SEU

Sustainable Energy Unit
Kingdom of Bahrain

وحدة الطاقة المستدامة
مملكـــة البحـــرين

The Kingdom of Bahrain

National Renewable Energy Action Plan (NREAP)

January 2017

Endorsed by Cabinet Resolution No 2384-08 (2016) and No 2392-2 (2017)

ACKNOWLEDGEMENTS

The Minister of Electricity and Water Affairs would like to thank the First Deputy Prime Minister's Office, the Electricity and Water Authority, the National Oil and Gas Authority, the Ministry of Housing, the Ministry of Works, Urban Planning and Municipalities, the Ministry of Industry Commerce and Tourism, the Ministry of Transport and Telecommunications, the Bahrain Defense Force, the Economic Development Board, the Supreme Council for Environment, large industry groups, academia, and all others who provided support in the preparation of this Plan with their valuable inputs, time, guidance, and expertise.

“**Bahraini nationals and residents enjoy a sustainable and attractive living environment**

Protecting our natural environment will include directing investments to technologies that reduce carbon emissions, minimize pollution and promote the sourcing of more sustainable energy”

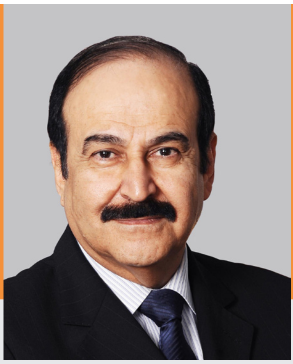
- Bahrain Economic Vision 2030

His Royal Highness
Prince Khalifa Bin Salman Al Khalifa
The Prime Minister

His Majesty
King Hamad Bin Isa Al Khalifa
The King of Bahrain

His Royal Highness
Prince Salman Bin Hamad Al Khalifa
The Crown Prince and Deputy Supreme Commander and First Deputy Prime Minister

Foreword



The Minister of Electricity and Water Affairs:
His Excellency, **Dr. Abdul Hussain bin Ali Mirza**

The government of the Kingdom of Bahrain is committed to the sustainability of the country's natural resources for future generations, as well as the protection of the environment. There is considerable potential for undertaking energy efficiency and renewable energy initiatives in Bahrain, which will extend the lifetime of oil and gas reserves, and enable long-term sustainable development. Bahrain's Economic Vision 2030 puts special emphasis on providing incentives for reducing and managing electricity demand, and investing in clean energy technologies; promoting energy efficiency standards to ensure sustainability; and ensuring better energy and water demand management.

Progress has already been achieved, indeed Bahrain has been a pioneer on the way to a more sustainable future. The Kingdom was one of the first countries to install utility-scale wind turbines on a new commercial development, the iconic World Trade Center in 2008; and Bahrain was the first country in the GCC to have a district cooling system. There are already several private sector renewable energy systems in operation; and a number of initiatives are underway to facilitate more efficient energy use.

In order to unify and consolidate efforts on energy efficiency and renewable energy, the Sustainable Energy Unit was established in November 2014. The Sustainable Energy Unit is mandated to develop strategies and policies for the integrated planning of energy sources in the Kingdom, as well as the rationalization of energy use, and to raise efficiency in all sectors through coordination with all concerned parties. To this end, the Sustainable Energy Unit, in consultation with key stakeholders, has formulated the National Renewable Energy Action Plan and the National Energy Efficiency Action Plan, which were endorsed by the Cabinet (resolution no. 2384-08).

These plans are an important milestone in setting out Bahrain's national targets for renewable energy deployment and the adoption of energy efficiency initiatives. As such, they represent the Kingdom's efforts to deliver the sustainable energy transition envisioned in the Economic Vision 2030 and the Government Action Plan 2015-2018. The plans also represent the implementation of the Kingdom's regional and international commitments under the Paris Agreement, the United Nations Sustainable Development Goals, and the League of Arab States Renewable Energy Framework and Guidelines on Energy Efficiency.

The initiatives within the plans, with the support of leadership across all ministries, and from key stakeholders and members of society, will enable the Kingdom's sustainable future. By working together, Bahrain can achieve its sustainable energy objectives, which will benefit the Kingdom economically and environmentally.


SUSTAINABLE DEVELOPMENT GOALS
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS

Foreword

United Nations Resident Coordinator and United Nations Development Programme Resident Representative:

Mr. Amin Al Sharkawi

In recognition of both the need and potential to diversify Bahrain's energy sector to include renewable sources, and to develop innovative ways to ensure the most efficient use of energy, the UNDP has been working with the Government of Bahrain for a number of years to respond to the important issue of sustainable energy. The UNDP is delighted to support the Office of the Minister of Electricity and Water Affairs in establishing the Sustainable Energy Unit, for the benefit of the people of Bahrain, and to further the sustainable development of the country.

The publication of the National Renewable Energy Action Plan and the National Energy Efficiency Plan is an important milestone in Bahrain's national development. The leadership of the Kingdom of Bahrain is to be applauded for taking active steps towards a sustainable future.

The plans align closely with the framework of the UN Secretary General's Sustainable Energy for All (SE4All) Initiative that supports universal access to modern energy services, acceleration in energy efficiency improvements, and the increased use of renewable energy in the energy mix.

It also supports the 2030 Agenda for Sustainable Development which includes the United Nation's 17 Sustainable Development Goals for social progress, economic growth and environmental protection. By focusing on renewable energy and energy efficiency, the Kingdom of Bahrain is supporting the realization of the United Nations Sustainable Development Goal No. 7: Ensuring acess to affordable, reliable, sustainable and modern energy for all.

The Bahraini National Renewable Energy Action Plan and the National Energy Efficiency Action Plan are on par with similar initiatives in other Arab countries, and will help to promote the exchange of successful international experiences for the benefit of Bahrain's ambitious development agenda.

To achieve these objectives, the UNDP will facilitate access to expertise from within the UN system and the international energy community. Most importantly, the plans will become a building block to achieve Bahrain's Economic Vision 2030 and has energy efficiency and renewable energy as top priorities. This vision marks a new era of development and modernization for the Kingdom of Bahrain and the UNDP will continue to support Bahrain's leadership in implementing these important sustainable energy initiatives.

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ACRONYMS AND ABBREVIATIONS

Alba	Aluminum Bahrain
BAPCO	Bahrain Petroleum Company
BD	Bahraini dinar
BIPV	building-integrated photovoltaic
CIO	Central Information Organization
CO2	carbon dioxide
CSP	concentrating solar power
DEWA	Dubai Electricity and Water Authority
EDB	Economic Development Board
EU	European Union
EWA	Electricity and Water Authority
GCC	Gulf Cooperation Council
GCCIA	GCC Interconnection Authority
GWh	gigawatt hours
INDC	Intended Nationally Determined Contribution
IPP	independent power producer
IWPP	independent power and water producer
kW	kilowatt
kWh	kilowatt hours
kWh/m2	kilowatt hours per square meter
kWp	kilowatt peak
MMbtu	million British thermal units
Mmcf	million cubic feet
Mtoe	million tonnes of oil equivalent
MW	megawatts
NOGA	National Oil and Gas Authority
NREAP	National Renewable Energy Action Plan
PV	photovoltaic
SDGs	Sustainable Development Goals
SEU	Sustainable Energy Unit
UNDP	United Nations Development Programme
Wp	peak Watt
WPCC	Water Pollution Control Center

EXECUTIVE SUMMARY

BACKGROUND

The Kingdom of Bahrain, despite being a small island country, possesses abundant renewable energy resources, including solar and wind that have been largely untapped. Renewable energy is a clean, non-exhaustible, and local source of energy, an important component for building a reliable, resilient, and sustainable energy system. Today the Kingdom's power generation system relies exclusively on natural gas, which is a scarce and diminishing resource. Current projections on the availability of gas reserves suggest that Bahrain will no longer be able to meet its domestic consumption, and will have to rely on imported gas as early as 2018. By introducing renewable energy into the energy mix and adopting energy efficiency policies, Bahrain can reduce its reliance on imported energy, prolong the lifetime of the indigenous gas resource, and optimize its economic value.

In clear recognition of the benefits of renewable energy, the Kingdom of Bahrain is committed to the development of renewable energy initiatives by harnessing the country's renewable energy resources. The National Renewable Energy Action Plan (NREAP) represents the Kingdom's efforts to deliver the sustainable energy transition envisioned in the Economic Vision 2030 and the Government Action Plan 2015-2018. This Plan also represents the implementation of the Kingdom's regional and international commitments under the Paris Agreement, the United Nations Sustainable Development Goals, and the League of Arab States Renewable Energy Framework.

The Plan identifies feasible renewable energy options for Bahrain, sets the targets, and proposes policies and actions to harness the identified renewable energy opportunities. The NREAP has been prepared by the Sustainable Energy Unit (SEU) through broad consultations with key stakeholder groups, including the Electricity and Water Authority, the National Oil and Gas Authority, the Ministry of Housing, the Ministry of Works, Urban Planning and Municipalities, the Ministry of Industry, Commerce and Tourism, the Supreme Council for Environment, the Economic Development Board, the Bahrain Defense Force, large industry groups, academia, and others.

TARGETS

Based on a broad survey of Bahrain's resource potential, economic viability of various renewable energy technologies, the current energy situation, and the country's unique geographical conditions, the Plan sets a national renewable energy target of:

-5% by 2025

-10% by 2035

The targets are based on the projected peak load electricity capacities, excluding industry's own generation, and equate to 255 MW of installed capacity by 2025, and to 710 MW by 2035. The targets will be met by a proposed renewable energy mix consisting of solar, wind, and waste to energy technologies.

BENEFITS AND IMPACT

Integrating renewable energy in the energy mix can help Bahrain optimize the use of indigenous gas resources, reduce greenhouse gas emissions, make the economy more competitive, decrease electricity peak demand, and improve energy security in the long-term. Achieving the 5% renewable energy target will result in:

- Clean energy generation of approximately 480 GWh per year
- Annual savings of 5,700,000 MMbtu of natural gas
- Annual financial savings of BD 1.6 million
- Reduction in greenhouse gas emissions by 392,000 tonnes of CO2 per year
- Attraction of more than BD 140 million of investment.

POLICIES TO ACHIEVE TARGETS

To achieve the stated targets and attract private sector investment in renewable energy technologies, the following complementary policies are proposed:

	Policy 1	Policy 2	Policy 3
	Net Metering	**Tender-based Feed-in Tariffs**	**Renewable Energy Mandate for New Buildings**
Objective	Enable **consumers** to generate on-site, grid-connected, renewable energy power	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 for target group	Reduced electricity bill through on-site power generation and the ability to credit the excess electricity fed back to the grid	Long-term power purchase agreement	Reducing energy demand of the building from the grid (reduced electricity bill)

The details of each policy will be outlined in relevant documents and regulations.

RENEWABLE ENERGY DEPLOYMENT STRATEGY AND PROJECTS

In Bahrain, land is a scarce resource, as such the deployment strategy of renewable energy focuses on decentralized urban generation, large-scale generation on available land, and offshore generation.

I. DECENTRALIZED URBAN GENERATION (100-150 MW)

Decentralized renewable energy applications, such as rooftop solar photovoltaic (PV), building integrated PV, solar lighting, biogas plants, and micro wind turbines, can be successfully integrated in the urban environment. This allows not only transitioning to a more sustainable energy system, but also engages all members of the society, including households, businesses, academia, and governmental authorities in building smart, modern, and resilient cities and communities. Viable opportunities for decentralized urban generation include:

- Solar systems for new housing units
- Solar systems for government buildings
- Decentralized solar in urban developments (solar lighting, solar parking)
- Decentralized rooftop solar on existing residential and commercial buildings
- Other decentralized renewable energy systems (biogas, micro wind).

II. LARGE-SCALE GENERATION ON AVAILABLE LAND (50-100 MW)

Economies of scale favor the development of large-scale renewable energy power plants. Therefore, it is prudent to consider the deployment of large-scale renewable energy where land is available. Viable opportunities for large-scale generation on land include:

- Solar farm on Askar landfill site
- EWA renewable energy initiative (5 MW hybrid solar and wind project)
- Utility-scale renewable energy plants by large industry groups
- Solar farms in new town developments
- Waste to energy plant at the Tubli wastewater treatment plant
- Renewable energy plants on other available land.

III. OFFSHORE GENERATION (50 MW)

Offshore renewable energy development presents an opportunity to pursue large-scale generation and achieve higher renewable energy targets. Bahrain has a good wind regime and shallow waters, therefore pursuing offshore wind power could be a cost-competitive option. Other offshore renewable energy options include integrating renewable energy in offshore large infrastructure projects connecting Bahrain and its GCC neighbors. This will not only generate clean energy, but also strengthen the regional partnerships in building a more sustainable future. Identified offshore generation opportunities include:

- Near shore or offshore wind farms
- Integrating renewable energy technologies in large infrastructure projects (causeways and railway systems).

GOVERNANCE

I. SUSTAINABLE ENERGY UNIT

The Sustainable Energy Unit (SEU) was established in November 2014 and is the designated agency for promoting sustainable energy policies and practices in the Kingdom of Bahrain. As such, the SEU will lead the coordination efforts in implementing the NREAP, and will provide technical assistance in the deployment of renewable energy projects. The SEU's responsibilities are to:

- Coordinate implementation activities among all stakeholders through developing partnerships and organizing regular coordination meetings;
- Inform stakeholders on the progress of implementation of the NREAP;
- Draft renewable energy policy regulations and support the establishment of standard operating procedures for their implementation;
- Carry out feasibility studies, resource potential assessment, cost-benefit analysis of various technology options and business models, as well as oversee the implementation of pilot projects;
- Provide technical assistance in developing tendering documents, drafting requests for proposals, evaluating bids, and assessing outcomes of pilot projects;
- Carry out information dissemination and awareness raising campaigns through launching a dedicated website, organizing press conferences, promoting renewable energy at various public events;
- Organize and support capacity building and training activities for government and non-government stakeholders.

