were amongst the 193 countries that signed the Sustainable Development Goals (SDGs) in 2015, as part of the wider UN 2030 Development Agenda. Several of the 17 SDGs refer to the resources mentioned above, e.g. zero hunger, clean water and sanitation, affordable and clean energy, sustainable cities and communities, responsible consumption and production, and climate action. The nexus-approach contributes to the realization of the SDGs.

The UAE and Dutch Governments signed a Memorandum of Understanding (MoU) on Innovation in 2017, including collaboration on the Nexus. The main ambition of this MoU was to encourage greater dialogue, awareness and engagement between governments, companies and knowledge institutes from the Netherlands and the UAE. With the current publication, yet another chapter will be added to bilateral engagement and reaching our shared sustainability goals.

The Embassy of the Kingdom of the Netherlands in Abu Dhabi initiated this research to explore the state of play in the United Arab Emirates in the sectors water, energy and food. Besides listing threats for the future, the findings of the report point to opportunities for the Netherlands to connect its expertise and integrated approach to the demands in the area.

The challenges of today, both regional and worldwide, can only be faced collectively if we are serious in providing sustainable solutions. Let the Netherlands and the United Arab Emirates join forces to take the next necessary steps towards sustainable development.

Sincerely,

HE Frank J. M. Mollen
Ambassador of the Kingdom of the Netherlands in the UAE, Abu Dhabi

Citation: Embassy of the Kingdom of the Netherlands in the UAE (2018), Water-Energy-Food Nexus in the United Arab Emirates.

- This first version was produced in June 2018 -

Contents

1. Abbreviation List

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
MVC	Mechanical Vapour Compression
PV	Photovoltaic
RAS	Recirculating Aquaculture System
RO	Reverse Osmosis
WEF	Water-Energy-Food
WtE	Waste to Energy
WWTP	Waste Water Treatment Plant

2. Introduction

2.1 Background context

With the discovery of oil in 1958, the UAE transformed from desert principalities 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 1 and Figure 2[1], 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 40%, reaching 13.1 million further straining the country's scarce natural resources.

Figure 1: Population growth in the UAE since 1960

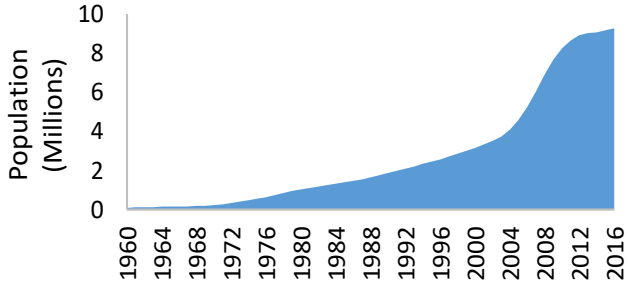
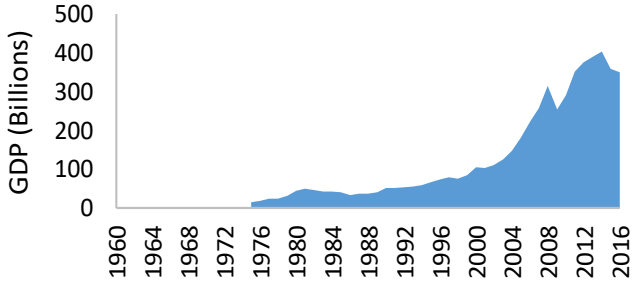


Figure 2: GDP in the UAE since 1975 in USD current



With 6.5%[2] of the world's proven oil reserves, the UAE has been an energy independent nation since its founding. This has enabled the dry and arid country to meet its potable water needs via fossil fuel powered seawater desalination. In addition, with the UAE being a major oil exporter, its oil revenues have traditionally been used and invested in structures and supply chains that enable greater food supply security.

The result is that the UAE is heavily reliant on its fossil fuel and fossil aquifer resources for maintaining 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 the UAE and highlights the importance of adopting a water-energy-food (WEF) nexus (the Nexus) approach when considering and addressing the country's future development.

2.2 UAE Structure

The UAE is a Federation consisting of seven Emirates: Abu Dhabi, Dubai, Sharjah, Ras Al Khaimah, Ajman, Umm Al Quwain and Fujairah. Each Emirate maintains a significant level of autonomy, power and ownership over their natural resources, having had their own governing institutions prior to the establishment of the Federation in 1971. As per the UAE Constitution, the rulers of the individual Emirates may give up certain authorities to the Federal Government and may assume or re-assume such authorities/functions accordingly.

Given the varying size, level of development, population size and other factors, the local governments of the seven Emirates differ in their structure and mechanics. However, each Emirate has an executive

[1] The world Bank, *Population growth and GDP in the UAE,* 2018
[2] OPEC, *World Share of Crude Oil Reserves,* 2016.

council which works under the supervision of the Ruler's Court of that Emirate. With Abu Dhabi and Dubai being the largest two Emirates by size, population and GDP, they play a leading role in the strategic direction of the country and steering national visions and strategies. Furthermore, from a water-energy-food nexus perspective, they represent the bulk of water, energy and food production and consumption – often servicing other Emirates.

2.3 Report objective

The WEF Nexus has risen on the national agenda as the UAE looks to secure its future and support ongoing development. The UAE and Dutch government signed a Memorandum of Understanding (MoU) in 2017 for collaboration on the Nexus. The main ambition for the MoU is to encourage greater dialogue, awareness and engagement, between the Netherlands Government, Dutch companies and the UAE on the Nexus. This may be achieved through technology transfer, expertise, research and development, joint ventures, investments and other mechanisms.

The objective of this report is to support this arrangement by contextualizing the current state of the WEF Nexus in the UAE particularly in relation to the availability of primary freshwater, energy and food resources along with the main 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 the UAE, along with the proposed engagement channels leading up to the Expo 2020.

2.4 UAE resources

2.4.1 Freshwater

Historically, the UAE relied almost entirely on two types of groundwater resources. Its shallow aquifers, recharged via rainfall, are the only source of renewable freshwater. Its deep aquifers were formed thousands of years ago[3] and are largely considered "fossil" or non-renewable. Groundwater is predominantly used for agriculture: with productive agriculture (excluding forestry and landscape management) using 32% of all water resources in the country and 50% in Abu Dhabi, whilst comprising less than 1% of the country's GDP[4].

The intensive irrigation use spurred by sector subsidies has resulted in over-abstraction of groundwater with water tables dropping anywhere between 1.5 to over 5 meters per year[4]. Water quality degradation, seawater intrusion, and the drying of shallow aquifers are further consequences of unsustainable water use[5].

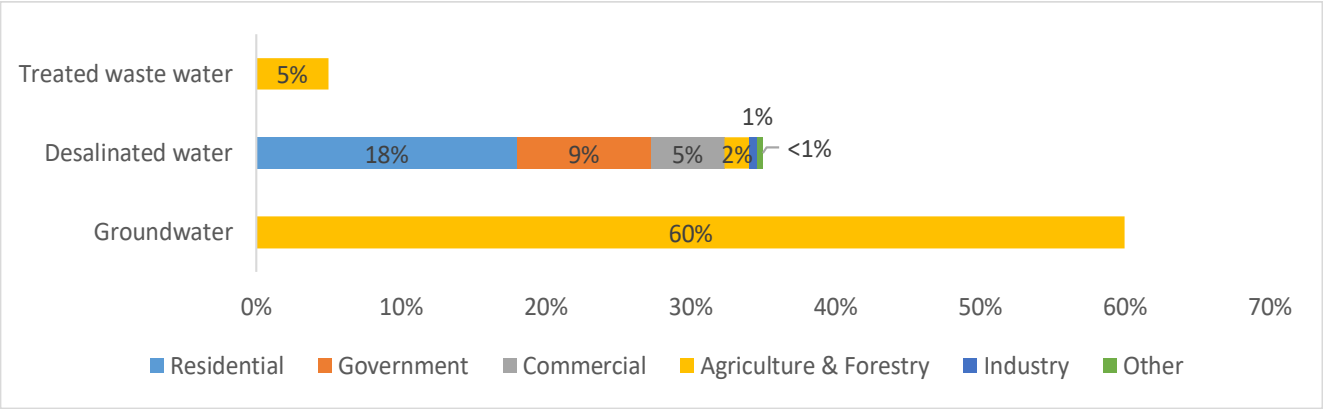
Seawater desalination infrastructure has therefore been developed to provide the majority of the country's domestic water needs. This energy intensive process results in carbon emissions and in brine discharge to the sea. More recently, treated wastewater has been given greater attention as an alternative to groundwater abstraction, particularly for agriculture, forestry and landscaping[2].

As illustrated in Figure 3 the UAE's water supply mix is composed of 60% groundwater, 35% desalinated

[3] Saif et al., *Water Security in the GCC Countries: Challenges and Opportunities,* 2014.
[4] EWS-WWF, *UAE Climate Change Risks & Resilience,* 2017
[5] Murad et al., *Comprehensive Assessment of Water Resources in the UAE,* 2006

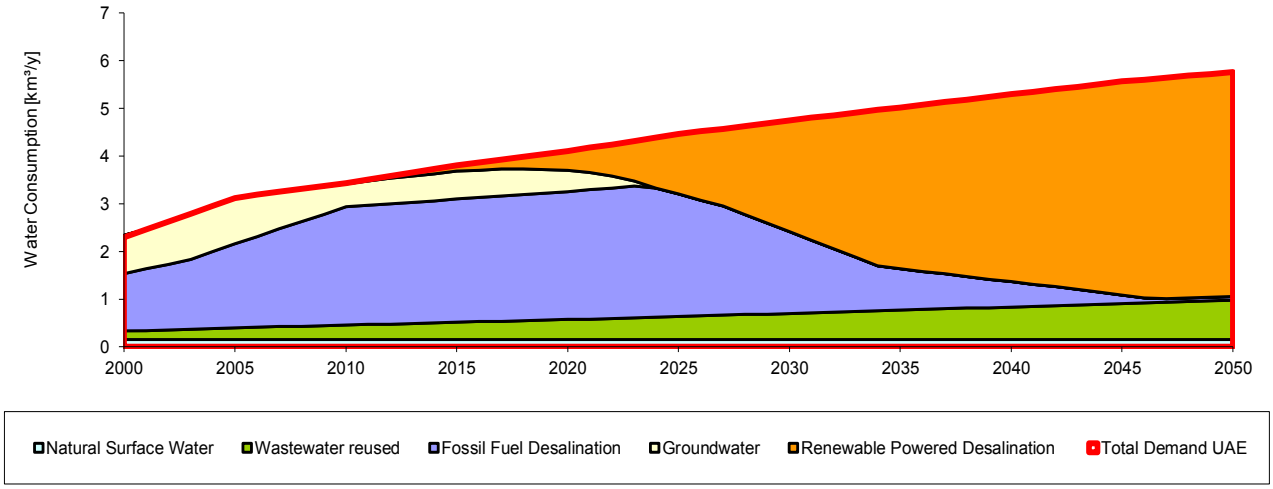
water and 5% recycled water.

Figure 3: UAE's water supply mix and breakdown of usage by sector[6]



The UAE's water demand has been growing significantly and is expected to double by 2055[7]. Figure 4 forecasts water demand, presenting a potential water mix that shifts away from groundwater and fossil fuel desalination to focus more on renewable powered desalination and waste water reuse[3].

Figure 4: Projected scenario of water demand by source



[6] Environment Agency Abu Dhabi, *State of the Environment Report,* 2017.

[7] UAE MOE, *UAE State of Energy Report,* 2017.

How will the UAE maintain its water security in the future?

Supply: As the demand for domestic and agricultural water increases, renewable-powered desalination is one option being considered as a replacement for current fossil fuel powered technologies. In addition, the use of treated wastewater will increasingly be employed to limit the depletion of groundwater. Finally, announcements have also been made highlighting the UAE's intention to continue to expand its strategic water storage capacity and to improve the resilience of its utilities network.

Demand: The UAE has witnessed a number of strategies and programs that encourage and implement greater demand side management efforts across all sectors – a trend that is expected to continue and amplify. Behavioral changes, application of new technologies and the removal of existing subsidies will bring about the change that is needed to reduce overall demand for water.

2.4.2 Energy

The UAE is capable of domestically meeting its energy demand, excluding power and water generation, which relies predominantly on imported natural gas. Fifty percent of the UAE's electricity is generated from natural gas imported from Qatar via the Dolphin Gas pipeline[8]. However, the country's recent visions and national strategies, discussed further in Section 2.6, are centered on diversifying its energy mix as represented in Figure 5. As such, the country has invested in developing its nuclear, sour gas and solar power capacity with other project development also underway in areas such as clean coal and hydro.

