Renewable Energy in Bahrain: Background Paper

Preprint · July 2019

DOI: 10.13140/RG.2.2.23998.64320

1 author:

Hanan Albuflasa
University of Bahrain
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Hanan Albuflasa

2018

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1 Introduction

In recent years, almost all Gulf Cooperation Council (GCC) countries have faced challenges brought on by climate change and have therefore been obliged to devise plans that include projects to address these challenges. Among the GCC countries, Bahrain is perhaps the most vulnerable to the threat of rising sea levels because of its location in a low-lying coastal zone, where most of its population and industries reside. According to Bahrain's Second National Communication, which was conducted under the United Nations Framework Convention on Climate Change by the Public Commission for the Protection of Marine Resources, Environment, and Wildlife in January 2012 [1], the current built-up and industrial areas in Bahrain account for 245 km^2 (or about 34%) of a total land area of 748 km^2 , and are located largely along the eastern coastline of Bahrain's main island. The report shows that 11% (83 km^2) of total Bahraini land will be inundated by 2050 if the sea level rises by 0.3 m., and 27% (200 km^2) by 2100 if the sea level rises by 1.5 m.

1.1 Overview of Bahrain Power and Water Production

Bahrain has five power stations, with a total installed capacity of 3920 megawatt (MW) [2]; three stations are operating by the private companies with a total installed capacity of 3095 MW, and two operating by the Electricity and Water Authority (EWA) with a total installed capacity of 825 MW. Also, Bahrain is connected to the GCC interconnection with a 400kV AC cables with a capacity of 600 MW [3], Table 1 lists the type and capacity of the power stations.

Table 1 Power stations installed capacity

Station	Station type	Power (MW)
Riffa	OCGT	700
Sitra	OCGT + ST	125
Hidd	OCGT + CCGT	929
Al-Ezzal	CCGT	942
Al-Dur	CCGT	1224
GCC	Exchange	600

Bahrain main source of water was the groundwater. The archipelago of Bahrain was famous with the onshore natural springs, submarine freshwater springs[1] and the aquifers. There are three main aquifers; Umm er Radhuma, the Khobar and Dammam - Neogene aquifer [4]. Till 1975, water use in Bahrain was almost exclusively met by the groundwater resources, but, the continuous withdrawal from the groundwater (controlled and uncontrolled) resulted in a significant decrease in the water table level and an increase of its salinity level.

On the other hand, Bahrain share from the renewable water resources, such as rain, is very limited, where the average rainfall from 2003 to 2014, for example, was less than 70 mm, Figure 1.

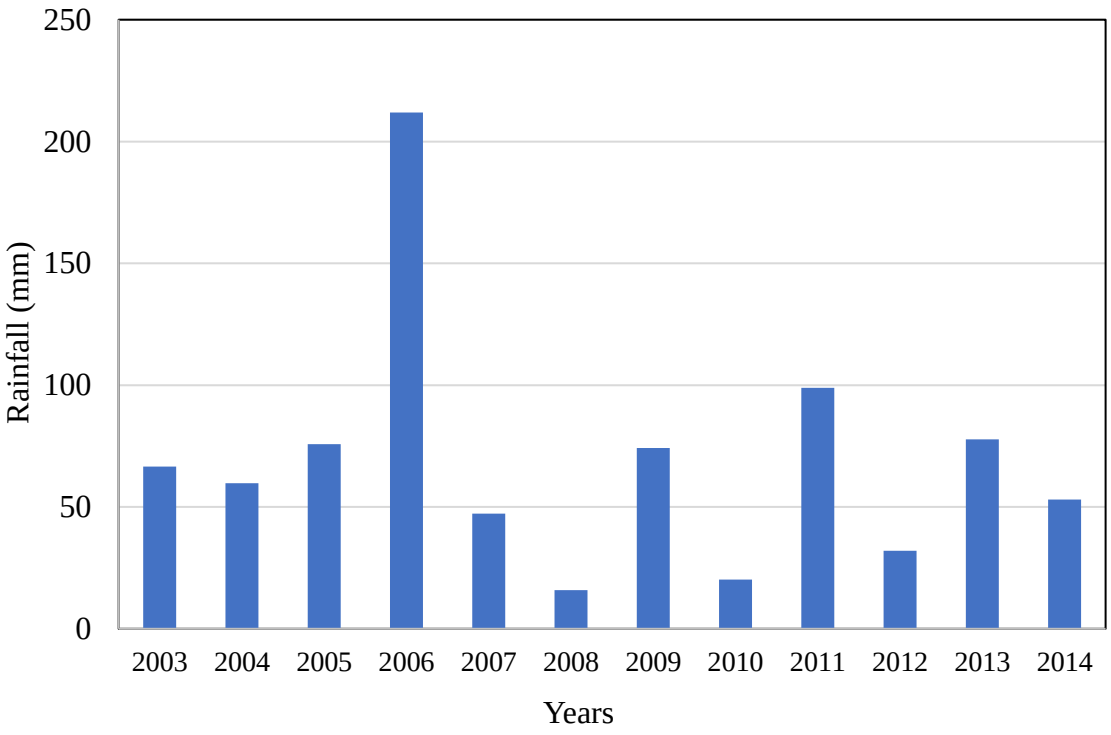

Figure 1 average yearly rainfall in Bahrain

The water consumption can be divided into three main sectors; domestic, commercial and industrial. The domestic sector has a share of more than 80% of the total demand, and

[1] The name of Bahrain, which means (two seas), has originated from the fact that Bahrain was famous with the fresh and sea water.

around 14% and 2% for the commercial and industrial sector respectively, Figure 2. The increase in water consumption per year in the domestic sector is 837 million gallons per day (MIGD) with 460 MIGD in the commercial sector and only 74 MIGD in the industrial sector. Most of the heavy industries in Bahrain, such as Aluminium Bahrain (Alba), Arab Shipbuilding and Repair Yard Company (Asry), Bahrain Petroleum Company (Bapco) and The Gulf Petrochemical Industries Company (GPIC) have their desalination plant.

