Bahrain's Second National Communication

Under the
United Nations
Framework Convention
on Climate Change

Kingdom of Bahrain
Public Commission for the
Protection of Marine Resources,
Environment and Wildlife

Feb 2012

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Prince Khalifa bin Salman Al Khalifa
The Prime Minister

His Majesty
King Hamad bin Isa Al Khalifa
King of The Kingdom of Bahrain

His Royal Highness
Prince Salman bin Hamad Al Khalifa
The Crown Prince
Deputy Supreme Commander

Foreword

It is my pleasure to present the Kingdom of Bahrain's Second National Communication under the United Nations Framework Convention on Climate Change.

At the heart of this Communication is our simple yet powerful conviction that all countries must do their part to contribute to urgent action to achieve steep reductions in greenhouse gas emissions and thereby strive to avoid the dangerous - perhaps catastrophic – impacts associated with climate change. With this document, Bahrain takes an important step toward meeting our international obligations and ensuring that climate change is considered in our country's policies, activities, and investment plans.

As a small-island state that is highly vulnerable to the impacts of climate change, Bahrain believes that meeting the climate change challenge lies in sustainable development initiatives that promote strong, clean and climate-resilient economic growth. We consider that transitioning to the new thinking, new frameworks, and new partnerships described in the Communication is a moral obligation to our children and their progeny.

While our contribution to global greenhouse emissions is, and will continue to be, very small, Bahrain will continue to support global efforts to address the threat of climate change. In the process, we look forward to building upon the plans discussed in this Communication in the spirit of global cooperation.

His Highness Shaikh Abdullah Bin Hamad Al Khalifa
President of the Commission
Public Commission for the Protection of Marine Resources, Environment and Wildlife
Manama, Bahrain
January 2012

Climate Change is considered to be one of the major environmental threat being faced by the global communities. In the context of international cooperation, to confront the serious and important issue of global climate change that will affect the world's natural resources, the Kingdom of Bahrain is carrying out its responsibilities and adherence to the international treaties and conventions related to the environment, in particular the United Nations Framework Convention on Climate Change (UNFCC) and Kyoto Protocol Commitments.

I am pleased to submit the Second National Report of the Kingdom of Bahrain, which has been prepared as per the framework and methodology of the UNFCC on Climate Change. The report is prepared by a group of national experts from many national institutions and universities with a view to incorporate stakeholders comments and building local capacities to incorporate the contribution and follow-up for future tasks in this area. These tasks have been assisted, supported and supervised by a group of international experts who helped us in putting it in the required format.

This report highlight the status of the Kingdom of Bahrain which is one of the most densely populated island in the region and is expected to be significantly affected by climate change and the implications associated with this phenomenon taking into consideration that majority of the population resides in the coastal areas. The report also indicate that the climate change impact will not only be limited to the coastal areas due to sea-level rise, but will also affect the scarce marine resources in the region, public health and biodiversity which is vulnerable, fragile and sensitive to natural conditions associated with the phenomenon of desertification and drought.

Accordingly, the Kingdom of Bahrain has taken practical procedures and has developed strategic plans to address the phenomenon of climate change with a view of enhancing environmental protection and conservation of natural resources. Moreover, the Kingdom has also taken steps to implement the United Nations Framework Convention on Climate Change through the development of strategic partnerships to work effectively with other government institutions, private sector organizations and civil society groups. The country has adopted a national strategy for the implementation of the Convention based on supporting actions to reduce greenhouse gas emissions with particular focus on changing consumption patterns, enhancing awareness and reducing vulnerability to climate change impacts.

Although the contribution of the Kingdom of Bahrain in greenhouse gas generation is very small and un-noticeable, yet the country will be greatly affected in case of any adverse eventualities occurring due to climate change as Bahrain is a small island country.

In the end, I want to reiterate that we will continue to support the global efforts to address the threat of climate change and will attend the problem by balancing between the development needs and requirements of the population and will continue keeping our commitments towards the environmental conservation and resources preservation by actively participating with the international community in all urgent environmental issues.

Dr. Adel Khalifa Al Zayani
Director-General
Public Commission for the Protection of Marine Resources, Environment and Wildlife
Manama, Bahrain, January 2012

The Kingdom of Bahrain's Second National Communication (SNC) under the United Nations Framework Convention on Climate Change (UNFCCC) was prepared with the support of the Global Environment Facility (GEF) and the United Nations Environment Programme (UNEP). The SNC applies country-specific information in proposing a set of adaptation and greenhouse gas mitigation polices that promote mainstreaming of climate change concerns into the national sustainable development planning process. The SNC reflects relevant aspects of the Bahrain Vision (BV2030) and a number of other national sector-specific policy documents.

We gratefully acknowledge the GEF, Arabian Gulf University (AGU), Bahrain University (BU), governmental organizations and all other contributors for their steadfast support and assistance. In preparing this Communication, capacity strengthening among national scientists, researchers and private sector professionals has been both an underlying theme and challenging goal for enhancing awareness of climate change in Bahrain.

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January 2012

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List of Acronyms

ALBA	Aluminum Bahrain
BAPCO	Bahrain Petroleum Company
bbl	barrels of oil
cap	capita
CCJC	Climate Change Joint Committee
CFL	compact fluorescent lighting
CH_4	methane
CIO	Central Informatics Organization
cm	centimeter
CO_2	Carbon dioxide
CO_2e	carbon dioxide equivalent
CVI	Coastal vulnerability index
EER	energy efficiency rating
EIA	Energy Information Administration (US)
ESD	Education for sustainable development
EU	European Union
EWA	Electricity and Water Authority
FAO	Food and Agriculture Organization of the United Nations
GCC	Gulf Cooperation Council
GDP	gross domestic product
GEF	Global Environment Facility
Gg	Giggram (billion grams)
GHG	Greenhouse gas
GIS	Geographic Information Systems
GPIC	Gulf Petroleum Industries Company
GWP	global warming potentials
HDI	Human Development Index
HFC	hydrofluorocarbons
HID	Health Information Directorate (Bahrain)
ICD	International Classification of Diseases
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
IPP	independent power producers
IUCN	International Union for Conservation of Nature
kg	kilograms
km	kilometer
km^2	Square kilometer
kWh	kilowatt-hours
LEAP	Long Range Energy Alternatives Planning system
LPG	liquefied petroleum gas
LULUCF	land use, land use change and forestry
m	meter
m^2	square meters
m^3	cubic meter

MAM	Ministry of Municipalities and Agriculture
MAR	Managedaquiferrecharge
MDG	Millennium Development Goals
mg/l	milligrams per liter
mm	millimeter
Mm^3	million cubic meters
MOE	Ministry of Education
MSW	municipal solidwaste
MW	mega-watts (million watts)
MOW	Ministry of Works
N_2O	nitrous oxide
NBB	National Bank of Bahrain
NBSAP	National Biodiversity Strategy and Action Plan
NCSA	National Capacity Self Assessment
NES	National Environmental Strategy
NG	natural gas
NGO	non-governmental organization
NMVOC	non-methanevolatileorganiccompounds
NOGA	National Gas & Oil Authority
NOx	nitrogen oxides
^oC	degrees Celsius
PCPMREW	Public Commission for Protection of Marine Resources, Environment and Wildlife
PFC	perfluorocarbons
PIRFD	Proportional incidence rates of food-bornediseases
QAAET	Quality Assurance Authority for Education and Training
R&D	research and development
SBI	Subsidiary Body for Implementation
SBSTA	Subsidiary Body for Scientific and Technological Advice
SF_6	sulfurhexafluoride
SLR	sea level rise
SMC	Salmaniya Medical Complex
SNC	Second National Communication
SO_2	Sulfur dioxide
tCO_2e	tonnes of CO_2-equivalent
TOE	tonnes of oil equivalent
TSE	Treated sewage effluent
TWh	terawatt-hours (billion kilowatt-hours)
UAE	United Arab Emirates
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USGS	United States Geologic Survey
WPCC	Water Pollution Control Centre (Tubli)
WRC	Water Resources Council
WRI	World Resources Institute

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Executive Summary

Bahrain's vulnerability to climate change as well as its levels of greenhouse gas (GHG) emissions are influenced by a multitude of factors. These include its climate, area, topography, geographic location, population trends, economic growth, energy production and consumption, use of land and natural resources, as well as other factors. Data were collected for the period from 2000-2006.

National Circumstances

Situated in the west central part of the Arabian Gulf, the Kingdom of Bahrain is an archipelago of more than 36 islands, shoals, and small islets that vary considerably in size and structure. The main island of Bahrain accounts for about 85% of the total area and is where Manama, the capital city is located. Over the period 1964 to 2007, land area increased by almost 90 km2as land reclamation policies have been and continue to be pursued.

Climate. Bahrain has very hot summers and relatively mild winters. Mean air temperature fluctuates between 14^{o}C and 41^{o}C. Average annual air temperatures have been steadily increasing over the period 1950-2010, while rainfall patterns over the same period are less clear.

Population. Bahrain has experienced dramatic population growth, about 7.0% per year over the past decade. Of a total population of 1,106,509 in 2008, expatriates slightly exceeded the number of citizens, in contrast to the year 2000 when expatriates were only about half the native population. At about 1,461 persons per km^2, Bahrain exhibits one of the highest population densities in the world. Most of the population is concentrated along coastal zones in the urbanized northern areas of Bahrain's main island.

Energy. Since the discovery of oil in 1932, oil exports have been the driving force behind Bahrain's growing economy. However, oil production has significantly decreased over the past decade. This trend is expected to continue with aggressive economic diversification efforts underway. Bahrain is unique among the Gulf States in that its oil refining capacity is far greater than domestic production capacity. Much of the oil exports to international markets are in the form of refined petroleum products.

In contrast, natural gas production has been growing at about 4% per year. All natural gas is consumed locally, with 33% used for electricity generation, 27% for aluminum production, 18% re-injected back to oil fields, 8% for the petrochemical production, and the remaining 14% is used for assorted industrial applications.

Electricity is used intensively meet the needs of an expanding economy and for desalinated water production. Most electricity is produced in relatively efficient natural gas-fired units. The household sector is the largest consumer followed by commercial and industrial sectors. Average annual per capita electricity consumption, about 12.8MWh/cap, is one of the highest in the world, and is expected to increase.

Economy. Economic growth has been about 5.5% per year over the past decade, due primarily to a thriving financial sector; flourishing manufacturing and construction sectors; and economic improvements in regional economies. Bahrain's Economic Vision 2030 aims to foster a private sector-driven economy, largely independent of oil. By encouraging investment in new sectors such as tourism, business services, manufacturing logistics, as well as export-oriented industries such as aluminum, Bahrain plans to grow its economy while keeping pace with a recovering global economy.

Water resources. Water supply in Bahrain comes from groundwater, desalination, and treated sewage effluent (TSE). Rapid population and economic development growth rates over the last four decades have led to about 4.4%/year growth in water demand over the past decade. Today, water demand is more than three times already unsustainable groundwater supply levels, making seawater desalination essential for Bahrain. Looking forward, plans are underway to develop integrated strategies for addressing water supply/demand challenges. These include optimizing water use, minimization of losses, and the increased use of desalinated water and TSE.

Agriculture. While agriculture is traditionally an important element of the Bahraini economy, it has been declining since the 1970s. Bahrain's food security is now highly dependent on imports. Nevertheless, agriculture consumes about 39% of the total water budget while accounting for less than 1% of GDP. Moreover, agricultural activities accounted for the overwhelming share of groundwater consumption, about 85%, with low irrigation efficiency of only about 55%.

Transport. Bahrain has an extensive land, air and marine transport system. Land transportation is dominated by privately owned vehicles. On average, there is one car for every two persons. At present, there are two airports and three major harbors. At present, Bahrain does not have a rail system although a study has been commissioned to explore the possibility of creating a 194km rail network by 2030.

Environment. A desert environment dominates Bahrain's terrestrial landscape, except for a narrow fertile strip that is found along the northern and northwestern coastlines. Bahrain's marine environment contains a wide variety of habitats including mangrove swamps, mudflats, coral reefs, sea grass beds, freshwater springs, lagoons and offshore islands. The Gulf of Salwa that encircles Bahrain, classified as a distinct bio-geographic province in the Arabian Gulf, is rich in sea grasses and accommodates the largest dugong population outside of Australia. In addition, salt marshes contain a variety of native plant species and are used as a feeding breeding site for an estimated 2-3 million migratory birds that passing through the Gulf each year during their migration between Eurasia and Africa.