Figure 5: UAE 2020 energy mix[7]

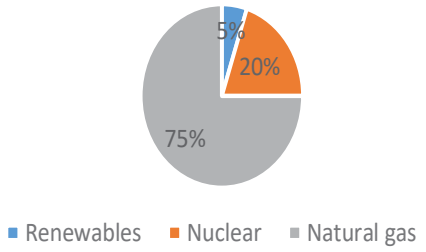
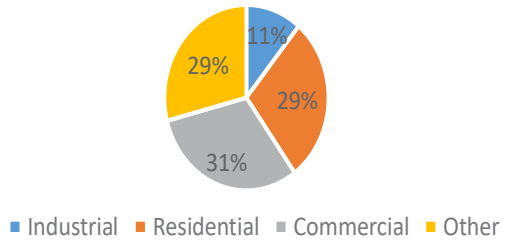


Figure 6: UAE Electricity consumption by sector in 2013[7]

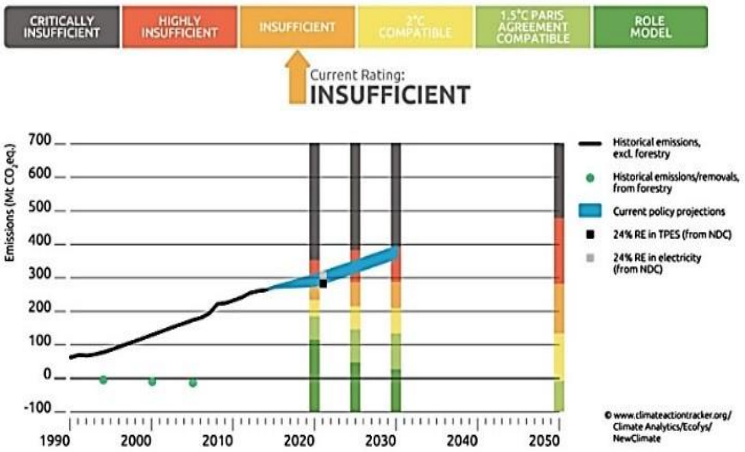


As the UAE continues to develop key industrial and manufacturing sectors, its electricity consumption will continue to increase. In Abu Dhabi, demand is forecast to increase by 62% between 2017 and 2030[9]. Figure 6 shows that the residential and commercial sectors are the largest power consumers in the UAE. Buildings alone consume around 80%[10] of the total generated electricity in the country, the bulk going towards cooling.

[8] International Energy Agency, *UAE Energy Balance,* 2015
[9] TRANSCO, *Electricity Seven Year Planning Statement (2018-2024),* 2017.
[10] EMS, *Energy Consumption in the UAE,* 2015.

Based on the current electricity generation infrastructure, the increase in energy demand will also result in greater greenhouse gas emissions. Figure 7 displays the expected projection up to 2030 by the Climate Action Tracker (CAT) which rated the UAE as insufficient in meeting the expected targets for keeping global warming below 2°C or limiting it to 1.5°C as per the Paris Climate Change Agreement.

Figure 7: Projected GHG Emissions until 2030 in the UAE1



How will the UAE maintain its energy security in the future?

Nuclear and solar power will steadily increase their contribution to the UAE's energy mix with many projects either complete or in the pipeline. Domestic sour gas fields will be further explored and developed. Demand side management initiatives will accelerate in the form of mandatory green building codes, ESCO markets, along with a greater adoption of energy saving smart technologies and systems across sectors. Other project developments are also underway in areas such as clean coal and hydro.

2.4.3 Food

The UAE'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 food (80% to 90%)[11], ranking as the world's 17th largest agricultural importer in 2016[12]. Additionally, through strategic investments in ports and infrastructure, the UAE strengthened its trade relations, easing its access to global food markets. This has gained the UAE a high rank on the Global Food Security Index (GFSI): it is 33rd globally with a score of 70.9%[13].

[11] MBRSG, *Advancing Food Security in the UAE,* 2018.
[12] UNCTAD, *World Exports and imports of agricultural products*, 2016
[13] EIU and The Economist, *Global Food Security Index,* 2018.

Figure 8: UAE's food import mix and import breakdown of the top 10 trading partners in 2016 (million USD)[14]

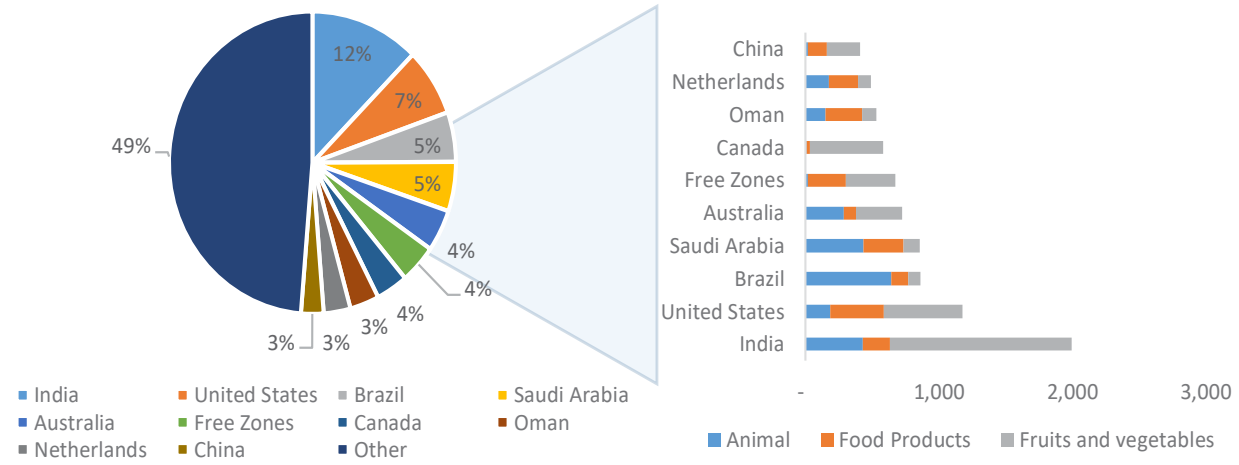
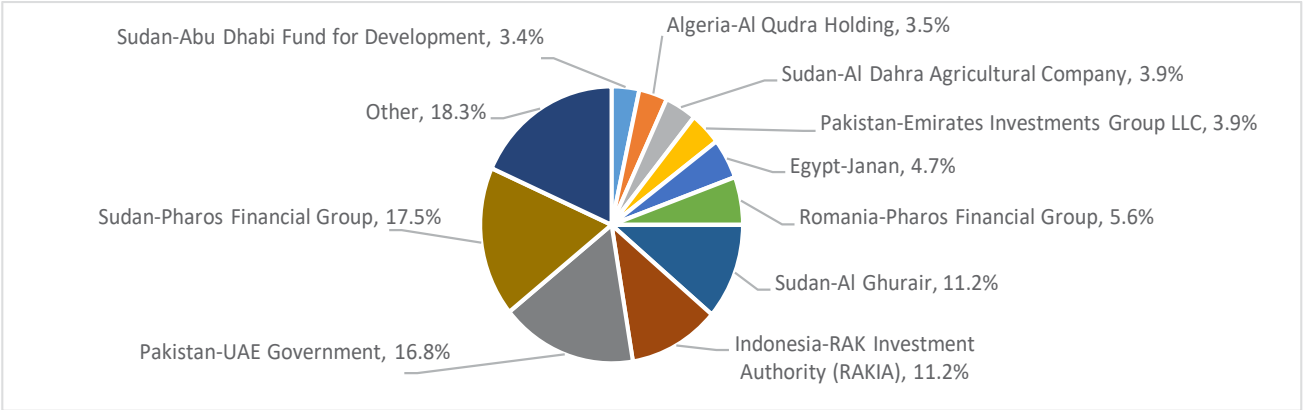


Figure 8 shows that, in 2016, food imports to the UAE totaled USD 16.21 billion, representing a compounded annual growth rate (CAGR) of 7.1% from 2010. In 2016, the UAE imported 3% of its food from the Netherlands. These imports amounted to USD 800 million and were dominated by food products, with a smaller portion of animal, fruits and vegetables.

While Figure 8 would suggest that the UAE's food imports are well diversified, specific crops tend to be dominated by specific food exporting countries[15]. For example, the majority of cereal imports (i.e. wheat, rice, barley, maize, oats, millet, and sorghum) are imported mainly from India, Pakistan, Australia, Argentina, Canada, and Thailand these account for 88% of cereal imports[15]. At the moment, although a newly formed ministry has been tasked to oversee this area (Ministry of Future Food Security), no clear efforts have been made by the UAE to address the climate and market risks related to its food imports and partners.

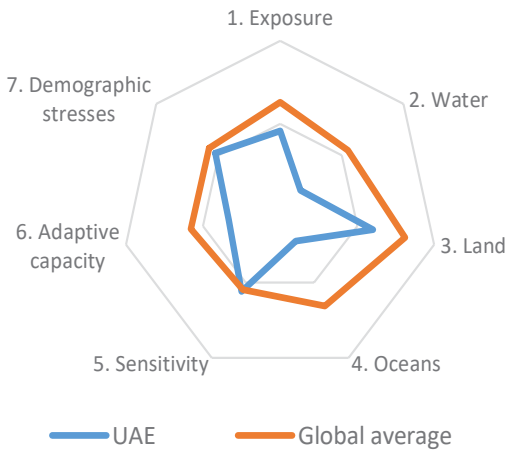
Figure 9: Top 10 UAE Agricultural Foreign Direct Investment projects, % of total 1mn hectares in 2014[16]



[14] WITS-World Bank, *United Arab Emirates Food imports*, 2016
[15] AEGDI, *FOOD SECURITY and Climate Change,* 2015
[16] Emirates NBD, *Dubai's agricultural sector overview*, 2014

Despite its current Food Security Index score, the UAE is highly prone to food insecurity in the future. Its poor resilience to food security pressures is highlighted in Figure 10, particularly with respect to water, oceans and adaptive capacity.

Figure 10: UAE Food Security Index pressures[13]



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

On the demand side, food waste and spoilage in the UAE is significant, estimated at USD 4 billion in 2016[17], with some initiatives to manage food waste beginning to emerge. In January 2017, the Dubai Municipality announced the formation of the UAE Food Bank, an NGO committed to eliminating food waste across the Emirates[18]. Furthermore, as a major waste stream, food waste is an untapped resource for fertilizer and energy generation that is ending up in landfills.

How will the UAE maintain its food security in the future?

Food imports, supplemented by agricultural Foreign Direct Investment (FDI) projects, will remain pivotal in the UAE's food security strategy. The UAE will look to consider climate and market risks more rigorously in its international food import strategy and adopt national risk management strategies such as early warning systems and physical stockpiling. Furthermore, Big Data will be used in Smart Farming to provide predictive insights in farming operations to drive real-time decision making. Hindered by depleting aquifers, domestic food production will shift away from animal feed and significantly modernize and leverage smarter and more efficient technologies along with more climate suitable crop variations. Efforts to curb food wastage and spoilage will continue through better

2.5 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.

[17] Gulf News, *Your leftover food is behind the large food wastage*, 2017
[18] The UAE Food Bank, 2017

Figure 11: Food security tradeoffs in the UAE[3]

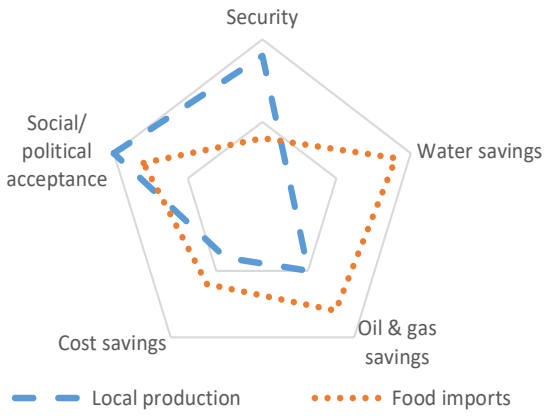


Figure 12: Water security tradeoffs in the UAE[3]

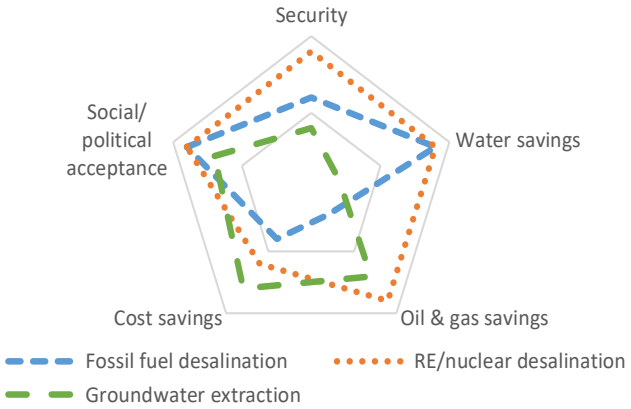


Figure 11 and Figure 12 illustrate conceptual, what-if scenarios of various supply side interventions in the UAE with respect to food and water security. If analyzing food security, the UAE has to look at fundamental tradeoffs associated with different food security strategies. For example, a strategy 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 the UAE looks to expand its local food production capacity (see section 2.6.1.10), it must address the associated constraints of food, water and energy. Strategies, technologies and initiatives taking place following the announcement of targets and policies in prior years to tackle such constraints are explored in Chapter 3.

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 the UAE. 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.

Federal level, and Emirate specific strategies, visions and objectives are detailed in sections 2.6.1 and 2.6.2. Strategies/visions pertinent to the Nexus are elaborated on in greater detail and often consist 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 behaviors.

Figure 13 and Figure 15 summarize the main strategies, visions and plans at the federal and Emirate level respectively.

2.6.1 Federal level

Figure 13: Federal level strategies and visions

2.6.1.1 Agenda 2030 and the SDGs

The UN Agenda 2030 for Sustainable Development is the central UN action plan that embeds 17 Sustainable Development Goals (SDGs) 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.