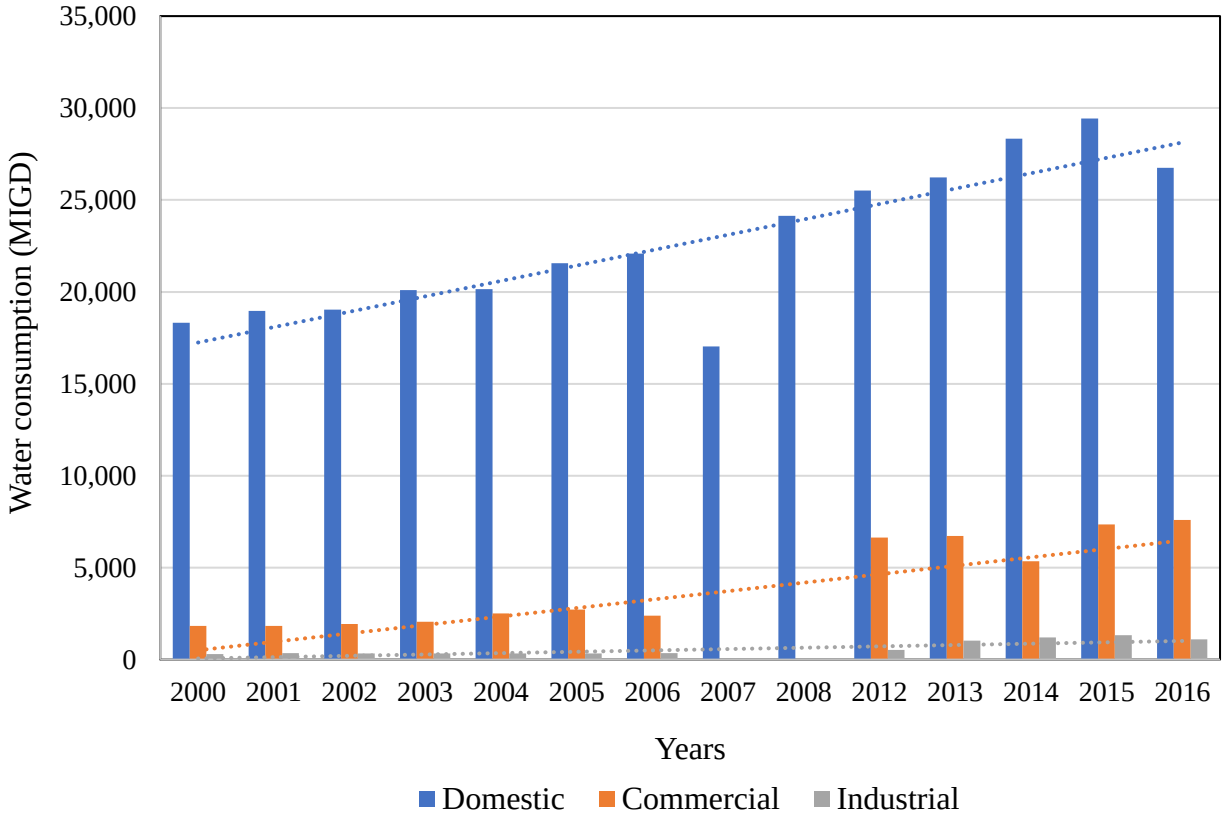

Figure 2 The average daily water consumption per year

Due to the substantial increase in water demand, a desalination programme was commenced in 1976, with Sitra power and water station to produce 2.5 MIGD. The desalination technologies have increased in Bahrain after since, using both the thermal and membrane-based technologies for seawater treatment and only membrane technologies for brackish[2] water treatment. The water from the desalination stations is blended with the

2 High salinity groundwater

groundwater both to provide enough supply and to ensure the acceptable water quality identified by World Health Organization [5]. The reduction in the groundwater and the increase in both RO and thermal desalination to supply the water demand in Bahrain is shown in Figure 3. The figure shows that there was a sharp drop in the percentage of groundwater share, followed by almost stable period until the year 2000. The thermal desalination stations have dominated the water production in Bahrain since the beginning, whereas the membrane-based technology, had suffered from technical challenges with the seawater treatment until the year 2015 where Al-Dur Power and Water station was commissioned to replace the old Al-Dur desalination only station, using different membrane technology. The other membrane-based technology desalination station, Ras Abu Jarjur, continued to run to treat ground brackish water, with no serious challenges recorded since the mid-1980.

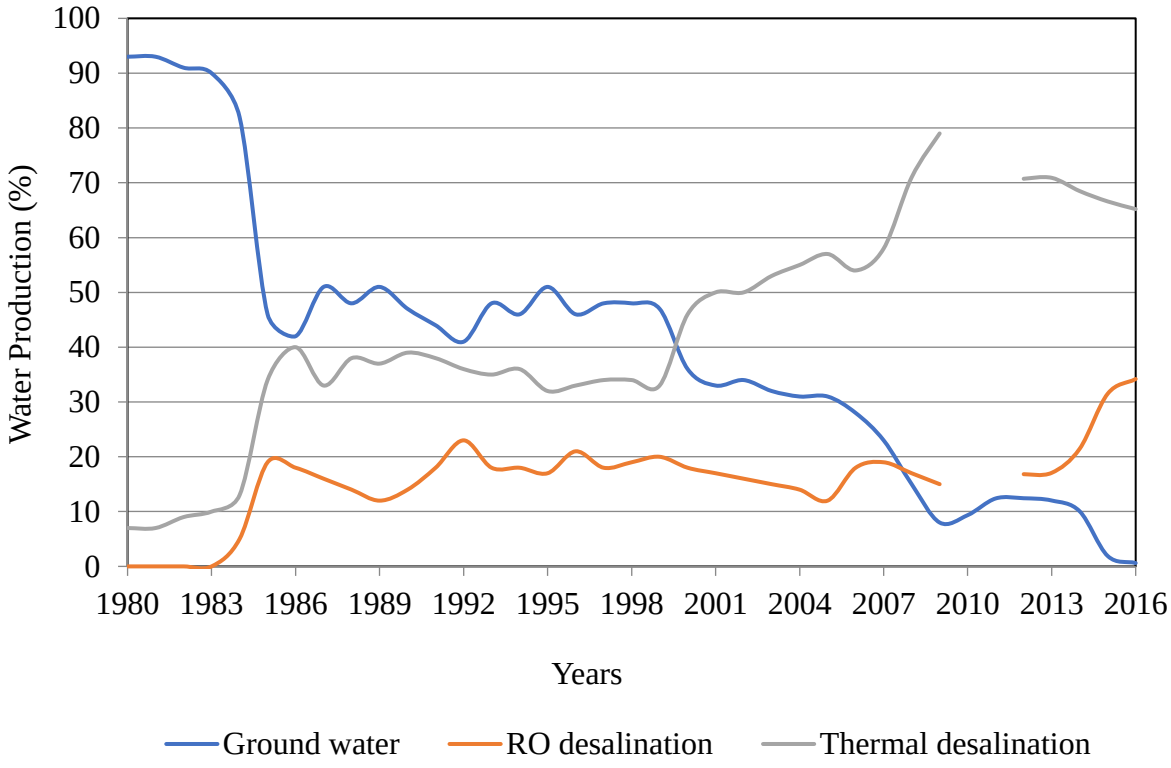

Figure 3 Percentage of the source of water production per year

There are two thermal desalination stations (Sitra and Hidd). Sitra Station is divided into two sections, four steam turbines and one gas turbine. The extracted heat from the four steam turbines is used as a heat source for the thermal desalination units. The heat

recovered from the gas turbine is directed to a heat recovery boiler to generate the required steam for another desalination units within the station. The total water production for Sitra station is 25 (MIGD). The Hidd power and water station is divided into Hidd I which produces 30 MIGD and Hidd II produces 60 MIGD.