Anthropogenic factors such as pollutants (e.g. oil, power plant and industrial discharges), urbanization (e.g. dredging and land reclamation), illegal fishing, and invasive alien species (e.g. Indian crow) are placing increasing stress on Bahrain's marine ecosystems. Today coral reefs are in a poor condition, and most reefs within 20-30km of Bahrain Island are in a state of ecological decline due to sedimentation and seawater temperature rise. Mangroves have been declining steadily since 1975.

Public Health. Bahrain's 2002-2010 Health Strategy seeks to promote stakeholder partnership in improving the health of the population of Bahrain and to ensure universal access to high quality, responsive health services. Health expenditure as a percentage of total government expenditure is about 9%; medical services are free to citizens. Bahrain's health indicators are good when compared to regional averages; life expectancy is 74 years; virtually all children are inoculated against children diseases; there are approximately 12 deaths per 1,000 live births; and there are approximately 19 maternal mortalities per 100,000 live births.

Education and awareness raising. Bahrain has achieved relatively high standards in education. A comprehensive reform initiative was launched to upgrade the quality of education to global standards, and ensuring compatibility between the educational outputs and the requirements of labor markets. Today, literacy rate among the 15-24 age bracket is 99.7% while the adult (15-

44 years) illiteracy rate has dropped to 2.5%. Education for all children below 15 years of age is compulsory and higher education is available through 2 governmental universities, 12 private universities, and numerous specialized training institutes. Various programs and initiatives have been launched to promote public awareness of environmental quality.

Towards sustainable development. Bahrain has made specific progress in meeting its Millennium Development Goals (MDGs) and towards sustainable development in general. Bahrain is committed to promoting sustainable development practices throughout all sectors and will continue working towards consolidating the achievements made for certain goals and prioritize activities to meet those MDGs as yet unrealized.

Framework for national communications. Bahrain is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), having become a party on 28March 1995. The Initial National Communication (INC) was prepared in a participatory approach by national teams under the auspices of National Steering Committee. Financial and technical assistance was provided by GEF-UNEP and INC was submitted in 2005.

Benefiting from the experience gained from the preparation of the INC and taking into consideration that climate change is the epitome of a cross-cutting issue, the national steering committee widened participation processes in the Second National Communication (SNC) to include more public and private involvement discussions in all topics addressed in the report. This was reflected in increasing number of participating institutions, local experts and consultative meetings and workshops that have been held across the country.

Greenhouse Gas Inventory

Bahrain's updated national inventory of greenhouse gas emissions was developed using the methodology described in the R*evised 1996 IPCC Guidelines for National Greenhouse Gas Inventories and the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* prepared by the Intergovernmental Panel on Climate Change.

Total emissions. Table ES-1 presents total GHG emissions and sinks for the year 2000. Total GHG emissions in 2000 were 22,374 GgCO_2-equivalent, which includes 17,254Gg from energy; 2,515Gg from industrial processes; and 2,605 Gg from waste.

The agriculture and land use change and forestry sectors are so small in Bahrain that emissions were assumed to be zero. Emissions from perfluorocarbons (CF_4 andC_2F_6) from the production of aluminum are small (about 0.044Gg), while data was unavailable for estimating emissions of hydrofluorocarbons (HFCs) and sulfur hexafluoride(SF_6).

Energy-related activities accounted for the dominant portion of GHG emissions in

Table ES-1: Total GHG emissions in Bahrain, 2000 (Gg)

GHG Sources & Sinks	CO_2-equiv	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	PFCs
1 Energy	17,254	15,951	61	0	51	138	26	16	0.000
2 Industrial Processes	2,515	2,219	0	0	2	104	21	11	0.044
3 Solvent& Other Product Use	0	0	0	0	0	0	0	0	0.000
4 Agriculture	0	0	0	0	0	0	0	0	0.000
5 Land-Use Change & Forestry	0	0	0	0	0	0	0	0	0.000
6 Waste	2,605	0	124	0	0	0	0	0	0.000
Total National Emissions	22,374	18,169	185	0	52	242	47	26	0.044
Net National Emissions	**22,374**	**18,169**	**185**	**0**	**52**	**242**	**47**	**26**	**0.044**

Bahrain in 2000. Approximately 77% of all GHG emissions are associated with the combustion of fossil fuels or the release of fugitive emissions from oil and gas operations. Industrial processes accounted for about 11% of all GHG emissions, followed by the waste sector, which accounted for about 12% of total emissions.

Emission trends. Over the period 1994 to 2000, GHG emissions have increased by about 13% (about 2.3%/year); from 19,468Gg of carbon dioxide-equivalent (CO_2e) in 1994 to 22,374Gg CO_2e in 2000. Emissions from energy and industrial processes increased by roughly 13% and 33%, respectively. Waste emissions also increased by 12%.

Much of the growth in GHG emissions is due to increases in energy use for power generation and process heat in manufacturing industries. In addition, industrial GHG emissions grew at a faster rate (i.e., 4.8% per year) than the national average due in large part to the increasing role of the manufacturing sector in achieving national economic development objectives, particularly the aluminum and ammonia production industries. However, the CO_2 per capita had reduced.

Energy emissions. GHG emissions from energy activities are due to fossil fuel combustion and fugitive emissions from oil and gas exploration activities, electric power generation, transport, and industrial production activities. All refined petroleum products are produced in national refineries from locally produced (15%) and imported (85%; from Saudi Arabia via Abu Sa'afa oil field) crude oil. Natural gas is used exclusively for power production and process heat in manufacturing processes to minimize the CO_2 emission per kWh. All of the diesel and gasoline are consumed in road transport for cars, light duty trucks, buses, and heavy-duty trucks.

Industrial process emissions. Industrial processes are the second largest emitter of anthropogenic GHG emissions in Bahrain, accounting for 2,515Gg of CO_2e, or about 11% of national CO_2e emissions in 2000. Metal production (i.e., aluminum production) accounted for the largest share of industrial process emissions, about 75%; followed by chemical production at about 25%.

Agriculture and LUCF emissions. Given its hyper-arid environment, the level of agricultural activity is quite small in Bahrain. Moreover, as a fraction of national levels, emissions from agriculture are typically small. For these reasons, they have been assumed to be zero in the updated GHG inventory. Also, GHG emissions from land use change and forestry are not pertinent for Bahrain.

Waste emissions. Waste-related emissions are associated with municipal solid waste (MSW), municipal waste water, and other wastes. MSW is the main source of GHGs and has been increasing at less than half the population annual growth rate. Municipal waste water produced by the residential, commercial, and industrial sectors is processed at the central Tubli Water Pollution Control Centre. Other wastes include by-products generated at health-care facilities, research centers/units and laboratories, and increasing amounts of electronic waste (e-waste) which contains plastic and harmful heavy metals such as lead and mercury.

PFC, HFC, and SF_6 emissions. PFCs were emitted from the production of aluminum. HFCs were not produced or imported/consumed as substitutes for ozone depleting substances in refrigeration and fire extinguishers because ozone-depleting substances were banned in Bahrain in 2000. The estimation of SF_6 emissions associated with electric power transmission proved to be a significant challenge due to data constraints and was assumed to be negligible.

Uncertainty assessment. Attention to two areas could help reduce uncertainty in Bahrain GHG inventory. First, enhancing the availability of detailed and high quality activity data will increase confidence in the inventory results. Although adequate methodologies have been developed to estimate emissions for some sources, problems arose in obtaining activity data at a level of detail in which aggregate emission factors can be applied. Second, improving the accuracy of emission factors to calculate emissions from a variety of sources is vital. Most of the emission factors noted in the above table are classified as having medium uncertainty (i.e., uncertainty between 10% and 50%).

Vulnerability & Adaptation

With climate change, it is expected that future increases in climatic variability will lead to adverse impacts on a number of vulnerable sectors, systems, and livelihoods in Bahrain. During the past several years, impact assessments were undertaken in four key sectors; coastal zones, water resources, human health, and biodiversity. The results of the assessments have been shared with a wide range of stakeholders in Bahrain, including both the general public and private sector. It is providing the basis for initial efforts to incorporate climate change into planning decisions made by policymakers, national agencies, and other stakeholders.

Coastal zones. The Kingdom of Bahrain is a small island state where almost all of the population and development activities are located in close proximity to the coastline, with very limited capacity to adapt to sea-level rise (SLR). Most of the coastal areas of the islands do not exceed 5 meters above current mean sea level and it will be physically and economically difficult, if not impossible, to establish zoning setbacks for new development or for marine habitats to migrate toward higher land elevations.

In order to account for both near-term and long-term impacts associated with sea level rise, two methodologies were applied. A scenario-based inundation analysis was carried out to examine long-term impacts relative to the latest IPCC sea level rise projections in the Fourth Assessment Report. To support near-term coastal zone planning, a vulnerability indexing approach was used, adapted from methods applied successfully elsewhere.

Table ES-2 summarizes the results of the long—term inundation analysis under each scenario for the years 2050 and 2100. Even under the "no accelerated deglaciation" scenario, 83km2, or 11% of the total land area, would be lost by 2050 from a 0.3-meter increase in mean sea level. Approximately 18km^2 of built-up and industrial areas would be under water. These areas account for about 7% of these areas, about 2% of the country's entire land area, and a substantial portion of its socioeconomic activity.

Table ES-2: Results of the long-term inundation scenario analysis

		No accelerated deglaciation				Low deglaciation rate				Extreme deglaciation rate			
		2050 (SLR=0.3 m)		*2100 (SLR=1.5 m)*		*2050 (SLR=0.5 m)*		*2100 (SLR=2.0 m)*		*2050 (SLR=1.0 m)*		*2100 (SLR=5.0 m)*	
Land use type	Total area (km2)	Inundation (km2)	(%)	Inundation (km2)	(%)	Inundation (km2)	(%)	Inundation (km2)	(%)	Inundation (km2)	(%)	Inundation (km2)	(%)
Built Up	209	10	5%	46	22%	10	5%	64	31%	46	22%	126	60%
Industrial	46	8	17%	29	63%	8	17%	32	69%	29	63%	38	82%
Vacant	79	5	7%	24	30%	5	7%	27	34%	24	30%	38	48%
Agriculture	71	5	7%	15	21%	5	7%	23	32%	15	21%	57	80%
Wetland	2	1	69%	1	77%	1	70%	1	80%	1	74%	2	100%
Barren	304	29	10%	52	17%	29	10%	68	22%	51	17%	122	40%
Heritage	2	0	0%	0	0%	0	0%	0	0%	0	0%	0	1%
Sabkhs	35	26	75%	33	97%	26	76%	34	98%	33	97%	35	100%
Total	**748**	**83**	**11%**	**200**	**27%**	**84**	**11%**	**248**	**33%**	**199**	**27%**	**418**	**56%**

Under the "extreme deglaciation rate" scenario, 418km^2, or 56% of the total land area, would be lost by 2100 due to a 5-meter increase in mean sea level. Of this amount of inundated land, 164km^2 would correspond to built-up and industrial areas, roughly 64% of these areas and about 22% of the country's entire land area.

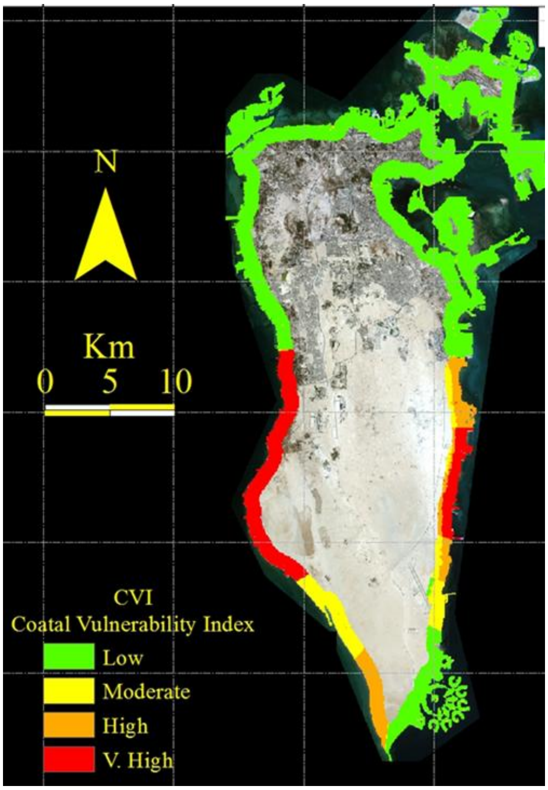
Regarding near-term vulnerability, the entire coastline of Bahrain's main island was classified into one of four levels of vulnerability; low, moderate, high, and very high based on the development of a coastal vulnerability index (CVI).