II. NREAP IMPLEMENTATION FOLLOW-UP COMMITTEE

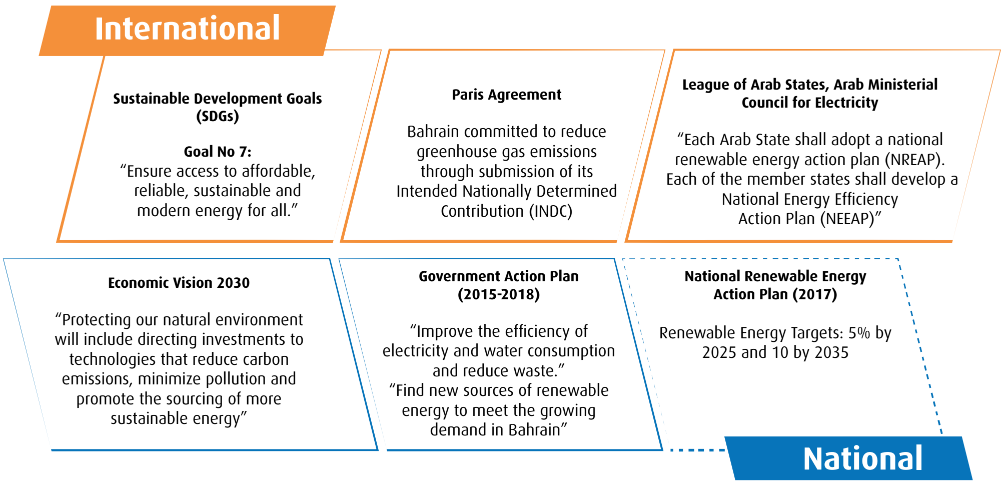
The Committee will be composed of high-level representatives of key government and non-government institutions who would play the role of change agents to provide guidance, support and oversight of the implementation process of NREAP. The Committee will be chaired by the Minister of Electricity and Water Affairs, 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. The Committee's responsibilities are to:

- Oversee the implementation of the NREAP and facilitate its execution;
- Identify action items to overcome implementation issues and challenges;
- Put recommendations and suggest actions to relevant ministries;
- Decide on making changes in the NREAP if required;
- Discuss the progress in the implementation process.

1. BAHRAIN'S SUSTAINABLE ENERGY AGENDA

The Kingdom of Bahrain is committed to the development of sustainable energy envisioned in the Economic Vision 2030, the Government Action Plan 2015-2018, and as a party to regional and international agreements

Figure 1: Bahrain's National and International Commitments



1.1 INTERNATIONAL COMMITMENTS

THE PARIS AGREEMENT

In December 2015, the 21st Conference of the Parties of the United Nations Framework Convention on Climate Change took place in Paris. As a result, 195 nations adopted the Paris Agreement on taking action toward holding the increase of global average temperature to well below 2°C above pre-industrial levels. The Paris Agreement is a historic international treaty to combat climate change, and accelerate actions and investments needed for a sustainable low carbon future. On 22 April 2016 Bahrain signed the Paris Agreement, and expressed its support through publication of its Intended Nationally Determined Contribution (INDC) in November 2015 [1].

The INDC is an official pledge by the Kingdom to support the global efforts in combating climate change, by taking specific actions to reduce its own greenhouse gas emissions. Renewable energy and energy efficiency represent key initiatives in Bahrain's INDC, as both hold great potential to reducing greenhouse gas emissions as well as promoting sustainable national development.

THE UNITED NATIONS SUSTAINABLE DEVELOPMENT GOALS

In September 2015, at the United Nations Sustainable Development Summit, world leaders officially adopted a new agenda entitled "Transforming Our World: The 2030 Agenda for Sustainable Development." The new global agenda includes 17 Sustainable Development Goals (SDGs) and 169 targets. The SDGs represent a consensus of the 193 member states of the United Nations to end poverty, protect the planet, and ensure the prosperity for all. SDG 7 calls the countries to "Ensure access to affordable, reliable, sustainable and modern energy for all." [2] This goal is supported by five targets to be achieved by 2030:

- Ensure universal access to affordable, reliable and modern energy services
- Increase substantially the share of renewable energy in the global energy mix
- Double the global rate of improvement in energy efficiency
- Enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology
- Expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support

The government of the Kingdom of Bahrain embraced the challenge of meeting the Millennium Development Goals (MDGs) by 2015, and expressed its commitment to the Post-2015 development agenda process at the press conference in the UN Sustainable Development Summit, held on 20 September 2015.

LEAGUE OF ARAB STATES – ARAB RENEWABLE ENERGY FRAMEWORK

In April 2013, the Arab Ministerial Council for Electricity of the League of Arab States adopted the "Arab Renewable Energy Framework," which seeks to promote renewable energy development in the Arab region (Arab Guidelines). Article 2 of these Guidelines states that "Each Arab State shall adopt a national renewable energy action plan (NREAP), setting out Arab States' national targets for the share of energy from renewable sources consumed in electricity generation,…" [3] The NREAP is drafted in accordance with the template suggested by the Arab Guidelines.

1.2 NATIONAL COMMITMENTS

Pursuing renewable energy is not only an international commitment of Bahrain, but also of national interest. Today the Kingdom's power generation system exclusively relies on natural gas, which is a scarce and diminishing resource. Current projections on the availability of gas reserves suggest that Bahrain will no longer be able to meet its domestic consumption, and will have to rely on imported gas as early as 2018. An increased reliance on imported energy is highly likely to increase energy prices for consumers. Renewable energy is a clean, non-exhaustible, and local source of energy, an important component for building a reliable, resilient, and sustainable energy system. Integrating renewable energy in the energy mix can help Bahrain optimize its use of indigenous gas resources, make the economy more competitive, and improve energy security in the long-term.

The development of sustainable energy is in line with the Kingdom's Economic Vision 2030. The Economic Vision 2030 recognizes economic, social and environmental sustainability as one of its key principles. It indicates explicitly that the economic growth must never come at the expense of the environment and the long-term well-being of the people. Furthermore, it encourages investment in technologies that reduce carbon emissions, minimize pollution, and promote sustainable energy [4].

In clear recognition of the benefits of renewable energy, the Kingdom of Bahrain is committed to the development of low-carbon energy initiatives by harnessing the country's renewable energy resource base. In 2015, the Government adopted the Government Action Plan 2015-2018 to deliver sustainable change in line with the Economic Vision 2030. The Government Action Plan reflects the Government of Bahrain's strategic priorities over the next four years, and seeks to capitalize on the Kingdom's resources and capabilities to meet the needs of all Bahrainis. Under the "Environment and Urban Development" pillar, the Government made commitments to finding suitable sources of renewable energy to meet the growing energy demand in Bahrain. To achieve this, the Government will seek to explore the optimal renewable energy options such as wind and solar energy, and will take necessary steps to implement pilot projects to pave the way for larger-scale deployment [5].

1.3 THE SUSTAINABLE ENERGY UNIT

In November 2014, under Cabinet Resolution 4/2238, the government established the Sustainable Energy Unit (SEU) to lead and promote sustainable energy policies and practices in the Kingdom of Bahrain. SEU was established under the office of Minister of Energy, with the support of the United Nations Development Programme (UNDP) [6]. Due to the broad central government restructuring in summer 2016, SEU became one of the initiatives governed by the Office of the Minister of Electricity and Water Affairs.

The key objectives of SEU are to develop a cohesive sustainable energy policy framework to promote renewable energy, energy efficiency, and conservation in the country. SEU will also work towards bridging the legal, institutional, and capacity gaps in order for Bahrain's energy sector to meet future challenges.

The mandate of SEU includes:

- Synergizing and consolidating existing efforts of public, private and international institutions in achieving goals as stated in the Bahrain Economic Vision 2030;
- Supporting the creation of an enabling environment for energy efficiency and renewable energy technology transfer, and private sector investments;
- Supporting the development of necessary policies, regulations and standards across various sectors;
- Promoting replication and up-scaling of successful pilot project and initiatives across the Kingdom;
- Strengthening national capacity on deployment of renewable energy and energy efficiency technologies;
- Coordinating the implementation of national, regional and international obligations related to energy efficiency and renewable energy; and
- Raising public awareness on the benefits of energy efficiency and renewable energy.

The NREAP represents one of the key components of the Kingdom's efforts to implement its national, regional and international commitments in the field of sustainable energy development and climate change. It identifies the viable renewable energy options, sets the targets, and proposes policies and actions to harness the identified renewable energy opportunities. SEU under the guidance of the Minister of Electricity and Water Affairs will lead the coordination of the implementation of the Plan.

2. BAHRAIN ENERGY OUTOUTLOOK

2.1 OIL AND GAS

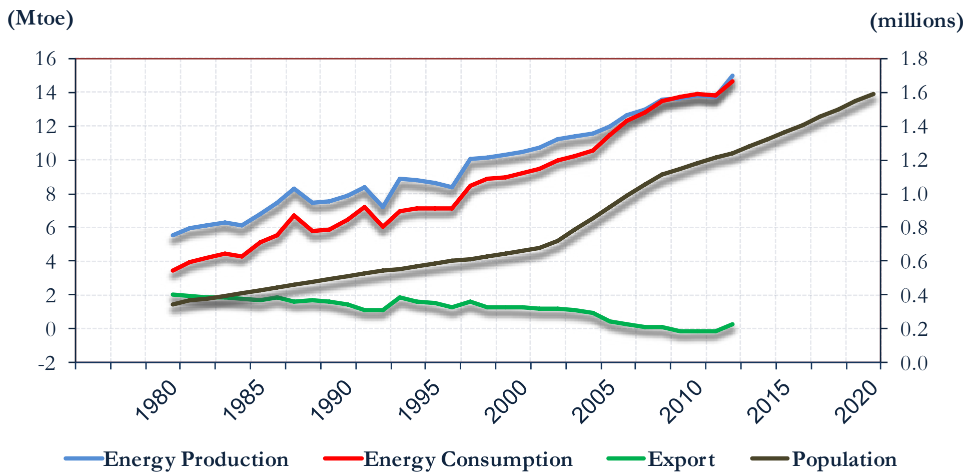
In 2014, Bahrain's total energy consumption came from two sources: oil (17%) and natural gas (83%). To meet its domestic energy demand Bahrain relies on its indigenous hydrocarbon resources. Bahrain was the first country in the GCC region to discover oil reserves in 1932. Crude oil production reached its peak in 1970, and since then it has been gradually declining. In 2014, crude oil production amounted to 202,000 barrels a day. Bahrain's crude oil production came from two fields: the Bahrain field with a production of around 49,000 barrels a day and the Abu Saafa joint offshore field with Saudi Arabia, with a production of around 154,000 barrels a day [7]. At current production levels, the oil reserves have a projected lifetime of about 11 years.

Natural gas is the backbone of the energy system and economy of Bahrain. Today Bahrain entirely relies on natural gas for its power and water generation. Natural gas is also economically critical for operation of the Kingdom's industrial sector. In 2014, Bahrain produced 728 billion cubic feet of natural gas [7]. All natural gas has been used for domestic consumption in the following sectors: 41% by the manufacturing sector; 33% for power and water generation; and 25% was re-injected for enhanced oil recovery [8]. The projected lifetime of natural gas reserves is about 15 years.

In 2014, the manufacturing sector was the third most important sector in the economy, accounting for 15% of the Kingdom's GDP, after oil and gas (23%) and financial services (15.5%) [9]. It also provided for 18% of all private sector employment [8]. The Economic Development Board reinforces the fact that it is economically more advantageous to save the natural gas for consumption by the more productive sectors of the economy, such as manufacturing, and find alternative cost-competitive energy sources for power and water generation [8].

Figure 2 depicts historical energy supply and demand trends in Bahrain. It shows that the overall levels of energy production and consumption have increased year on year. As the population continues to grow, and the limited amount of fossil fuels begins to diminish, it may not be possible for Bahrain to meet its growing energy demand without relying on imported energy. Bahrain is already planning to import natural gas as early as 2018, and the steps are underway to complete the construction of an LNG import facility by 2018.

Figure 2: Energy Supply and Demand Trends



An increased reliance on imported energy is highly likely to result in an increase of energy prices for consumers. In anticipation of the diminishing gas supply, the government adopted a new gas pricing policy in 2015. Under this policy, the price of natural gas sold to domestic companies will increase by USD 0.25 per MMbtu[1] each year on 1 April. The pricing policy will be reviewed when the price reaches USD 4 per MMbtu[2] by 1 April 2021 [8]. The first price increase took place on 1 April 2015, from USD 2.25 to 2.50 per MMbtu.

Introducing renewable energy into the energy mix and adopting energy efficiency policies, can help Bahrain reduce its reliance on imported energy, prolong the lifetime of the indigenous natural gas resource, and optimize its economic value. This approach will improve energy security in the long-term and will have an overall positive impact on competitiveness of the manufacturing industry and environmental performance of the energy sector.

1 Equivalent to BD 0.0942 per MMbtu
2 Equivalent to BD 1.508per MMbtu

2.2 ELECTRICITY AND WATER

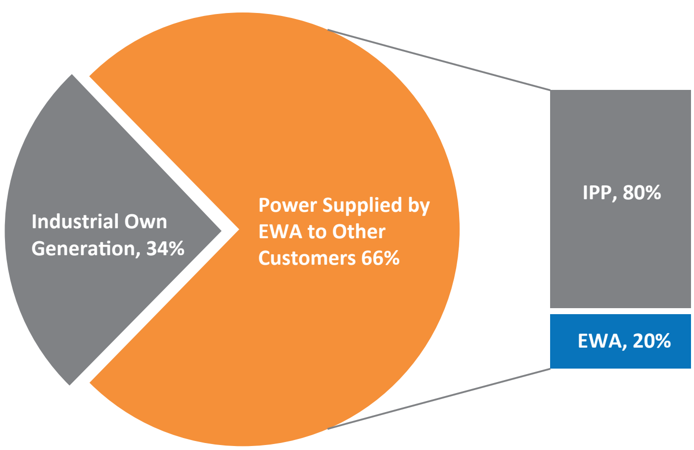
2.2.1 ELECTRICITY SUPPLY AND DEMAND

With the adoption of the Electricity Law in 1996, the private sector has been allowed to participate in the power generation market [10]. Today Bahrain has one of the most privatized power generation markets in the region. Independent power producers (IPPs) generate 80% of grid-supplied electricity.

In 2014, the Kingdom had 6,204 MW of installed capacity. Of this 2,274 MW were captive power plants, owned and operated by large industry groups such as Alba, BAPCO and GPIC. Independent power and water producers (IWPPs) own and operat

e 3,100 MW, and 825 MW are owned and operated by Electricity and Water Authority (EWA). In addition, Bahrain can import and export electricity through its 600 MW capacity GCC interconnection with the GCCIA (the GCC Interconnection Authority). Power produced by captive power plants is consumed on site by large industry groups. Power produced by IWPPs and EWA is distributed and sold to customers by EWA. EWA is the sole body responsible for electricity transmission, distribution, and grid operation.