Table 2 Water Production Capacity

Station	Desalination technology	Water (MIGD)
Sitra	MSF	25
Hidd	MSF	90
Al-Dur	RO(Seawater)	48
Ras Abu Jarjur	RO (Brackish water)	16

Furthermore, desalination is an energy-intensive process and more energy is required both in the form of heat and electricity. The theoretical minimum power[3] requirement for producing 1 m^3 of seawater is 0.70 kWh/m^3. In practice, much more power is used (for pumping salt water from the intake, heat losses and air leakage). Even if power were available free of charge, a relatively large investment would be necessary to build desalination plants. In Bahrain, the power and desalination investments are very large, and the desalination stations are providing enough water to satisfy the need of the local community, with a maximum of three days storage.

Nevertheless, the seasonal water variation can be considered fairly constant even though at very different scales: an increase of 114% for power compared to 9% only for water, from winter to summer, Figure 4. Consequently, energy diversification would require a careful investigation to determine potential needs and requirements for upscaling both water and power production, to ensure that the introduced energy sources and technology will satisfy both the demand for water and power.

[3] Any sort of energy that can be completely converted to mechanical work to desalinate a ton of sea water (34,300 part per million).

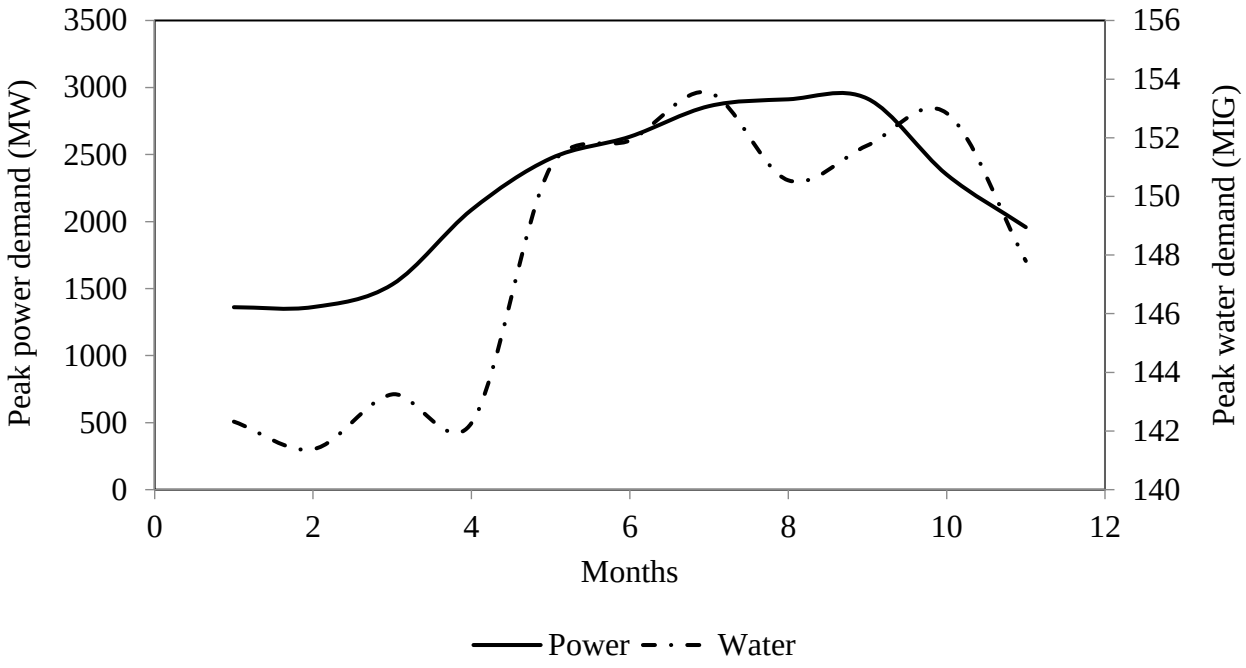

Figure 4 the average monthly peak water and power demand

1.2 Renewable Energy Resource Assessment

Bahrain's solar and wind resources have been investigated by many researchers at research institutions inside and outside the Bahrain [6-9]. Data used for analysing the renewable energy resources is mainly collected from the weather stations operated by the Directorate of Meteorology. Bahrain has four weather stations, located at Bahrain International Airport (North), Sitra (Middle-East), King Fahd Causeway (Middle-West) and Durat Albahrain (South). The four stations provide, 10 minutes averages and hourly data for different weather parameters including the solar irradiance and wind speed and direction.

Solar Energy

The average annual solar radiation available in Bahrain is around 2,600 kWh/m^2/year and the technical potential for electric generation using solar thermal technology is about 33 TWh per year.

Wind Energy

The wind atlas was first produced in 2009 [8], Figure 5. The annual mean wind speed was found to be 4.6 m/s at 10 m height and mean Weibull scale and shape parameters, which describes the quality of the wind speed in a location, C[4] and k[5] of 5.2 m/s and 1.9 respectively. At a typical wind turbine hub height of sixty metres, these values are extrapolated to 6.9 m/s, 7.8 m/s and 1.8 respectively, which suggests that the area has good wind resources. Bahrain official wind atlas was launched by the Minister of Electricity and Water Affairs to be available on 12 of April 2018.