Bahrain's near-term vulnerable hotspots are located along the central portions of the western and eastern coastlines. The vulnerability of these areas is mostly driven by their characteristically shallow coastal slopes, low elevations, and erosion-prone nature of the sandy soils present. These areas comprise a total of 54km, or about 8% of the shoreline and should be the priority focus of near-term adaptation planning.

Another 33 km of coastline are classified as highly vulnerable (5%). As shown on Figure 3-4, these areas are located along the eastern coast adjacent to the vulnerable hot spots. In addition, the western coast of the southern tip of the main island is also a highly vulnerable area. For the purposes of adaptation planning, these areas are also considered priority vulnerable hotspots.

The remaining coastal areas are classified as low to moderate vulnerability. Comprising a total length of 630km (88% of the total length of the coastline), these areas benefit from a combination of hard coastal protection structures and high rates of shoreline change (i.e., reclamation activities). Figure ES-1 summarizes the CVI assessment results.

Figure ES 0 1: Coastal vulnerability hot spots



The major implication is that mainstreaming adaptation to account for the impact of sea level rise needs to be integrated as soon as possible into the national policymaking process. Protection is the only adaptation option for Bahrain in the long-run. Capacity strengthening, integrated planning, local/regional stakeholder engagement, and hard coastal protection are core principles underlying a future climate change adaptation plan for Bahrain's built-up coastal areas.

Water resources. Bahrain is a water-scarce country characterized by an extremely arid environment, high average annual temperatures, erratic and scanty rainfall, high evapo-transpiration rates, and no perennial rivers. Over the last four decades, rapid population growth and urbanization, coupled with the expansion of irrigated agriculture and industrialization have led to very high water demand and increasing vulnerability of water supply.

Groundwater is the only natural relatively freshwater source available to Bahrain. It is obtained from the Dammam aquifer, a large transboundary groundwater system that extends from central Saudi Arabia, where the aquifer crops out and where its main recharge area is located, to the Arabian Gulf waters, including Bahrain, Kuwait, southern Qatar, UAE and Oman.

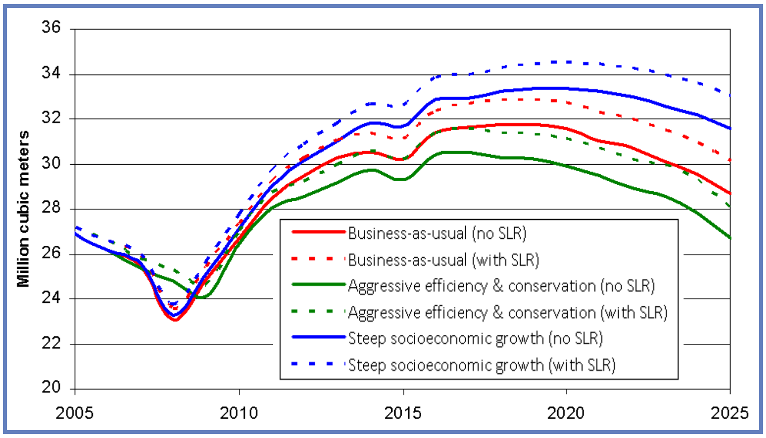
Bahrain relies on the Dammam aquifer for more than 30% of its water supply. However, the aquifer is now in a state of severe decline and quality deterioration due to decades of unsustainable use. Hence, the main water resource management challenge is how to balance decreasing water supply and increasing water use (i.e., the supply-demand gap) on a long-term sustainable basis while promoting national development with the least social, economic, environmental and other costs.

With climate change, this challenge becomes even more urgent and pressing, particularly regarding seawater intrusion into groundwater supply due to sea level rise. To assess this impact, quantitative predictions of aquifer behavior were made for three plausible socioeconomic development scenarios, with and without sea level rise, using the best available regional groundwater models.

Figure ES-2 shows the magnitude of seawater intrusion into the aquifer up through 2025 for the scenarios. Without considering the impact of sea level rise, the amount of seawater intrusion increases under each of the three scenarios (solid lines) due to unsustainable groundwater consumption.

With sea level rise, there will be additional pressure placed on already stressed groundwater resources. The amount of seawater intrusion is greater (dashed lines) than the levels in the three scenarios without sea level rise. Even under the *Aggressive efficiency & conservation* scenario, the impact of sea level leads to an additional 1 million cubic meters of seawater annually entering the aquifer by 2025, relative to Base Year levels.

Figure ES-0-2: Seawater intrusion in the Bahrain aquifer, with and without sea level rise



In short, sea level rise makes an already dire groundwater supply situation in Bahrain even worse. Moreover, if sea level rise proceeds in a manner more consistent with the assumption of the *Low deglaciation rate* scenario applied in the coastal zone vulnerability assessment, seawater intrusion levels would probably double or more by 2025, and the downward seawater intrusion trend in the post-2020 period would likely disappear.

Finally, groundwater vulnerability to climate change would be larger still if it accounted for indirect impacts in up-gradient areas (i.e., in eastern Saudi Arabia). Reducing groundwater use to sustainable levels in Bahrain alone would not necessarily promote recovery of the Dammam aquifer – much depends on groundwater development along the central and eastern regions of Saudi Arabia and the emergence of a mechanism for collaborative transboundary management of this vital resource.

At a broad adaptation planning level, it will be important for Bahrain to establish an effective aquifer management framework that can promote recharge, enhance storage, reduce demand, protect quality, and limit discharge. Important steps in this direction are already underway.

At a more detailed adaptation planning level, the promotion of managed aquifer recharge (MAR) has been identified as a high priority near-term strategy. MAR involves building infrastructure and/or modifying the landscape to intentionally enhance groundwater recharge. The implementation of MAR requires suitable conditions, all of which are met in Bahrain. These include falling groundwater levels, hydrogeologic suitability, and the availability of surplus unused treated sewage effluent (TSE) for aquifer recharge.

The potential benefits associated with MAR were evaluated for several sites. For one of these, the Malikiya site, results showed that groundwater levels can increase significantly, between 1.5 and 2.5 meters after a 5-year period. Average aquifer salinity levels also dropped by about 50%.

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Human Health. Climate change is understood by governmental and other stakeholders to pose a potentially significant threat to public health. Increased exposures to thermal extremes, changing disease vector dynamics, an increased incidence of food-related and waterborne infections are likely to be experienced throughout the Bahraini population, with the elderly, patients with pre-existing medical conditions, and children, likely among those hit the hardest.

Given the paucity of environmental health information in Bahrain that could be used in a vulnerability assessment regarding the impacts of climate change on human health, the impact assessment focused on the identification, synthesis, and analysis of pertinent baseline data that could serve as inputs to future vulnerability assessment of climate change impacts on human health in Bahrain.

Specifically, systematic databases were developed and analyzed to examine the influence of climate in six human health areas: morbidity, expatriate laborer health, children's health, food-borne diseases, hospital discharges, and mortality. Such baseline information could be used both to inform future health impact assessments as well as begin to fashion adaptive responses.

The results of a study on morbidity showed that one quarter of the primary healthcare center visits were climate-related with children below the age of 10 having the highest prevalence rate (about 35%). There was seasonal variation exhibited in overall morbidity with the highest rates occurring in autumn and lowest in summer (see Figure 3-13).Visits due to respiratory conditions accounted for the majority of the health center visits and showed a similar pattern across all centers.

The results of a study on expatriate health showed a prevalence of climate-related diseases, particularly heat-stress related. This contributes to a loss of productive hours which ultimately affect the country's economic welfare. In addition, high health center visit rates leads to high direct costs for prescription medications. No association could be found with age, nationality or place of work of expatriate workers.

The study on pre-school children's health showed that the percentage of climate-related diseases was highest among children aged 3-4 years. These differences may reflect the fact that children under the age of 2 years are less likely to be outdoors. There were statistically significant differences between preschool children by family size and nationality but not by gender.

The results of the study on food-borne diseases confirm that food-borne diseases are more prevalent in hot weather in Bahrain. With even higher temperatures predicted in the summer months due to climate change, this represents an important finding that can guide subsequent adaptation planning.

The study on hospital discharges concluded that asthma, dermatitis, eczema and diaper rash demonstrated strong seasonal pattern while none could be detected in the other diseases. The lack of such an association might be explained by the use of discharges as a morbidity indicator instead of incidence and prevalence data. For the purpose of a baseline association, the study concluded that there appears to be a potential relationship between climate and asthma, dermatitis, eczema and diaper rash that should be further explored in future studies.

The study or mortality patterns concluded that a strong case could not be made, on the basis of the data assembled and analyzed, that extreme temperatures in the summer months are a significant contributor to mortality in Bahrain. Nevertheless, this is a critical issue that should be revisited in future, more comprehensive studies

Several conclusions have emerged from the above studies that have a strong bearing on the formulation of a comprehensive climate change adaptation strategy for human health in Bahrain. First, climate contributes substantially to morbidity in Bahrain. Second, children represent a particularly vulnerable population to climate related diseases. Third, expatriate laborers represent a vulnerable population for climate related diseases, particularly for respiratory diseases. Fourth, the potential for food borne diseases are highest during the summer months. Finally, there is an apparent relationship between ambient air pollution concentration and climate related diseases.

Biodiversity. The terrestrial landscape in Bahrain is predominately arid desert with virtually no inland waters. Its marine environment is very diverse and includes extensive sea grass beds, mudflats, coral reefs as well as offshore islands. Sea grass beds are important foraging grounds for some threatened species such as dugongs and the green turtle.

With climate change, these and other elements of biodiversity in Bahrain will experience additional stress. While no biological modeling was conducted to assess the impact of climate change on key species and habitats in Bahrain, a biodiversity inventory and what could be potential biodiversity vulnerability hotspots were assembled in an effort to inform and guide any such modeling in the future.

There are sixteen different marine habitats in Bahrain. Of these, there are six for which a strong consensus exists within Bahrain scientific community to be considered as priority systems for any subsequent climate change adaptation action planning, namely algae beds, coral reefs, seagrass beds, oyster beds, mangrove forests, mudflats, and salt marshes/coastal dunes.

Thirty species in Bahrain are classified as being *vulnerable* to *critically endangered* by the IUCN. At least one species, the hawksbill turtle, is classified as being *critically endangered*; dugongs are classified as an *endangered* species, and the Socotra cormorant is classified as *vulnerable*. A key concern for future adaptation planning in Bahrain is the tolerance of these species toward projected changes in the marine environment (e.g., increased water temperature, declining salinity levels).

Systems that may be under the greatest threat from climate change were identified as a way to prioritize future vulnerability risk assessment and adaptation planning activities. These vulnerable hotspots include fish stock levels, coral reefs, mangroves, coastal date plantations, and migratory birds.

Core principles that should underlie the development of a future adaptation planning framework include conserving existing biodiversity, minimizing socio-economic activity impacts on key ecosystems and species, maintain/restoring biodiversity, establish ecological networks, Applying integrated ecosystem management approaches, and mainstreaming biodiversity in planning processes and decisions made across sectors, departments and economic activities.

Key actions that should be undertaken in the near-term include knowledge sharing, awareness-raising, impacts research, protected area network development/support, rehabilitation of sensitive habitats, installation of artificial coral reef areas, and the development of programmes to reduce anthropogenic stresses.

Greenhouse Gas Mitigation

Most GHG emissions are associated with energy use activities. For both the 1994 and recently completed 2000national GHG inventories, energy represented over 85% of all emissions. Since about 1990, Bahrain has steadily improved its energy intensity – that is, energy use per unit of gross domestic product (GDP). Carbon intensity follows a similar trend.

Sustainable energy initiatives. Driven by strong economic and population growth, energy consumption is projected to increase significantly in the coming years in Bahrain. At the same time, a general commitment to sustainable systems of production and consumption as an integral component of the energy mix is gradually emerging. Energy efficiency and renewable energy technologies, which can help meet Bahrain's current needs without compromising those of its future generations, are increasingly regarded as fundamental to a sustainable energy future.