The UAE's National Committee on Sustainable Development Goals monitors national data and reports the progress on the SDGs[19]. In 2018, this progress will be reported as part of the first Voluntary National Review (VNR) submission to the High-Level Political Forum (HLPF). The VNRs provide a platform for partnerships and are intended to accelerate the implementation of the Agenda 2030 worldwide.

2.6.1.2 Centennial Plan 2071[20]

Launched in 2017, the Centennial Plan 2071 is a long-term plan, extending 5 decades post 2021. It aims to establish the UAE as the best country in the world, by focusing primarily on investing in UAE youth and addressing the issues of future generations.

2.6.1.3 UAE Vision 2021[20]

Launched in 2010, the UAE Vision 2021 aims to make the UAE among the best countries in the world. The vision identifies six pillars/ national priorities that represent the key focus sectors of government action in the coming years.

2.6.1.4 National Strategy for Innovation[20]

Several years ago the UAE federal government launched UAE Vision 2021 and then followed this with the more recent National Strategy for Innovation. The latter focuses on innovation and technology as the center of progress. Government entities and private enterprise are encouraged to work collectively to make the UAE one of the most innovative countries of the world[21]. The National Strategy for Innovation has identified water and renewable energy as two of seven priority sectors. The notion of encouraging

[19] FCSA, *UAE Statistics,* 2017.
[20] UAE Government, *UAE Future*, 2018
[21] UAE Cabinet, *The National Strategy for Innovation,* 2018.

innovation in the fields of clean technology and renewable energy, and of researching innovative solutions to the water scarcity issues are deeply rooted in this strategy.

2.6.1.5 The UAE Water Security Strategy

The UAE Water Security Strategy 2036[22], was unveiled in 2017 by the Ministry of Energy and Industry. The strategy aims to reduce water demand by 21% compared to 2017, increase the reuse of treated wastewater to 95% and increasing the national water storage capacity by two days. To deliver on these objectives, the strategy focuses on detailed goals and forecasts for the following three programs: demand side management, water supply management and emergency production and distribution. The UAE water security strategy is a crucial component of the country's long term security and growth.

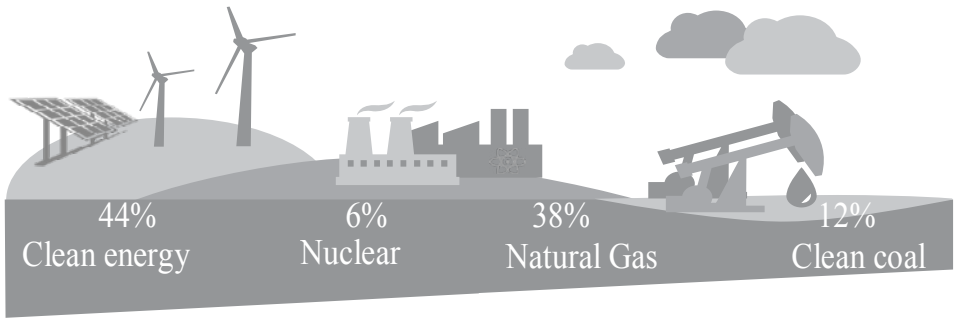
The strategy has also prioritized further development of the nation's interconnected water network and its water storing capacity, as well as increasing desalination capacity and levels of water recycling. The strategy comprises the development of six connecting water and electrical power networks across the country, which will deliver 91 L/day/capita of water during emergencies. The full implementation of this strategy is expected to bring about AED 74 million in savings in addition to the mitigation of 100 MMT of carbon dioxide emissions.

In January 2018, the Abu Dhabi Water and Electricity Authority (now the Department of Energy) announced the completion of the Liwa Strategic Water Storage and Recovery Plant. This project, which feeds desalinated freshwater from the Shuweihat desalination plant into an underground aquifer, can hold enough drinking water for 1 million people for a period of 90 days[23].

2.6.1.6 The UAE Energy Strategy 2050[20]

The UAE Energy Strategy 2050 documents the nation's effort to diversify its energy sources with focus on renewable energy and energy efficiency. The UAE will invest AED 600 billion in alternative energy projects that are targeted at increasing clean energy use by 50%, cutting carbon dioxide emissions by 70% and improving energy efficiency by 40%. The complete implementation of this strategy is projected to result in AED 700 billion in savings. The deployment of renewables for power generation is expected to reduce water withdrawals by an estimated 20% by 2030. The targeted 2050 energy mix is depicted in Figure 14.

Figure 14 Targeted make-up of energy sources in the UAE by 2050[24]



[22] UAE Government, *The UAE Water Security Strategy 2036,* 2018.
[23] Khaleej Times, *Abu Dhabi Water Security,* 2018.
[24] UAE Government, *UAE Energy Strategy 2050,* 2018.

2.6.1.7 UAE Strategy for Artificial Intelligence[20]

Launched in 2017, the UAE Strategy for Artificial Intelligence (AI) addresses the post-mobile government phase in which all future government services, sectors and infrastructure projects will rely on AI. It aims to enhance government performance and efficiency, with the target of having the UAE achieve 100% reliance on AI for government services and data analysis by 2031.

2.6.1.8 UAE Blockchain Strategy 2021[25]

Launched in 2018, the UAE Blockchain Strategy 2021 aims to put 50% per cent of government transactions on blockchain platform by 2021, with the objective of reducing time, costs, man-hours and paper transactions/records.

2.6.1.9 The National Advanced Sciences Agenda 2031[20]

The National Advanced Sciences Agenda 2031 details the UAE's priorities for scientific objectives to be realized by 2031. The 2031 Agenda sets out eight scientific priorities up to 2031 and 30 scientific targets up to 2021 to make the most of all strategic natural resources in the country.

2.6.1.10 UAE Food Security Strategy

In October 2017 the UAE announced the creation of the Ministry of Future Food Security. The ministry is tasked with enhancing the country's food security. The ministry is currently in the process of articulating the country's food security strategy in consultation with various stakeholders and other government entities.

2.6.1.11 Ministry of Climate Change and Environment

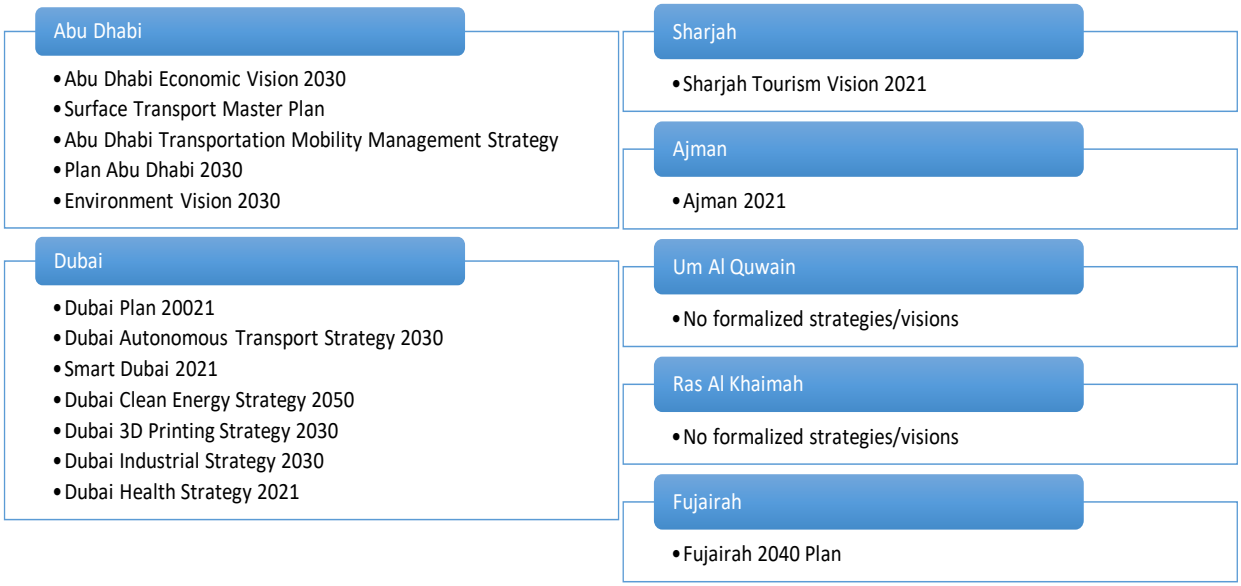
The Ministry of Climate Change and Environment's Food Diversification Team has worked since early 2017 on developing a Federal Food Diversification Policy[26]. The Policy, which is currently in its final approvals, will address both supply and demand issues covering the entire food chain. Some of these issues include: trade diversification; developing guidelines for investments abroad; water consumption in domestic agriculture; crop choice; food wastage, amongst other issues.

2.6.2 Emirate level

Figure 15 captures the multiple visions, strategies and plans by each Emirate in the UAE. Emirate specific activities that are pertinent to the Nexus are explored in the subsections below.

[25] Gulf News, *Mohammad Bin Rashid launches the Emirates Blockchain Strategy 2021*, 2018
[26] FAO, *UAE and FAO hold a Stakeholder Consultation on the UAE's Food Diversification Policy Development*, 2017

Figure 15: Emirate level visions, strategies and plans[20]



2.6.2.1 Dubai desalination and water security targets

During the fifth edition of the World Government Summit 2018, DEWA announced its ambition to reduce the cost of freshwater production through the implementation of solar-powered reverse osmosis desalination technologies. With the ambition to generate 305 million gallons per day by 2030, the Emirate has projected to achieve USD 13 billion in savings. To improve water security, DEWA will also look to develop underground reservoirs that can store 50 million gallons of freshwater. These will be able to supply the Emirate of Dubai for 75 days[27].

2.6.2.2 Dubai Clean Energy Strategy[28]

Dubai aims to generate 75% of its total power output from clean sources by 2050, with gas constituting 61%. To promote investments in the clean energy sector, Dubai created the Dubai Green Fund worth of AED 100 billion in 2015. The Mohammed bin Rashid Al Maktoum Solar Park, which is built to generate 5,000 MW by 2030, is one key elements for the successful implementation of this strategy.

2.6.2.3 Expo 2020

Between October 2020 and April 2021, Dubai will host the next world Expo under the theme of "Connecting Minds, Creating the Future". The event recognizes the importance of worldwide collaboration in generating sustainable technologies that are aimed at solving global problems, including water scarcity, food security and renewable energy.

[27] Gulf News, *Solar energy to power Dubai desalination plants,* 2018.
[28] UAE Government, *Dubai Clean Energy Strategy,* 2018.

3. UAE WEF Nexus Snapshot

This chapter aims to provide a snapshot of the current state of the WEF Nexus within the UAE. 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, Tables, 2, 3 and 4Table 3 outline the various technologies and approaches currently utilized in the UAE 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	
Score	Description
1	Non-existent
2	Interest/awareness present
3	Pilot project or significant research on the area exists
4	Emerging in the market
5	Well established

Approach/technology growth potential	
Score	Description
1	Declining growth
2	No growth
3	Low growth
4	Medium growth
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 and interviews of the different initiatives and programs carried out across all seven Emirates of the UAE. The scores are presented in Tables 2, 3 and 4 and were validated through expert opinion in the UAE.

3.1 Water-Food

Figure 16 shows the UAE's Water-Food Nexus Map which explores food production and its various inputs from the perspective of water. 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: UAE Water-Food Nexus Map