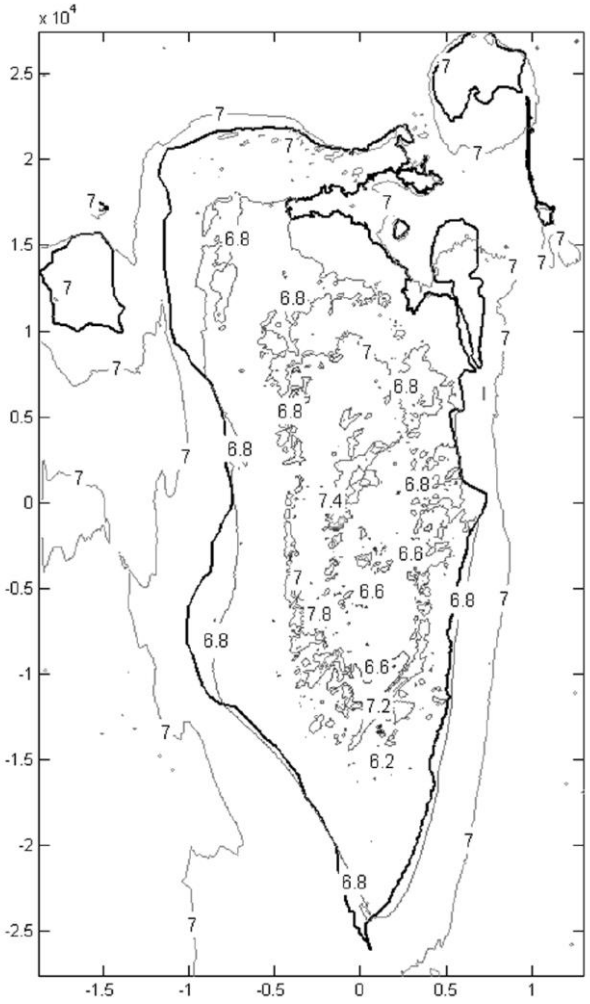

Figure 5 Bahrain wind Atlas showing wind speed contour in m/s [8]

[4] C the scale parameter is proportional to the mean wind speed, if the value is smaller than the mean, then the wind speed is strong for a short period, and if the value is larger, the wind speed is spread through the whole period.

[5] K value ranges between 1 and 3, the larger the value the more constant the wind speed. Most good wind speed sites around the world will have k values close to 2.

Solid Waste

In 2016 around 1.4 million persons in Bahrain generated around 1.8 million tons of the overall MSW streams (i.e. 1.3 tons per capita). The generation of Municipal Solid Waste (MSW) in Bahrain has experienced an increase of 74.4% in the total MSW disposal quantities from 1,034,921.1 tons in 2005 to 1,805,124.2 tons in 2016 with a growth rate of 6.77%, as shown in Figure 6.

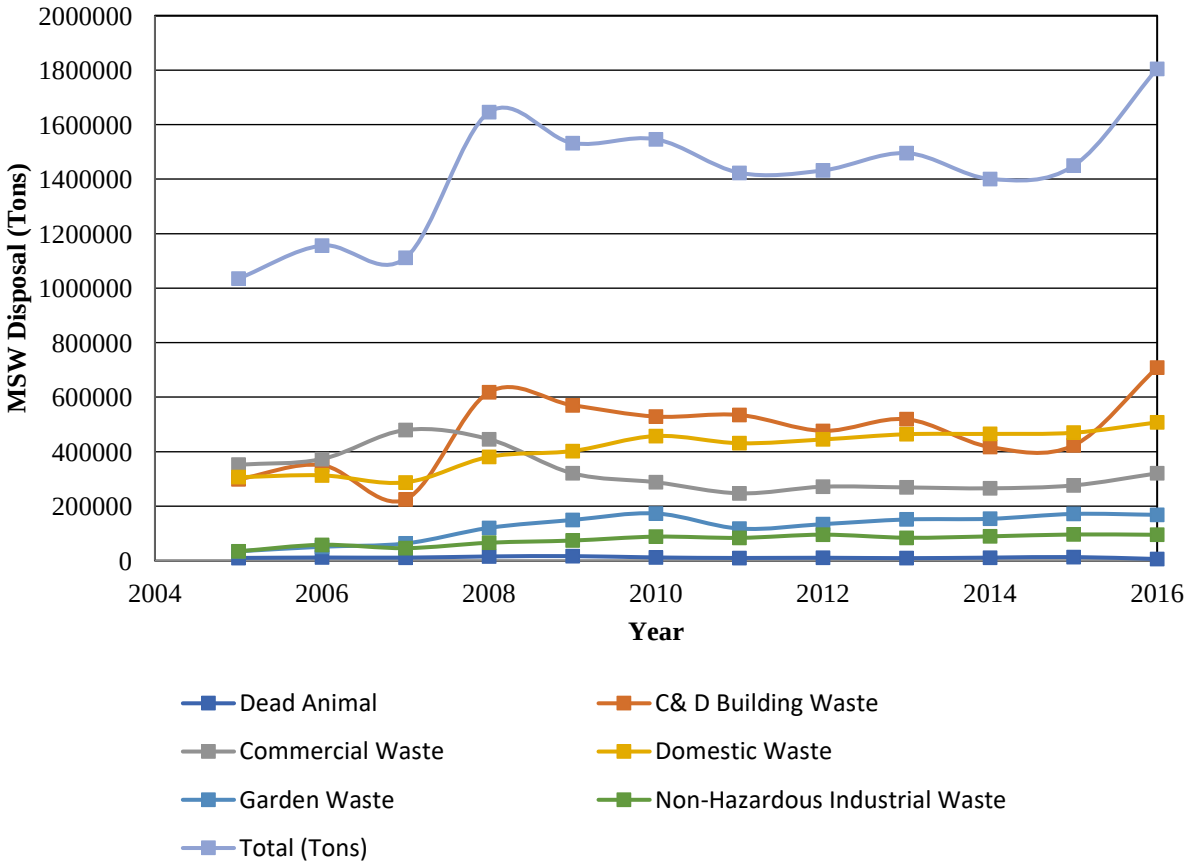

Figure 6 generation of Municipal Solid waste in Bahrain

The domestic waste stream (DW) is the second highest waste source, after Construction & Demolishing (C & D) building waste. In 2005, DW had a 29.6% share of the total MSW and 28.11% of total MSW in 2016, however, it had an increase of 65.69% for the period 2005 to 2016 and an average annual growth rate of some 6% during the 11 years period.