Indeed, energy efficiency has become increasingly understood as essential for Bahrain's sustainable economic development. There is now a widespread perception among policymakers that promoting energy efficiency can be economically beneficial by increasing oil supply available for exports, extending indigenous gas resources, enhancing industrial competitiveness in world markets, creating new jobs, improving environmental quality, and reducing GHG emissions.

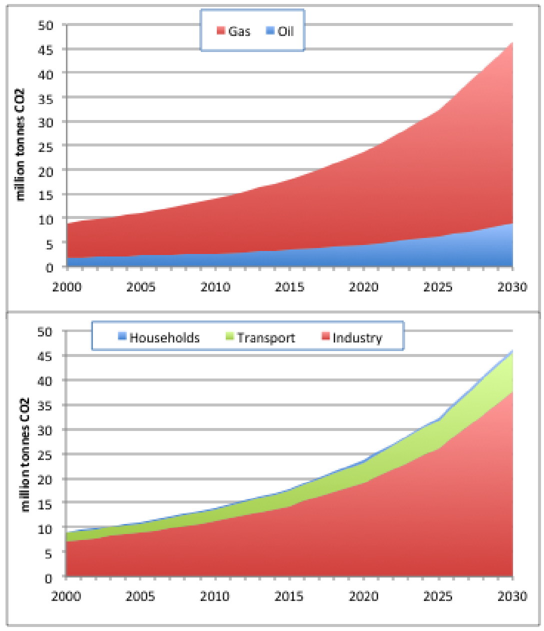
Regarding renewable energy, there is growing awareness that Bahrain's future energy situation necessitates an urgent review of the potential development and use of renewable energy resources. Average annual solar radiation available in Bahrain is quite high, around 2600 kWh/m^2/year and the technical potential for electric generation using solar thermal technology is about 33 TWh per year, or roughly 3 times current national electric generation levels. There have been some noteworthy pilot renewable energy projects including wind turbine installed on the World Trade Center in Manama, a national wind energy assessment, and several pilot renewable solar and wind power installations.

At present, the National Economic Strategy (2009-2014) identifies energy efficiency and renewable energy as two strategic options to achieve a reduction in GHG emissions. While a clear action plan is not yet in place, there are a number of separate initiatives underway to promote sustainable energy legislation, including the development of *Economic Vision 2030*, a comprehensive strategy document that outlines a set of sustainability policies and the implementation of several industrial energy efficiency pilot projects. Such initiatives are intended to facilitate the eventual development of comprehensive sustainable energy legislation in Bahrain. Such legislation is widely recognized as essential to promote increased energy efficiency and renewable energy at the national level.

Future carbon emissions. In the absence of high penetration of energy efficiency and renewable energy, future energy sector GHG emissions through 2030 are expected to rise rapidly. As shown in Figure ES-3, annual GHG emissions from the energy sector are projected to increase to about 46 million tonnes of CO_2 by 2030, an increase of over 37 million tonnes from levels in the year 2000, or a growth rate of about 5.6% per year.

For the power sector, the following represent the most attractive GHG mitigation strategies: solar thermal technologies, advanced natural gas combined cycle technology, and nuclear power technology. For the household and commercial sector, efficient air conditioning, compact fluorescent lighting (CFL), and solar hot water heaters represent the most attractive strategies.

Figure ES-0-3: GHG emission projections for the energy sector by fuel (top) and sector (bottom)



For the industrial sector, GHG mitigation measures include CFLs, efficient motors and pumps, waste heat recovery, and combustion efficiency improvements, greater use of combined cycle technology to replace single

Table ES-3: Summary results of the assessment of the costs and benefits of GHG mitigation options

Sector	Option	Potential GHG Emission Reductions by 2030	Cost per Tonne	Priority for follow-up analysis
Power supply	Solar thermal	H	H	H+
	Advanced NG combined cycle	M	M	H
	Nuclear power	H	H	L
Household & commercial	High efficiency space cooling	H	L	H+
	Compact fluorescent lighting	H	L	H+
	Solar hot water heaters	H	L	H+
Industrial	Energy audits	NA	NA	H
	Efficient motors/pumps	M	M	M
	Waste heat recovery	M	M	M
	Combined cycle technology	H	L	H+
	Fuel switching	H	L	H+
	PFC reduction in aluminum industry	L	H	L

DEFINITIONS

Potential GHG Emission Reductions by 2030:
L = less that 0.1 million tCO2e; M = between 0.1 and 0.5 million tCOO2e; H = greater than 0.5 million tCO2e

Cost per Tonne avoided:
L = less than $0/tCO2e; M = between $0/tCO2e and $40/tCO2e; H = greater than $40/tCO2e

Priority for follow-up analysis:
L = low priority; M = medium priority; H = high priority; H+ very high priority

cycle power generation, switching away from oil products to lower carbon intensity natural gas, and PFC reduction activities in the aluminum smelting industry.

Using cost and performance characteristics assembled from Ministries and other public agencies, a first-cut assessment of the incremental costs, GHG reduction benefits, and priorities for follow-up analysis of the above technologies was conducted on a head-to-head basis. A summary of the results of the assessment is provided in Table ES-3.

Overcoming barriers. Overcoming a variety of policy and market barriers is a priority in order to promote the integration of sustainable energy technologies within Bahrain's economy. Key actions that need to be advanced in the near-term include promoting awareness of the benefits of energy efficiency and renewable energy, developing suitable financing mechanisms to address high initial capital costs of renewable technologies, building local expertise for maintenance, and undertaking the needed institutional reforms to create an enabling environment for energy efficiency and renewable energy investments.

Steps to Implement the Convention

Bahrain's ongoing national response to climate change is focused on the development of strategic partnerships for effective action among government institutions, private sector organizations, and civil society groups. This is considered fundamental in order to integrate emerging climate change risks and threats into new programs, practices, and plans.

Framework for action. Specifically, three main aspects underscore Bahrain's strategy to implement the Convention, namely climate change awareness-raising, promotion of a range of actions to reduce GHG emissions, and the identification of practical and sustainable strategies to reduce vulnerability to the impacts of climate change, with a particular emphasis on changing consumption-oriented habits.

Strategy formulation.. Bahrain considers that strategy formulation to implement the Convention is more of a journey than a destination. It involves vision setting from which long-term strategies and plans emerge to achieve the vision. It also involves the implementation of near-term objectives, pathways, and initiatives to ensure success in meeting long-term goals. In particular, synchronization between short and long-term objectives is essential. Moreover, overcoming fragmented planning, a key challenge for Bahrain, remains a priority in order to meet the objectives of the Convention.

Vision. Bahrain's vision for the ongoing implementation of the Convention has four strategic elements - public engagement, educational reform, institutional coordination, and technical capacity building.

Regarding public engagement, all segments of Bahraini society need to become engaged in addressing climate change in appropriate ways. That is, all people living in Bahrain, whatever their age, nationality, level of education, or occupation need to become engaged on the climate change issue, a global phenomenon that threatens everyone.

A key initial strategy for promoting public engagement is the development of a set of "Climate Change Best Practice Guides". The aim of these guides is to inform stakeholders of practical conservation measures (e.g., recycling), concrete ways to reduce carbon footprints (e.g., energy efficient appliances), and simple strategies to increase resilience to climate change impacts (e.g., multiple uses of scarce freshwater supplies).

Educational reform consists of a four-part strategy. First, *Education for sustainable development*

(ESD) principles will be better integrated in the primary school study curricula overseen by the Ministry of Education. Second, the scope of the Quality Assurance Authority for Education and Training (QAAET) will be expanded to address climate change. Third, an environmental auditing system will be established at the primary school level. Finally, a hands-on approach to climate change will be promoted at all educational levels.

Institutional coordination of climate change awareness-raising activities across governmental and non-governmental institutions is both a challenge and necessity. These entities are essential to effectively engage households, decision-makers, and the private sector on concrete actions such as conservation, recycling, green energy and building options. Key future initiatives include community advisory services, telephone hot lines, civil society support, information exchange, and Media engagement.

Technical capacity building involves training workshops to ensure that policy-makers, civil society, trade groups, and the private sector have simple and straight forward access to climate change information. It also involves a number of proposed future initiatives such as research and development, technology transfer, incentives development, development of niche markets, and partnership-building.

1

National Circumstances

Bahrain's vulnerability to climate change as well as its levels of greenhouse gas (GHG) emissions are influenced by a multitude of factors. These include its climate, geographic location, population trends, economic growth, energy production and consumption, use of land and natural resources, as well as other factors.

The kingdom of Bahrain is a constitutional monarchy with an elected parliament and an independent judiciary. Its National Council is composed of a Parliament and State Council, each having 40 members. Each of the five governorates has equal representation in Parliament. Bahrain is proud to have participated in its third parliamentary elections which took place in the year 2010.

The rest of this chapter focuses on other national circumstances. These include both current circumstances as well as departures from historical trends since the Initial National Communication submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in April of 2005. This chapter also reflects important changes that have taken place in Bahrain relevant to climatic change since that initial communication.

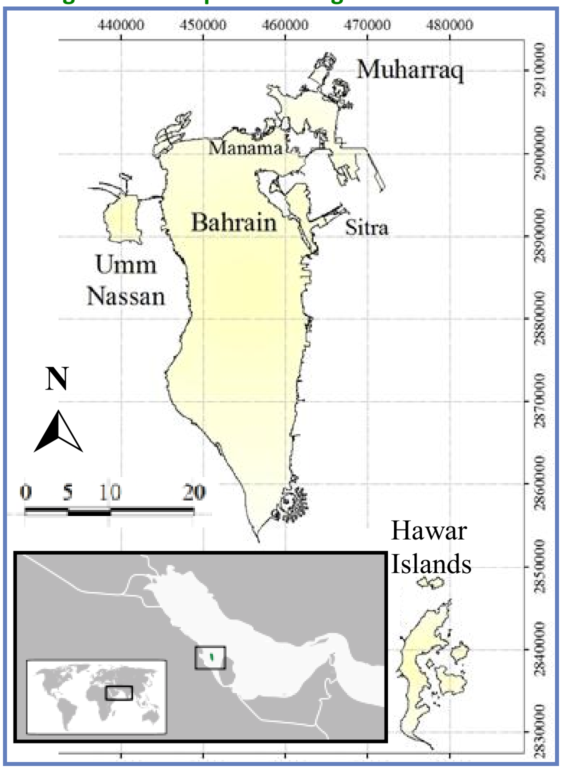
Geography

Situated in the west central part of the Arabian Gulf, the Kingdom of Bahrain is located approximately 25km east of Saudi Arabia and is bounded by latitude 25°32'N and 26°20'N and longitude 50°20'E and 50°50'E. It is an

archipelago of more than 36 islands, shoals, and small islets that vary considerably in size and structure.

The main islands occur in two groups of unequal size as shown on Figure 1-1. The main island of Bahrain accounts for about 85% of the total area and is where Manama, the capital city is located. The next largest island is Hawar, followed by Muharraq Island, Umm Nassan, Jiddah, and Sitra. The many remaining small islands and islets are uninhabited.

Figure 1-1: Map of the Kingdom of Bahrain



For decades, due to Bahrain's limited land area, government policy has encouraged land reclamation to accommodate development. Over the period 1964 to 2007, land area increased by almost 90km² (from 663km²to 751km², or about 13%). Most of this reclaimed land is on the northern built-up portions of Bahrain's main island, as shown Figure 1-2 (Zainal et al., 2009). Land reclamation policy continues to be aggressively pursued today as total land area has now increased to about 790km², with a total coastline of about 537km.

Climate

Located in a very arid part of the world, Bahrain has very hot summers and relatively mild winters. Mean air temperature fluctuates between 14°Cand 41°C. There are two seasons; winter extends from November to April and summer lasts for the rest of the year. January is the coldest month of the year whereas temperature peaks in August.