Figure 3: Bahrain Power Supply, 2014



In 2014, the Kingdom consumed 24,705 GWh. Grid electricity supplied by EWA accounted for 15,186 GWh, or 66% of total electricity consumption. The remaining 34% was generated and consumed by large industrial users. All the electricity was produced from natural gas. The residential sector used most of the grid electricity, at 46% of total grid consumption. Grid electricity consumption grew from 5,516 GWh in 2000 to 15,186 GWh in 2014, with an annual average growth rate of 7.5%. The commercial sector was the second-largest user, accounting for 36.4%, followed by the industrial sector, at 17.3%. The agricultural sector was a marginal user at 0.3% [11].

Similar to other GCC countries, Bahrain has a large seasonal variation in electricity consumption. Due to very hot summers, electricity consumption during the months from May to October increases significantly. This is mainly due to the heavy use of air-conditioning units, which account for 60%-65% of electricity usage in buildings. In 2014, the highest peak electricity consumption occurred in August (1,720 GWh) and the lowest electricity consumption occurred in January (701 GWh). Total electricity consumption in August was two and a half times higher than electricity consumption in January.

Figure 4: Electricity Monthly Consumption, 2014

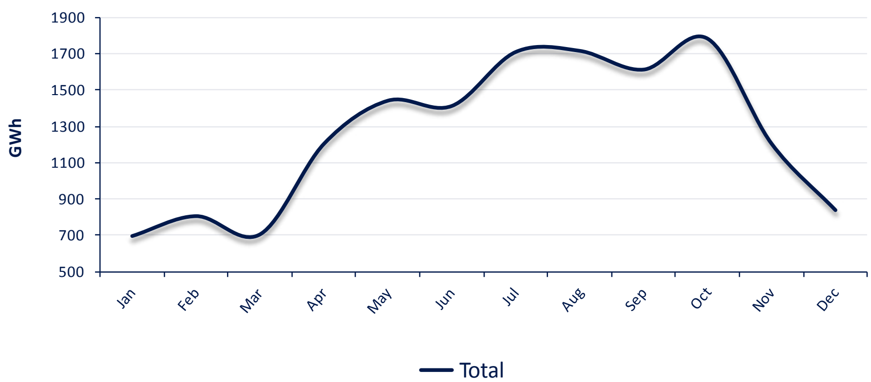
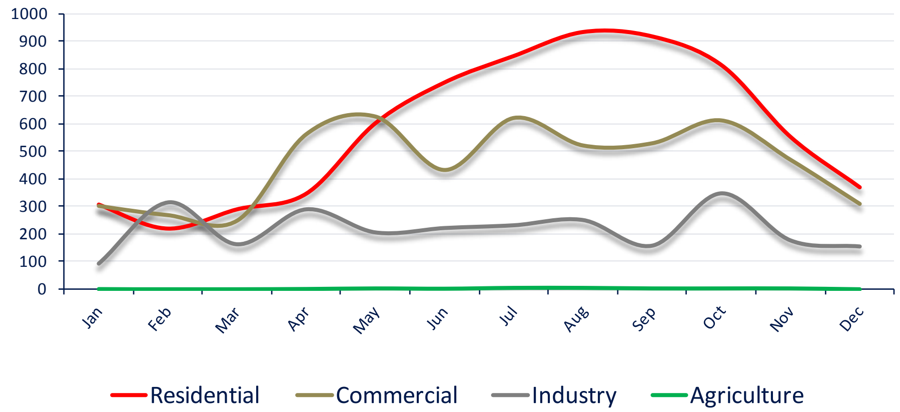


Figure 5: Electricity Monthly Consumption by Sector, 2014



Aside from seasonal peaks, Bahrain also has daily electricity consumption peaks. Bahrain has two daily peaks: the first peak occurring between 11:00 and 16:00, and the second occurring between 18:00 and 19:00. Table 1 shows peak consumption on a typical summer day (31 August 2015), compared with electricity consumption during a typical winter day (31 January 2015).

Table 1: Electricity Peak demand

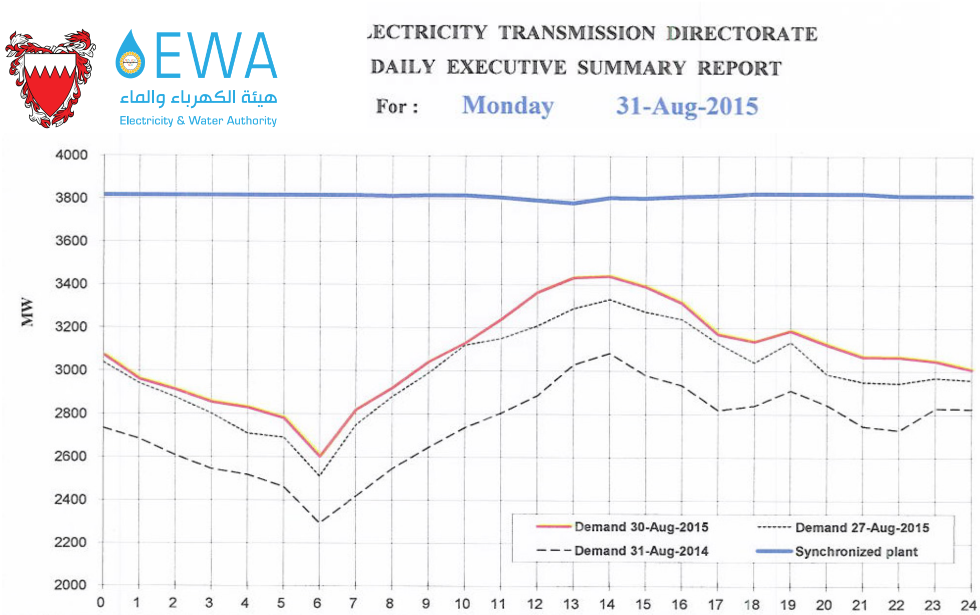
	Day Peak		Night Peak	
	Time	MW	Time	MW
31 August 2015	13:39	3,441	18:36	3,189
31 January 2015	12:03	1,137	18:09	1,208

Source: EWA

To meet peak demand the government needs to have extra generation capacity units, which is costly. According to the World Bank analysis of the demand curve recorded in 2014, the network required an additional 500 MW, which operates for less than 50 hours a year. The estimated cost for the government to maintain 500 MW over a 20-year period is over USD 600 million[3]. This amount excludes the fuel costs of producing electricity, and variable operation and maintenance costs [11]. The inclusion of solar PV power in the energy supply mix can provide a valuable benefit by reducing the daytime peak, as the solar radiation hours correlate with day peaking hours.

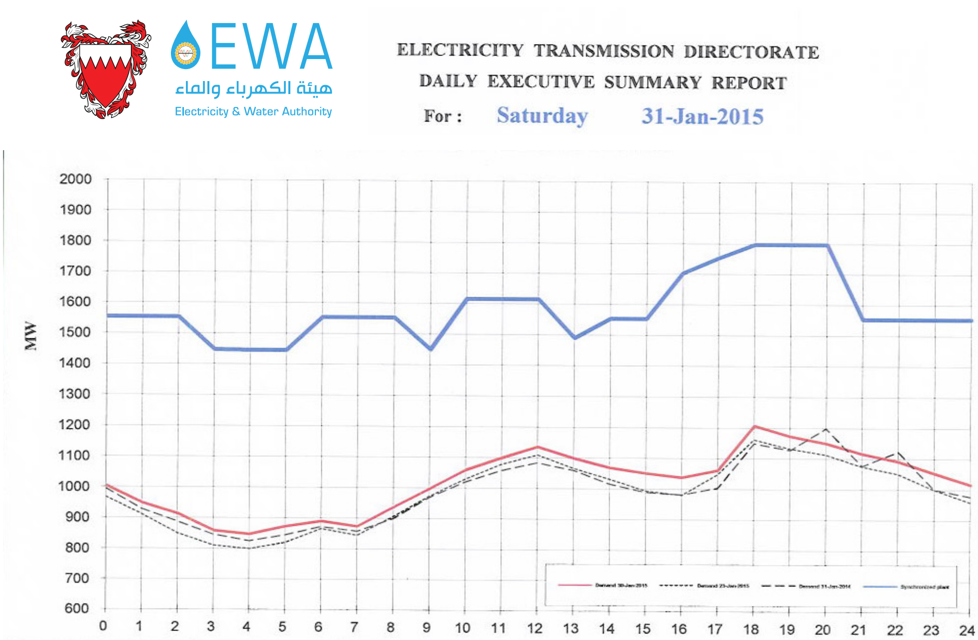
3 Equivalent to BD 226 million

Figure 6: Summer Day Electricity Demand



Source: EWA

Figure 7: Winter Day Electricity Demand

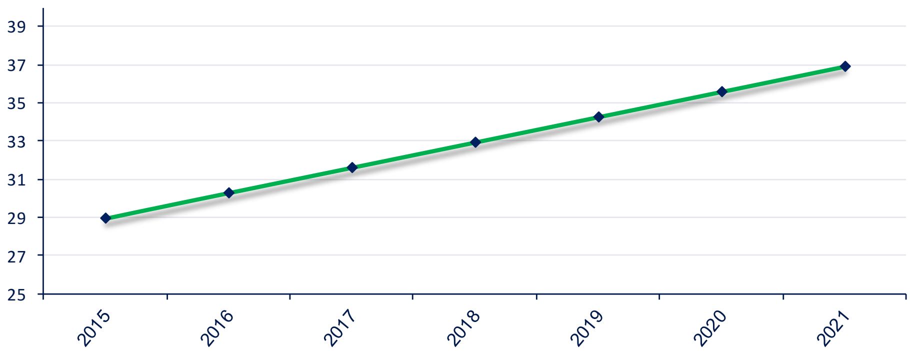


Source: EWA

2.2.2 COST OF POWER GENERATION

As the power in Bahrain is entirely produced from natural gas, the cost of power generation largely depends on the fuel price. The current cost of power generation is 22 fils/kWh. The electricity transmission cost is 3.3 fils/kWh, and the distribution cost is 3.7 fils/kWh. In total, it costs 29 fils/kWh for EWA to supply power to end customers. This cost is based on a natural gas price of USD 2.5 per MMbtu. As the cost of natural gas will increase by USD 0.25[4] per year, the cost of electricity supply will also increase. According to unofficial expert estimations, the cost of electricity supply (including transmission and distribution costs) from natural gas could increase to 36 fils/kWh by 2020, based on the planned gas price increases (see Figure 8).

Figure 8: Estimated Future Electricity Cost



Historically natural gas has been the most cost effective way to provide the country with electricity. However, from an economic and financial perspective, planned gas price increases make renewable energy, such as solar and wind power, a cost-competitive alternative source of energy, in the electricity generation mix.

Up until recently electricity and water tariffs were subsidized. Effective from 1 March 2016, new electricity and water tariffs have been applied to electricity and water consumers in accordance with the new tariff schedule announced by the Electricity and Water Authority. The electricity tariffs will be gradually increased to meet the cost of power generation of 29 fils/kWh by 2019. The new tariffs are applicable to all residential, commercial, and industrial consumers. Bahraini citizens holding a single EWA account are exempt from tariff increases [12].

4 Equivalent to BD 0.0942 per MMbtu

Figure 9: Electricity and Water Tariff Increases

Electricity Tariffs (Fils/ kWh)

Domestic Residential Tariff (kWh/month)	Now	2016	2017	2018	2019
From 1 - 3000	3	6	13	21	29
From 3001 - 5000	9	13	18	23	29
More than 5000	16	19	22	25	29
Non- Domestic Tariff (kWh/month)					
From 1 - 5000	16	16	16	16	16
From 5001 -250000	16	19	22	25	29
From 250001 -500000	16	21	23	26	29
More than 500000	16	29	29	29	29

Water Tariffs (Fils/ m3)

Domestic Residential Tariff (m3/month)	Now	2016	2017	2018	2019
From 1 - 60	25	80	200	450	750
From 61 - 100	80	200	300	500	750
More than 100	200	300	400	600	750
Non- Domestic Tariff (m3/month)					
From 1 - 450	300	400	550	650	750
More than 450	400	500	600	700	750

* Electricity and water tariff increases do not apply to Bahraini nationals holding a single EWA account

2.2.3 SHARE OF RENEWABLE ENERGY

According to the League of Arab States Arab Renewable Energy Framework, countries need to present a unified energy baseline based on 2010 in terms of energy generation from all sources, both renewable and non-renewable. The energy baseline for 2010 and 2014 are presented in Table 2 below.

Currently the share of renewable energy in the electricity generation mix is negligible. In 2014, two pilot renewable energy projects were in place: a 0.5 MW building-integrated wind project at the Bahrain World Trade Center; and a 5 MW solar PV system installed by BAPCO. The BAPCO 5 MW PV plant is a distributed smart solar PV system deployed in three locations: (1) 501 kW at the campus of Bahrain University; (2) 2.7 MW on the BAPCO refinery car parking lot; and (3) 1.8 MW at Awali town. The BAPCO PV plant was installed as a pilot project to test and demonstrate the technical viability of the project [13].

Table 2: Baseline Definition for 2010 and 2014

	2010		2014	
	Installed Capcity	Generated Electricity	Installed Capcity	Generated Electricity
	MW	GWh	MW	GWh
EWA supplied electricity	3,157	12,142	3,925	15,186
Natural gas	3,157	12,142	3,925	15,186
Renewable sources	0	0	0	0
Industry's own generation	2,274	14,000	2,279	14,008
Natural gas	2,274	14,000	2,274	14,000
Renewable sources	0	0	5	8
TOTAL	**5,431**	**26,142**	**6,204**	**29,194**

Source: EWA Electricity Statistics (2014)

The utilization of renewable energy in the rest of the Arab world is comparatively higher. Table 3 presents an overview of non-hydro renewable energy installed capacities, and renewable energy projects under construction in other Arab countries in 2014. In the past two years, these countries have progressed and more renewable energy projects have been installed. The deployment of wind power was leading in earlier years in countries with favorable wind regimes. However, the trend is moving towards more solar PV installations as the prices have decreased, as evidenced by the number of projects under construction in each country [14].