2 Bahrain National and International Environmental Commitments

The Government of Bahrain has committed to working toward protecting the local environment by encouraging sustainable investment in clean technologies that will help to minimize pollution and conserve our national resources [10]. Also, the government has issued the Government Action Plan (2015-2018) to improve the efficiency of electricity and water and reduce waste, and to work on finding alternative sources of energy to meet the growing demand. Furthermore, as part of the international community, Bahrain has ratified the Paris Agreement on Climate Change and adopted measures to protect the environment and the bases of sustainable development, and committed to reduce its Green House Gases (GHG) emission by the submission of its "Intended National Committed Contribution" (INDC)[6] in 2015 [11]. In this INDC, Bahrain has included 13 strategies, plans and actions which may contribute to low greenhouse gas emission, and committed to the UNDP Sustainable Development Goals (SDGs), by assuring access of its nation to affordable, reliable, sustainable energy. Correspondingly, Bahrain has committed to develop and submit as part of the League of Arab States[7], the National Renewable Energy Action Plan (NREAP) and the National Energy Efficiency Action Plan (NEEAP).

In 2008, the kingdom launched Bahrain Economic Vision 2030, which describes and emphasises the urgent need to reduce the dependence on oil, improve sustainability, reduce overconsumption of water, electricity and gasoline, reduce carbon emissions, protect the natural environment, minimize pollution and promote the sourcing of more sustainable energy. Therefore, a general commitment to sustainable production and consumption and energy efficiency systems as an essential element of the energy mix is gradually emerging, which will result in expanding the oil supply for export, increase in tapping into the national reserves of natural gas resources, and decreasing GHG emanations.

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[6] COP 21 Paris Agreement on Climate Change

[7] Arab Ministerial Council for Electricity

2.1 Sustainable Energy Unit (SEU)

Established in late 2014, it is the designated agency for promoting sustainable energy policies and practices in the Kingdom of Bahrain. As such, the SEU is leading the coordination efforts in implementing the NEEAP and NREAP and will provide technical assistance in the design and implementation of specific initiatives. SEU's responsibilities include drafting policies and regulations to support the establishment of standard operating procedures for their implementation. Also, they are responsible for carrying out feasibility studies and cost-benefit analyses of various technology options and business models, and to oversee the implementation of pilot projects.

3 Energy Efficiency

One of the government's first main initiatives to promote energy efficiency was the establishment of the Directorate of Electricity and Water Conservation (EWCD) under the Electricity and Water Authority, in 1999. EWCD's main objective was to sustain the water and energy resources. Alongside the energy and water conservation, the directorate also is responsible for the energy and water efficiency. The directorate conduct different activities including drafting the regulation, providing the technical support and increasing the conservation awareness in Bahrain. Moreover, in 2015 two gulf technical regulations were adopted by the Standards and Metrology Directorate (BSMD) at the Ministry of Industry, Commerce & Tourism. These are;

Regulation for non-directional household lamps

This regulation establishes requirements of the non-directional household lamps for placing on the market, including when they are marketed for non-household use or when they are integrated into other products. It also establishes product information requirements for special purpose lamps. Companies or individuals who are found to be importing or selling non-compliant products would be liable by the provision of the laws and regulation of the kingdom of Bahrain [12].

Regulation on energy labelling and minimum energy performance requirements for air-conditioners

The objective of this regulation is to:

1- Provide detailed information on the performance and energy labelling requirements which an air-conditioning appliance has to meet in order to carry a valid energy efficiency level, and
2- Provide detailed information on the performance requirements which an air-conditioning appliance must meet in order to meet minimum energy performance standard requirements.

   The regulation covers single-package (such as window type) and split-system non-ducted air conditioners using air and water-cooled condensers, and heat pumps employing air-cooled condensers, and ducted air-conditioners using air-to-air heat pumps for residential, commercial and industrial sector [13].

3.1 The National Energy Efficiency Action Plan (NEEAP)

Energy saving target of 6% by 2025 has been adopted by Bahrain, the reduction is equivalent of 5,800 GWh on primary energy equivalent basis [14]. The action plan formulated and estimated the target based on the methodology suggested by the Arab Guidelines on Energy Efficiency [15]. The action plan which is prepared by the SEU proposed 22 initiative which covers all sectors of the economy and target efficiency improvements in both the energy demand and supply sides. Each sector contains a range of initiatives to drive savings within that sector Figure 7.

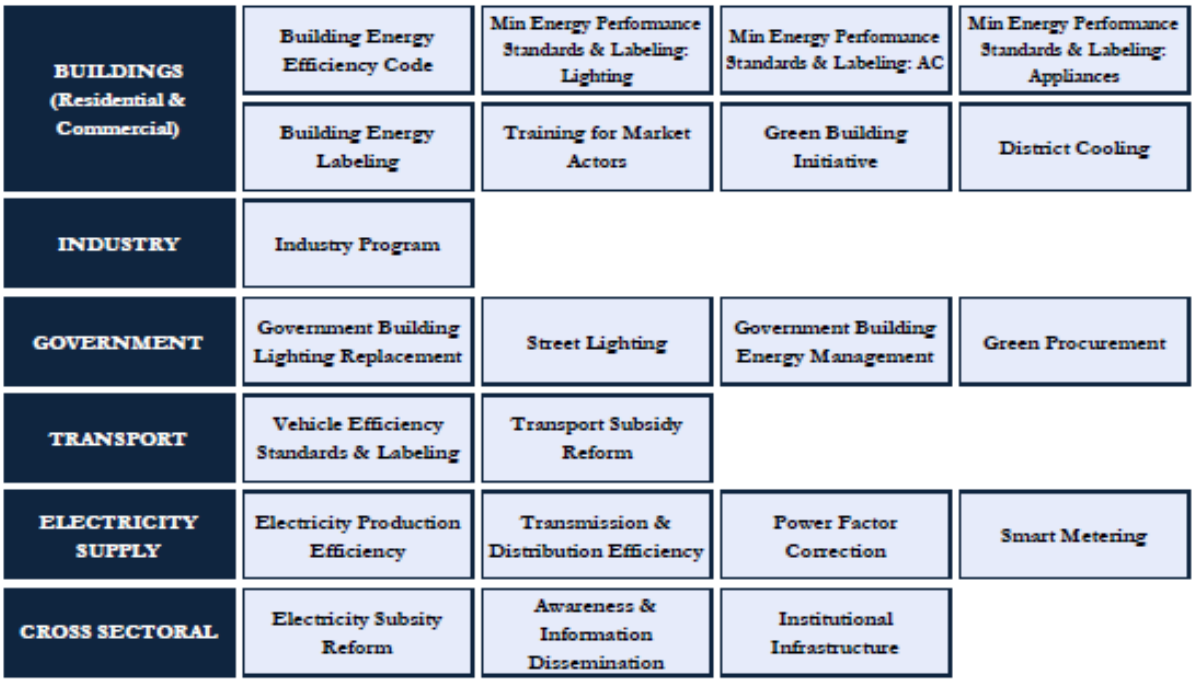

Figure 7: Proposed Energy Efficiency Initiatives per Sector [14]

The Implementation and monitoring of the NEEAP is the responsibility of a committee chaired by the Minister of Electricity and Water and may include representatives from the Electricity and Water Authority, the Ministry of Finance, the Office of the First Deputy Prime Minister, the Ministry of Industry and Commerce, the Ministry of Housing, the Ministry of Works, Urban Planning and Municipalities, the Ministry of Oil, and the Supreme Council for Environment. The Committee will meet on a quarterly basis.

