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Building integrated renewable energy to achieve zero emission in Bahrain

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ABSTRACT

Bapco in Bahrain created a zero emission lounge having PV (4 kW), wind turbine (1.7 kW) and hydrogen fuel cell (1.2 kW). The system produced a daily 13 kWh and 30% of the expected theoretical output.

The performance of this lounge for 200 days shows it produced 2909 kWh which indicates that if each house in Bahrain is equipped with a 4 kW PV, then its monthly amount of solar electrical will be 360 kWh, i.e. 12% of the monthly average used electrical energy per household; saving 748 GWh (1 GWh = million kWh) of conventional electricity, annually, which is equal to CO_2 emission of 672,892 t.

Herein, the economic aspects of using building integrated renewable energy (BIRE) – based on the actual cost of this lounge is projected to reach 225,137 in 2030. It is found that BIRE may contribute to 13% of total electricity produced in Bahrain by 2030 and has the potential to create hundreds of green jobs. This project is an incentive for Bahrain to establish the Bahrain Green Council.

It is found that (BIRE) in Bahrain would have a positive environmental impact and meet the goals of Bahrain Vision 2030.

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1. Introduction

The Kingdom of Bahrain is an archipelago composed of around 40 islands located in the Arabian Gulf between latitude 25°32′–6°20′ N and longitude 50°20′–50°50′ E. The total area of Bahrain is 762 km^2 with 126 km of coastline and 3000 km^2 of territorial waters. Bahrain population has increased by about 10 folds compared to 1940 (Fig. 1) which has had an impact on energy consumption and production [1]. The share of electricity production from renewable in Bahrain, in 2011, was 0.006% [2].

The Bahrain Economic Quarterly report [3] forecasted changes in the demand of housing in Bahrain over the next two decades. It is predicted that the demand for more housing units will continue to rise over the next two decades due to the expected rapid growth in the number of Bahrainis, especially after a slow-down in the construction sector. The report announced that the total Bahraini housing – assuming that is equal to the number of Bahraini households – is projected to grow from 124,065 housing units in 2010, to 173,069 in 2020 and 225,137 in 2030. Given a moderate rate of deterioration of the existing housing stock (assuming 50% of existing houses will need to be replaced over the next 20 years), Bahrain will need to build 40,000 homes to satisfy current unmet Bahraini demand, and an additional 65,817 housing units to satisfy Bahraini demand by 2020 and 77,288 by 2030.

The Economic Development Board (EDB) expects 47,865 households to qualify for social (subsidized) housing by 2020 and 56,208 by 2030. The report shows that non-Bahraini housing demand is expected to increase from an estimated 61,117 housing units today to 90,467 in 2020 and 121,581 in 2030. Total housing demand (Bahraini and non-Bahraini) is expected to increase to 263,536 housing units in 2020 and then to 346,718 in 2030 from a current stock of 145,181.

The total annual cost of satisfying total social housing demand from today to 2020 is estimated to be BD 419 million (€800 million) and between 2020 and 2030 BD 242 million (about €480 million) in constant 2010 Bahraini Dinars.

Unfortunately, nearly all domestic houses in Bahrain do not use any type of renewable energy technology, even for solar water heating or for those in remote locations using PV for fence or garden lights using LED lights, even though the daily average solar energy is very encouraging (550 W/m^2) and the average daily wind speed at 10 m is acceptable (5.3 m/s). However, we have to admit here that the Bahrain Petroleum Company (Bapco) recently installed around 4.5 MW of smart PV (Petra Solar product) in the town of Awali and at the refinery plant. Another 0.5 MW was installed at University of Bahrain on a ground having an area of 100,000 m^2. Fortunately,

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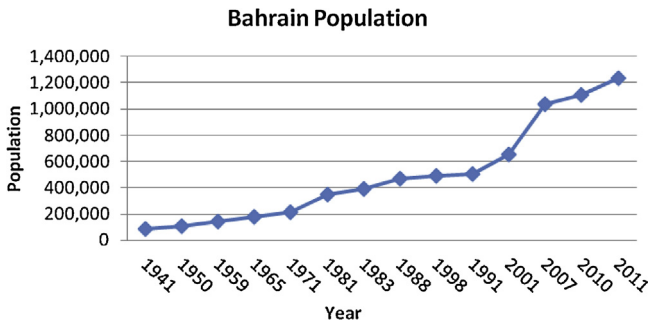

Fig. 1. Population of Bahrain [1] (CIO, 2013).

all PV solar electricity in Bapco project is feed to the national grid [4].

The primary reasons for not using renewable energy in Bahrain are: the cost of installation to the citizens, the absence of governmental incentive, no feed in to the national grid, no feed-in-tariff, a lack of maintenance of renewable energy systems, and most importantly the low cost of the current electricity tariffs and the huge subsidy in the energy and food sectors [5].