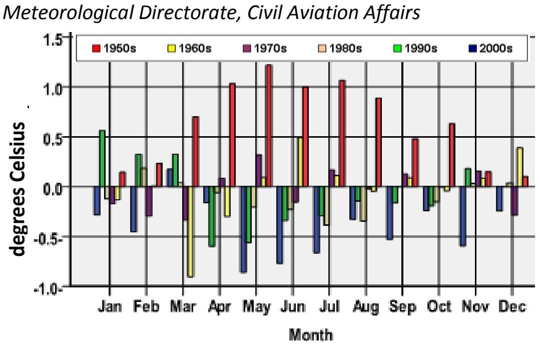
Figure 1-2: Land area change due to reclamation activities in Bahrain, 1962-2008

Air temperatures have been steadily increasing in Bahrain over the period 1950-2010. This unmistakable pattern is illustrated on Figure 1-3 (top) which shows the change in average monthly temperature in each decade relative to the overall average monthly temperatures over that period. Except for March, temperatures in the 1950s were all at least 0.2°C lower than average monthly temperatures for the entire period. For the 2000s, each month's average temperature was at least 0.1°C higher than average monthly temperatures for the entire period.

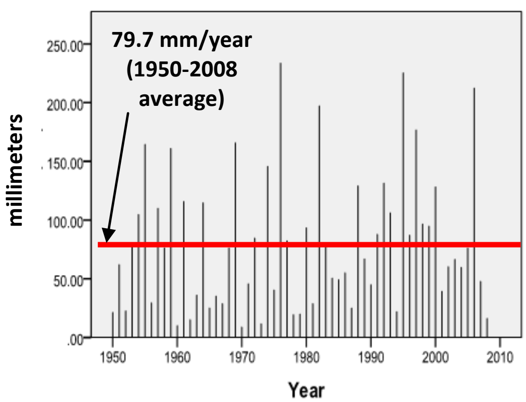
Rainfall patterns are less clear. While mean annual rainfall is 79.7mm for the period 1950–2008, there is a wide range of spatial and temporal variation between months of the year as well as from year to year, as shown on Figure 1-3 (bottom). Only in three years which recurred at long intervals did the total annual precipitation exceed 200 mm (intervals of 11 and 19 years). Annual rainfall was lower than 20mm in only six years; these recurred at shorter intervals (between 2 and 10 years).

Figure 1-3: Climatic trends in Bahrain

The figure below shows the change in average monthly temperatures over the past 6 decades in Bahrain relative to the monthly means of the overall period (59 years) *Source: Meteorological Directorate, Civil Aviation Affairs*



The figure below shows the change in yearly rainfall over the past 6 decades in Bahrain relative to the annual meanof the overall period (58 years) *Source: Meteorological Directorate, Civil Aviation Affairs*



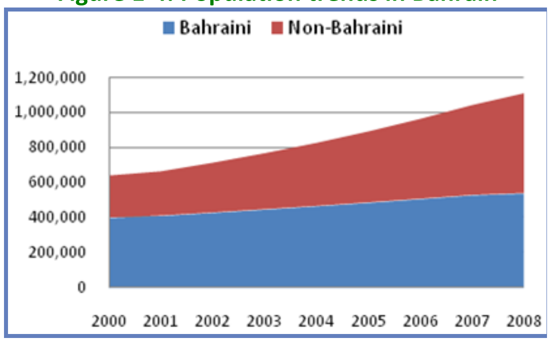
Winds are predominantly northerly and north-westerly for most of the year. While evaporation exceeds precipitation by more than ten fold most of the year, certain months exhibit high relative humidity levels due to high sea water temperatures. Mean monthly relative humidity is about 67%, with the mean daily maximum ranging from 78% to 88%.

Population

Bahrain has experienced dramatic population growth. Average annual population growth rates nearly doubled from 3.6% per year during 1981-1991 (INC, 2005) to about 7.0% per year during 2000-2008 (CIO, 2009).

Population growth is influenced by two key factors. First, improving socio-economic conditions have encouraged the growth of the native Bahraini population. Second, Bahrain's increasingly diversified economy has produced a growing demand for skilled labor, particularly within the industrial and service sectors which has attracted foreign laborers. Of a total population of 1,106,509 in 2008, expatriates slightly exceeded the number of citizens in that year, in contrast to the year 2000 when they were only about half the native population (see Fig 1-4).

Figure 1-4: Population trends in Bahrain



The influx of foreign nationals is reflected in Bahrain's gender and age ratios. While male and female populations are roughly equal in the native Bahraini population, the non-Bahraini male population is about 2.5 times greater than the non-Bahraini female population. The result is that the overall population is weighted towards males which account for approximately 61% of the total population. Similarly, the population is dominated by those whose age falls between the 20-45 year-old age bracket. After 45, the population drops steadily. The median age is 30.

At about 1,461 persons per km^2 in 2008, Bahrain exhibits one of the highest population densities in the world. Most of the population is concentrated along coastal zones in the urbanized northern areas of Bahrain's main island. In other parts of Bahrain, urbanization rates have been intensifying such that the overall urbanization rate has increased to about 89% compared to 70% in 1941. Of the 5 governorates in Bahrain, the four northern governorates account for 90% of the total population yet only about 35% of total land area.

Energy

Since its discovery in 1932, oil exports have been the driving force behind Bahrain's growing economy. However, oil production has decreased from 13.7 million barrels in 1999 to 11.8 million in 2009. This trend coincides with rapidly rising domestic demand for refined oil products, resulting in decreased exports, particularly since 2005.

As Bahrain diversifies its economy and energy consumption grows in petrochemical and aluminum production, oil exports likely will continue to decrease. This confronts Bahrain with important economic development issues since in 2011, oil production and oil refining accounted for over 60% of Bahrain's exports and 70% of government revenues.

Bahrain is unique among the Gulf States in that its oil refining capacity is far greater than domestic production capacity. Indeed, Bahrain imports about 210,000bbl/day of Arab Light crude oil from Saudi Arabia which is then refined and sold mainly to India and other Asian markets. In fact, much of the oil exports to international markets are in the form of refined petroleum products.

Natural gas trends stand in strong contrast to oil. Bahrain's proven natural gas reserves are currently estimated at 920 billion cubic meters. Between 1999 and 2009, natural gas production grew from 8.5 to 11.3 billion cubic meters per year, an average growth rate of about 4.0%/year (EIA, 2011). Natural gas production comes from two main sources; natural gas representing about 80% and associated gas which is 20%. All natural gas is consumed locally, with 33% used for electricity generation, 27% for aluminum production, 18% re-injected back to oil fields, 8% for the petrochemical production, and the remaining 14% is used for assorted industrial applications.

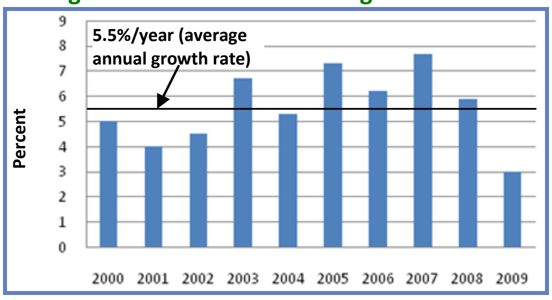
Electricity is used intensively to meet a growing dependence on desalinated water, as well as to meet the needs of an expanding economy, rapidly growing population, and ambitious urban development projects. Most electricity is produced in relatively efficient natural gas-fired units; most electricity is consumed by the household sector followed by the commercial and industrial sectors.

Bahrain's average annual per capita electricity consumption of 12.8MWh/cap, already one of the highest in the world, is expected to increase. Electricity generation has been growing about 9% per year. Official electricity generation projections show more than a potential doubling from 9.3 TWh in 2006 to 20.8 TWh in 2020. Meeting electricity demand in the future is likely to be challenging; supply agreements with neighboring countries are being explored.

Economy

Over the past decade, economic growth has been consistently strong. This has been due primarily to rising oil prices, a thriving financial sector and economic improvements in regional economies. From 2000 to 2009, GDP in constant prices grew a total of 140%, with an average annual growth rate of 5.5% per year (see Figure 1-5). In 2009, Bahrain's GDP was about US$19.3 billion (2005$). The IMF forecasts that Bahrain's GDP will reach US$35.8 billion (2005$)by the year 2016.

Figure 1-5: Annual real GDP growth rates



Up until the global economic crisis in 2008, Bahrain was able to take good advantage of a strong global economy because of a comprehensive set of economic reforms that had been enacted in the late 1990s. These reforms included corporatizing and privatizing government businesses, removing impediments to foreign investment, acceding to a Gulf Cooperation Council (GCC) customs union, and signing free trade agreements with the United States.

The reforms led to significant structural changes. Perhaps the most noteworthy has been the change in the investment to GDP ratio. This ratio increased from 20% in 2003 to 25% in 2007, suggesting steady and growing confidence on the part of international and local investors in Bahrain's economy.

Another important change has been in the structure of GDP itself. Consumption, as a share of GDP, decreased from 65% to 56% over the period 2000-2009. This was due primarily to lower private consumption, followed by a small decrease in public expenditures. Nevertheless, in absolute terms, total consumption increased by 47% between 2000 and 2009, reflecting a strong and growing economy.

The overall structure of the economy also witnessed important changes. As a share of GDP, the oil & gas sector decreased from 25% in 2000 to about 12% in 2009. This was in contrast to other sectors led by the financial sector whose share of GDP grew from 22% in 2000 to 25% in 2009. Other sectors showed increasing shares of GDP: manufacturing grew from 12.0% to 15.3%, construction grew from 3.7% to 6.0%; and transport and communication grew from 7.0% to 8.8%.

Prior to the economic crisis, Bahrain had experienced rising import and export volumes, leading to a trade balance surplus during 2004 – 2007. The services trade balance surplus increased threefold during the same period. The overall balance of payments was a record surplus in 2007, US$2.9 billion compared to US$0.4billion in 2004. While most of this increase was due to higher oil prices, non-energy exports also evidenced substantial increases. Also, net remittances (i.e., money flows to other countries from expatriate labor, net of money inflows) decreased by half; from US$0.6billion in 2004 to US$0.3 billion in 2007.

Between 2003 and 2008, Bahrain enjoyed robust export levels, with oil revenues rising by 172% and exports increasing by nearly as much, 166%. As a result, total wages nearly doubled in nominal terms and total national debt declined from about 37% of GDP in 2003 to 15% of GDP in 2008.

After the global economic crisis in 2008, Bahrain's economic growth slowed dramatically. Oil prices and trade volumes experienced a precipitous decline. This was quickly followed by the accumulation of nearly US$5.3 billion in national debt, a situation that followed nearly 5 years of firm surpluses. While the country was able to avoid recession and performed better that many of its GCC neighbors, average real GDP growth for 2009 dropped to 3.1% - half the rate of the pervious year.

Looking forward, the most pressing economic challenge is Bahrain's fiscal deficit. This is compounded by a stagnant job market which is generating only about 1,100 jobs per year while about 4,000 college-educated Bahrainis are entering the job market each year. Non-Bahraini's are preferred for those relatively few new jobs in the private sector where salaries are over 5 times greater. The Bahraini education system must better equip young people with the skills and knowledge to succeed in their own labor market.

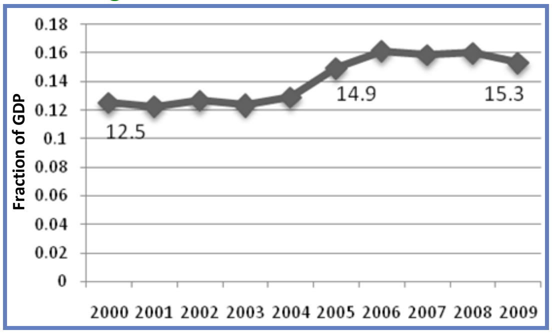
Bahrain's Economic Vision 2030 aims to foster a private sector-driven economy, largely independent of oil. This is in contrast to past policies in which employment and wage imbalances were addressed by oil revenue redistribution and job creation in the public sector. Over time, this has led to an oversized, unsustainable public sector that has become vulnerable to volatility in oil markets.

By encouraging investment in new sectors such as tourism, business services, manufacturing and logistics, Bahrain plans to grow its economy while keeping pace with a recovering global economy. Export-oriented sectors will also be promoted to ensure that Bahraini companies can compete in world markets for products and services as well as create an enabling environment for local innovation.

Industry

Manufacturing and oil production are the most important industrial subsectors of Bahrain's economy. In particular, the manufacturing subsector is critical for achieving several national objectives including technology transfer; diversification of income; and increased employment and exports. These priorities are reflected in the manufacturing share of GDP which grew from 12.5% in 2000 to 15.3% in 2009 (see Figure 1-6), and now accounts for a larger share of GDP than oil production.