4 Renewable Energy Initiatives and Projects

Renewable energy installations in Bahrain varies between pilot projects to standalone and grid-connected installation. It is worth mentioning that there were small units designed and installed for small projects related to research (such as the solar, wind RO desalination system designed by University of Bahrain and the wind turbine for water pump) and some thermal systems (solar heaters installed for Aluminium Bahrain company medical centre). The traditional houses in Bahrain and old original neighbourhoods are well designed to benefit from the wind circulation, to increase the cooling effect by introducing the wind towers in the buildings or the incorporating a

curved house structure to allow the flow of air around the houses. Also, the houses designs were known to boast thick walls made mainly from local materials which provide good insulating characteristics.

4.1 National Renewable Energy Action Plan (NREAP)

Beside the NEEAP, the National Renewable Energy Action Plan (NREAP) was developed by the SEU [16]. Considering all technologies based on a preliminary feasibility analysis using the available data for resources such as Solar, Wind and Waste. The action plan encourages using solar Photovoltaic (PV) technology more than the thermal Concerted Solar Power (CSP)[8] or "district cooling" technology, due to the significant requirement for water of the latter. Wind energy was found to be an attractive alternative source of energy for Bahrain, especially offshore projects[9]. The waste-to-energy approach, using both Municipal Solid Waste (MSW) and wastewater, can be not only a source of energy but also an environmental solution for Bahrain. The NREAP considered options such as, Anaerobic Digestion (AD) process and Landfill Methane Recovery.

In the National Renewable Energy Action Plan, a target of 5% of renewable energy by 2025 is specified, with a generation[10] of around 480 GWh of clean energy per year, and 10% by 2035, generating 1460 GWh of clean energy per year[11]. Figure 8 shows different scenarios used in NREAP projecting a growth by around 50% from 2025 to 2035.

[8] CSP systems are more sensitive to dust than PV systems

[9] Bahrain has shallow waters which is an advantage for the development of the offshore wind energy projects.

[10] It is important to note that the generation per year would depend on the technology used and available resources, which is intermittent, and accordingly more assessments would be required to accurately size the required installed capacity from renewable energy.

[11] Based on the projected peak load capacities.

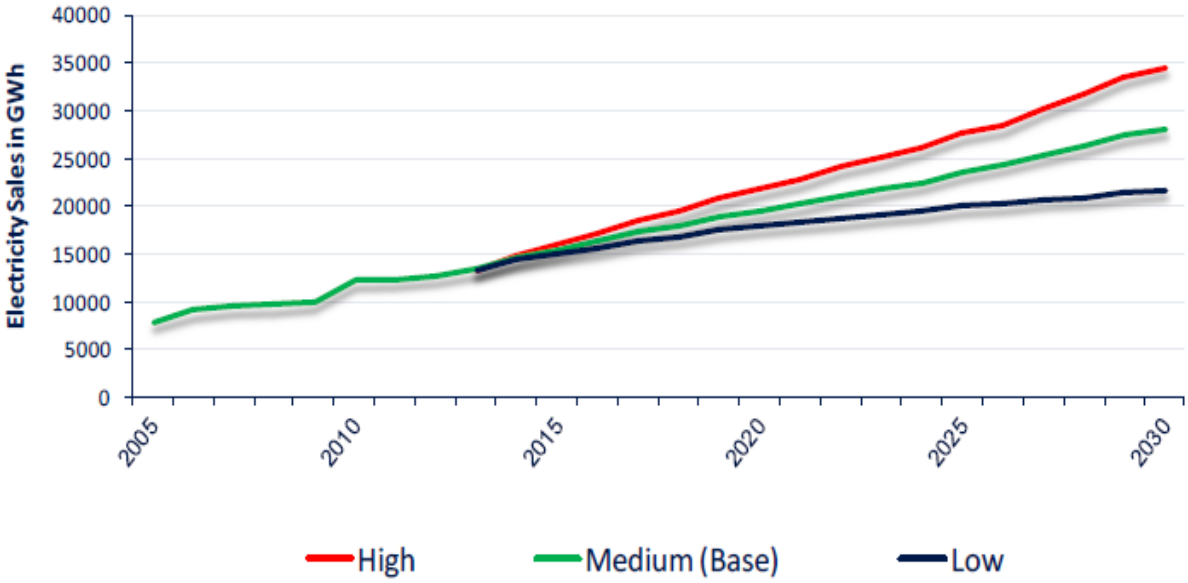

Figure 8 Projected Electric Power Consumption [16]

To achieve the renewable energy targets, some projects were proposed including, the following:

1. Decentralized Urban Generation (100-150 MW)
2. Large-scale Generation on Available Land (50-100 MW)
3. Offshore Generation (50 MW)

Three complementary polices were proposed to attract investment and ensure achieving the target of 5% by 2025, Table 3. In February 2018, the Minister of Electricity and Water Affairs announced the implementation of the net metering in Bahrain and the successful completion of a workshop for licenced installers, with a total of 33 participants.

Table 3 Bahrain's policies for promoting renewable energy [16]

	Policy 1	**Policy 2**	**Policy 3**
	Net metering	**Tender-based feed-in tariff**	**Renewable energy mandate for new buildings**
Objective	Enable consumers to generate their own power from renewable energy sources for self-consumption.	Attract private investors to develop renewable energy projects through a competitive procurement process.	Require new buildings and real estate developers to integrate renewable energy technologies in the building design.
Target group	Residential, commercial and industrial electricity customers.	Renewable energy developers and large electricity customers.	New building and real estate developers.
Incentive	Reduced electricity bill through on-site power generation and the ability to credit the excess electricity fed back to the grid.	Long-term standardized power purchase agreement.	Reducing energy demand of the building (reduced electricity bill).