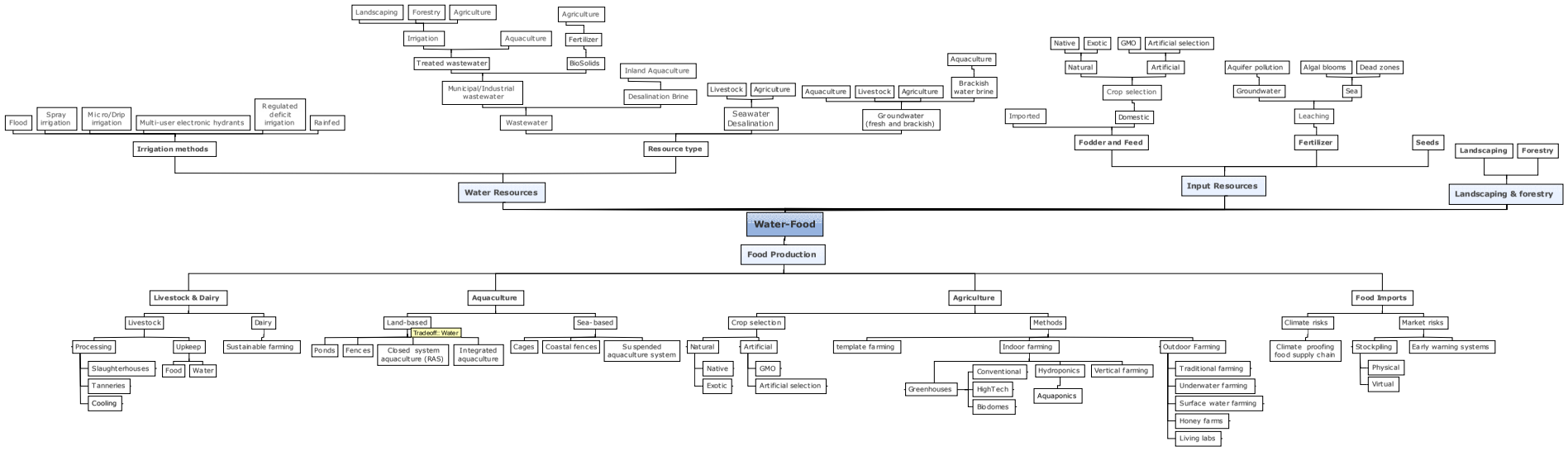


Table 2: UAE Water-Food Nexus Initiatives

SN	Category 1	Category 2	Approach/ technology	Approach strengths	Approach limitations	Maturity	Growth opportunity	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	- Livestock Chain Monitoring Committee, Ministry of Climate Change and Environment, UAE
WF -2			Sustainable breed selection	- Particular breeds can be less resource intensive (i.e. water) and more heat tolerant	- Consumers may prefer particular breeds based on quality - Farmers are inclined to raise those with the highest profit margins	3	3	- The Abu Dhabi Farmers' Services Centre Breeding Programme
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 the UAE, certain production systems are constrained by: - Climate (i.e. temperature, rainfall etc.) - lack of natural shrub/vegetation for grazing	4	3	- Various production systems for livestock and poultry exist across the UAE (i.e. caged livestock vs. free range)
WF -4			GMOs	- Opportunities to improve yields through disease resistance, saline water tolerance and heat tolerance	- Public hesitation/resistance towards GMOs	2	4	- Discussions on GMO use in the UAE are taking place, however no conscious efforts have been made towards GMO livestock production
WF -5		Poultry	Farming of poultry	- Suitable for the 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 the UAE with various setup types (i.e. commercial farmed eggs vs. free-range organic eggs)
WF -6	Agriculture	Crop Selection	Native and climate compatible species	- Salt and heat tolerant crops - Reduced need for freshwater - Synergy with voluntary and mandatory green building standards	- Limited variety of crops - Legal challenges in registering new crop varieties	4	4	- Date palm salinity tolerance, Biosaline institute - Quinoa initiative, UAE
WF -7			Seaweed and macro-algae farming for animal feed	- Low input requirement - High in nutrients	- Requires controlled conditions - May prove difficult to scale up	1	5	- No initiatives. Approach is still in its early stage within the UAE
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	- End of water intensive fodder subsidies, ADFCA, Abu Dhabi - Support for fodder imports, ADFCA, Abu Dhabi
WF -9			Artificial (Artificial Selection & GMOs)	Opportunities for improved yields, and disease, draught, heat and salt resistance	- Public hesitation/resistance towards GMOs	2	4	- Discussions on GMO crop use in the UAE taking place, but no conscious efforts are made towards GMO crop production

SN	Category 1	Category 2	Approach/ technology	Approach strengths	Approach limitations	Maturity	Growth opportunity	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	3	5	A number of smart greenhouses are emerging in the UAE, such as: - Pure Harvest, UAE - Van der Hoeven in Al Ain
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	2	4	- The Sahara Forest Project (2009), UAE
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	2	4	- EAD-Philippine Global School, Abu Dhabi
WF -13			Hydroponic farming	- High irrigation efficiency compared to traditional methods - Increased crop productivity - Reduced use of pesticide & fertilizer	- High CAPEX - Risk of water microorganisms contamination - Does not facilitate pollination	4	5	- ADFSC, Abu Dhabi - Emirates hydroponics farms, Dubai and Abu Dhabi - Pegasus agriculture group, UAE - Bani Yas Agricultural Research Center - Hydroponic Agriculture Project - Hydroponic initiative, Ajman, 2009
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	- Bani Yas center growing tilapia fish, Abu Dhabi - Jebel Ali resort & hotel growing cherry fish & cherry tomatoes, Dubai
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	2	4	- Urban Agriculture research center, Dubai
WF -16			Surface Water Farming	- Extensive coastline and access to sea	- Uncontrolled conditions - Dependent on availability of salt and heat tolerant crops	2	5	- No initiatives. The concept is still in its early stage within the UAE
WF -17			Honey Farms	- Opportunities for coupling for pollination Strong cultural interest & demand	- Weather conditions, including temperatures, dust and humidity	4	3	- Al Najeh honey, UAE
WF -18			Organic Fertilizers	- Reduced environmental damage caused by eutrophication and leaching into aquifers	- Potentially more expensive - Potentially more difficult to collect and process	4	4	- Adfert organic fertilizer made of seaweed, Abu Dhabi
WF -19			Organic Farming	- Reduced environmental damage and wide public/commercial appeal	- Could result in reduced yields and higher disease outbreaks if not properly managed	5	5	- 54 organic farms in the UAE due to government initiatives, UAE

SN	Category 1	Category 2	Approach/ technology	Approach strengths	Approach limitations	Maturity	Growth opportunity	Initiative(s)/Programme(s)
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	4	5	- Dubai Center for Research and Development of Fisheries (DCRDF), Dubai - Sheikh Khalifa Bin Zayed Marine Research Center, Umm Al Quwain - Advanced technological production of caviar & sturgeon meat, Abu Dhabi
WF -21			Sea-based	- Extensive coastline available for coastal aquaculture - Declining fish stocks	- Heat and salinity threat - Risk of invasive species	3	5	- Aquaculture project for 3 sea cage aquaculture sites, Dalma Island, Abu Dhabi
WF -22	Land-scaping & Forestry	Landscaping & Forestry	Landscaping	- Widespread landscaping across the UAE - 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	5	- Green Abu Dhabi initiative, Abu Dhabi
WF -23			Forestry	- Strong support due to the late Sheikh Zayed's vision of greening the UAE	- High water use with no tangible benefit towards food security	5	1	- Barari Forest Management, Abu Dhabi Emirate
WF -24	Water Resources	Smart Irrigation	Drip irrigation	- High water efficiency - Smart monitoring and scheduling	- Relatively high maintenance and replacement cost	4	5	- Drip irrigation project initiative by Dubai Silicon Oasis - Dacom intelligent irrigation system pilot study by ADFCA - ADFCA project fund of $ 133 million for advanced irrigation - Barari research & development center on irrigation technologies
WF -25			Spray irrigation	- Ease of installation, use and maintenance - Smart monitoring and scheduling	- Less water efficient than some other irrigation methods (high evapotranspiration)	5	3	- Efficient sprinkler system for reduced water consumption in Masdar City, Abu Dhabi
WF -26		Cooling	Misting fans for animal cooling	- Widespread on farms	- High water use	4	3	- Al Rawabi Dairy Farm, UAE
WF -27		Wastewater	Treated/ recycled wastewater	- Conservation of freshwater sources - Reduced use of synthetic fertilizer - No tertiary treatment of wastewater required - Current policies promoting usage of treated wastewater in agriculture	- Risks of heavy metal contamination to soil, crops & groundwater - Some cultural/public backlash to practice	4	5	- Sewage used in landscaping, Ajman - Environmental impact assessment of TWW in agriculture, Abu Dhabi - Treatment of municipal wastewater for agricultural use, UAE - ADFCA project on wastewater treatment use for irrigation of 143 farms, Abu Dhabi

SN	Category 1	Category 2	Approach/ technology	Approach strengths	Approach limitations	Maturity	Growth opportunity	Initiative(s)/Programme(s)
WF -28			Aquaculture effluent	- Use effluent with salt tolerant crops - Cultivation of otherwise barren lands	- Salt tolerant crops are not widespread	3	3	- Aquaculture effluents for cultivation of halophytes in coastal desert areas, Umm al Quwain
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 byproduct of the desalination process in the UAE, which can negatively impact marine ecosystems and fisheries through thermal, chemical and saline pollution.	3	5	- Dilution/dispersion already exists in the UAE at many desalination plants - Usage of brine for aquaculture exists inland as byproduct from BWRO
WF -30	Food imports	Food import	International trade partnerships	- Ability to import food from various countries based on quality, price, availability etc. thereby constantly balancing the UAE's supply-demand gap	- Significant market and climate risks associated with over dependence on imports	5	5	- Represents the major mechanism for food acquisition in the UAE
WF -31		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	- Food Watch, Dubai
WF -32			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	- No current system in existence but discussed as a policy option by Emirates Diplomatic Academy

3.2 Water-energy

Figure 17 shows the UAE's Water-Energy Nexus 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: UAE Water-Energy Nexus Map

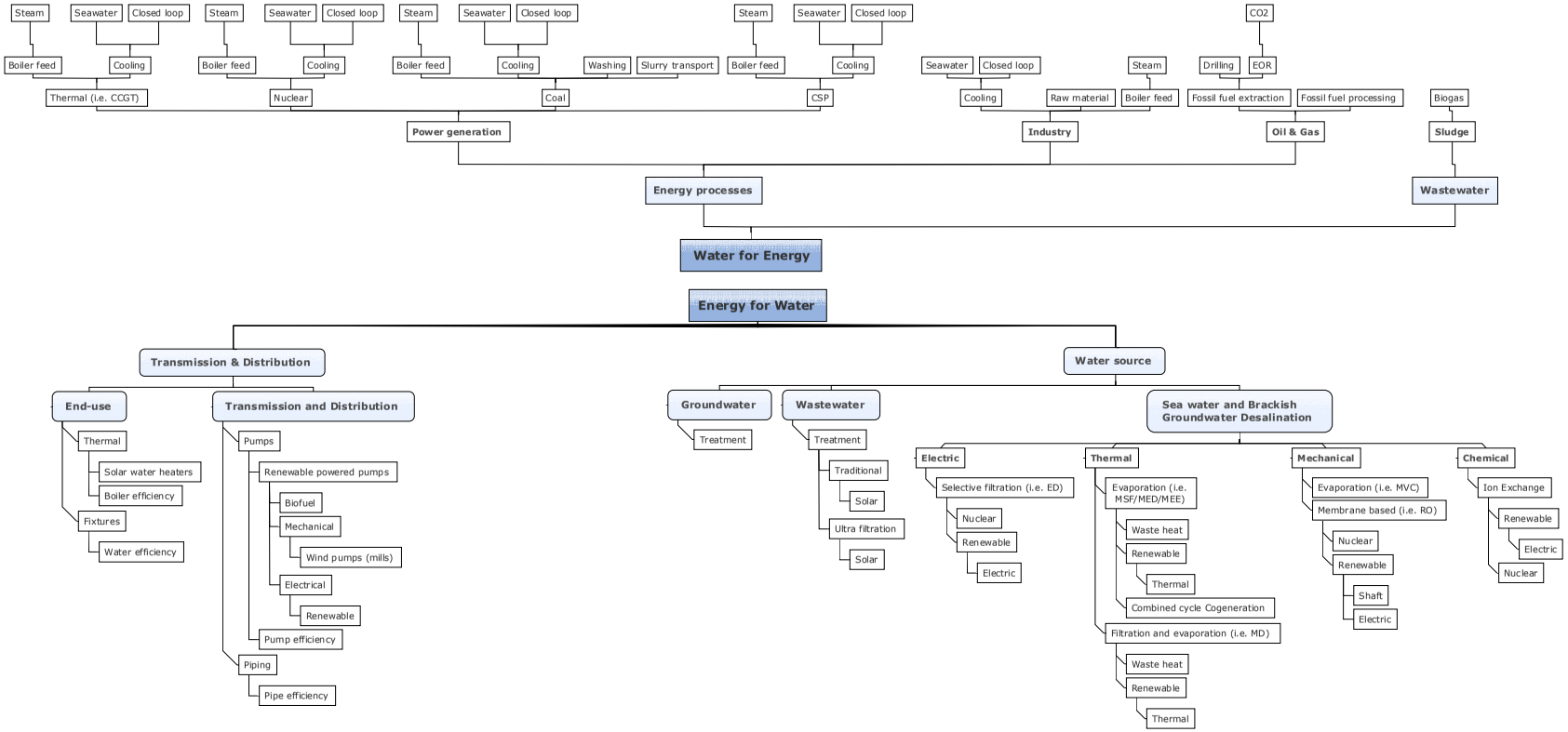


Table 3: UAE Water-Energy Nexus Initiatives

SN	Category 1	Approach/ technology	Approach strengths	Approach limitations	Maturity	Growth opportunity	Initiative(s)/Programme(s)
WE-1	Waste to Energy	Wastewater sludge to methane based biogas	- Significant sewage generated across UAE - Anaerobic digestion of sludge is a net energy producing process, in the form of biogas - Nutrient recovery (phosphate and nitrogen) can be used in agriculture/industrial applications - Local climate favorable to technology	- High investment cost for anaerobic digestion tanks and system	3	5	- Taqa Technology incubation unit, Abu Dhabi - Date pits and sludge, University of Sharjah
WE-2	Renewable energy powered desalination	MED/MSF/MEE with solar thermal	- High solar irradiance in UAE - Dropping costs of CSP brought on by largescale national projects like Shams 1 - Thermal storage is already being implemented in the UAE alongside most CSP projects	- 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)	3	5	- RO plants currently receive renewable sources of electricity through the existing energy mix (which includes PV, CSP and Nuclear) however only one project exists that directly couples renewables and desalination, the Masdar Renewable Energy Water Desalination Programme at Ghantoot, Abu Dhabi
WE-3		Reverse Osmosis with PV/nuclear/storage	- High solar irradiance in UAE - Dropping costs of PV brought on by largescale national and regional projects like the Mohammed bin Rashid Al Maktoum Solar Park - 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	- Reduced RO membrane lifetime due to high salinity and high temperature of Arabian gulf seawater - High OPEX (associated with membrane replacement) - PV is yet to be directly combined with RO	3	5	
WE-4	Cogeneration	Combined cycle - MSF/MED	- Cogeneration (combined cycle with MSF/MED) is the predominant technology utilized in the UAE - Availability of coastline makes power and water generation coupling easy - Low natural gas costs (through the Dolphin pipeline) - 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	- Various plants across the UAE (i.e. Jabal Ali M)
WE-5	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 may not be conducive to technology/solution adoption - Cost of systems - Technical challenges related to the Arabian Gulf (depth, high temperature and salinity)	4	5	- All industries, power plants and desalination plants on the coast that discharge cooling water, treated wastewater or brine into the sea
WE-6	RE powered WWTP	Solar powered WWTP	- High solar irradiance in UAE	- Intermittency, unless a hybrid system - Currently, higher cost than grid connection	1	4	- No initiatives