Figure 1-6: Industrial share of GDP

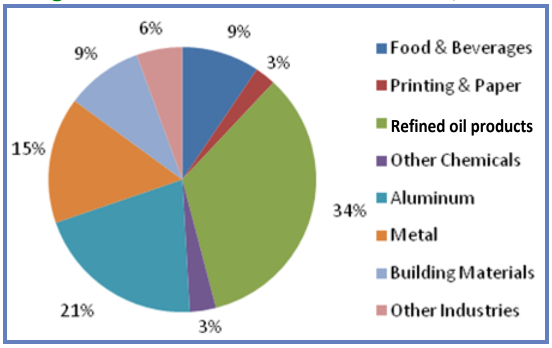


Several measures have been taken to promote this trend since 2005. These measures include liberalizing capital transfer, enabling direct foreign investment, establishing industrial free trade zones, developing port facilities, lessening the burden of administrative procedures, exempting custom duties on industrial equipment and raw materials, supplying cheap energy, providing a trained workforce, and the signing of several important free trade agreements.

Combined, these measures have led to an increase in manufacturing output by 80% over the last 5 years. The manufacturing subsector is a major source of jobs in Bahrain and now employs more people than the oil production subsector – in 2007 manufacturing employed 4,716 people compared to 4,165 for oil production.

Figure 1-7 summarizes the structure of manufacturing sector in 2009. Refined petroleum products and aluminum accounted for the bulk of the value of manufacturing activities, 34% and 21%, respectively. Economic diversification policies have led to an expanding focus on food & beverages, metals, and other chemicals which together accounted for 27% of the value of manufacturing activities. The remaining 18% of manufacturing output value is split among small shares for building materials, printing & paper, and all other industries.

Figure 1-7: Industrial subsector shares, 2009



In 2006, aluminum production was about 1.2 million tones of which nearly 70% was exported. In the same year, the total output of refined oil products was about 1.5 million tonnes, comprising 41.3% urea, 28.7% methanol and 30% ammonia. A major portion of these products, especially urea and methanol, were also exported.

Solid waste associated with industrial activity is disposed of at the Hafira landfill. In 2008, about 7,541 m^3 of industrial waste were added. Industrial non-hazardous liquid waste is disposed of at the Askar landfill and in 2008 the amount was estimated to be 3.8 million gallons. Some liquid waste is exchanged between specialized companies and some is exported. The export of waste in 2008 equaled 396 million tonnes.

There is an increased awareness and interest among officials towards the recycling of waste. Several factories have established facilities to recycle solid waste such as metals, plastic, car batteries and paper. New pollution control technology has been introduced into large factories to limit gas pollution and the need to expand such activities is well recognized.

Water resources

Water supply in Bahrain comes from rainfall, groundwater, desalination, and treated sewage effluent (TSE). Bahrain's groundwater is drawn from the Alat and Khober zones of the Dammam aquifer, as well as the underlying Rus-Umm ErRadhuma aquifer.

Rapid population and economic development growth rates over the last four decades have led to about 4.4%/year growth in water demand over the period 1997-2007. Notably, current water demand levels are more than three times already unsustainable groundwater supply levels, making seawater desalination essential for Bahrain.

The main water-consuming sectors in Bahrain are the municipal, agricultural and industrial sectors. In 2009, these sectors accounted for 219 Mm^3(60%), 144 Mm^3(39%)and 6 Mm^3 (1%) of water consumption, respectively.

Municipal sector water requirements are met mainly by water from desalination plants (203 Mm^3; about 55% of total supply) and are complemented by groundwater (either for blending purposes or to meet deficits), while the agricultural sector water requirements are met mostly by groundwater (126 Mm^3) and tertiary treated wastewater (40 Mm^3).Figure 1-8 illustrates Bahrain water supply and demand for 2009.

Increasing demands for water has caused the gradual depletion and resulting salinization of Bahrain's aquifers, particularly the Kobar zone of the Dammam aquifer. Much of Bahrain's groundwater water is now brackish and must be treated before being used for drinking or industrial purposes.

Bahrain's desalinated water is produced by several desalination plants which use a range of techniques including reverse osmosis, multi-stage flash technology, and multiple effect distillation (Al-Masri and Al-Kaabi, 2009). Several new water projects are currently at various planning stages to enhance production and transmission. These include a new water production plant, a water pipeline from the aluminum production facility, and plant expansion for the Ras Abu Jarjur water desalination facility.

The water sector in Bahrain is governed by three independent entities. The Electricity and Water Authority (EWA)is responsible for the provision and management of water supplies and services, including quality assurance of potable water supplies. The Ministry of Works (MOW) is responsible for wastewater collection, treatment and production of treated sewage effluent. The Ministry of Municipalities and Agriculture (MAM) is responsible for the management of ground water. The high-level Water Resources Council (WRC), established in 1982, coordinates these institutional arrangements.

Looking forward, plans are underway to develop integrated strategies for addressing water supply/demand challenges. These include optimizing water use, minimization of losses, and the increased use of desalinated water and TSE.

Agriculture and land use

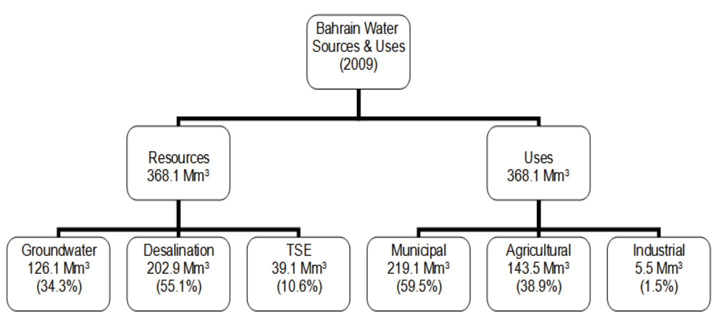
While agriculture is traditionally an important element of the Bahraini economy, it has been declining since the 1970s. Bahrain's food security is highly dependant on imports.

Today, agriculture represents just 0.6% of GDP in Bahrain. This is due to poor soils, limited manpower and continual conversion of land for urban, industrial and recreational development.

Major crops are dates, fruits, vegetables, alfalfa, and other forage crops. Date palms are cultivated on nearly 60% of available arable land while vegetables and alfalfa/forage crops are cultivated on about 18% and 24%, respectively (Al-Masri, 2009).

Figure 1-8: Water supply and demand, 2009

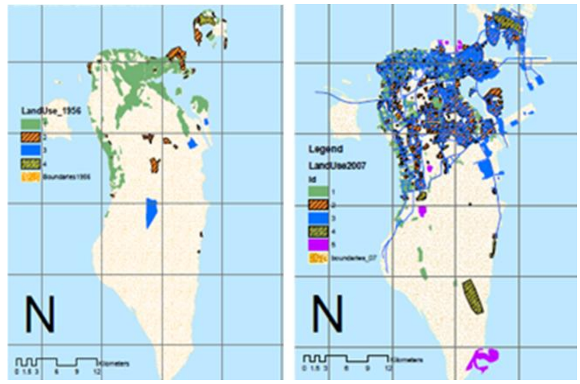
Source: Water resource Directorate, 2009



Arable land is quite limited in Bahrain and is steadily decreasing. In 1985, there were about 11,000 hectares of arable land. In 2009, just 8,360 hectares of land were arable. This represents only 11% of total land area and a loss of available arable land at a rate of about 1.1% per year. These land use trends are illustrated in Figure 1-9 for the years 1956 and 2007.

Figure 1-9: Trends in land use change in Bahrain

The map on the left corresponds to 1956 and shows extensive agriculture (green shaded areas) in the northern parts of Bahrain. The map on the right corresponds to 2007 and shows the replacement of these agricultural areas with urban infrastructure (blue-shaded areas).



Despite efforts to combat the loss of arable land, it continues to decrease. This is attributed to adverse climatic conditions, scarcity of irrigation water, agricultural land abandonment and/or conversion to other economic uses, as well as the lack of interest of young Bahrainis to work in the agricultural sector (FAO, 2002, Annual Agricultural Statistics Bulletin, 2007).

Sustainable water supply is a major challenge for agricultural activities. In a country with very low annual rainfall, there is a necessarily high dependence on irrigation. However, about 75% of irrigation is from groundwater which is being withdrawn at unsustainable levels from the underlying aquifer. Treated sewage effluent and desalinated water account for remaining water supply at 24% and 1%, respectively.

Agricultural activities use a disproportionately high share of scarce water resources relative to their share of GDP. In 2009, agricultural activities consumed about 143.5 million m3 of irrigation water, or about 39% of total water budget in the country (personal communication, Bahrain Water Directorate, 2009). Moreover, agricultural activities accounted for the overwhelming share, about 85%, of groundwater use. The average efficiency of water use in agriculture is also rather low, estimated at only 55%.

Transport

Bahrain has an extensive land, air and marine transport system. Land transportation is dominated by privately owned vehicles. Over the past decade, the number of registered vehicles has more than doubled, rising from 227,108 in 2000 to 465,011 in 2009. Fuel consumption has risen less rapidly than vehicle ownership rates due to rising fuel economies. Additionally, Bahrain limits pollution by using unleaded gasoline only.

On average, there is one car for every two persons. Not surprisingly, this has led to mounting traffic congestion problems. The Bahrain-Saudi causeway has promoted trade with GCC countries and encouraged tourism. However, it has also contributed to more cars entering Bahrain and increased the challenge of traffic congestion.

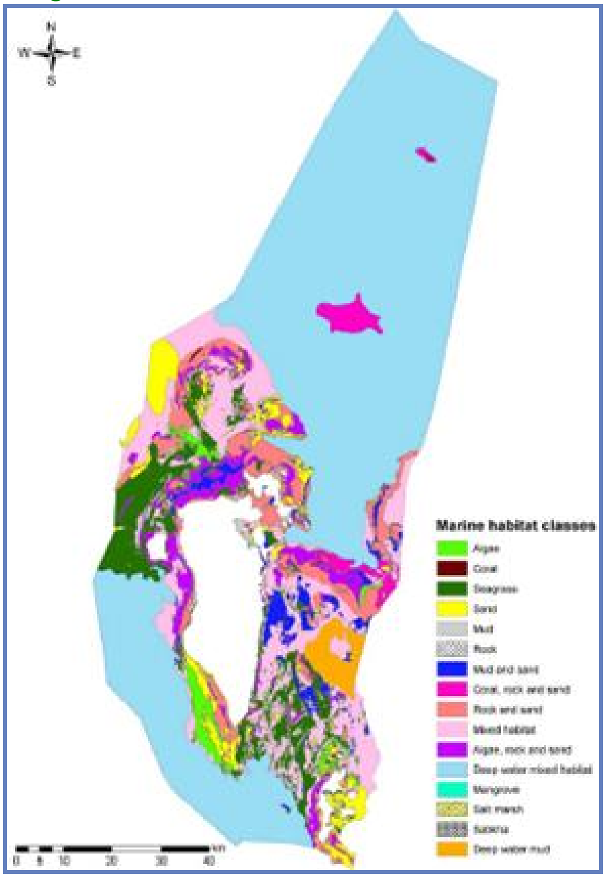
At present, there are two airports. In 2006, the number of plane landings was 40,666 compared to 29,942 in 2000, an annual increase of 5.2%/year.

There are three major harbors located in Manama, Mina Salman, and Sitrah. In 2006, the number of ships anchoring in one of Bahrain's ports was 738 with an annual average of 723 ships during 2002-2006. At present, Bahrain does not have a rail system. However, in 2010 the government commissioned a study to explore the possibility of creating a 194 km rail network by 2030.

Environment

A desert environment dominates Bahrain's terrestrial landscape, except for a narrow fertile strip that is found along the northern and northwestern coastlines (Larsen, 1983). In contrast, Bahrain's marine environment contains a wide variety of habitats that include mangrove swamps, mudflats, coral reefs, sea grass beds, freshwater springs, lagoons and offshore islands (see Figure 1-10). Of these ecosystems, mangroves, sea grass beds and coral reefs are particularly important for supporting marine life.

Figure 1-10: Marine habitats around Bahrain



The Gulf of Salwa which encircles Bahrain has been classified as a distinct bio-geographic province in the Arabian Gulf region. The area is rich in sea grasses and accommodates the largest dugong population outside of Australia. Bahrain's dugong population was estimated in 2006 at 1,164 (Hodgson, 2009). Dugongs are classified as vulnerable to extinction at a global scale (IUCN, 2010). In addition, salt marshes contain a variety of native plant species and are used as a feeding breeding site for birds and other species (Fuller, 2006).