This paper will consider the zero emission lounge at Bapco as a field of reference in studying the benefit of using renewable energy systems in the sector of domestic future houses or making up the existing one which is believe to put Bahrain in a better rank in the Environmental performance index produced by Yale University, USA, where Bahrain is ranked 82 among 178 countries gaining a score of 51.83 out of 100 [6] with Switzerland in the top (score 87.67) which is at much lower rank than its neighbors in the Gulf Cooperation Council, i.e. UAE 33 (score 67.52), Saudi Arabia 35 (score 66.66), Kuwait 42 (score 63.94), Qatar 44 (score 63.03), Oman 99 (score 47.75).

2. Electrical energy consumption and subsidy in Bahrain

The Bahrain communication report produced by the Public Commission for the Protection of Marine Resources, Environment and Wildlife [7] found that nearly 95% of CO_2 emission in Bahrain comes from the Energy sector (oil production and refinery). The total GHG emissions in 2000 were 22,374 Gg (Giga g or Gg = million kg) of CO_2 equivalents, which include 17,254 Gg from energy; 2,515 Gg from industrial processes; and 2605 Gg from waste.

Fig. 2 shows the load demand in the Kingdom of Bahrain. The minimum load is during winter (1102 MW) in January and the maximum load is summer (2728 MW) in July. This is primarily caused by the use of air conditioners during summer due to the harsh climate during this season (with average temperature of nearly 35 °C,

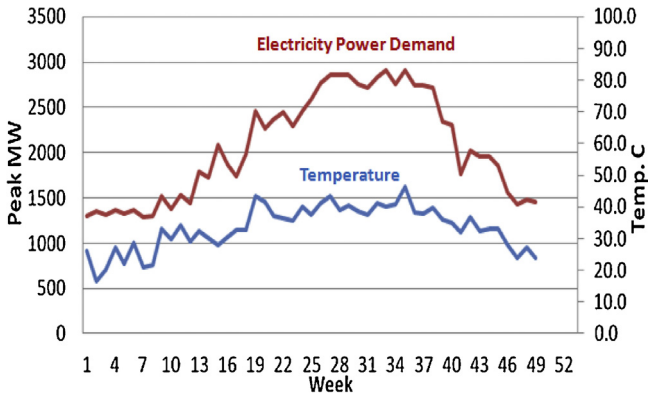

Fig. 2. The electrical load (power) in Bahrain in 2013 [8].

Table 1
Power plants in the Kingdom of Bahrain [8].

Location	Owner	Capacity (MW)	Technology
Riffa	Government	700	11 gas turbines
Sitra		125	11 gas turbines4 steam turbines
Al-Azel		950	4 gas turbines 2 steam turbines
Al-Dour	Private	1234	4 gas turbines 2 steam turbines
Al-Hidd		929	5 gas turbines
Total		4938	

Table 2
Tariff for 1 kWh of electricity in the Kingdom of Bahrain [8].

Actual cost of kWh is 28 fils (¢$7.4)	Subsidy cost		
	From	To	Fils/kWh (¢$)
Domestic	1	3000	3 (0.8)
	3001	5000	9 (2.4)
	5001	Over	16 (4.2)
Non-domestic			16 (4.2)

relative humidity of 70%, and sunshine duration of 13.7 h with solar radiation reaches 1100 W/m^2 at noon on 21 June). Bahrain has five power plants (Table 1) that use both natural gas and steam turbines to produce electricity at approximately 45% efficiency. No oil is used in Bahrain in any of the power plants due to its high CO_2 emission compared to natural gas [8].

Table 1 indicates that Bahrain's total power capacity is 4838 MW and the maximum consumption in summer does not exceeds 3000 MW which means that current power plants can satisfy the need of electrical energy in Bahrain. On the other hand, Bahrain depends on turbines that use natural gas, and if the limitations of this type of fossil fuel are considered, strategic plans should be made to create other technological alternatives for energy production. Natural gas in Bahrain will not sufficient for future projects in 2017, according to World Bank study [9].

3. Energy subsidy in Bahrain

Bahrain offers a generous subsidy for electricity, water and energy (diesel and fuel). Table 2 proves that consumers (Bahraini and non-Bahraini pay only 11% of the actual cost of the kWh (28 fils = 0.28 ¢€ as each fils = 0.1¢€ = 4 ¢$) if his consumption is below 3000 kWh per month, pay 33% if consumption is less than 5000 kWh and pay 57% for consumption more than 5001 kWh!

Furthermore, Bahrain has a limited number of aquifers which force the country to use energy intensive technologies such as water desalination to provide residents with usable water. This too is subsidized as consumers pay less than 4% of the actual cost, since the cost of 1 m^3 of water is 725 fils (¢$190) as illustrated in Table 3.

It was reported in 2012 that the Kingdom of Bahrain spent 650 million Bahraini dinars (US$1.7 billion or about €1300 million) a year on energy subsidies, which is 5.6% of our GDP (US$30.4 billion) [10].

Table 3
Tarrif of 1 m^3 of water in the Kingdom of Bahrain [8].

Actual cost of m^3 is 725 fils (¢$190)	Subsidy cost		
	From	To	Fils/m^3 (¢$)
Domestic	1	60	25 (6.7)
	61	100	80 (21.1)
	101	Over	200 (52.6)
Non-domestic	1	450	300 (79.0)
	451	Over	400 (105.3)

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