SN	Category 1	Approach/ technology	Approach strengths	Approach limitations	Maturity	Growth opportunity	Initiative(s)/Programme(s)
WE-7	Water pumping and transport	Solar water pumps	- High solar irradiance in UAE - Off-grid usage makes system mobile, and avoids electrification costs	- Intermittency, unless a hybrid system	4	5	- SunEnergy solar pumps, Dubai and Abu Dhabi - DUSOL solar pumps, Dubai
WE-8		Biofuel water pump	- Algae biofuel production and application being researched in UAE	- Dependent on maturity of biofuel technology	2	4	- No initiatives
WE-9		Piping efficiency and T&D monitoring	- Water system savings - Identification of system nodes requiring maintenance and/or replacement through monitoring system (i.e. SCADA)	- Pipe replacement and/or maintenance can be costly and disruptive - High marginal cost of improvement due to existing high network efficiency	5	4	- Water pipeline project contract of AED 248 Million for DEWA using remote control & monitoring systems Dubai
WE-10	Water heating & cooling	Solar-water heaters	- High solar irradiance in the UAE 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	4	5	- Solar hot water system per Estidma's Pearl Villa Rating System, Abu Dhabi - Solar water heater system implemented at IRENA, Abu Dhabi
WE-11		Solar-Cooling systems	- High solar irradiance in UAE - High cooling load in UAE - Dropping PV and other solar technology costs	- Intermittency, unless a hybrid system	3	5	- SOLAB, Ras al Khaima - Green Technologies FZCO, Dubai
WE-12	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	5	- EMPOWER, Dubai - Tabreed, Abu Dhabi
WE-13	Water fixtures	Water fixture efficiency	- Market adoption of existing voluntary green building codes such as LEED - Emergence and adoption of mandatory green building codes such as Estidama and Saa'fat - Rising water tariffs among all Emirates and sectors	- No significant constraints	5	5	- Estidama green building code, Abu Dhabi - Saa'fat green building code, Dubai - Energy efficient fixtures by ESMA, Abu Dhabi - Water flow reducers initiative by DEWA, Dubai
WE-14	Water use in Oil & Gas	Fossil fuel extraction	- Water steam savings from EOR process by CO2 injection substitution - Reduced aquifer pollution compared to using produced water - Form of carbon sequestering	- Risk of CO2 contamination into aquifers	3	4	- Al Reyadah CCUS project partnership between ADNOC& Masdar - Rumaitha North CO_2 injection facility, Abu Dhabi
WE-15		Monitoring systems	- Ability to monitor and analyze water and energy consumption and losses across Oil & Gas value chain	- Challenges in data collection and integration of assets across value chain	3	4	- Atmata' automation initiative (partnership between ENOC and MoE), Dubai, UAE

3.3 Energy-Food

Figure 18 shows the UAE Energy-Food Nexus 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: UAE Energy-Food Nexus Map

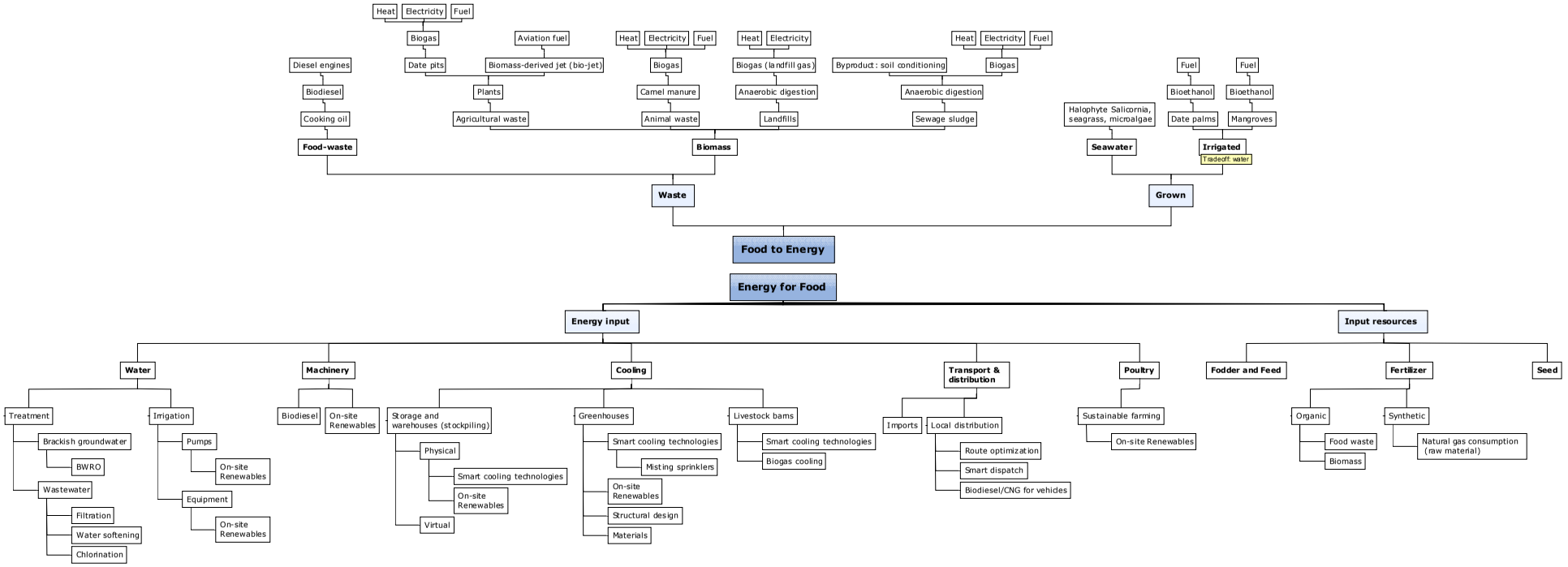


Table 4: UAE Food-Energy Nexus Initiatives

SN	Category 1	Category 2	Approach/ technology	Approach strengths	Approach limitations	Maturity	Growth opportunity	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	2	4	- Biojet initiative, Abu Dhabi - Integrated Seawater Energy and Agriculture System (ISEAS), Masdar City, Abu Dhabi
FE-2			Bioethanol	- Strong market interest in sustainable fuels (i.e. existing CNG taxis in Abu Dhabi)	- Unless resulting from a waste stream, process will be water intensive - Limited number of native species that can be used at commercial scale - More expensive than conventional fuels	3	5	- ISEAS Masdar project on bioethanol production from oil rich native plants Study on bioethanol potential of lignocellulosic biomass such as date palm & mangroves
FE-3		Biofuels from Waste	Biogas from animal waste	- Animal waste is a significant and un-utilized waste stream in the UAE	- Biomass yield is dependent on the kind of bio-waste (e.g. cattle or camel manure, chicken droppings etc.) - Not feasible for all farms given size	2	4	- Opportunities discussed by EAD policy brief 'High potential of camel manure in biogas production', Abu Dhabi
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 UAE (100m3 of gas/tonne of MSW)	- Large infrastructural investments required	3	5	- Tadweer/Taqa 100 MW WtE facility in Abu - Masdar/Bee'ah 30 MW WtE facility in Sharjah (to start in 2020) - Dubai Municipality, 180 MW WtE facility in Dubai (to start in 2020)
FE-5			Biodiesel from food waste	- Significant food waste exists in the UAE, 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	- Neutral Fuels, UAE - ENOC Biodiesel 5, Dubai - Lootah fuels, Dubai - Biodiesel from date pits, UAE - Cooking oil to biodiesel fueling station in Jebel Ali, Dubai - Cooking oil to biodiesel at Tadweer, Abu Dhabi
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	- 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	- Cooling systems may present high initial investment cost with a long ROI	3	5	- Active air cooling, PureHarvest, UAE

SN	Category 1	Category 2	Approach/ technology	Approach strengths	Approach limitations	Maturity	Growth opportunity	Initiative(s)/Programme(s)
FE-8			Cooling of storage	Opportunities exist for more energy efficient cooling technologies, coupled with smart systems for monitoring and process optimization	- Inherent tradeoffs of some cooling systems (i.e. high water efficiency but high energy or vice versa)	3	4	- Smartcool, Dubai
FE-9		Greenhouses	Reducing cooling load through design and materials	- Greenhouses are widespread in the UAE and the main viable method of non-animal food production in the country - Greenhouses consume significant amounts of energy for cooling - Opportunities for synergies with other technologies and setups (i.e. aquaculture)	- Materials must be tolerant to harsh UAE climate - Potentially higher cost	3	4	- No initiatives
FE-11		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	- No initiatives
FE-12		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	2	5	- No initiatives
FE-13			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	2	4	- No initiatives
FE-14			Biodiesel for equipment	- Renewable source of fuel that can be generated from onsite agricultural waste streams and byproducts	- More expensive than conventional fuels if purchased	1	4	- No initiatives
FE-15	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	4	- No initiatives
FE-17			Physical/ emergency stockpiling	- Strategic storage reserves allow for release of stockpiles during emergencies or price hikes	- Investment cost and maintenance - Cooling and humidity control	4	5	- Al Wathba Mega Production & Distribution Complex, Abu Dhabi
FE-18		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	4	5	- No initiatives

CASE STUDY: Pure Harvest Smart Farm, an up-and-coming technology enabled agri-business in the UAE

An interview with Majed Halawi, Chief of Staff at Pure Harvest Smart Farms Ltd. was conducted to provide an understanding of: (a) the main drivers and challenges faced in local fresh fruits & vegetables production; (b) the vision for food production in the UAE; and (c) the potential areas in which companies abroad can support.

What is Pure Harvest?

Pure Harvest is a technology enabled agri-business in the UAE that focuses on the production of locally grown, fresh fruits and vegetables all year-round – overcoming the challenges presented by the harsh, arid climate in the Middle East. The business aims to deliver the best possible quality products through investing in and deploying world-leading controlled environment agriculture (CEA) technologies.

What are the challenges to local food production?

One of the most important drivers for local food production is the UAE's unusually high dependence on food imports. However, the UAE is blessed with abundant sunlight, land (with limited alternative uses), low-cost & reliable energy supply, low labor costs, near-zero taxes and high domestic purchasing power. Once you control for climate (using technology), these factors together make the UAE an attractive place to produce fresh produce. This is compounded by new technological innovations and changing cost curves. For example, the decreasing cost of renewable energy sources is expected to enable the production of freshwater via renewable-powered desalination – which would be extremely valuable to local producers like Pure Harvest.

What are the drivers for producing food domestically?

There are a number of challenges to local food production that need to be addressed. These include physical, financial and regulatory challenges.

Physical	Financial	Regulatory
• Availability of freshwater • Salinity of water and soil • Temperature and humidity • Significant energy requirements to manage climate	• Nascence of industry – no 'proof points' to influence investors/ government leaders • Dearth of investment into 'hardware' technology companies in the region (including tech-enabled food production) • Lack of sector commercialization • Costly set-up of new businesses • Access to skilled local labor • Availability of equipment financing and leasing	• Access to land • Indistinct permitting regulations • Forced use of high salinity aquifers

What is Pure Harvest's vision for the future of food production in the UAE?

Pure Harvest's vision is the large-scale commercialization of the sector into agricultural complexes that are inclusive of easy access to land for the setup of greenhouses and utilities such as high quality irrigation water, low-cost / renewable power sources, food-grade CO2 supply and (potentially) district cooling (optimize energy consumption).

How can companies abroad support and what should they consider before engaging the UAE market?

Companies/entities outside the UAE with the right expertise can support through their technical expertise as well as offering financial schemes or partnering through investments with local food producers. Prior to entering the UAE market, companies need to understand the market in terms of the specific market & non-market constraints of the country and its technological capabilities/ skill gaps & limitations as well as an understanding of the business culture.

4. Investment and Engagement Opportunities

Investment/engagement opportunities in the UAE were identified for Dutch companies based on the technologies and approaches outlined in Tables 2, 3 and 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 the UAE). 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 the UAE. Knowledge partnerships can include more than one local or Dutch partner. The WEF stakeholder groups in the UAE identified in Table 7 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. 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/expertise on the most suitable choice of crops, best practices in system maintenance, analysis of data and so forth. The latter can be delivered via training, consulting, joint research projects etc.