A total of 1,913 species have been identified, 13 of which are potentially threatened, 18 of which are mammals and 25 of which are reptiles or amphibians. In addition, 307 species of flora (Fuller, 2005) and over 330 species of birds have been recorded in the archipelago. About 239 finfish species belonging to 84 families and four marine turtle species have been recorded in Bahrain's waters.

Bahrain acts as an important breeding site for migratory birds such as terns and flamencos (see Figure 1-11). An estimated 2-3 million birds pass through the Gulf each year during their migration between Eurasia and Africa. The Hawar island chain, located about 26km southeast of the main island of Bahrain is a sensitive wetland ecosystem area. The islands possess rich inshore waters that support a variety of fish and other marine organisms and are an important breeding area for resident and migrant sea birds and are internationally designated as an Important Bird Area.

Figure 1-11 Migratory birds in Bahrain

At left are shown nesting Terns on a beach of Rubud Al Gharbiyah on the Hawar Island chain; at right are shown flamencos in flight over the Hawar Islands

Within the Hawar chain, the islands of Rubud Al Gharbiyah and Rubud Ash Sharquiyah are breeding sites for the Western Reef Heron (*Egrettagularisschistacea*) and wintering grounds for Slender Billed Gulls (*Larusgenei*) and Greater Flamingos (*Phoenicopterus*). They are also a staging post for migrant waders.

Bahrain ratified the Convention on Biological Diversity in 1996 and the Convention on the Conservation of Wildlife and Natural Habitats in GCC Countries in 2002 and acceded to RAMSAR in 1997. Institutional management of environmental resources is centered on the Public Commission for the Protection of Marine Resources, Wildlife and the Environment.

With support from the UNDP, Bahrain has developed a National Environmental Strategy (NES) and is in the process of completing a National Biodiversity Strategy and Action Plan (NBSAP) and a National Capacity Self Assessment (NCSA), all of which are important policy initiatives for protecting critical ecosystems and biodiversity in Bahrain. However, these policy efforts have achieved little tangible progress in protecting ecosystems due to financial and institutional constraints. Thus, many of Bahrain's critical ecosystems remain under mounting pressure.

Anthropogenic and climatic factors such as pollutants (e.g. oil, power plant and industrial discharges), urbanization (e.g. dredging and land reclamation), illegal fishing, and invasive alien species (e.g. Indian crow) are placing increasing stress on Bahrain's marine ecosystems. Today coral reefs are in a poor condition, and most reefs within 20-30km of Bahrain Island are in a state of ecological decline due to sedimentation and sea water temperature rise (Al Khuzai, et al., 2009). Mangroves have been declining steadily since 1975, when 300 hectares of mangrove habitat were destroyed by land reclamation activities (Al Zayani, 1999).

The 2006 First National Report on Biological Diversity notes a 12% decline in productive agricultural areas and major reduction in inter-tidal habitats from land reclamation and coastline modifications. The report also noted significant losses in ecosystem integrity across Bahrain, with the exception of the Hawar Islands and southern Bahrain.

The Arabian Oryx, common in Bahrain, was hunted to near extinction but has since been reintroduced to the Hawar islands. Commercial species of fish are in slow decline, as are reptiles, insects and butterflies proportional to loss of habitat. Table 1-1 summarizes projected trends for various ecosystems.

improvements in health care. Health services continue to be offered free of charge to citizens. There are 18 hospitals, 6 maternity clinics, and 24 health centers. Health expenditure as a % of total government expenditure increased from 7.8% in 2000 to 9.3% in 2008. That same year there were approximately 474 people per physician and 19 hospital beds per 10,000 people. The World Bank estimates

Table 1-1: Ecosystem- level biodiversity trends and biodiversity management sectors in Bahrain

The sectors below are prioritized by the Convention on Biological Diversity to promote consistent global categorization (Source: First National Report to the Convention on Biological Diversity, 2005)

Sector	Expected Trends
Agricultural	• Decline in cultivated area • Increase in the introduction of non-traditional crops
In-land Waters	• Depletion of underground aquifer • Increase in salinization of underground aquifer • No likely recovery of freshwater springs
Marine	• Increased pressure from fishing activities leading to decline in commercial species • Hawar Island Protected area remains largely intact
Coastal	• Accelerated coastline modification in the northern Bahrain through “reclamation” with major reduction in inter-tidal habitats
Dry and Sub-Humid	• Reduction in dry habitats in Northern Bahrain • Rock desert habitats remain intact in southern Bahrain

Human Health

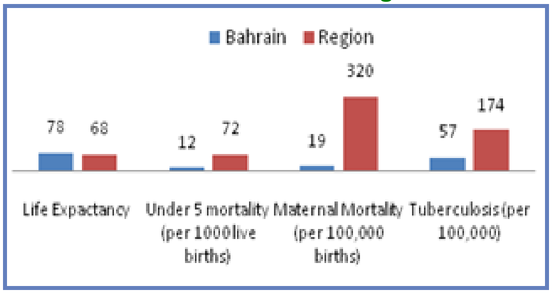
Bahrain’s 2002-2010 Health Strategy seeks to promote stakeholder partnership in improving the health of the population of Bahrain and to ensure universal access to high quality, responsive health services (Ministry of Health, undated). The strategy had adopted 12 strategic goals including; 1) health gain, 2) quality, clinical excellence and performance improvement, 3) primary care development, 4) service development, 5) new investment, 6) partnership working, 7) community involvement, 8) organization and management, 9) human resources, 10) education, research and development, 11) financial management, and 12) information and communication.

Despite high population growth rates, Bahrain has been able to achieve important

access to improved drinking water and sanitation facilities at 100% since 1990.Medical hazardous wastes red is posed of through burning.

Life expectancy at birth increased from 51 years during the period 1950-55, to 74 years (73 for male, 75 for female) in 2009. In addition, virtually all children have been inoculated against children diseases (polio, whooping cough, German measles, tetanus and diphtheria). For children below five years of age, there are approximately 12 deaths per 1,000 live births and there are approximately 19 maternal mortalities per 100,000 live births. Bahrain’s health indicators appear good when compared to regional averages (see Figure 1-12).

Figure 1-12: Key human health indicators for Bahrain and the GCC region



Education and awareness raising

Bahrain has achieved relatively high standards in education. The Bahraini literacy rate among the 15-24 age bracket is 99.7% (CIO, 2010). Furthermore, the adult (15-44 years) illiteracy rate dropped from 2.7% in 2001 to 2.46% in 2010 (CIO, 2010). A comprehensive reform initiative was launched in the country to upgrade the quality of education to global standards, and ensuring compatibility between the educational outputs and the requirements of labor markets.

With the general Education Act of 2005, education for all children below 15 years of age became compulsory. In addition, higher education is available through 2 governmental universities, Bahrain University and Arabian Gulf University, as well as 12 private universities, and specialized training institutes. There has been a steady increase in student enrollment in the past decade at these universities and training institutes (Ministry of Education, 2008).

Formal environmental education is relatively widespread in Bahrain. A number of institutes are offering programs in environmental sciences and management. Yet, environmental awareness throughout Bahraini society has not progressed as rapidly as economic development. Increasing environmental education is being prioritized through actions and programmers taken by the Ministry of education; the Public Commission for the Protection of Marine Resources, Environment, and Wildlife, the Ministry of Works; the University of Bahrain; Arabian Gulf University and seven registered environmental NGOs.

Various programs and initiatives have been launched to promote public awareness of environmental quality. For instance, the ministry of education has incorporated various subjects and issues related to environment in school curricula and many projects like green schools are carried out to a large extent. Ministries such as Water and Electricity promote public awareness on climate change and importance of water conservation and energy efficiency through periodic campaigns. Of particular importance is the Globe program which has been well established in Bahrain as more than 40 schools are participating on and contribute to public awareness among community and participated students.

Towards Sustainable Development

Bahrain has made specific progress in meeting its Millennium Development Goals (MDGs) and towards sustainable development in general (CIO 2010). With few exceptions, MDG #1 (Eradicate Extreme Poverty and Hunger), MDG #2 (Achieve universal primary education), MDG #4 (Reduce Child Mortality), MDG #5 (Improve Maternal Health) and MDG #6 (Combat HIV/AIDS, Malaria, and other Diseases) have been achieved.

Unrealized MDGs remain a high priority for national authorities. Specifically, MDG #3 (Promote Gender Equality And Empower Women)has been given high priority and progress on this goal is envisaged in near future. Regrettably, MDG #7 (ensuring environmental sustainability) still represents a major challenge. Substantial achievements have been reported in some areas, though other high priority issues have witnessed a slower rate of progress. Finally, there is strong evidence that MDG #8 (integration into the world economy and the use of technology) is progressing well in general.

The MDG's are being integrated into national planning and implementation of strategies. Bahrain is committed to promoting sustainable development practices throughout all sectors and will continue working towards consolidating the achievements made for certain goals and prioritize activities to meet those MDGs as yet unrealized.

Institutional Framework for National Communications

Bahrain is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), becoming a party to the Convention on 28March 1995. The Initial National Communication (INC)was prepared in a participatory approach by national teams under the auspices of National Steering Committee. Financial and technical assistance was provided by GEF-UNEP and INC was submitted in 2005.

Benefiting from the experience gained from the preparation of the INC and taking into consideration that climate change is the epitome of a cross-cutting issue, the national steering committee widened participation processes in the Second National Communication (SNC) to include more public and private involvement discussions in all topics addressed in the report. This was reflected in increasing number of participating institutions, local experts and consultative meetings and workshops that have been held across the country.

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2

Greenhouse Gas Inventory

This chapter presents estimates for the Kingdom of Bahrain of national anthropogenic greenhouse gas emissions (GHG) and sinks for the year 2000. The inventory includes five categories: energy; industrial processes; agriculture; land use, land use change and forestry (LULUCF) and waste.

Methodology

To ensure that Bahrain's GHG emissions inventory is comparable to those of the other parties to the UNFCCC, the results presented here are based on the methodology described in the Revised 1996 *IPCC Guidelines for National Greenhouse Gas Inventories*(IPCC, 1996) and the IPCC Good Practice *Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (Good Practice Guidance; IPCC, 2000) prepared by the Intergovernmental Panel on Climate Change (IPCC). As recommended by the IPCC Guidelines, country specific methods have been used as appropriate for certain GHG emitting sectors.

In the subsections that follow, GHG emissions are reported both in absolute units of carbon dioxide, methane and nitrogen oxide emissions, as well as in units of CO_2-equivalent by applying 100-year global warming potentials (GWP)of 1 for CO_2, 21 for CH_4, 310 for N_2O nitrous

oxides, 6,500 for CF_4 and 9,200 for C_2F_6, as recommended by the IPCC in its Second Assessment Report (IPCC, 1995).

Total GHG Emissions

Table 2-1 presents total GHG emissions and sinks for the year 2000. Total GHG emissions in 2000 were 22,374Gg CO_2-equivalent, which includes17,254Gg from energy; 2,515 Gg from industrial processes; and 2,605Gg from waste.

The agriculture and land use change and forestry sectors are so small in Bahrain that emissions were assumed to be zero. Emissions from perfluorocarbons (PFCs) from aluminum production are small, while data was unavailable for estimating emissions of sulfur hexafluoride (SF_6) and hydrofluorocarbons (HFCs).