Table 3: Renewable Energy Installed Capacities in Selected Arab Countries, 2014

	Solar (MW)			Wind (MW)		
	Installed	Under Construction	**TOTAL**	Installed	Under Construction	**TOTAL**
Algeria	32	343	375	10	0	10
Egypt	35	38	73	610	600	1210
Jordan	13.6	249	263	1.45	183	184
Kuwait	1.8	60	62	0	10	10
Morocco	35	160	195	750	370	1120
Saudi Arabia	19	65	84	0	0	0
Tunisia	20	10	30	245	0	245
UAE	133	200	333	0	0	0

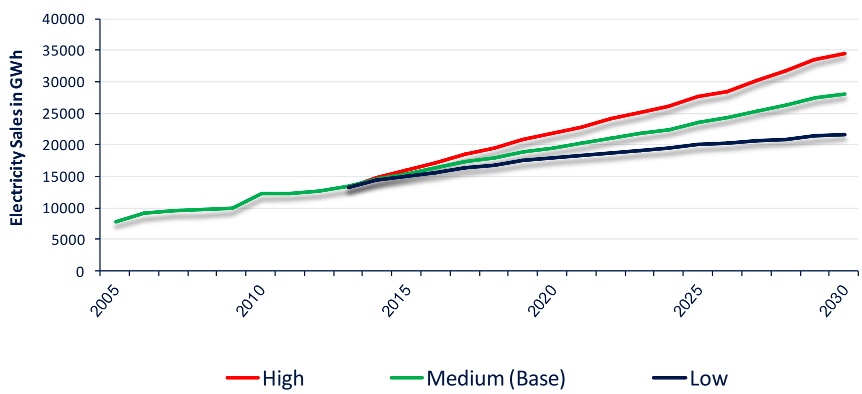
Source: Arab Future Energy Index, 2015

2.3 PROJECTED ENERGY DEMAND

Currently Bahrain has 1.3 million people, of which 48% are Bahraini nationals [15]. According to projections from the Central Information Organization, the population of Bahrain is expected to reach 1,850,000 by 2020 and 2,130,000 by 2030. In addition to population growth, Bahrain's industrial sector is projected to expand. One of the largest industrial expansion projects includes 'Line 6 Expansion Project' of Alba, one of the world's largest aluminum smelting companies. With the construction of the Line 6 Expansion Project, Alba's gas consumption is projected to increase. Other major industrial expansion projects include BAPCO's Modernization Program, the Bahrain Gas Plant Project, and others. The development of mega infrastructure projects such as the regional GCC high-speed rail link and a new causeway between Bahrain and Saudi Arabia, will have a significant impact on improving transportation logistics. These projects are expected to further increase the operations of industrial sector.

With the current projections of population growth, economic development, and expansion of industries, the demand for energy will increase. EWA has projected electricity demand for 2020 and 2030 under three growth scenarios starting from 2013: low, medium, and high, depicted in Figure 10. According to these projections under the low growth scenario power demand in 2030 of grid-supplied electricity will reach 21,700 GWh, under the medium growth scenario power demand in 2030 will nearly double reaching 28,180 GWh, and under the high scenario power demand will reach 34,550 GWh.

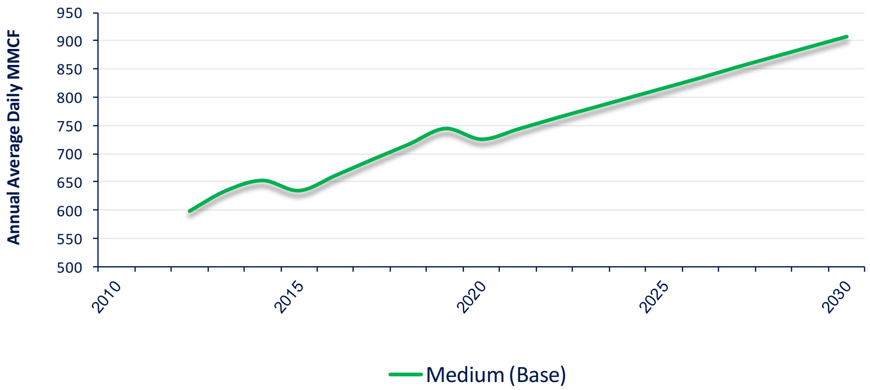
Figure 10: Projected Electricity Consumption Demand



Source: EWA

Figure 11 provides a forecast of natural gas consumption for the power generation process. Gas demand for power generation is expected to increase from a daily consumption of 654 million cubic feet (Mmcf) of natural gas in 2014, to 800 Mmcf in 2025 and to 909 Mmcf in 2030.

Figure 11: Gas Consumption Forecast for Electricity Production



Source: EWA

3. RENEWABLE ENERGY OPPORTUNITIES

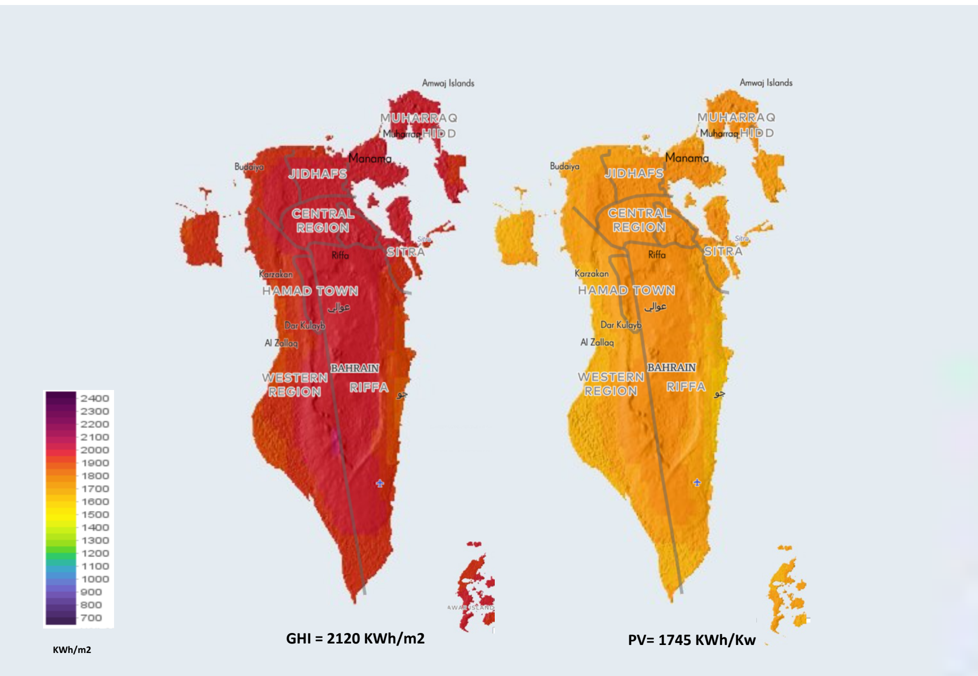
In the last two decades a variety of clean energy technologies have been deployed. Solar and wind technologies have witnessed major advancements, becoming financially competitive alternatives to energy generated from fossil fuel. As Bahrain is blessed with renewable energy resources, an overview of opportunities has been conducted in consultations with key stakeholders. The overview focused on resource potential, high-level economic viability[5], and technology specific benefits and challenges. The main technologies considered include solar, wind, and waste to energy.

3.1 SOLAR

3.1.1 RESOURCE POTENTIAL

Similar to its GCC neighbors, Bahrain enjoys relatively strong solar resource potential. Global horizontal irradiance is around 2,120 kWh/m2 and the estimated annual PV generation is around 1,600-1,700 kWh/kWp/year, as shown in Figure 12. According to measurements taken at the PV plant installed at the Bahrain University campus, the average solar radiation was around 5.18 kWh/m2/day, with an average sunshine duration of 9.2 hours [13].

Figure 12: Solar Radiation in Bahrain



Source: PVOUT map © 2017 Solargis

5 The levelized cost of electricity (LCOE) is used in establishing the economic viability of renewable energy technology options. LCOE takes into account all costs during the lifetime of the project including upfront capital costs, operation and maintenance and other costs.

3.1.2 SOLAR TECHNOLOGIES

There are three primary technologies that convert solar energy into useful energy: photovoltaic (PV), which directly converts solar light into electricity; concentrating solar power (CSP) which uses concentrated sunlight and converts it to heat to drive conventional power generation turbines; and solar heating and cooling systems which collect solar thermal energy to provide hot water and air conditioning. This section presents an overview of these technologies, including specific advantages and disadvantages.

SOLAR PHOTOVOLTAIC (PV)

Photovoltaic (PV) cells convert sunlight directly into electricity. A solar panel is comprised of many PV cells. A wide range of PV cell technologies are available on the market today. The most commonly used PV cells in the market are crystalline silicon (c-Si) and thin films PV cells. According to the Fraunhofer Institute for Solar Energy global PV production in 2015 was dominated by multi-crystalline silicon (69%), followed by mono-crystalline silicon (24%), and thin film (6%) [16]. There is a lot of literature describing differences, advantages and disadvantages of each PV technology. In general, crystalline silicon cells are more efficient (13-19%), more space efficient, but more expensive to produce. They are also rigid and must be mounted in a rigid frame to protect them. Thin films are less efficient (7-13%), have lower space-efficiency, and are less expensive to manufacture. They can be made flexible, which allows them to be used in multiple applications [17, 18, 19].

A solar PV system comprises of different components including solar panels, inverters, metering system, and interface protection. There are two main types of PV systems: grid-connected and stand-alone off-grid systems. A grid-connected PV system can be used to feed on-site consumption and the surplus can be delivered to the electricity grid. Off-grid PV systems require batteries and are thus more expensive. Off-grid solutions are usually better for remote areas, or loads, which are not connected to the electricity network.

Solar PV presents two advantages that are important in the context of Bahrain. First, the modular nature of solar PV makes it well suited for small-scale decentralized applications. Decentralized renewable energy generation refers to power production close to the point of consumption, such as rooftop PV. Unlike any other electricity technology, solar PV can be deployed economically at virtually any scale. A residential solar PV system depending on the efficiency of the panels on average requires 5-10 m2/kWp, which can be deployed on roofs, parking lots and other spaces. Having limited land resources to accommodate large-scale renewable energy projects, distributed solar PV generation at the level of households, commercial and government buildings can play an important role in Bahrain's energy mix.

Second, solar PV has experienced the most rapid technology advances and cost reductions of any renewable technology in use today. Solar PV prices have declined by 75-80% since 2006, making solar PV an attractive and cost-competitive source of power generation. In Germany, the cost of power from utility-scale PV plants fell from over 40 EUR cent/kWh[6]

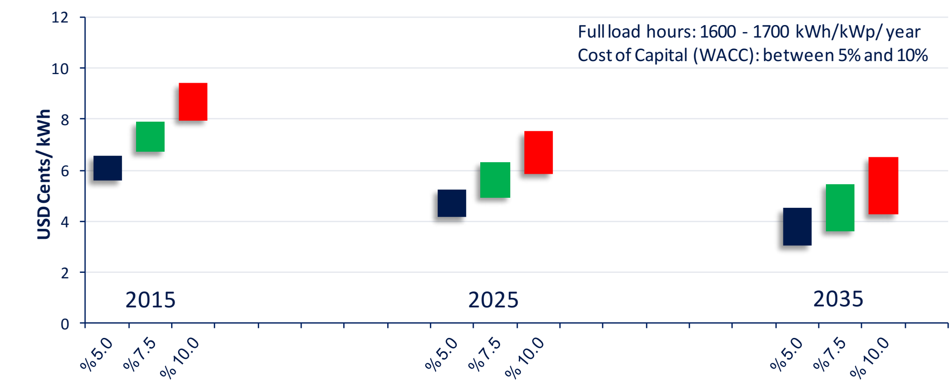
in 2005, to 9 EUR cent/kWh[7] in 2014 [20]. In early 2015, the Dubai Electricity and Water Authority (DEWA) awarded a 200 MW utility-scale PV plant contract at the price of 5.84 US cents/kWh[8]. One year later, DEWA received an even lower bid of 2.99 US cents/kWh[9] for the development of 800 MW PV project, which made major news headlines as the world's cheapest solar PV price [21].

Solar PV has an average lifespan of 20-25 years and its efficiency degrades at the rate of 0.5 to 1% per year. Recent data indicates that the upfront capital investment requirement is around USD 1,100/kWp[10] for PV projects above 1 MW and about USD 1,400/kWp[11] for small-scale PV.[12] Impressive progress has also been achieved in lowering the cost of inverters. Prices for inverters declined from 1 EUR/Wp[13] in 1990, to almost 0.10 EUR/Wp[14] in 2014, while efficiency and power density have increased significantly.

The following chart illustrates current and future projected levelized cost of electricity for utility-scale PV projects (larger than 1 MW) in Bahrain with three different discount rates. The estimations were calculated using the model prepared by the leading German think tank institution Agora Energiewende [22]. In 2015, the LCOE for utility-scale PV ranged from 6.7 to 7.9 USD cents/kWh[15] (based on a discount rate of 7.5%). This is comparable to PV prices tendered in neighboring Arab countries.[16] The LCOE is expected to continue to decrease due to the decline in the cost of PV panels, inverters, installation, and financing.

6 Equivalent to 171 fils/kWh
7 Equivalent to 39 fils/kWh
8 Equivalent to 22 fils/kWh
9 Equivalent to 11 fils/kWh
10 Equivalent to BD 415/kW
11 Equivalent to BD 528/kW
12 Based on information received from solar PV installers in Jordan and Bahrain
13 Equivalent to 429 fils/Wp
14 Equivalent to 43 fils/Wp
15 Equivalent to 25 – 30 fils/kWh
16 In 2015, the four lowest prices received for the 50 MW scale solar PV projects during the second round of the direct proposal submission process in Jordan were 6.1, 6.5, 6.9 and 7.7 US cents/kWh. In 2015, DEWA concluded a power purchase agreement with a private developer for a 200 MW solar PV plant at a price of 5.85 US cents/kWh.