4.2 Net Metering

In February 2018, the Minister of Electricity and water affairs announced during the SUN Utilities Network the commissioning of the net metering in Bahrain to encourage the integration of the renewable energy into Bahrain power system. The net metering will allow electricity consumers to connect their renewable energy systems to the distribution network through the Net Metering Resolution and Connection Agreement. The main objective of the Resolution is to establish a clear legislative framework regulating the Connection of Renewable Energy Generators to the Electricity Distribution System. The metering system consists of two meters; one is a bi-directional meter ('tariff meter') that will be installed by the Electricity and Water Authority (EWA) without any additional cost to the producer.

The second is the "renewable energy meter" to be installed by the independent contractors approved by EWA.

For the preparation of the launching of the Net Metering, the SEU has delivered a training course, awarding 33 installers a Solar PV Installers Certification. The installer list is available through EWA website to customers. On 29th March 2018, the government announced that Bahrain had connected the first house with the rooftop solar photovoltaic system to the national grid. As part of this initiative, the Ministry of Housing has started installing solar panels on the roofs of newly built community houses around Bahrain.

4.3 Renewable Energy projects:

The following is a list of the renewable energy initiatives and projects within the goal of encouraging the energy mix in Bahrain:

Bahrain World Centre

This is a 50-storey office tower which sits on top of a shopping centre (Moda Mall). The sail-shaped building has integrated three wind turbines projected to be providing a total of between 1,100 and 1,300 MWh per year which represents 11% to 15% of the office towers' electrical energy consumption. The three wind turbines, which started operation in 2008 have made the building the first building in the world that has an integrated wind propeller.

The shape of the building was carefully thought to increase the wind speed and consequently, the turbines power output[12]. Also, the building was designed to reduce

[12] The building was later shaded by the construction of the Bahrain financial harbour, however, no information given on the reduction of the generated wind power. Also, the building has been suffering from vibration caused by the turbine rotation.

the carbon emission compared to other new buildings in Bahrain, considering high efficient insulation and low energy systems, incorporating the following features:

1. Total heat energy recovery heat wheels of fresh air intake and exhausts to recover (coolth) from the vitiated air and recover it to the fresh make up air;
2. Solar powered road and amenity lighting.
3. Energy efficient, high efficacy, high-frequency fluorescent lighting with zonal control.
4. Dual drainage systems that segregate foul and wastewater and allow greywater recycling to be added later. [9]

The Five-Megawatt Bapco PV Pilot Project

Bahrain first grid-connected renewable energy pilot project is the 5 (MW) PV project owned by Bahrain Petroleum Company (Bapco)[13] commissioned in 2012. The 25 million USD project which was assigned to the US company "Petra Solar" was installed in three locations: namely, Awali, the Refinery and at the University of Bahrain[14]. The project consists of 21,000 solar panels on the ground, parking shades, light poles and roof tops installations covering a total area of 34,000 m^2 [17].

Dar Al Nakheel Green Building

The Building which is located in Princess Sabika Bint Ibrahim Al Khalifa Park, was a project initiated in 2010 by Bapco, demonstrating the use of 4 kW Solar (PV) and 5.1 kW Wind Power. The hybrid system is supported by a storage system, which comprises a hydrogen production and storage and fuel cell.

[13] In cooperation with Economic Development Board (EDB), Petra Solar, Caspian Energy Holdings, the National Oil and Gas Authority (NOGA), the Electricity & Water Authority (EWA) and University of Bahrain (UoB).

[14] The solar farm installed at UoB, completed in 2013 and it is the largest PV installation at a university campus. It is feeding the national grid with 0.5 MW through the University substation and allowing access to data from the solar farm for research and teaching.

Tatweer Petroleum One-Megawatt PV Project

Tatweer Petroleum commissioned its own ground-installed 1 (MW) PV project at one location in a Southern part of Bahrain. The project was in operation in 2016 providing the country with its second grid-connected solar power and providing Tatweer company with 10% of its power consumption.

Solar Irrigation Units

In 2012, Solar PV irrigation units were installed in different areas across the governorates, providing about 200 W to the units which each equipped with an automatic irrigation system.

Solar Powered Mosques

Ministry Of Justice & Islamic Affairs & Waqf established in 2006 a project to power number of mosques, ma'tams and Quran learning centres in the country by Solar PV, completing currently (February 2018) three mosques.

Gulf Petrochemical Industries Company Solar Thermal Project

In 2011, Gulf Petrochemical Industries Company (GPIC) installed 5 kW solar thermal system with a total capacity of 1600 litre/hour with a saving of 14181 kW/year power consumption.

Solar Powered Bus Shelters

Ministry of Transportation and communications, as part of their initiative to improve the public transport sector in Bahrain, and to electric-power the bus Shelters for lighting, advert panels and later to include schedule screen and camera. The Ministry

installed solar PV for some bus shelters for mainly lighting and advert panels, aiming to power all shelters with solar[15].

Street Lighting

Electricity and Water Authority (EWA) started a PV street lights project in different locations in Bahrain, the main purpose of which is to study the performance of the systems under the different weather conditions.

Bahrain Solar Panel Manufacture (Solar One)

With a capacity projected to reach 60,000 panels per year, Solar One is the first Solar Panel manufacture fabricating a 1.6 m *x* 0.99 m panel with 250 watts rated power. Solar One, which is started in 2017 claims a price of 0.6 USD per watt for their panels.

Renewable Energy Investments

The Egyptian Electricity Holding Company assign the 3.5 billion USD solar plant in Egypt to the Bahrain-based energy Terra Sola. Terra Sola will help fund the implementation of a European-technology driven solar 2,000 (MW) of solar PV project.

Proposal for a 100-Megawatts Solar Power Plant

The renewable energy action plan, which includes the development of both distributed generation and large-scale solar projects, sets the national target of renewable energy in the Kingdom of Bahrain at 5% by 2025 which will be further boosted to become 10% by 2035. To fulfil this goal, Bahrain has approved in late 2017 to develop a solar farm with the collaboration of the private sector. The project which is expected to be completed in 2019 has a nominal capacity of 100 MW. This farm is proposed to be built in Hafeera landfill site

[15] Excluding air-conditioned Shelters, considering the large power consumption.

Electricity and Water Authority Pilot Plant

A project of a five MW wind and solar power plant, EWA built 2 MW wind power and 3 MW solar power as a polit plant. The project which cost USD 17.1 million is still under construction.

Waste-to-Energy Project

In early 2018, a private company (OAK) has been awarded to build Bahrain first waste-to-energy project using Tubli Treated Sewage Sludge to generate 10 MWh using High Temperature Pyrolysis technology.

4.4 Academic and research institutions

The academic and research institutions in Bahrain were involved in investigating the potential of renewable energy in Bahrain, including solar, wind and water power. However, biomass has not been an attractive research topic for Bahrain, despite the available environmental needs and resources.