Table 6: Identified technologies and approaches for partnership opportunities

Nexus	Approach/ technology	Scoring		Category Type	
		Maturity	Growth Opportunity	1	2
WF-19	Organic farming	5	5	X	
WF-22	Landscaping	5	5	X	
WF-30	International trade partnerships on food imports	5	5	X	
WF-20	Land-based aquaculture	4	5	X	
WF-13	Hydroponic farming	4	5	X	
WF-24	Drip irrigation	4	5	X	
WF-10	High-tech greenhouses	3	5		X
WF-14	Aquaponics	3	5		X
WF-21	Sea-based aquaculture	3	5		X
WF-29	Brine management	3	5		X
WF-31	Food safety monitoring systems for food imports	3	5		X
WF-16	Surface water farming	2	5		X
WF-32	Early warning systems for food import monitoring	2	5		X

Nexus	Approach/ technology	Scoring		Category Type	
		Maturity	Growth Opportunity	1	2
WF-7	Agricultural seaweed and macro-algae farming for animal feed	1	5		X
WF-27	Treated/recycled wastewater applications	4	5	X	
WF-6	Native and climate compatible crops for agricultural use	4	4	X	
WF-18	Organic fertilizer use in farming	4	4	X	
WE-12	District cooling	5	5	X	
WE-13	Water fixture efficiency	5	5	X	
WE-5	Industrial water discharge management	4	5	X	
WE-7	Solar water pumps	4	5	X	
WE-10	Solar water heaters	4	5	X	
WE-1	Wastewater sludge to methane based biogas	3	5		X
WE-2	Solar thermal integrated MED/MSF/MEE desalination	3	5		X
WE-3	PV/nuclear integration with RO	3	5		X
WE-11	Solar cooling systems	3	5		X
WE-9	Water piping efficiency and T&D monitoring	5	4	X	
FE-17	Physical/emergency stockpiling for food transport and distribution	4	5	X	
FE-18	Route & inventory optimization of local food distribution	4	5	X	
FE-2	Bioethanol production	3	5		X
FE-4	Biogas production from landfills	3	5		X
FE-7	Cooling of greenhouses	3	5		X
FE-12	PV for irrigation and pumps	2	5		X

5. Road to EXPO 2020

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 the UAE at 35 and fast rising, the Expo 2020 presents the two countries with a timely opportunity to collaborate on developing and implementing innovative solutions.

Furthermore, the UAE has the opportunity to become a global innovation hub, in line with its National Strategy for Innovation. The country can benefit from its human and financial capital to drive innovative research and development in addition to attracting foreign investments. The UAE can focus on creating an environment of innovation for food production technologies in arid climates. The UAE is uniquely situated to propel this due to its well established regional and global partnerships, ease of doing business, and strong national commitment towards food security, innovation and sustainability.

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

5.1 Success through engagement

For Dutch companies looking to enter the UAE WEF market, engaging with the right stakeholders is pivotal. Doing business in the UAE 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 the UAE, the ministries are driving the strategies on resource conservation and diversification linked to the WEF Nexus. While WEF security is high on the government agenda in the UAE, 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.

5.1.1 Direct engagement with local entities

Though by no means exhaustive, Figure 19 and Table 7 illustrates some of the key WEF stakeholders in the UAE. 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 7 identifies high level engagement strategies by stakeholder group.

Figure 19: UAE Water Energy Food Nexus Map

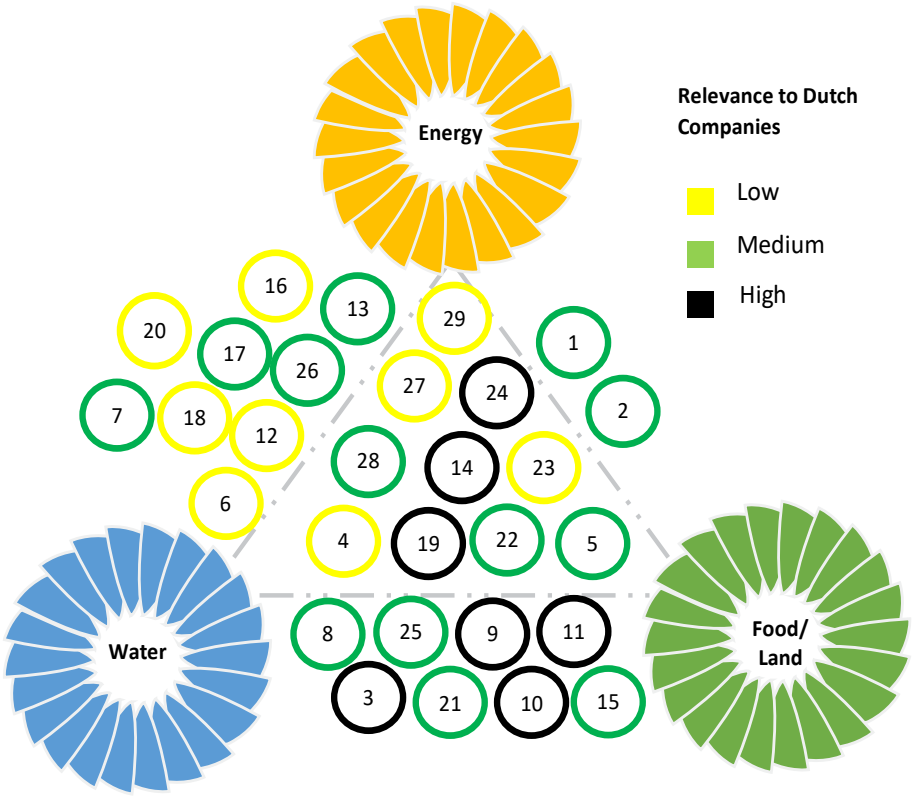


Table 7: Engagement strategy of WEF stakeholder groups in the UAE

Entity Type		Engagement Strategy
Government operator entities		1. Information collection: Dutch Companies need to form a solid understanding of the strategies, objectives and operations of the various government operators in the UAE 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 UAE-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.
1	Centre for Waste Management Abu Dhabi (Tadweer)	
2	Bee'ah	
3	Abu Dhabi Farmers' Services Centre	
4	Abu Dhabi Sewerage Services Company	
5	Dubai Municipality	
6	Water & Electricity Authorities (DoE, DEWA, SEWA & FEWA)	
7	Department of Urban Planning & Municipalities	
Government regulator entities		1. Establish focal point: Dutch companies need to establish a key focal point within their organization that will regularly engage with the UAE government regulator entities to improve communications and access to
8	The Environment Agency of Abu Dhabi	

Entity Type		Engagement Strategy
9	UAE Ministry of Climate Change & Environment	information. This can be complemented with meetings in person to establish key contact points within priority departments in UAE government entities to build a trust-based relationship. Dutch companies can capitalize on UAE-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 UAE government regulators familiarize themselves with new information. As the UAE 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
10	Abu Dhabi Food Control Authority	
11	Food Security Centre Abu Dhabi	
12	The Regulation & Supervision Bureau	
13	Ministry of Energy and Industry	
14	Ministry of Food Security	
15	Emirates Authority for Standardization and Metrology	
Industry		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 UAE industry leaders to increase their chances of success. Sharing new insight might be challenging as UAE 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.
16	Emirates Nuclear Energy Corporation	
17	ADNOC Group Companies	
18	Emirates National Oil Company	
19	Agribusinesses	
20	Masdar company	
International organizations and NGOs		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 UAE market which could support companies in their engagement with government operators/regulators.
21	Arab Authority for Agricultural Investment & Development	
22	IRENA	
23	Food and Agriculture Organization	
Other		1. See section 5.2.
24	Expo 2020	
Universities and Research Institutes		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
25	International Center of Biosaline Agriculture	
26	National Center of Meteorology	
27	Abu Dhabi Global Environmental Data Initative	
28	Masdar Institute of Science & Technology	
29	Emirates Diplomatic Academy	

5.1.2 Dutch Business Councils and the Economic Network

Dutch Business Councils in the UAE are useful channels of entry for Dutch companies looking to enter the UAE's WEF market. These councils are established as a means of networking and promoting business links between the UAE and the Netherlands. Currently, two councils exist, The BeNeLux Business Council in Abu Dhabi[29] and the Netherlands Business Council (NBC) in Dubai[30]. Dutch companies can strengthen their trade and investment opportunities in the region, by becoming members of these business councils, connecting with over 200 registered companies, and gaining valuable insights from the region.

[29] BeNeLux Business Council, 2018.

[30] Netherlands Business Council Dubai, 2017.

Another entry channel for Dutch companies is the Dutch Economic Network in the Gulf Region, including Abu Dhabi and Dubai, which is established to help Dutch businesses in identifying business opportunities within the Gulf Countries. [31] 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.

5.2 EXPO 2020 engagement channels

Between October 2020 and April 2021, Dubai will host the next world Expo under the theme of "Connecting Minds, Creating the Future". This event recognizes the importance of worldwide collaboration in generating sustainable technologies that are aimed at solving global problems, including water, energy and food security.

The UAE is working towards becoming a global innovation hub, in line with the country's National Strategy for Innovation. As a part of this, the UAE can act as a living innovation lab for food production technologies in arid climates.

The Expo 2020 presents the UAE and the Netherlands with a timely opportunity whereby the two nations can work together on developing and implementing innovative solutions. This Expo provides opportunities of collaborations for Dutch companies over the short-term six month period of the Expo as well as the long-term pre-Expo period starting from today. The Dubai Expo has a number of main themes which are illustrated in Figure 20. The figure also highlights the several channels by which Dutch companies can engage with the Expo, be it before or during the event.

Figure 20: Dubai Expo 2020 main themes for collaborations and interactions[32]

**Channels that Dutch companies can use to engage with the Expo*

5.2.1 Business Connect

One of the main objectives of the Expo 2020 is to connect people and ideas in order to allow businesses to progress. The Expo underlines this under the theme 'Business Connect' allowing businesses to share

[31] Kingdom of the Netherlands, *Dutch Economic Network in the GCC,* 2018.
[32] Expo 2020 Dubai UAE, 2018.

ideas and experiences to facilitate recommendations that allow them to bring about the best solutions. Business connect has already been put in place where it helped bring together senior representatives across 1,300 businesses from a wide variety of industries.[33] This channel is an opportunity for Dutch companies to get involved pre-Expo and provide valuable opportunities for the Expo in meeting its objectives in which potential areas of partnership and collaboration can arise.

5.2.2 Procurement

The Dubai Expo 2020 has an online portal for companies (small, medium and large) to submit bids for tenders through the Expo committee.[34] Over 100 tenders are available on a monthly basis thereby providing Dutch companies with a vast amount of opportunities. Through the online tender portal of the Expo, the supplier quick guide option will help the user to search and respond to online tenders.

5.2.3 Expo Live

One of the opportunities that are open for collaboration in which Dutch companies can get involved is the Expo Live Innovation Impact Grant Programme launched by the Expo. This programme is based on innovation and partnership in which it invites anyone to get involved by sharing their innovative ideas both pre-Expo and during the Expo. The initiative not only promotes creative solutions for a more prosperous future but also helps accelerate these solutions through funding[35]. The main focus themes identified as drivers of progress by the Expo are 'Opportunity, Mobility and Sustainability', which Dutch companies can align with.

5.2.3.1 Partnerships

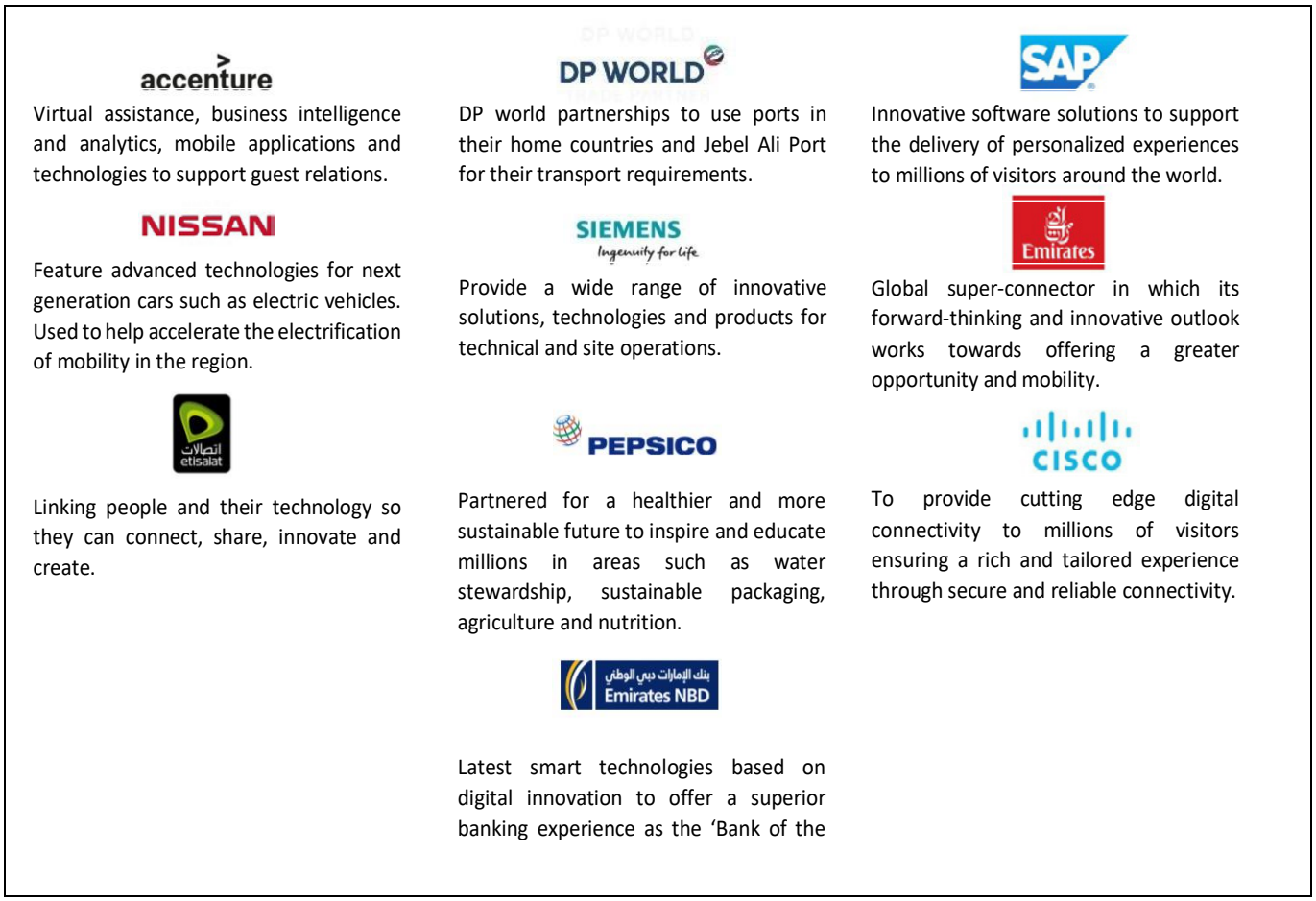
Expo 2020 is constantly encouraging organizations of all shapes and sizes, across a range of industries and from all over the world to become involved with the variety of projects. Partnerships are key for the Expo to meet their targets for an event of such proportion where it invites partners from different sectors to become involved. Dutch companies can add value to the activities of the Expo through this program. Using this channel, Dutch companies can directly contact the organizers and identify the areas in which they can add value such as innovation and advanced technologies. Table 8 summarizes the different levels of partnership according to the Expo. Figure 21 highlights existing Expo partners along with their strategic contributions to the Expo.