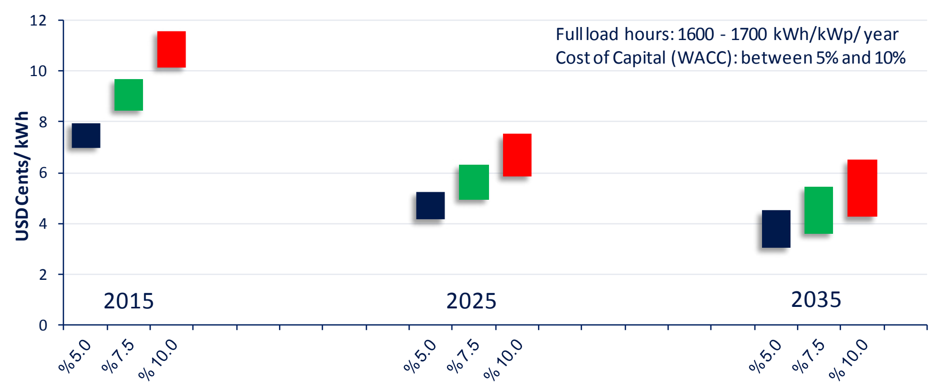
Figure 13: Estimated LCOE for Solar PV above 1 MW



Year	2015						2025						2035					
WACC	5%		7.5%		10%		5%		7.5%		10%		5%		7.5%		10%	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
	5.6	6.5	6.7	7.9	7.9	9.4	4.1	5.2	4.9	6.3	5.8	7.5	3.0	4.5	3.6	5.5	4.2	6.5

The trend of declining PV prices has also been experienced for small-scale residential PV systems. In Germany, the end customer price paid for 10-100 kWp PV systems fell from 5,000 EUR/kWp[17] in 2006, to 1,300 EUR/kWp[18] in 2015 [20]. The following chart presents LCOE calculations for small-scale PV projects in Bahrain.

Figure 14: Estimated LCOE for Solar PV less than 1 MW



Year	2015						2025						2035					
WACC	5%		7.5%		10%		5%		7.5%		10%		5%		7.5%		10%	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
	7.0	7.9	8.5	9.7	10.1	11.5	4.1	5.2	4.9	6.3	5.8	7.5	3.0	4.5	3.6	5.5	4.2	6.5

17 Equivalent to 2,140 BD/kWp
18 Equivalent to 557 BD/kWp

Utility-scale PV plants can be 25% more cost-competitive compared to decentralized small-scale PV plants. However, utility-scale PV plants require large land areas,[19] which is a challenging requirement in the Bahraini context, as the country is limited in its land availability.

Taking into account the above factors, Bahrain will focus on promoting decentralized small-scale PV applications, unless available land is identified for the deployment of utility-scale PV plants.

BUILDING INTEGRATED PHOTOVOLTAIC

Building integrated photovoltaic (BIPV) can be a particularly interesting option for Bahrain as it requires little or no land space. BIPV refers to the solar photovoltaic materials that become part of the building elements such as roofs, skylights, windows, shading systems or façade. In other words, BIPV serves both as a building element and as a means of electricity production. In addition, BIPV can add to the architectural appeal of a building. By substituting BIPV for standard materials during the initial construction, building developers can reduce the incremental costs of PV systems and eliminate costs and design issues for separate mounted systems.

A recent survey of BIPV projects in Europe, by the University of Applied Sciences and Arts of Southern Switzerland, found key essential facts about BIPV [23]:

- The European market is supported by approximately 200 commercially available BIPV products
- When integrating PV in the roof of the building the cost of the roof increased on average by EUR[20] 200/m2
- When integrating PV in the façade of the building, the cost was very similar to the costs of the conventional façade material (stone or glass).
- The BIPV market is expected to experience significant growth in the near future due to the adoption of European Directive 2010/31/EU, which requires all new buildings from 2020 and onwards to be made 'nearly zero-energy' buildings. Zero-energy building refers to the building with zero net energy consumption. In other words, the total annual energy consumption of the building should be roughly equal to the energy produced on-site usually from renewable sources. BIPV products will play an essential role in meeting this requirement.

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19 Depending on the efficiency of PV panels, land requirements for a 1 MW crystalline ground mounted PV plant are around 16,000 m2.

20 Equivalent to BD 86 m2

Based on these findings, it is more economic to promote BIPV in new buildings and new real estate development projects in Bahrain, as PV can be integrated into the overall building design, minimizing the impact on the overall cost of construction.

CONCENTRATING SOLAR POWER

Concentrating solar power (CSP) systems generate electricity by using mirrors or lenses to concentrate a large area of sunlight onto a small area. Electricity is generated when the concentrated light is converted to heat, which drives a heat engine (usually a steam turbine) connected to an electrical power generator. One advantage of CSP over solar PV, is that CSP plants can integrate low-cost thermal energy storage, which allows them to meet power needs several hours after sunset. However, CSP plants have three major disadvantages, which makes this technology a less suitable option for Bahrain:

- CSP plants have high upfront capital requirements compared to solar PV. Unlike PV, CSP has not experienced a sharp decline in technology costs. Investment costs for CSP plants (without storage) range between USD 4,600 and 8,000/kW21 in OECD countries, and in non-OECD countries range between USD 3,500 and 7,300/kW[22] [24]. These prices are reported for parabolic trough collectors, which is the dominant technology used in CSP plants today (85% of all CSP projects installed globally are parabolic trough collectors). The operation and maintenance costs are estimated to be in the range of USD 0.02 to USD 0.04/kWh[23] [24].

- Similar to utility-scale PV plants, CSP plants require large land areas. According to the US Solar Energy Industries Association, a typical CSP plant requires 2 to 4 hectares of land per MW of installed capacity. Although CSP plants can be built in smaller sizes, a CSP plant operates most efficiently, and most cost-effectively, when built in capacities of 100 MW and higher [25].

- CSP plants require water for cooling. CSP plants are often designed to use cooling water at the back-end of the thermal cycle. A typical 50 MW parabolic trough plant uses 0.4-0.5 million m3 of water per year for cooling [26]. Water is also used for cleaning the mirrors to maintain their high reflectivity. Meeting these requirements for water might be challenging in Bahrain, given that most of the fresh water in Bahrain comes through an energy intensive process of desalination.

Taking into account the above factors, Bahrain is unlikely to consider pursuing the deployment of CSP technologies at this stage.

21 Equivalent to BD 1,735 – 3,018/kW
22 Equivalent to BD 1,320 – 2,753/kW
23 Equivalent to 7.5 – 15 fils/kWh

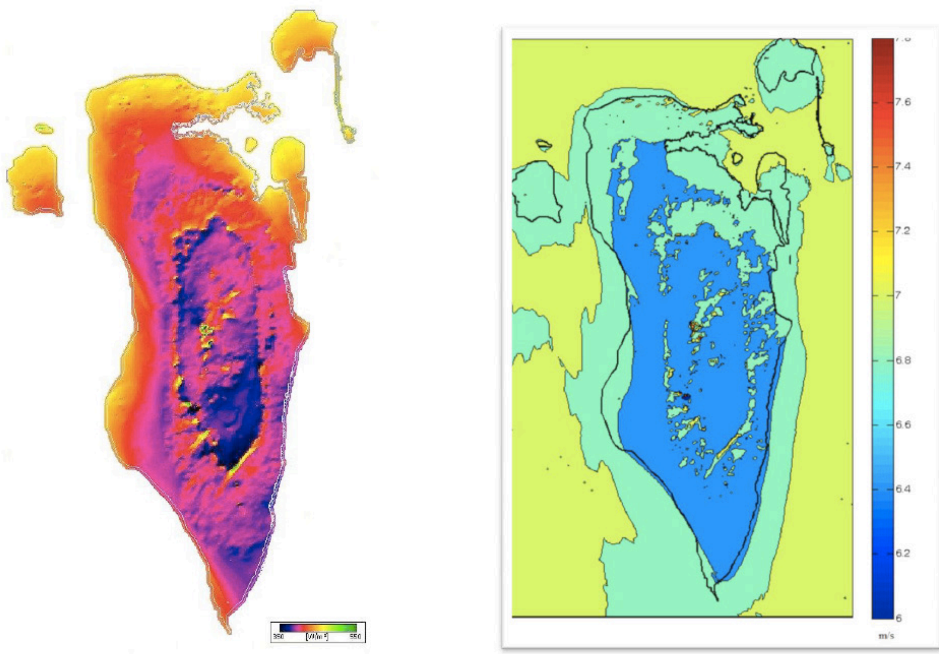
3.2 WIND

3.2.1 RESOURCE POTENTIAL

A possible option for deployment of large-scale renewable energy plants in Bahrain is to pursue onshore and offshore wind power generation. Wind turbines harness the energy of moving air to generate electricity. Preliminary assessment of existing wind data suggests that there is good wind power potential in Bahrain.

Analysis conducted by the University of Bahrain of the 10-year wind data set from the meteorological weather station[24] shows that Bahrain enjoys an annual mean wind speed of 6.9 m/s at 60 meters height (extrapolated), resulting in an average annual power density of 440 W/m2. The strongest wind regime was found in the central and southern parts of the main island of Bahrain [27]. According to the one-year measurements of wind speed from tall mast at 50 meters height, the most prevailing wind speed occurred at around 6 m/s. The highest wind speed reached almost 7 m/s.

Figure 15z: Wind Atlas Developed by the University of Bahrain

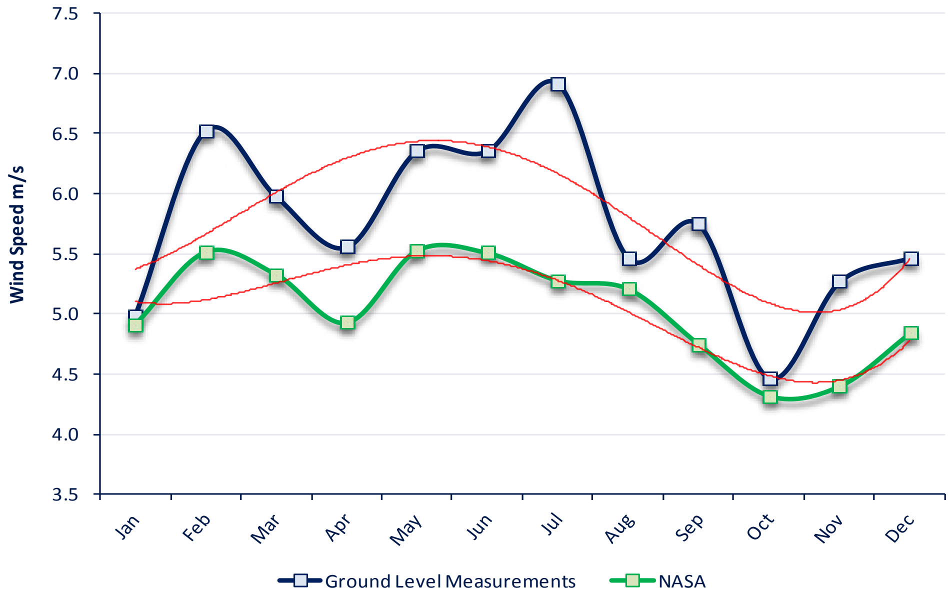


Wind Power Intensity at 60 metres height *Wind speed at 60 metres height*

24 The data was analyzed using industry-standard software package for siting the wind turbines and wind farms – WAsP.

Preliminary assessment of these findings suggests that Bahrain enjoys a wind resource suitable for power generation. However, a more detailed and conclusive analysis of wind speeds is required to establish the economic viability of wind power.

Figure 16: Wind Speed Measurements Acquired from Tall Mast at 50 m Height



3.2.2 WIND TECHNOLOGIES

ONSHORE WIND

The current economics of wind power favors onshore wind. The capital requirements for onshore wind power plant is about USD 1,700/kW[25]. Wind turbines have an average lifetime of about 25 years. The main cost component in a wind project, is the cost of a wind turbine, which accounts for about 70% of the total cost [28]. A typical horizontal-axis wind turbine comprises of several components, including the blades, the hub, the nacelle, the gearbox, the tower, and associated electrical equipment.

Other costs in such projects include civil works, grid connection costs, project planning and development costs. A survey of over 5,000 turbines installed in Denmark since 2006, shows that operation and maintenance costs of onshore wind declined from 3% to less than 2% per year of invested capital. Other sources indicate that operation and maintenance costs of onshore wind range between 20%-25% of LCOE [28].

25 Equivalent to BD 640/kW

The LCOE largely depends on the wind resource – how fast it blows, how often, and when. In very windy regions, the LCOE can be as low as 0.03-0.04 USD/kWh[26], per the recent bids in Morocco and Egypt [29]. The following table illustrates the weighted average LCOE in different parts of the world.

Table 4: LCOE Onshore Wind by Region, 2014-2015

Country	Weighted average LCOE (USD/kWh)	Weighted average LCOE (fils/kWh)[1]
China	0.053	20
Other Asia	0.12	45
North America	0.06	23
Europe	0.07	26
India	0.08	30
Central and South America	0.08 - 0.10	30 - 38
Oceania and Africa	0.08 – 0.10	30 - 38

Source: IRENA (2016), Power to Change, p. 59

Similar to solar PV technology, wind technology has experienced improvements and cost reductions. Since 2009, wind turbine prices decreased by 30% to 40% and are expected to decline further [28]. According to projections made by IRENA, the future global weighted average installed costs of onshore wind could fall by 12% by 2025, resulting in a 34% reduction of total LCOE [28].

A wind turbine takes up little ground space, as almost all the components are up to 60-80 meters in the air. However, a wind farm (several wind turbines) requires available land without structures that might impede wind speeds, which is a limiting factor in Bahrain.

OFFSHORE WIND

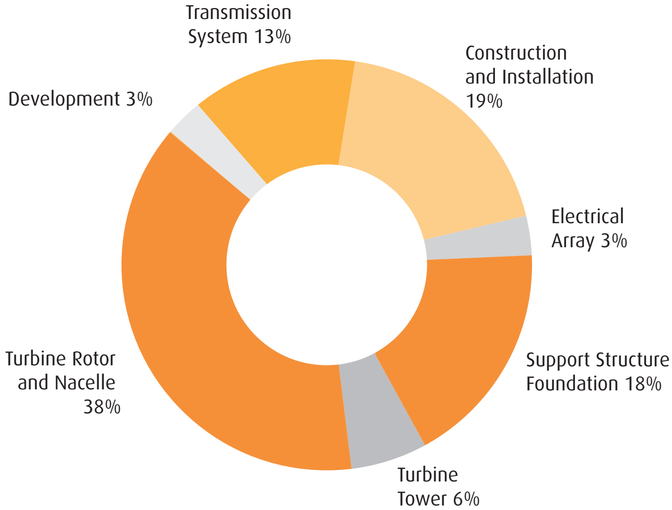
Offshore wind power is where turbines are sited in water areas, such as coastal shallow water. Whilst offshore wind farms typically enjoy higher wind speeds, the marine environment exposes the units to high humidity, salt water, and salt-water spray making installation and operation and maintenance more challenging.