On the other hand, there is a lack of formal communication between the power sector and the research institutions to address issues related to the challenges and opportunities to introducing renewable energy into Bahrain power systems. Also, there are no awards, or research funds allocated to encourage research in renewable energy, which limits the research to the institutions own interest and available knowledge in the area.

4.4.1 Renewable Energy Activities:

Bahrain has hosted number of conferences, workshops, forums in renewable energy, sustainability and energy in general. Some of the events were part of a collaboration between the hosted organisations and international bodies, such as, international universities, renewable energy laboratories and renewable energy organizations and societies.

4.4.2 Renewable Energy Research Centre

The establishment of a permanent Research Centre for Sustainable Energy and Water at the University of Bahrain with a budget of more than 560,000 USD which is strongly linked to the Centre for Renewable Energy Systems Technology (CREST) at Loughborough University and to the Bahrain Sustainable Energy Unit (SEU).

The new Centre will have a strong positive impact on the priority areas of energy and water. This will be achieved by working alongside the Electricity and Water Authority, providing research and technical support in the development and implementation of the National Renewable Energy Action Plan (NREAP) and, more broadly, in developing a quantified and technically viable scenario for a pathway towards a sustainable energy and water system for Bahrain in 2030. The collaboration will have a strong focus on capacity building at the new Centre.

Also, the centre at UoB is working on two separate research projects with a total budget of 360,000 USD to optimise the Reverse Osmosis desalination operated with renewable energy for Hawar Islands, and investigating new pre-treatment techniques. The two projects foresee a three and four-year collaboration with Aston University and the University of Oxford, respectively.

5 Socio-economic Aspect

The social awareness and acceptances are the main driver of any plans related to energy. To measure the public readiness, a survey was conducted to measure the public awareness and willingness to the use of renewable energy, especially solar energy for houses. An online questionnaire was distributed, mainly focused on public acceptance of installing solar panels on their houses' rooftops.

The survey was answered by 1,044 individuals of which 94.4% are Bahraini, and 5.6% are non-Bahraini, with mostly females (65.2%) and young people (more than 60% of the respondents were aged between 15-25 years)[16]. It was found that 95% of the respondents

[16] The age group is the future electricity customer responsible for paying the electricity bills.

are willing to install solar PV on the roof of their houses with 3.3% only believing that this would help in reducing their electricity bill. This shows that although the idea of using solar energy is highly accepted by the public, the confidence level toward the direct impact on their utility bill is low.

6 Conclusions and recommendations

This background paper demonstrated the measures that the kingdom of Bahrain has undertaken to improve the energy efficiency and to promote the introduction of the renewable energy into the power system. The result and analysis of this paper are based on a limited data provided through the official websites of the governmental organisation, such as the Water and Electricity Authority (EWA), the Ministry of Industry, Commerce & Tourism, companies, the sustainable energy unit document and publish research articles and data.

This lack of data (sources) for the renewable energy activities at Bahrain is hampering any attempt to quantify the scale of installations, projects and institutional activities. To be able to justify the effort undertaken by Bahrain, a database centre must be established to record and monitor the progress of the implementation of the initiatives for the clean and the energy efficiency, and accordingly provide the government and related organisations with a reliable, concurrent and up to date data. The database centre may include, but not limited to, the following:

1- Real renewable energy generation, by type in Bahrain (fed into the grid);
2- Investment in Renewable Energy;
3- Human capacity working in renewable energy;
4- Budget allocated for renewable energy research activities;
5- Number of students enrolled in academic programmes or courses related to renewable energy;
6- Number of Conferences, workshops.

Despite the data limitation, Bahrain progress in the deployment of energy efficiency regulations and strategies to achieve the announced targets in the NEEAP and the NREAP is evident. However, more engagement between the research institutions and the private and public sector need to be encouraged to address challenges and opportunities. Environmental impact

assessment for the renewable energy projects needs to be considered, especially for wind power projects, both offshore and onshore.

Other renewable energy sources need to be investigated thoroughly, such as biomass and water power and solar thermal. These resources will bring projects, that not only generate energy but also have an general environmental benefits, the following some potential projects:

Municipal solid domestic waste incinerator will provide a source of energy and help to tackle one of the main urgent environmental issues in Bahrain. This would require the introduction of a waste segregation system at the collection point, which is not currently implemented.
All the municipal solid waste in Bahrain ends up in Asker landfill covering a total area of 3.1 km^2 with depth ranges between 10 to 15 meters. The site has been in use for waste disposal since 1986. A potential Methane production has not been investigated, although the quantity may not be feasible for large projects, it can be sufficient enough to run a small local power generator.

The landfill site was proposed for solar PV project, the technical challenges need to be addressed carefully, especially that the site is subject to subsidence due to the bio-degradable of solid waste and the possible Methane leakage that may cause fire accidents.

On the other hand, wastewater is also an attractive source of energy. Bahrain has three main wastewater treatment plants and other small facilities. The main plants are Tubli, Muharraq and the University of Bahrain with a total capacity of 420,504 m3/day. The energy production can be part of the treatment process using the Anaerobic Digestion (AD) technology, this is a more mature technology and widely used worldwide comparing to the Pyrolysis technology. The AD technology can be introduced to the current plants, which is using aerobic treatment, and that will require a modification to the plants current process. The AD systems can be introduced in the new residential projects such as East Hidd Housing Project or Al Madina Al Shamaliya Development (Northern Town).

Offshore renewable energy applications can be considered for Bahrain, starting from the offshore wind to tidal and wave power. Bahrain wind assessment shows a good potential for large wind farms in Bahrain. In addition to wind, wave power is linked to the quality of wind in the area and given the good wind resource and Bahrain geographical characteristic, wave power must be considered for energy resource assessment. Wave power can be used for offshore construction, bridges and marine systems.

Finally, solar thermal heating systems have not been addressed through NREAP. Introducing these systems to hotels, business offices, industrial buildings need to be addressed, especially that water heater is used in this building throughout the year, which adds extra stress on the power demand besides air-conditions. Although, this idea not been used in the region, solar thermal air-condition can be an attractive area for study, and comparing systems by testing under the local weather condition which will help to develop the technology not only for Bahrain but also for the region as whole.

Adopting strategies to engage industries, businesses and research insititutions is an essentional step to maintaine a sustainble progress to the implementation and the development toward the national energy effciency and renewabel energy targets, and will allow a contious assesssment to the projects to avoid stagnation.

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