Table 8: Different levels of partnerships available for the Expo and their criteria[36]

Official Provider	Official Partner	Premier Partner
• Local rights • Lowest level of partnership and visibility • Focus on delivery of Value in Kind (VIK)	• Global rights • Second level of partnership and visibility	• Global rights • Highest level of partnership and visibility • Prioritized assets and offering • Making significant contributions to the vision, delivery and legacy of the Expo

[33] Expo 2020 Dubai UAE, *Doing Business with Expo 2020 Dubai,* 2018.
[34] Expo2020 Dubai UAE, *Supplier Quick Guides*, 2018.
[35] Expo2020 Dubai UAE, *Expo Live*, 2018.
[36] Expo 2020 Dubai UAE, *Planning an exceptional Expo Annual Review,* 2016.

Figure 21: Premium Partners of the Expo along with their value added through partnership



5.2.4 Economic legacy: Collaborative entrepreneurship

One of the channels identified for Dutch companies to become involved pre-Expo is the collaborative entrepreneurship programme established to maintain the economic legacy of the Expo. This initiative seeks to support economic growth both regionally and internationally by creating partnerships for value creation through fostering entrepreneurship. The aim is to get corporations, SMEs, startups and investors involved so as to create mutually beneficial business partnerships for a positive impact on the economy.[37]

5.2.5 Pavilions

The overall theme of the Expo is guided by the three pillars 'Opportunity, Mobility and Sustainability', each theme having its own Pavilion. Along with the thematic pavilions, Dutch companies can utilize the Dutch Pavilion to showcase their country's innovative technologies, solutions and ideas.

[37] Expo2020 Dubai UAE, *Economic Legacy*, 2018.

5.2.5.1 The Dutch Pavilion

Dutch Pavilion Focus:

As in every World Expo, each country is requested to identify a theme for its national pavilion. After consultations with Dutch businesses, knowledge institutions and governmental bodies, the theme '*The water, energy & food nexus*' was chosen as the theme of not only the Dutch participation to the World Expo 2020, but also of the wider engagement of the Netherlands with the Gulf.

Pavilion Opportunities:

The World Expo 2020 provides Dutch businesses and knowledge institutions, active in the field of the water, energy & food with the following opportunities:

1. To contribute to and profit from the calendar of activities that is being set up for the period running up to and during the EXPO 2020 Dubai.
2. To participate in the tender for the design, construction, content/experience, maintenance and deconstruction of the Dutch pavilion;
3. To use the Dutch pavilion at World Expo 2020 as a meeting point with customers or platform with experts, and for events like business seminars, congresses, etc.

Calendar of Activities

In the years leading up to Expo 2020, and during the Expo itself, a calendar of events will be developed, consisting of activities (e.g. trade missions, seminars, projects and workshops) organized by Dutch government institutions, businesses and knowledge institutions related to the WEF Nexus theme . The aim of the calendar is to coordinate the activities organized by the public and private sector, to enhance the Dutch visibility on the WEF Nexus, and to strengthen the Dutch profile in the Gulf region. Dutch businesses, knowledge institutions and governmental bodies that are interested to share information on their activities related to the Nexus theme or one of the three sectors (water, energy, food), can do so by e-mailing to: DIO-EXPO2020@minbuza.nl.

Participation in the tender for the design, construction, content and deconstruction of the Dutch pavilion

The tender for the design, construction, content/experience and deconstruction of the Dutch pavilion is to be published on June 15th 2018, on www.tenderned.nl. The pavilion has to be the innovative, unconventional embodiment of the Dutch water, energy and food campaign. Both in the exhibition or experience for the day visitors, and in the construction of the pavilion and landscaping, the Netherlands will showcase the best of what it has to offer with respect to the WEF Nexus. Dutch businesses can thus use this platform and participate in the tender in particular as a platform for their products and services.

Use of the Dutch pavilion during the six months of the EXPO 2020 Dubai

The Dutch pavilion will be used to showcase the best Dutch innovations and sustainability projects with respect to the WEF Nexus. Apart from an area in which the general public is drawn into a WEF 'experience', the pavilion will also have a number of special features, including a VIP/business area that will be available for rent by Dutch businesses. The business facilities area can be used to host business meetings, seminars etc. Dutch businesses interested in renting the pavilion facilities for corporate events during the Expo 2020, can contact the Dutch project team Expo 2020 through DIO-EXPO2020@minbuza.nl.

6. Appendix A

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

SN	Initiative(s)/Programme(s)	Links
WF-1	- Livestock Chain Monitoring Committee, Ministry of Climate Change and Environment, UAE	http://gulfnews.com/news/uae/government/new-panel-to-monitor-livestock-chain-1.2161212
WF-2	- The Abu Dhabi Farmers' Services Centre Breeding Programme	http://gulfnews.com/news/uae/general/breeding-programme-for-3-3m-goats-and-sheep-in-abu-dhabi-farms-1.1318276
WF-3	- Various production systems for livestock and poultry exist across the UAE (i.e. caged vs. free range livestock)	http://www.deenafarms.com/about-us/
WF-4	- Discussions on GMO use in the UAE are taking place, however no conscious efforts have been made towards GMO livestock production	http://gulfnews.com/news/uae/environment/genetically-modified-organisms-can-help-with-food-security-1.2171656
WF-5	- Poultry farms are widespread throughout the UAE with various setup types (i.e. caged vs. free range)	https://www.greenheartuae.com/product/eggs-organic-free-range/
WF-6	- Date palm salinity tolerance, Biosaline institute	http://www.biosaline.org/sites/default/files/Projectbrieffiles/Project_Brief_Investigation%20of%20Elite%20Date%20Palm.pdf
	- Quinoa initiative, UAE	http://www.biosaline.org/sites/default/files/Projectbrieffiles/Quinoa-Project_Brief-Final-2.pdf
WF-7	- No initiatives, approach is still in its infancy within the UAE	–
WF-8	- End of water intensive fodder subsidies, ADFCA, Abu Dhabi	https://www.thenational.ae/uae/environment/end-to-subsidy-for-farmers-rhodes-grass-1.567671
	- Support for fodder imports, ADFCA, Abu Dhabi	https://www.adfca.ae/English/MediaCenter/News/Archived%20News/Imported.aspx
WF-9	- Discussions on GMO crop use in the UAE taking place, but no conscious efforts made towards GMO crop production	http://gulfnews.com/news/uae/environment/genetically-modified-organisms-can-help-with-food-security-1.2171656
WF-10	- A number of smart greenhouses are emerging in the UAE, such as those done by Pure Harvest, UAE	http://pureharvest.ae/
WF-11	- The Sahara Forest Project (2009), UAE	https://www.thenational.ae/uae/environment/greenhouses-cooled-by-seawater-to-grow-crops-in-the-uae-desert-1.342299
WF-12	- EAD-Philippine Global School, Abu Dhabi	https://geodomas.eu/portfolio/o6m-biodome-philippine-global-school/
WF-13	- ADFSC, Abu Dhabi	https://www.adfsc.ae/en/pages/our-projects.aspx
	- Emirates hydroponics farms, Dubai and Abu Dhabi	http://www.Emiratesfarms.com/
	- Pegasus agriculture group, UAE	http://pegasusagriculturegroup.com/the-project/
	- Bani Yas Agricultural Research Center	http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=11214
	- Hydroponic Agriculture Project	http://wam.ae/en/details/1395302632784
	- Hydroponic initiative, Ajman, 2009	http://www.fujairahobserver.ae/municipality-news/crown-prince-court%E2%80%99s-employees-launch-%E2%80%9Cal-bayt-mitwahid%E2%80%99-across-uae-8588.html
WF-14	- Bani Yas center growing tilapia fish, Abu Dhabi	https://www.thenational.ae/uae/uae-aquaponics-project-hailed-as-a-success-1.394940
	- Jebel Ali resort & hotel growing cherry fish & cherry tomatoes, Dubai	https://www.khaleejtimes.com/article/20130518/ARTICLE/305189998/1002
WF-15	- Urban Agriculture research center, Dubai	
		https://www.uowdubai.ac.ae/news/uowd-and-plantagon-establish-urban-agriculture-research-centre-dubai
WF-16	- No initiatives, concept is still in its infancy within the UAE	Not Applicable
WF-17	- Al Najeh honey, UAE	http://alnajeh.ae/
WF-18	- Adfert organic fertilizer made of seaweed, Abu Dhabi	http://adfert.com/products/special_fertilizer.html
WF-19	- 54 organic farms in the UAE due to government initiatives, UAE	https://government.ae/en/information-and-services/environment-and-energy/agriculture-sector
WF-20	- Dubai Center for Research and Development of Fisheries (DCRDF), Dubai	https://www.ldk.gr/index.php/en/component/ldkprojects/?view=project&id=611-dubai-center-for-research-and-development-of-fisheries-dubai

SN	Initiative(s)/Programme(s)	Links
	- Sheikh Khalifa Bin Zayed Marine Research Center, Umm Al Quwain	https://www.ldk.gr/index.php/en/component/ldkprojects/?view=project&id=591-sheikh-khalifa-bin-zayed-centre-for-marine-research-umm-al-quwain
	- Advanced technological production of caviar & sturgeon meat, Abu Dhabi	http://www.Emiratesaquatech.ae/2013/11/26/Emirates-aquatech-the-worlds-most-technologically-advanced-aqua-farm-launched-in-abu-dhabi/
WF-21	- Aquaculture project for 3 sea cage aquaculture sites, Dalma Island, Abu Dhabi	http://www.bmtargoss.com/news/article/market/149417/bmt-secures-new-aquaculture-project-in-abu-dhabi
WF-22	- Green Abu Dhabi initiative, Abu Dhabi	https://www.moccae.gov.ae/en/media-center/news/6/8/2017/dmat-launches-green-abu-dhabi-initiative-for-date-trees-and-landscaping.aspx
WF-23	- Barari Forest Management, Abu Dhabi Emirate	http://www.barari.ae/forest-management.html
WF-24	- Drip irrigation project initiative by Dubai Silicon Oasis	https://www.dsoa.ae/en/news/dubai-silicon-oasis-implements-regions-first-water-saving-subsurface-irrigation-system/
	- Dacom intelligent irrigation system pilot study by ADFCA	https://oxfordbusinessgroup.com/analysis/developing-and-maintaining-efficient-forms-irrigation
	- ADFCA project fund of $ 133 million for advanced irrigation	https://www.adfca.ae/English/MediaCenter/Publications/Documents/INITIATIVES%20TO%20ENSURE%20SUSTAINABILITY%20OF%20WATER%20RESOURCES.pdf
	- Barari research & development center on irrigation technologies	http://www.barari.ae/research.html
WF-25	- Efficient sprinkler system for reduced water consumption in Masdar City, Abu Dhabi	http://www.masdar.ae/en/intiatives/detail/masdar-innovating-for-a-water-secure-future
WF-26	- Al Rawabi Dairy Farm, UAE	http://www.dairyglobal.net/Articles/General/2016/3/Dubai-farm-to-focus-on-good-quality-fodder-and-animal-cooling-2772329W/
WF-27	- Sewage used in landscaping, Ajman	http://biosaline.org/sites/default/files/Projectbrieffiles/project_brief_ajman_sewerage_v1-eng-pages-bleeds.pdf
	- Environmental impact assessment of TWW in agriculture, Abu Dhabi	http://www.fao.org/3/i8527en/I8527EN.pdf
	- Treatment of municipal wastewater for agricultural use, UAE	http://www.biosaline.org/sites/default/files/project_brief_benefits_and_risks_of_using_treated_municipal_v3-eng-web.pdf
	- ADFCA project on wastewater treatment use for irrigation of 143 farms, Abu Dhabi	https://www.adfca.ae/English/MediaCenter/Publications/Documents/INITIATIVES%20TO%20ENSURE%20SUSTAINABILITY%20OF%20WATER%20RESOURCES.pdf
WF-28	- Aquaculture effluents for cultivation of halophytes in coastal desert areas, Umm al Quwain	http://www.biosaline.org/sites/default/files/icba_wins_Expo_2020_grant_press_release_final_english.pdf
WF-29	- Dilution/dispersion already exists in the UAE at many desalination plants	http://gulfnews.com/news/uae/environment/waste-dump-threatens-arabian-gulf-1.72058
	- Usage of brine for aquaculture exists inland as byproduct from BWRO	http://www.biosaline.org/sites/default/files/icba_wins_Expo_2020_grant_press_release_final_english.pdf
WF-30	- Represents the major mechanism for food acquisition in the UAE	http://gulfnews.com/news/uae/society/uae-s-long-term-food-security-strategy-under-study-1.2170588
WF-31	- Food Watch, Dubai	https://freshproducesafety-anz.com/2017/11/28/ae-dubai-launches-high-tech-food-watch-programme/
WF-32	- No current system in existence but discussed as a policy option by Emirates Diplomatic Academy	http://eda.ac.ae/images/pdf/EDA_Insight_Food_and_Climate_Synergies_EN.pdf