Most of the offshore wind is currently concentrated in Europe. The capital cost for offshore wind ranges from USD 2,500 to 5,600 per kW[27]. The capital cost largely depends on water depth, distance from shore, turbine size and other factors. According to IRENA's projections, the future installed costs for a reference wind farm could be reduced by 15% from 2015 costs, given technological innovations, economy of scales, and learning by doing.

26 Equivalent to 11 – 15 fils/kWh
27 Equivalent to BD 943 – 2,112 /kW

Offshore wind farms are characterized by a larger size of the wind turbines. The typical size of offshore wind turbine is in the range of 3 to 5 MW. The average size of an offshore wind farm in 2015 was around 300 MW. Figure 19 represents an example of a cost breakdown of a typical offshore wind farm in European waters in 2015.

Figure 17: Cost Breakdown of a Typical Wind Farm in European Waters, 2015



Source: IRENA (2016), Power to Change, p. 74

Whilst onshore wind has favorable economics, as an island country, Bahrain clearly has technical potential for offshore wind power. In general, sea winds are stronger and steadier than on land. While the landscape, trees and buildings distort the flow of onshore wind, offshore wind flow can blow without obstacles with higher wind speeds and a more even flow close to the surface which allows lower tower heights [30]. The fact that the depth of water in Bahrain in general is shallow (less than 10 meters) at the coastal areas would in principal favor the deployment of cost-effective offshore wind. However, a number of parameters (e.g. nature of seabed, offshore wind conditions, grid connection, etc.) are not well known yet, and therefore the technical and economic feasibility for offshore wind power in Bahrain's coastal waters requires further analysis.

3.3 WASTE TO ENERGY

Many technologies have been developed and deployed to use waste as a fuel input for energy. This section presents an overview of some of the key waste to energy technologies that can be potentially deployed in Bahrain.

3.3.1 BIOGAS

According to data from the Ministry of Works, Urban Planning and Municipalities Bahrain produces more than 1.7 million tons of solid waste per year, which instead of being landfilled can be used to produce electricity and reduce greenhouse gas emissions. Organic material, which is mostly food waste, makes up 60% of total municipal solid waste. Today all municipal solid waste in Bahrain is landfilled. According to unofficial expert estimations from the Ministry of Works, Urban Planning and Municipalities, Bahrain has only four to five years of landfill capacity left.

Organic waste presents an excellent opportunity to turn waste into useful energy by extracting biogas through anaerobic digestion process. Anaerobic digestion is a bacterial decomposition process that stabilizes organic wastes and produces biogas, which is a mixture of methane and carbon dioxide. Agricultural and marine byproducts, crops, sewage sludge, municipal solid waste or any other biodegradable feedstock, under anaerobic conditions, can produce biogas. Biogas can be used for a number of applications including electricity generation, injection into the national gas grid, and as a vehicle fuel. It is estimated that Bahrain has a potential to generate 190 million m^3 of biogas per year from its organic waste.

In the European Union, anaerobic digestion is recognized as an essential step in a sustainable waste management process and as an efficient waste recycling method [31]. Today there are more than 13,800 biogas plants in operation in Europe. In Sweden, out of 230 biogas plants, 135 plants are at wastewater treatment facilities [32]. Adding an anaerobic digestion step to the wastewater treatment plant brings a number of benefits, including reducing the volume of sludge, reducing the greenhouse gas emissions from landfilling the sludge and generating renewable energy in the form of biogas.

The investment requirements of a biogas plant depend on a number of factors including the type of technology, the type of waste, the size of the plant, and the automation involved. The average cost of a biogas-fueled power plant of 1 MW capacity, or larger, ranges between EUR 3,000 – 4,500 per kW[28]. Table 5 provides information on biogas production potential from different substrates.

28 Equivalent to BD 1,286 – 1,930/kW

Table 5: Biogas Production Potential

Substrate	Total Solids (TS)	Biogas Production		Methane Concentration
	%	m^3/ton TS	m^3/ton wet weight	%
Sewage sludge	5	300	15	65
Fish waste	42	1,279	537	71
Sorted food waste	33	618	204	63

An important precondition for implementing a biogas project is to have food and other organic waste to be separated out and collected from the rest of the

municipal solid waste. This requires implementing a waste management strategy, an important component of which is education and raising awareness of households and businesses about separating out the waste. Unlike other organic waste streams, sewage sludge is already collected and concentrated in one place, which presents an opportunity for Bahrain to immediately pursue the energy recovery process from sewage sludge.

3.3.2 LANDFILL GAS RECOVERY

Another waste to energy opportunity for potential consideration in Bahrain is landfill gas recovery. Landfill gas recovery has strong environmental benefits, as it is a means to collect the already available methane gas in the landfill, and prevent it from being released into the atmosphere. Landfill gas is a natural byproduct of a decomposition of organic material in the solid municipal waste and it is typically composed of 50% methane. Methane has a global warming potential 21 times greater than carbon dioxide, which makes it important to capture for both environmental and energy reasons. The recovered landfill gas can be used to produce medium-Btu gas (sometimes called 'direct use'), or pipeline quality gas (sometimes called 'high-Btu gas'), thereby reducing consumption of the indigenous gas resource [33].

Electricity can be produced from either medium or high-Btu gas through reciprocating engines, combustion turbines, steam cycle power plants, and co-firing landfill gas with fossil fuels in conventional power plants. When landfill gas is used as a medium-Btu gas, it is directly used as a substitute for fossil fuel with little treatment. The typical application of medium-Btu gas is co-firing in existing conventional power plants. High-Btu gas production involves an extensive cleanup of the landfill gas to a level of quality so that it can be introduced into existing pipelines as a direct substitute for natural gas.

3.3.3 OTHER WASTE TO ENERGY OPPORTUNITIES

There are other waste to energy options available, including waste incineration, pyrolysis, biodiesel, and others. However, these options should be pursued after establishing a waste management strategy. The waste management strategy will lay down the rules and conditions for identifying, sorting and collecting waste streams that could be re-used or recycled such as plastic, paper or construction material. Depending on the composition of non-recyclable waste, the appropriate waste to energy options can be further considered. The international best practice on waste management suggests the following waste management hierarchy:

1. Reduction
2. Re-use
3. Recycling (e.g. using aluminum cans as raw material in aluminum production)
4. Resource recovery (e.g. recovering biogas from food waste)
5. Disposal (e.g. landfilling, waste incineration without energy recovery)

Waste disposal is the management option used for the remaining fraction of waste when all forms of diversion, reuse, and resource recovery are exhausted. Waste to energy options such as waste incineration or pyrolysis should be considered after reducing, re-using, and recycling of waste.

3.4 OTHER RENEWABLE SOURCES

Biomass, geothermal and hydropower have been cost-competitive sources of power generation for many years in regions with high resource supply potential. Hydropower and biomass were excluded from the evaluation in this Plan since Bahrain has no or very limited resource supply potential.

Geothermal energy uses the heat from beneath the earth's surface to generate electricity. High temperature geothermal resources (90-150 °C) can be used to generate electricity. Lower temperature geothermal resources can be used for direct heating applications. The constant temperature that exists at shallow depths can be used as an energy-efficient method of heating and cooling using heat pumps. Geothermal power is a mature, cost-competitive, commercially available renewable energy technology that can be used to provide base load capacity in areas with excellent high-temperatures resources that are close to the surface [24].

Geothermal co-production can potentially be an attractive option for Bahrain, where geothermal power is generated from the hot wastewater coming from the oil and gas extraction process. According to the US Department of Energy, co-produced geothermal energy can deliver near-term energy savings, extend the economic life of oil and gas fields, and profitably utilize abandoned oil and gas field infrastructure. There are already several pilot projects in the US testing the production of geothermal power at oil and gas fields [34].

An assessment of geothermal resource potential for Bahrain is yet to be undertaken. To draw conclusions on economic viability of geothermal power for Bahrain, further research and investigation is required.

3.5 SUMMARY OF RENEWABLE ENERGY OPPORTUNITIES

Different factors affect the selection of renewable energy technologies, some of these relate to the technology itself while others relate to geography and valued socio-economic components. Resource potential, capital investments, knowhow, land requirements, grid stability, weather and climate conditions are amongst the most influential factors. The following table presents a summary of advantages and disadvantages of selected renewable energy technologies.

Table 6: Pros and Cons of Selected Renewable Energy Technologies

	Advantages	Disadvantages
PV small-scale	- Strong resource potential - Cost-competitive technology - Can be deployed on various surfaces - Does not require much land space - Can partially shave the day peak - On-site consumption can avoid power losses during transmission and distribution - Raise public awareness about renewable energy	- Generates power only during the day hours - Overcoming dust challenge might entail additional costs - Difficult to achieve a high share of renewables
PV large-scale	- Strong resource potential - Cost-competitive technology - Can shave the day peak - Can be deployed in modules	- Requires large land areas - Overcoming dust challenge might entail additional costs - Generates power only during the day hours
CSP	- Strong resource potential - Ability to store heat that can be used to generate power after sunset	- Requires large land areas - Requires water for cooling and for cleaning mirrors - Significant upfront investment costs

	Advantages	Disadvantages
Onshore wind	- Estimated good resource potential - Cost-competitive technology	- Power generation is less predictable - Requires unobstructed land parcels - Resource potential is not clearly identified, need to compile a detailed wind atlas
Offshore wind	- Estimated good resource potential - Can be deployed in large-scale with minimum land requirements - In shallow waters might be a cost competitive option	- Power generation is less predictable - Resource potential is not clearly identified, need to compile a detailed wind atlas - Seabed and other conditions are not well known, need to launch a feasibility study
Biogas	- Avoid greenhouse gas emissions from landfilling the waste - Reduce the volume of waste to be landfilled, saving landfill capacity - Stabilization, sanitation and odor reduction - Generate useful energy that can be used for multiple applications - Biogas can be used to generate electricity that is able to be dispatched, predictable and available at night.	- Energy recovery is limited to the quantity of organic waste produced - Food and other organic waste need to be collected and sorted out first
Landfill gas	- Reduction in greenhouse gas emissions from landfill - Reduction in odor emissions - Reduction in emissions of hazardous organic air pollutants to the atmosphere - Recovery of a low-cost, useful energy that can be used to generate electricity that is able to be dispatched, predictable and available at night.	- Energy recovery is limited to the quantity of landfill gas available - Risk of methane leakage.

4. RENEWABLE ENERGY ACTION PLAN

4.1 TARGETS

The goal of the Plan is to create a renewable energy market in order to increase the share of renewable energy in the energy mix of Bahrain. This includes creating a business environment favorable to renewable energy investments, building expertise within industries and government agencies in developing renewable energy projects, strengthening institutional capacity to support the deployment of renewables, integrating renewable energy in the government strategies, policies and plans and raising overall awareness about the benefits and importance of sustainable energy development. To achieve this it is necessary to formulate ambitious, yet realistic renewable energy targets supported by an enabling policy framework, streamlined administrative procedures, and a general commitment by all government authorities to pursue renewable energy.

The renewable energy deployment strategy is based on a broad assessment of Bahrain's resource potential, economic viability of various renewable energy technologies, current energy situation, and its unique geographical and socio-economic conditions.

Based on the findings, and through consultations with key stakeholders, a renewable energy target of 5% is proposed for 2025, and 10% for 2035. The targets are calculated as a share of the future projected peak load demand, excluding industry's own generation. Values for electricity generation in GWh are derived based on these targets and the local resource potential as set out in Table 7.

Table 7: Renewable Energy Targets

	2025		2035	
Projected Energy Demand	Peak Load Capacity	Generated Electricity	Peak Load Capacity	Generated Electricity
	MW	**GWh**	**MW**	**GWh**
	5,085	23,640	6,867	31,786

Renewable Energy Targets	2025		2035	
	MW	**GWh**	**MW**	**GWh**
Wind	50	125	300	750
Solar	200	340	400	680
Biogas	5	13	10	26
TOTAL:	**255**	**478**	**710**	**1,456**

TARGET as a share of projected	Peak Load Capacity	Generated Electricity	Peak Load Capacity	Generated Electricity
	5.0%	**2.0%**	**10.3%**	**4.6%**

Note: Electricity figures include only grid-supplied electricity by EWA. They do not include industry's own generation.

4.2 DEPLOYMENT STRATEGY

The deployment strategy is driven by a number of factors including scarcity of land, resource potential, cost-effectiveness of renewable energy systems, socio-economic and geo-political considerations:

I. DECENTRALIZED URBAN GENERATION (100-150 MW)

Decentralized renewable energy applications such as rooftop PV, BIPV, solar lighting, biogas plants, and micro wind turbines can be successfully integrated in the urban environment and can help in creating a more sustainable future. With continuous technological improvements, the opportunities for integrating renewable energy in the urban design are tremendous. Decentralized urban generation is also an excellent way to engage all members of society including households, businesses, academia, and government authorities in building smart, modern and more resilient cities and communities. Viable opportunities for decentralized urban generation include:

- Solar systems for new housing units
- Solar systems for government buildings
- Decentralized solar in urban developments (solar lighting, solar parking)
- Decentralized rooftop solar on existing residential and commercial buildings
- Other decentralized renewable energy systems (biogas, micro wind).

II. LARGE-SCALE GENERATION ON AVAILABLE LAND (50-100 MW)

Economies of scale favor the development of large-scale renewable energy power plants. Therefore, it is prudent to consider deployment of large-scale renewable energy where land is available. A good example is the deployment of a solar farm on a land that is otherwise not useful, such as a closed landfill site. Another option to pursue large-scale renewable energy development is through joint GCC efforts (using land in neighboring countries and bringing electricity through existing interconnection network). Viable opportunities for large-scale generation on land include:

- Solar farm on Askar landfill site
- EWA renewable energy initiative (5 MW hybrid solar and wind project)
- Utility-scale renewable energy plants by large industry groups
- Solar farms in new town developments
- Waste to energy plant at the Tubli wastewater treatment plant
- Renewable energy plants on other available land.

III. OFFSHORE GENERATION (50 MW)

Offshore renewable energy development presents an opportunity to pursue large-scale renewable energy generation and achieve higher renewable energy targets. As Bahrain has a good wind regime and shallow waters, pursuing offshore wind power could be a cost-competitive option. Other offshore renewable energy options can include integrating renewable energy in offshore large infrastructure projects such as causeways connecting Bahrain and its GCC neighbors. This will not only generate clean energy, but also strengthen partnerships in building a more sustainable future in the region. Identified offshore generation opportunities include:

- Near shore or offshore wind farms
- Integrating renewable energy technologies in large infrastructure projects (causeways and railway systems).

4.3 BENEFITS AND IMPACT

Integrating renewable energy in the energy mix can help Bahrain optimize the use of indigenous gas resources, reduce greenhouse gas emissions, make the economy more competitive, and improve energy security in the long-term. Other benefits include improving local air quality, shaving day peak through solar PV, creating a new industry, and meeting international obligations.

Achieving 5% targets by 2025 will result in:

- Clean energy generation of approximately 480 GWh per year
- Annual savings of 5,700,000 MMbtu of natural gas
- Reduction of greenhouse gas emissions by 392,000 tonnes of CO_2 per year
- Attracting more than BD 140 million of investment.

4.4 FACILITATING RENEWABLE ENERGY DEPLOYMENT

An important aspect of creating a renewable energy market is removing structural and non-structural barriers. According to the IEA 2015 Renewable Energy Market Analysis report, high levels of incentives are no longer necessary for solar PV and onshore wind, but their economic attractiveness still strongly depends on the regulatory framework and market design. To facilitate renewable energy deployment in Bahrain, policies will be implemented to enable power to be produced from renewable energy sources, to stimulate investment and the take up of renewable energy technologies. These policies will aim to address the following regulatory and power market structure related barriers:

4.4.1 ADDRESSING REGULATORY BARRIERS

The power sector by default is a heavily regulated sector. Typically, private production of electricity requires authorization from government authorities, either through legislation or concessions. In Bahrain, the current Electricity Law (1996) allows for the private generation of power. However, each IPP scheme requires a written authorization from the Minister and an approval from the Cabinet. This scheme is not suitable to stimulate private investments in renewable energy as it is geared towards large-scale conventional power plants, where fuel input is an important consideration. It was drafted in times when renewable energy was not considered a viable alternative source of energy. Today the situation is different. Renewable energy technologies have substantively matured, the costs have declined, and the options have improved.

To stimulate investment in renewable energy, the current legislation needs to allow private deployment of renewable energy plants, without an extensive prior authorization process from the government. However, renewable energy systems would still be subject to all necessary building code requirements, grid connection rules, and other administrative safety regulations.

4.4.2 ADDRESSING MARKET STRUCTURE RELATED BARRIERS

The Electricity Law allows on-site electricity generation for self-consumption purposes (captive generation), and has mainly been used to allow large industry groups to install their own power generation capacities. However the Law does not authorize exporting on-site generated energy to the main grid. To stimulate investments in renewable energy, especially by households and commercial users, it is important to allow renewable energy plants to export the excess power to the grid. Thus, it is critical to develop a grid code for renewable energy systems together with other safety regulations to ensure safe connection to the grid.

Under the current legal framework and market structure, EWA is the sole buyer and distributor of electricity in the Kingdom. To motivate private developers to invest in renewable energy, there needs to be a mechanism whereby private investors are able to sell the power produced from renewable sources and generate income. The key components of such mechanism are price and guarantee of purchase of electricity from renewable sources. Thus, it is important to set a policy that will define a purchase price for electricity from renewable sources and guarantee the purchase of such electricity. Such policies can be either feed-in tariff policy, or auctions or public competitive tenders.

4.4.3 DRIVING INVESTMENT IN RENEWABLE ENERGY

In 2015, the government announced a scheme to gradually increase electricity tariffs to meet the cost of power generation of 29 fils/kWh. The new tariffs became effective starting March 2016 for residential, commercial, and industrial consumers. Bahraini nationals holding an EWA single account are exempt from the tariff increases and continue to pay electricity tariffs of 3 fils/kWh. Bahraini nationals make up 50% of the population and account for around 20% of electricity consumption, and are likely to have roof space for small-scale PV systems. To motivate this segment of customers to install renewable energy systems on their roofs, a special incentive scheme needs to be proposed, combined with targeted information dissemination and awareness raising campaign.

Bahrain has a fast growing real-estate industry. There are many real estate development projects underway under private and public domains. New buildings and real estate development projects present an excellent opportunity for integrating cost-effective renewable energy solutions. Integrating renewables in the building design is more efficient and cost-effective than retrofitting renewable energy sources at a later stage. In addition, buildings are the biggest consumers of electricity in Bahrain. More than 80% of grid electricity is consumed by buildings. Currently there is no scheme in place to encourage building and town developers to integrate renewable energy in the building and urban design, such as a renewable energy mandate.

4.5 POLICIES TO ATTRACT PRIVATE INVESTMENT

To achieve the stated targets and attract private sector investment in renewable energy technologies, three complementary policies are proposed: (1) a net metering scheme; (2) tender-based feed-in tariffs; and (3) a renewable energy mandate for new buildings. The following subsections present brief information on each policy. The details of each policy will be outlined in relevant documents and regulations.

4.5.1 NET METERING SCHEME

To support the deployment of decentralized small-scale solar systems, the Government of Bahrain will adopt a Net Metering scheme. Net Metering will enable residential, commercial, and industrial customers to generate and consume electricity on-site by installing renewable energy systems on their premises, and exporting the excess electricity to the EWA network. Customers will be billed only for the 'net' energy used, according to the latest electricity retail tariffs approved by the Government. The excess electricity produced will be credited in the next billing period. The smart meter roll-out programme has commenced and will facilitate the net metering scheme.

Net metering is a strong incentive mechanism when electricity retail prices are sufficiently high. With the recent increases of electricity tariffs, the net metering scheme will likely be most attractive to the unsubsidized large energy consumers, such as malls, hotels, and other commercial and industrial customers.

Table 8: Bahrain Net Metering Scheme

Net Metering Scheme	
Objective:	Enable **consumers** to generate on-site, grid-connected electricity from renewable energy sources
Target Group:	Residential, commercial, and industrial electricity customers
Incentive for Target Group:	- Reduced electricity bill through on-site power generation - Ability to credit the excess electricity fed back to the grid against future consumption

Net Metering Scheme	2017 QR 1	2017 QR 2	2017 QR 3	2017 QR 4	2018 QR 1	2018 QR 2	2018 QR 3	2018 QR 4	2019 QR 1	2019 QR 2	2019 QR 3	2019 QR 4	2020 QR 1	2020 QR 2	2020 QR 3	2020 QR 4	Responsible Entity
Develop net metering regulations to be presented for government approval	■	■															SEU
Obtain government approval of net metering regulations		■	■														Minister of Electricity & Water
Develop and approve a grid code for small-scale solar PV systems	■	■	■														EWA
Develop necessary standard operating procedures to implement net metering scheme	■	■	■														EWA with technical assistance from SEU
Develop all necessary technical documents to ensure safe installation of solar systems	■	■	■														
Establish a quality assurance scheme for solar PV equipment and system installers		■	■	■													
Develop information and awareness raising plan to promote net metering scheme			■	■	■												SEU & EWA
Apply net metering scheme				■	■	■	■	■	■	■	■	■	■	■	■	■	EWA
Implement information and awareness raising plan				■	■	■	■	■	■	■	■	■	■	■	■	■	SEU & EWA
Implement quality assurance scheme for solar PV equipment and system installers					■	■	■	■	■	■	■	■	■	■	■	■	EWA

4.5.2 TENDER BASED FEED-IN TARIFF

To encourage the deployment of renewable energy projects by private developers, the Government of Bahrain will adopt a tender-based feed-in tariff scheme. The feed-in tariff scheme will provide a long-term purchase guarantee of electricity from renewable sources at a pre-determined price. The appropriate feed-in tariff will be set based on the bids received from private developers. A feed-in tariff is important in attracting professional renewable energy developers who have expertise, know-how, and access to finance, in developing renewable energy projects. Because land is a major limiting factor in Bahrain, the government will aid the private sector by identifying and/or designating sites for the development of renewable energy projects. Such sites may include government buildings such as schools, hospitals, and other public facilities. This, however, will not limit the private sector to find their own sites for the development of renewable energy projects, under the tender-based feed-in tariffs scheme. Tenders will be announced on a regular basis.

The tender-based feed-in tariff scheme will enable the government to take advantage of the best available market prices for the development of renewable energy projects. This is particularly important with regards to renewable energy systems that are experiencing fast-paced technological improvements and cost reductions, such as solar PV. The scheme will also allow the government to control the quantity of renewable energy procured.

Table 9: Bahrain Feed-in Tariff Scheme

Tender based Feed-in Tariff Scheme	
Objective:	Attract **private investors** to develop renewable energy projects through a competitive procurement process
Target Group:	Renewable energy developers and large electricity customers
Incentive:	Long-term power purchase agreement at a pre-defined price

Implementation Timeline

Tender-based Feed-in Tariff Scheme	2017 QR 1	2017 QR 2	2017 QR 3	2017 QR 4	2018 QR 1	2018 QR 2	2018 QR 3	2018 QR 4	2019 QR 1	2019 QR 2	2019 QR 3	2019 QR 4	2020 QR 1	2020 QR 2	2020 QR 3	2020 QR 4	Responsible Entity
Designate 50-100 (1st batch) government buildings for private development			■	■													Ministry of Works
Estimate the size of available space for solar PV and divide into several lots				■	■												SEU
Prepare tendering documents for solar PV systems						■											EWA & SEU
Invite private developers to submit their offers for the development of the first 50 MW solar PV projects							■										EWA with technical assistance from SEU
Selection of the successful bidders and concluding power purchase agreement							■	■									
Construction, conection to the grid and commissioning of solar PV plants							■	■	■								Private Developer/EWA
Extend the best price offers received for gov buildings as a FiT to private buildings						■	■										SEU & EWA
Conclude power purchase agreements for development of solar PV on private buildings										■	■						EWA
Develop tools and guidelines to assist the private sector in deployment of RE projects							■	■	■	■	■	■	■	■	■	■	SEU
Designate 2nd batch of gov buldings for private development							■	■									Ministry of Works

4.5.3 RENEWABLE ENERGY MANDATE

To take advantage of cost-effective renewable energy solutions and reduce the energy demand from buildings, the Government of Bahrain will adopt a Renewable Energy Mandate for new buildings. The Renewable Energy Mandate will require all new buildings and new real estate developments, to source a minimum certain percentage of energy from renewable sources such as roof-top PV, building integrated PV, solar water heaters, and urban wind systems. The generated renewable energy will be consumed on-site; and the excess electricity will be fed to the grid according to the Net Metering regulations.

To recognize the outstanding performance of buildings and real estate developers in integrating renewable energy, where the minimum percentage has been exceeded, SEU will issue a certificate of award.

Table 10: Bahrain Renewable Energy Mandate Scheme

Renewable Energy Mandate	
Objective:	Require **new buildings** and real estate developers to integrate renewable energy technologies in the building design
Target Group:	New building and real estate developments
Incentive:	Reducing energy demand of the building from the grid (reduced electricity bill)

Implementation Timeline

Renewable Energy Mandate	2017 QR 1	2017 QR 2	2017 QR 3	2017 QR 4	2018 QR 1	2018 QR 2	2018 QR 3	2018 QR 4	2019 QR 1	2019 QR 2	2019 QR 3	2019 QR 4	2020 QR 1	2020 QR 2	2020 QR 3	2020 QR 4	Responsible Entity
Develop RE Mandate regulations to be presented for government approval				■	■												SEU
Obtain government approval of RE Mandate regulations					■	■											Minister of Electricity & Water
Develop necessary standard operating procedures to implement RE Mandate scheme					■	■											SEU in coordination with EWA, Min of Works
Develop all necessary technical documents to ensure safe installation of solar systems					■	■											
Develop information and awareness raising plan to promote net metering scheme					■	■											SEU
Conduct trainings to the relevant stakeholders on the implementation of RE Mandate							■										SEU
Implement/enforce RE Mandate scheme								■	■	■	■	■	■	■	■	■	EWA & Min of Works
Implement information and awareness raising plan								■	■	■	■	■	■	■	■	■	SEU, EWA & Min of Works
Issue certificate of award to recognize the most outstanding performance													■	■			SEU
Propose incentive scheme to encourage buildings to go beoynd the min requirement														■	■	■	SEU

5. PROJECTS TO ACHIEVE 2025 TARGETS

This section presents key renewable energy projects identified through a broad consultative process with different stakeholders to achieve the 2025 targets. The list is not exhaustive and may be updated as time progresses and more opportunities are identified.

5.1 SOLAR SYSTEMS FOR GOVERNMENT BUILDINGS

The Assistant Undersecretary of Construction Projects and Maintenance at the Ministry of Works, Urban Planning and Municipalities is responsible for the construction of new government buildings and for refurbishment of existing government buildings for the Kingdom of Bahrain.

This Ministry is one of the champions in the government sector in promoting green building and sustainable energy practices. In 2011 the Assistant Undersecretary of Construction Projects and Maintenance developed a strategy to implement green building practices in new and existing government projects. To implement the Strategy particular building specifications have been developed containing 14 green building practices. Since 2013 the Ministry has been actively implementing these practices, achieving great energy savings and exceeding the requirements of the Bahrain thermal insulation regulations. Although the focus has been primarily on improving building energy efficiency, the Ministry has also started implementing experimental solar projects such as solar water heater systems on school buildings and solar PV panels on car parking lots.

To make government buildings more efficient and sustainable and to continue to demonstrate leadership in sustainability actions, the Ministry of Works, Urban Planning and Municipalities is committed to incorporate further renewable energy solutions in government projects (roof-top PV, building integrated PV, solar parking lots).

5.2 SOLAR SYSTEMS FOR PUBLIC WORKS

In addition to the construction and maintenance of government buildings, the Ministry of Works, Urban Planning and Municipalities is responsible for public works, infrastructure and engineering covering:

- Roads: Planning, design, supervision of construction and maintenance of roads, bridges, and traffic facilities.