SN	Initiative(s)/Programme(s)	Links
WE-1	- Taqa Technology incubation unit, Abu Dhabi	http://gulfnews.com/news/uae/environment/abu-dhabi-plans-major-waste-to-energy-projects-1.1423679
	- Date pits and sludge, University of Sharjah	http://sesam-uae.com/quality14/presentations/Wameed_Mohamad_Ali_Radeef.pdf
WE-2	- RO plants currently receive renewable sources of electricity through the existing energy mix (which includes PV, CSP and Nuclear) however only one project exists that directly couples renewables and desalination, the Masdar Renewable Energy Water Desalination Programme at Ghantoot, Abu Dhabi	http://www.masdar.ae/assets/downloads/content/3588/desal_lr.pdf
WE-3		
WE-4	Cogeneration performed at various plants across the UAE (i.e. Jabal Ali M cogeneration plant, Dubai)–	No Applicable
WE-5	- All industries, power plants and desalination plants on the coast that discharge cooling water, treated wastewater or brine into the sea	Not Applicable
WE-6	- No initiatives	Not Applicable
WE-7	- SunEnergy solar pumps, Dubai and Abu Dhabi	http://www.sunergysolar.ae/en/contents/view/solar-water-pumping-system-uae.html
	- DUSOL solar pumps, Dubai	http://www.dusol.ae/projects.php?pid=swp
WE-8	- No initiatives	–
WE-9	- Water pipeline project contract of AED 248 Million for DEWA using remote control & monitoring systems Dubai	https://www.dewa.gov.ae/en/about-dewa/news-and-media/press-and-news/latest-news/2017/06/dewa-awards-aed-248-million-contract-for-water-pipeline-project
WE-10	- Solar hot water system per Estidma's Pearl Villa Rating System, Abu Dhabi	https://www.upc.gov.ae/en/estidama/pearl-rating-system/pearl-villa-rating-system
	- Solar water heater system implemented at IRENA, Abu Dhabi	http://www.masdar.ae/assets/downloads/content/4996/irena_hq.pdf
WE-11	- SOLAB, Ras al Khaima	https://www.sciencedirect.com/science/article/pii/S1876610214003774
	- Green Technologies FZCO, Dubai	http://www.greentechno.com/design-solar-assisted-cooling-system-abu-dhabi-united-arab-Emirates/
WE-12	- EMPOWER, Dubai	https://www.zawya.com/uae/en/story/UAEs_Empower_puts_spotlight_on_smart_district_cooling-SNG_107781195/
	- Tabreed, Abu Dhabi	https://www.tabreed.ae/
WE-13	- Estidama green building code, Abu Dhabi	https://www.upc.gov.ae/en/estidama/pqp-and-ica/estidama-villa-product-database/water-fixtures-and-fittings
	- Sa'fat green building code, Dubai	https://www.dm.gov.ae/wps/wcm/connect/336d1d11-ae11-4271-a614-07dd98d18520/english+alsafat+book.pdf?MOD=AJPERES
	- Energy efficient fixtures by ESMA, Abu Dhabi	http://Emiratesgbc.org/wp-content/uploads/2017/03/AbuDhabi-Green-Building-City-Market-Brief_May-2017_Final.pdf
	- Water flow reducers initiative by DEWA, Dubai	https://www.dewa.gov.ae/en/customer/sustainability/spread-the-message/be-water-smart
WE-14	- Al Reyadah CCUS project partnership between ADNOC& Masdar	http://www.ogj.com/articles/2018/01/adnoc-plans-sixfold-hike-in-carbon-dioxide-injection.html
	- Rumaitha North CO_2 injection facility, Abu Dhabi	https://www.protenders.com/companies/alsa-engineering-construction-company/projects/rumaitha-north-carbon-dioxide-co2-injection-facility
WE-15	- Atmata' automation initiative (partnership between ENOC and MoE), Dubai, UAE	https://www.enoc.com/en/media-center/news-releases/enoc-signs-mou-with-uae-ministry-of-energy.aspx

SN	Initiative(s)/Programme(s)	Links
FE-1	- Biojet initiative, Abu Dhabi	https://www.etihad.com/en-us/about-us/etihad-news/archive/2015/biojet-abu-dhabi-presents-roadmap-for-sustainable-aviation-biofuel-industry-in-the-uae/
	- Integrated Seawater Energy and Agriculture System (ISEAS), Masdar City, Abu Dhabi	http://www.biofuelsdigest.com/bdigest/2017/10/02/sustainable-bioenergy-research-consortium-celebrates-first-harvest-of-salicornia-feedstock/
FE-2	- ISEAS Masdar project on bioethanol production from oil rich native plants	https://thearabweekly.com/take-abu-dhabis-aviation-biofuel-initiative
	Study on bioethanol potential of lignocellulosic biomass such as date palm & mangroves	http://www.scopemed.org/?mno=184787
FE-3	- Opportunities discussed by EAD policy brief	https://www.ead.ae/Publications/Waste%20Management%20Policy%20Brief/20-05-2015_Policy%20Brief%20Waste%20Management_EN-006.pdf
	High potential of camel manure in biogas production, Abu Dhabi	http://www.scopemed.org/?mno=184787
WE-1	Please refer to WE-1	
FE-4	- Tadweer/Taqa 100 MW WtE facility in Abu - Masdar/Bee'ah 30 MW WtE facility in Sharjah (to start in 2020) - Dubai Municipality, 180 MW WtE facility in Dubai (to start in 2020)	http://www.ramboll-mea.com/projects/re/sharjah-first-waste-to-energy-in-uae https://www.taqaglobal.com/media/taqaworld-magazine/taqaworld-issue-3/articles/waste-energy https://gulfnews.com/news/uae/environment/dubai-announces-launch-of-dh2-5b-waste-to-energy-plant-1.2164681
FE-5	- Neutral Fuels, UAE	http://www.neutral-fuels.com/innovation/
	- ENOC Biodiesel 5, Dubai	https://www.khaleejtimes.com/enoc-launches-biodiesel-5-in-uae
	- Lootah fuels, Dubai	http://www.lbf.ae/
	- Biodiesel from date pits, UAE	http://www.biofuelsdigest.com/bdigest/2017/11/20/uae-researchers-produce-biodiesel-from-date-pits/
	- Cooking oil to biodiesel fueling station in Jebel Ali, Dubai	http://www.biofuelsdigest.com/bdigest/2017/09/27/uae-services-company-installs-biodiesel-fueling-station-for-its-waste-compactor-trucks/
	- Cooking oil to biodiesel at Tadweer, Abu Dhabi	http://www.biofuelsdigest.com/bdigest/2018/01/11/tadweer-to-open-uco-recycling-facility-in-abu-dhabi-by-years-end/
FE-6	- No initiatives	Not Applicable
FE-7	- No initiatives	Not Applicable
FE-8	- Smartcool, Dubai	http://smartcool.ae/
FE-9	- No initiatives	Not Applicable
FE-11	- No initiatives	Not Applicable
FE-12	- No initiatives	Not Applicable
FE-13	- No initiatives	Not Applicable
FE-14	- No initiatives	Not Applicable
FE-15	- No initiatives	Not Applicable
FE-17	- Al Wathba Mega Production & Distribution Complex, Abu Dhabi	https://www.foodprocessing-technology.com/projects/alwathba-productiona/
FE-18	- No initiatives	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	Centre for Waste Management Abu Dhabi (Tadweer)	Safe and effectual waste management in Abu Dhabi	https://www.tadweer.ae/en/Pages/default.aspx
2	Bee'ah	Environmental management, systematic waste management, renewable energy utilization and community engagement initiatives to set a benchmark for sustainability	https://beeah.ae/en
3	Abu Dhabi Farmers' Services Centre	Strategic agricultural practice for natural resource conservation in Abu Dhabi	https://www.adfsc.ae/en/pages/home.aspx
4	Abu Dhabi Sewerage Services Company	Collection and treatment of all commercial and residential wastewater in Abu Dhabi for safe waste disposal	https://www.adssc.ae/en-us/Pages/default.aspx
5	Dubai Municipality	Plan and develop Dubai as a happy and sustainable city	https://www.dm.gov.ae/wps/portal/home
6	Water & Electricity Authorities (DoE, DEWA, SEWA & FEWA)	Diversification of clean and renewable energy to attain sustainability in the energy sector Provide services to the community through sustainable practices and efficiency improvements at demand and supply sides. Provide customers with a supply of high quality electricity, water and natural gas. Provide electricity and water services to meet growing demand in Fujairah while rationalizing resource use for sustainable development.	http://www.doe.gov.ae/en/ https://www.dewa.gov.ae/en/ https://www.sewa.gov.ae/en/ http://www.fewa.gov.ae/en/Pages/default.aspx
7	Department of Urban Planning & Municipalities	Sustainable urban development of Abu Dhabi	https://www.upc.gov.ae/en
Government regulator entities			
8	The Environment Agency of Abu Dhabi	To protect and improve the environment for sustainable development through policy measures	https://www.ead.ae/SitePages/home.aspx
9	UAE Ministry of Climate Change & Environment	The development of policies and regulations to address environmental issues locally and globally	https://www.moccae.gov.ae/en/home.aspx
10	Abu Dhabi Food Control Authority	To ensure safe and good quality food for human consumption	https://www.adfca.ae/English/AboutADFCA/Pages/default.aspx
11	Food Security Centre Abu Dhabi	The development and implementation of a food security strategy for the UAE	http://www.fscad.ae/English/AboutUs/Pages/default.aspx
12	The Regulation & Supervision Bureau	To regulate electricity, water and wastewater in Abu Dhabi	http://rsb.gov.ae/en/
13	Ministry of Energy and Industry	To develop policies for stakeholders in the energy sector for the conservation of the country's energy sources	https://www.moei.gov.ae/en/home.aspx
14	Ministry of Food Security	To enhancing the country's food security	No current website

15	Emirates Authority for Standardization and Metrology	To develop and present national strategies that include protecting the UAE's economy and environment	http://www.esma.gov.ae/en-us
Industry			
16	Emirates Nuclear Energy Corporation	To provide the UAE with clean and efficient nuclear energy	https://www.enec.gov.ae/about-us/
17	ADNOC Group Companies	To provide energy worldwide contributing to the UAE's economic and social development while taking necessary measures for environmental protection	https://www.adnoc.ae/
18	Emirates National Oil Company	To provide energy at a global level contributing to Dubai's economic diversification and sustainable development	https://www.enoc.com/en/
19	Agribusinesses	To provide world-class agricultural products Focuses on sustainable farming practices and investments in agricultural innovation	http://www.agcl.ae/ http://www.aldahra.com/
20	Masdar company	To advance solutions in energy, water, urban development and advanced technologies	https://www.mubadala.com/en/what-we-do/renewables/masdar
International organizations and NGOs			
21	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
22	IRENA	To provide data on renewable energy and promote economic, social and environmental benefits of renewables	http://www.irena.org/
23	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
Other			
24	Expo 2020	To create collaborations and partnerships to promote innovation	https://www.expo2020dubai.com/
Universities and Research Institutes			
25	International Center of Biosaline Agriculture	Research focused on innovative technologies and non-traditional crops to address food security	http://www.biosaline.org/
26	National Center of Meteorology	Research projects focused on weather systems	https://www.abudhabi.ae/portal/public/en/departments/ncm
27	Abu Dhabi Global Environmental Data Initative	Interpret environmental data for best practice implementation and support policy-makers in their decision-making	https://agedi.org/
28	Masdar Institute of Science & Technology	Research focuses on advanced technologies and sustainable energy solutions	http://www.masdar.ae/en/research/detail/about-the-masdar-institute-of-science-and-technology
29	Emirates Diplomatic Academy	Research focused on national security through innovative solutions and partnerships	http://www.eda.ac.ae/

8. Endnotes

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