- Sanitary and Drainage: Planning, design, supervision of construction and operations and maintenance of networks, treatment plants, pumping stations and treated sewage effluent systems.

Energy consumption makes up a large share of the Ministry's expenditures, especially for the operation of water pumping stations. To make public works more efficient and sustainable, and to reduce the energy bill, the Ministry of Works, Urban Planning and Municipalities is committed to incorporate renewable energy sources in the design and engineering of public works and infrastructure. Preliminary identified initiatives include:

- Implementing solar PV systems for water pumping stations; and

- Installation of solar powered street lighting systems.

5.3 SOLAR SYSTEMS FOR NEW HOUSING UNITS

The Ministry of Housing is responsible for building affordable social housing units for the low-income Bahraini households. The Ministry of Housing plans to develop 40,000 housing units in Bahrain's four Governorates. The projects are planned to be funded under the government budget and GCC development program. The first 25,000 housing units will be built in the next four years.

The Ministry of Housing is committed to delivering cost-effective, efficient and quality housing. It is already implementing energy efficiency measures in housing units to comply with Bahrain building thermal insulation regulations. It has also started implementing experimental solar projects (solar water heaters).

To make houses more efficient and sustainable, the Ministry of Housing is committed to incorporate further renewable energy sources in the housing units (roof-top PV, building integrated PV, solar parking lots). This will help minimize the impact on the environment, improve air quality, reduce reliance on fossil fuel, and shave the energy peak demand during hot summer seasons, when the bulk of electricity demand is used for air-conditioning purposes.

The work will start with the initiation of demonstration projects in one of the new town developments. Upon delivery of the demonstration projects, capacity-building workshops will be organized for housing developers, architects, contractors, and installers, on lessons learned and on successful integration of renewables in the building design. This will be an opportunity to:

- Increase confidence of building owners and the general public about solar PV as a viable energy technology;

- Improve knowledge and the skills of PV installation and construction companies, as well as architects through learning-by doing;
- For Electricity and Water Authority, to test the integration of intermittent renewable resources into the electricity grid.

These lessons will be vital for the continued deployment of PV (and other renewable resources) in Bahrain.

5.4 RENEWABLE ENERGY SYSTEMS IN URBAN DEVELOPMENTS

Many of the new social housing units will be built in new town developments such as Northern City, Bahir, and Southern New Town. This presents an opportunity for the Ministry of Housing to incorporate renewable energy sources not only in the housing units, but also in the urban design. The Ministry of Housing has already started the process of integrating principles of sustainability in new town developments. One of such examples includes Southern New Town development in collaboration with the Prince Charles Foundation.

The Southern New Town development will have around 4,000 homes and will be built around principles of environmental and social sustainability. This includes minimizing the environmental impact of the urban environment; creating healthier living spaces for people; and promoting social dialogues through integrating creative solutions in the urban design and management.

The sustainability strategy of the town plans seeks to incorporate renewable energy sources in the town development as a means to reduce reliance on fossil fuel, and minimize the impact on the environment. Two types of renewable energy initiatives are proposed: (1) community scale PV array to provide clean power to the future residents of the town; and (2) various decentralized renewable energy solutions integrated in the urban environment (solar roof tops, building integrated PV, solar street lighting, solar parking lots).To create more sustainable urban spaces, the Ministry of Housing in coordination with other Ministries, is committed to incorporating renewable energy initiatives in other new town developments.

5.5 LARGE-SCALE SOLAR FARM ON AVAILABLE LAND

Economies of scale favor the development of large-scale renewable energy plants; therefore, it is prudent to consider deployment of such projects where land is available. A good example is the deployment of a solar farm on land that is otherwise not productive such as a closed landfill site. Askar landfill is the largest landfill site in Bahrain. Spread over an area of more than 300 hectares, the landfill is expected to reach its capacity in the next few years. The Askar landfill site mostly caters to solid municipal waste, agricultural waste, and industrial non-hazardous waste. Currently around 80-100 hectares of Askar landfill is full and closed. This parcel of land in general is not suitable for construction, or development of residential or commercial projects due to the risks associated with landfill sites (high concentration of toxic and hazardous materials posing serious health threats to people and pollutions risks to environment).

One of the more successful ways of rehabilitating closed landfill sites is to turn them into solar fields to generate clean power for the residents of nearby towns and villages. Generation of solar power can be coupled with a landfill gas recovery project to enhance the utilization of the land and provide for more safety. This will not only minimize the environmental impact of the overall power generation system (by reducing greenhouse gas emissions), but also will make more economic use of the otherwise unproductive land parcel, and promote more sustainable development. Today there are many examples worldwide where landfill sites have been successfully turned into solar fields.[29]

The Ministry of Works, Municipality and Urban Planning is committed to promoting sustainable development in Bahrain, and strongly supports the rehabilitation of the closed landfill site in Askar, into a solar field to provide clean power to the residents of nearby towns, reduce reliance on fossil fuels for power generation, and contribute to shaving the energy peak demand during hot summer seasons.

29 For some examples of solar landfill sites please see the report of the National Renewable Energy Laboratory (NREL) "Best Practices on Sitting Solar Photovoltaic on Municipal Solid Waste Landfills" (2012), Appendix A.

5.6 SLUDGE TO ENERGY

The Tubli Water Pollution Control Center (WPCC) is the largest municipal wastewater treatment plant in Bahrain serving most of the residential communities in the country. With the recently completed upgrade to the Tubli WPCC the plant treats approximately 304,000 m3 of wastewater per day compared to the previous figure of 200,000 m3 per day. The treated effluent is partially used for irrigation and the surplus is discharged into the nearby Tubli bay, which is a protected natural reserve under both national and international legislation.

On average more than 50 ton of dry solids (sludge) is produced at Tubli WPCC on a daily basis. Currently, there is no further process to treat the generated activated sludge from the Tubli WPCC; most sludge is sent to the landfill site for sanitary disposal. This amount of sludge presents an excellent opportunity to extract useful energy either through anaerobic digestion process (biogas) or other waste to energy solution such as pyrolysis. The extracted energy can be used to generate electricity to power the Tubli WPCC, thereby reducing electricity bill of the Tubli plant.

Recovering energy from sludge at the wastewater treatment plants will have a number of environmental benefits:

- Avoid emission of greenhouse gas emissions by 89,000 tonnes of CO2 per year from landfilling the sludge
- Reduce volume of sludge to be landfilled, saving the landfill capacity
- Stabilization, sanitation and odor reduction
- Generating renewable energy that can be used to power the Tubli WPCC.

5.7 RENEWABLE ENERGY PLANTS BY LARGE INDUSTRY GROUPS

Large industry groups are taking a lead in launching renewable energy projects to show their commitment in preserving the Kingdom's natural resources and protecting the environment. One prominent example includes the recently commissioned Tatweer Petroleum's 1 MW solar PV project. The new solar plant was commissioned in February 2016 with a total capital cost of USD 1.8 million[30]. It is connected to Tatweer's own grid and delivers enough power to provide autonomy to its headquarters. After successful implementation of the first solar project Tatweer is looking into further deployment of solar PV plants with a more optimized cost structure. It is planning to install an additional 3-4 MW of solar PV capacity.

30 Equivalent to BD 680,000

The energy intensive aluminum smelting company, Alba is also looking to develop solar projects to take advantage of its available large industrial roof areas. It has already approached the Sustainable Energy Unit for technical advice and assistance. Gulf Petrochemical Industries Company (GPIC) has been a pioneer of sustainability actions in Bahrain. As part of its sustainability program GPIC plans to expand the use of renewable energy projects at its premises in four phases, starting in 2014 and completing by 2019. It has already built a 10 kWp solar water heating system, and is in the process of installing a 0.5 MW solar PV project.

5.8 NEAR SHORE AND OFFSHORE WIND FARMS

The assessment of preliminary wind data suggests the viability of taking formal steps to build a medium scale wind farm. The first wind farm can be used to demonstrate the technical and financial viability of such projects. In order to maintain a relatively reasonable LCOE and attract private developers, the government is considering a prefeasibility study for a wind farm with a capacity of around 50 MW (around 16 to 20 turbines). This process will be initiated after the publication of the comprehensive wind resource assessment map for the Kingdom of Bahrain.

5.9 EWA RENEWABLE ENERGY INITIATIVE

To demonstrate commitment in renewable energy, EWA is developing Bahrain's first 5 MW hybrid renewable energy system in Al Dur district. The project consists of a 3 MW solar PV system and a 2 MW wind turbine. EWA has already completed detailed technical studies and selected the successful contractor to perform engineering, design and installation of the power plant. The construction of the project is expected to start in 2017.

6. GOING FORWARD

A number of factors must come together to ensure that the National Renewable Energy Action Plan effectively transitions from a desk document, to actions that capitalize on the potential benefits described:

- A governance structure that provides guidance and executive sponsorship;
- Incorporation of renewable energy initiatives in ministries' action plans and work programs;
- Developing tools enabling deployment of renewable energy initiatives;
- Identifying funding opportunities for projects and activities.

An effective energy governance structure is critical to implementation of the National Renewable Energy Plan. Current roles within government structures can be utilized and built upon to support good governance.

6.1 GOVERNANCE

An effective energy governance structure is critical to implementation of the National Renewable Energy Plan. Current roles within government structures can be utilized and built upon to support good governance.

SUSTAINABLE ENERGY UNIT

SEU is the designated agency for promoting sustainable energy policies and practices in the Kingdom of Bahrain. As such SEU will lead the coordination efforts in implementing the NREAP, and will provide technical assistance in the deployment of renewable energy projects.

Responsibilities:

- Coordinate implementation activities among all stakeholders through developing partnerships and organizing regular coordination meetings.
- Inform stakeholders on the progress of implementation of the NREAP.
- Draft renewable energy policy regulations and support the establishment of standard operating procedures for their implementation.
- Carry out feasibility studies, resource potential assessment, cost-benefit analysis of various technology options and business models, as well as overseeing the implementation of pilot projects.

- Provide technical assistance in developing tendering documents, drafting requests for proposals, evaluating bids, and assessing outcomes of pilot projects.
- Carry out information dissemination and awareness raising campaigns through launching a dedicated website, organizing press conferences, promoting renewable energy at various public events.
- Organize and support capacity building and training activities for government and non-government stakeholders.

NREAP IMPLEMENTATION FOLLOW-UP COMMITTEE

The Committee will be composed of high-level representatives of key government and non-government institutions who would play the role of change agents to provide guidance, support and oversight of the implementation process of NREAP. The Committee will be chaired by the Minister of Electricity and Water Affairs 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.

Responsibilities:

- Oversee implementation of the NREAP and facilitate its execution;
- Identify action items to overcome implementation issues and challenges;
- Put recommendations and suggest actions to relevant ministries;
- Decide on making changes in the NREAP if required;
- Discuss the progress in the implementation process.

SEU will assist in preparing the agenda of the meeting, the minutes, including the action list; the progress report on the status of the implementation process since the last meeting; and any other documents to be discussed or considered during the meeting.

6.2 INTEGRATING RENEWABLES IN MINISTRIES' ACTION PLANS

To demonstrate leadership and ensure successful development of renewable energy it is important that individual Ministries and government institutions incorporate renewable energy initiatives in their action plans and work programs.

This will reinforce the role of the government as the leader in sustainability actions and make renewable energy technologies more visible to people and businesses. It will also allow government staff to build expertise and training with technologies (purchasing, installation, suppliers, options, operation, maintenance, economics), and aid in further development and improvement of renewable energy policies.

6.3 TOOLS ENABLING RENEWABLE ENERGY

To further aid the successful development of renewable energy systems, SEU in collaboration with other research and think-tank institutions will provide and develop on continuous basis, information, evidence based research, and tools to support the deployment of renewable energies. Such activities include:

- Developing proof of concept tasks to demonstrate feasibility and economic viability of various renewable energy initiatives through cost-benefit analysis and pilot projects;
- Providing guidance on various technologies and building a stronger case for adoption of renewables;
- Conducting resource potential assessment of new renewable energy sources and identifying potential technical, economic, regulatory and institutional barriers;
- Streamlining regulatory and administrative procedures;
- Providing benchmarking, reporting, education, and capacity building activities.

6.4 FUNDING

A key factor in advancing renewable energy systems is the capability to fund renewable energy initiatives. There are two types of activities that require funding:

(1) Funding for deployment of renewable energy systems; and

(2) Funding to carry out other activities enabling deployment of renewable energy systems.

Deployment of renewable energy systems requires significant capital funding. These can come from private sector and public sector. The current Plan proposes three policies that are aimed at attracting private investment in renewable energy projects: (1) Net Metering; (2) Tender-based Feed-in Tariff; and (3) Renewable Energy Mandate for New Buildings.

Funding requirements for activities enabling the deployment of renewable energy projects such as capacity building, resource potential assessment, or feasibility studies are less capital intensive, but more difficult to source from private sector. Many countries have established clean energy funds to support research, development and demonstration of renewable energy technologies. These funds are often financed either through direct allocation of funds from government budget, private and public donations, or tax proceeds.

SEU will investigate best practices on setting up such fund and will develop a proposal for the establishment of the Bahrain clean energy fund, to support the research, development, and demonstration of renewable energy and energy efficiency initiatives. In additional, funding from global clean energy financing mechanisms and global financial institutions will also be explored.

6.5 SETTING PLAN INTO MOTION

This section presents the top ten actions to set the Plan into motion. Some of these are fundamental activities that should be implemented quickly to enable further progress, others have already begun and are in the process of implementation. A few actions are large impact, multi-stakeholder projects that require attention, or additional research in order to deliver longer term results. The top ten actions are set out below:

- Develop and approve net metering regulations;
- Develop and approve the grid code, and necessary technical guidelines for small-scale solar PV systems;
- Designate 50-100 government buildings with large roof/parking lot areas for the private development of solar PV systems through the tender-based feed-in tariff scheme;
- Based on available wind speed data compile a detailed wind atlas for Bahrain;
- Launch a feasibility study on integrating renewable energy sources in large infrastructure projects such as causeways;
- Designate a batch of new housing units to implement solar PV systems as demonstration projects;
- Designate Askar landfill site for the development of the large-scale solar PV farm;
- Explore the possibility of extracting energy from sludge at the wastewater treatment plants;
- Launch a prefeasibility study for offshore wind power generation;
- Launch a pilot waste to energy project.

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