Table 2-1: Total GHG emissions in Bahrain, 2000 (Gg)

GHG Sources & Sinks	CO_2-equiv	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	PFCs
1 Energy	17,254	15,951	61	0	51	138	26	16	0.000
2 Industrial Processes	2,515	2,219	0	0	2	104	21	11	0.044
3 Solvent& Other Product Use	0	0	0	0	0	0	0	0	0.000
4 Agriculture	0	0	0	0	0	0	0	0	0.000
5 Land-Use Change & Forestry	0	0	0	0	0	0	0	0	0.000
6 Waste	2,605	0	124	0	0	0	0	0	0.000
Total National Emissions	22,374	18,169	185	0	52	242	47	26	0.044
Net National Emissions	**22,374**	**18,169**	**185**	**0**	**52**	**242**	**47**	**26**	**0.044**

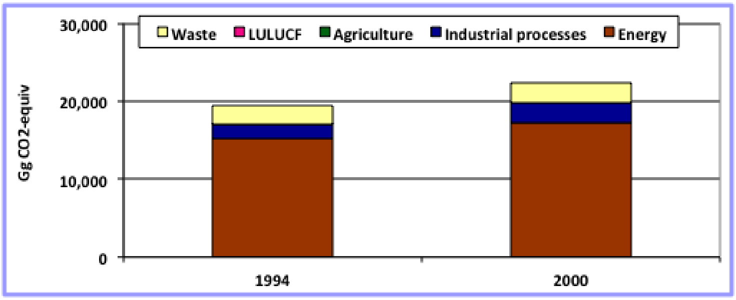
Energy-related activities accounted for the dominant portion of GHG emissions in Bahrain in 2000. Approximately 77% of all GHG emissions are associated with the combustion of fossil fuels or the release of fugitive emissions from oil and gas operations. Industrial processes accounted for about 11% of all GHG emissions, followed by the waste sector that accounted for about 12% of total emissions.

GHG Emission trends

Figure 2-1 presents the trend in total GHG emissions for 1994, the year of the initial GHG inventory, and 2000. GHG emissions have increased by about 15%; from 19,468 Gg of carbon dioxide-equivalent (CO_2e) in 1994 to 22,374Gg CO_2e in 2000. Emissions from energy and industrial processes increased by roughly 13% and 33%, respectively. Waste emissions also increased although by a smaller amount, 12%.

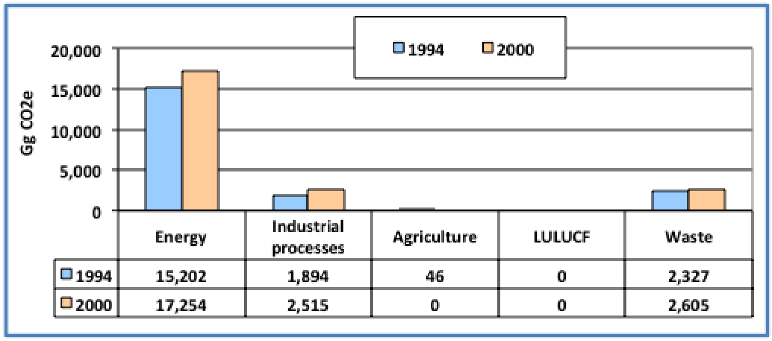
Figure 2-2 compares GHG emissions for all sectors for the years 1994 and 2000. Over the period, CO_2e emissions from energy use have been growing about 2.3% per year. As the average annual GDP growth rate during this period was about 6.1% per year, or roughly three times higher than the GHG growth rate, Bahrain's carbon intensity relative to economic output has shown considerable improvement during this period.

Figure 2-1: Total GHG emission trends, 1994 & 2000



Much of the growth in GHG emissions is due to increases in energy use for power generation and process heat in manufacturing industries. In addition, industrial GHG emissions grew at a faster rate (i.e., 4.8% per year) than the national average due in large part to the increasing role of the manufacturing sector in achieving national economic development objectives, particularly the aluminum and ammonia production industries.

Figure 2-2: Total GHG emission trends, 1994 & 2000



Energy

Table 2-2 summarizes GHG emissions associated with energy activity in 2000. Relative to overall anthropogenic GHG emissions, the 17,254Gg CO_2-equivalent represented about 77% of total national emissions. All activity data for energy production and consumption was acquired from energy and trade statistics available from the national statistics office.

GHG emissions from energy activities are due to fossil fuel combustion and fugitive emissions from oil and gas exploration activities, electric power generation, transport, and industrial production activities. Fuel combustion emissions are associated with the use of natural gas as well as a variety of petroleum products such as gasoline, diesel, liquefied petroleum gas (LPG) and kerosene.

All refined petroleum products are produced in national refineries from locally produced (15%) and imported (85%) crude oil. Natural gas is used exclusively for power production and process heat in manufacturing processes. All of the diesel and gasoline are consumed in road transport for cars, light duty trucks, buses, and heavy duty trucks. Bahrain has no light rail system.

Relatively small quantities of diesel are used for power production during peak periods and for some industrial processes. LPG is used in the residential and commercial/institutional sectors solely for cooking. Relatively small quantities of kerosene are used for cooking and lighting purposes in certain commercial establishments.

Figure 2-3 illustrates the breakdown in energy-related GHG emissions in 2000 by consuming activity. Industrial activities in the form of manufacturing (mostly aluminum and ammonia production) and construction activities accounted for about 42% of all energy-related emissions. Power production is based overwhelmingly on the use of natural gas and accounted for

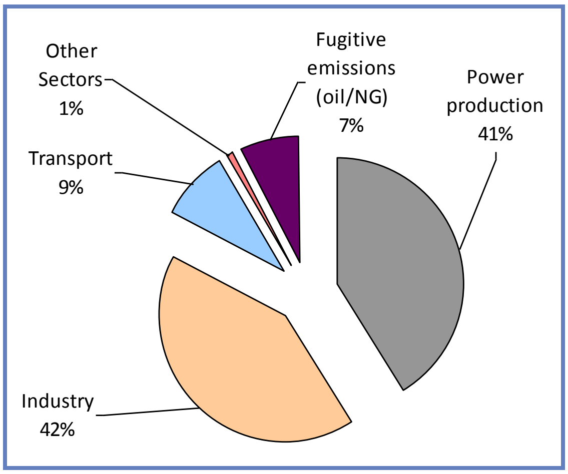
Table 2-2:GHG emissions from energy use, 2000 (Gg)

GHG Source Categories	CO_2-equiv	CO_2	CH_4	N_2O	NO_x	CO	NM VOC	SO_2
All energy emissions	**17,254**	**15,951**	**61**	**0**	**51**	**138**	**26**	**16**
A Fuel Combustion Activities	*15,979*	*15,951*	*1*	*0*	*51*	*138*	*26*	*16*
1 Energy Industries	7,090	7,083	0	0	18	2	1	7
2 Manufacturing Industries & Construction	7,193	7,187	0	0	18	4	1	7
3 Transport	1,514	1,498	1	0	14	132	25	2
4 Other Sectors	183	183	0	0	0	0	0	0
B Fugitive Emissions from Fuels	*1,275*	*0*	*61*	*0*	*0*	*0*	*0*	*0*
1 Solid Fuels	0	0	0	0	0	0	0	0
2 Oil and Natural Gas	1,275	0	61	0	0	0	0	0
Memo Items	*1,115*	*1,111*	*0*	*0*	*5*	*2*	*1*	*0*
International Bunkers	1,115	1,111	0	0	5	2	1	0
CO2 Emissions from Biomass	0	0	0	0	0	0	0	0

about 41% of total emissions from energy-consuming activities in Bahrain.

Notably, fugitive emissions of methane, a gas that has a high global warming potential equal to 21 times that of carbon dioxide, accounted for about 7% of all GHG emissions in the energy industries sector, as Bahrain continues to be a supplier of the world's energy needs. Transport emissions for road transport, with fuel use split about 27% diesel and 73% gasoline, accounted for about 9% of total emissions from the energy sector in 2000.

Figure 2-3: Breakdown of GHG emissions associated with energy activities, 2000



Industrial Processes and Other Product Use

Table 2-3 summarizes GHG emissions associated with industrial processes and product use in 2000. Industrial processes are the second largest emitter of anthropogenic GHG emissions in Bahrain, accounting for 2,515Gg of CO_2e, or about 11% of national CO_2e emissions in 2000.

Activity data for the industrial sector was based on Trade Statistics and surveys of key industries. Metal production (i.e., aluminum production) accounted for the largest share of industrial process emissions, about 75%; followed by chemical production (i.e., ammonia) at about 25%. Notably, there are no emissions from mineral production as there is no cement production in Bahrain

Agriculture

Given its hyper-arid environment, the level of agricultural activity is quite small in Bahrain. Moreover, as a fraction of national levels, emissions from agriculture are typically small. For these reasons, they have been assumed to be zero in the updated GHG inventory.

Land use change and forestry

As noted in the previous chapter, there has been considerable land use change in Bahrain. In contrast to other countries where land use change is from clearing forested land for agricultural activities, Bahrain's land use change during the period of the update (i.e., 1994-2000) is due to land reclamation of its marine

Table 2-3: GHG emissions from industrial activity, 2000 (Gg)

GHG Source Categories	CO_2-equiv	CO_2	CH_4	N_2O	NO_x	CO	NM VOC	SO_2	CF_4	C_2F_6
Industrial Processes	**2,515**	**2,219**	**0**	**0**	**2**	**104**	**21**	**11**	**0.04**	**0.004**
A Mineral Products	0	0	0	0	0	0	19	0	0	0
B Chemical Industry	639	639	0	0	0	3	2	0	0	0
C Metal Production	1,877	1,580	0	0	2	100	0	11	0.04	0.004
D Other Production	0	0	0	0	0	0	0	0	0	0
E Production of Halocarbons & SF_6	0	0	0	0	0	0	0	0	0	0
F Consumption of Halocarbons & SF_6	0	0	0	0	0	0	0	0	0	0
Total Solvent and Other Product Use	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	0
A Paint Application	0	0	0	0	0	0	0	0	0	0
B Degreasing and Dry Cleaning	0	0	0	0	0	0	0	0	0	0
C Chemical Products, Manufacture & Processing	0	0	0	0	0	0	0	0	0	0
D Other	0	0	0	0	0	0	0	0	0	0

environment for residential, commercial, and industrial activities. As such, incremental GHG emissions from land use change are captured in the other categories of the emissions inventory (i.e., energy, industrial processes, and waste).

Land use is also associated with the abandonment of agricultural lands. This is not pertinent for Bahrain except in the case of coastal date palms which undergone deterioration in the recent past and have lost their capacity for the sequestration of carbon.

However, there is inadequate data and information for developing an assessment of the net GHG emissions impact associated with these developments. A process is underway to provide an estimate of coastal palm degradation for the update to the GHG emission inventory for the next national communication.

Waste

Table 2-4 summarizes GHG emissions associated with waste management activity in 2000. Relative to overall anthropogenic GHG emissions, the 2,605Gg CO_2e represented about 12% of total national emissions. Sources for waste management data included expert judgment regarding municipal solid waste management in Bahrain, published literature on population from the Ministry of Planning, and available data from waste treatment plants.

The main types of waste generated in Bahrain are municipal solid waste (MSW), municipal wastewater, and other wastes.

Regarding MSW, levels have been increasing at an average annual rate of 2.9% (Khonji, 2008), a rate that is less than half the population growth rate of 7.0% per year as noted in the previous chapter (CIO, 2009). The principal components of municipal solid waste are food, paper, wood, textiles, nappies rubber, leather, plastics, metals, glass, and others (e.g. ash, dirt, dust, soil, electronic waste, disposable diapers).

Since the 1970s, most of the municipal wastewater produced by the residential, commercial, and industrial sectors has been processed at the central Tubli Water Pollution Control Centre (WPCC). Other parts of the population are served by private as well as municipal fleet of tankers that transport the contents of local septic systems to the main treatment center at Tubli (Al-Masri, 2010).

Regarding other wastes, these include by products generated at health-care facilities, research centers/units and laboratories, including health-care waste generated at home. Hazardous health care waste includes infectious, pathological, pharmaceutical, genotoxic, chemical, heavy metal and radioactive waste and accounts for about 0.08% of Bahrain's total waste stream (Rasool, 2009). Bahrain is also producing increasing amounts of electronic waste (e-waste) which contains plastic and harmful heavy metals such as lead and mercury. Information on actual e-waste levels is currently lacking.

As shown in Table 2-4, the main source of greenhouse gases within Bahrain's waste sector is MSW, which accounted for nearly all waste-related emissions. Domestic and commercial

Table 2-4: GHG emissions from waste management activity, 2000 (Gg)

GHG Source Categories	CO_2-equiv	CO_2	CH_4	N_2O	NO_x	CO	NM VOC	SO_2
All Waste Emissions	**2,605**	**0**	**124**	**0**	**0**	**0**	**0**	**0**
A Solid Waste Disposal on Land	2,600	0	124	0	0	0	0	0
B Wastewater Handling	5	0	0	0	0	0	0	0
C Waste Incineration	0	0	0	0	0	0	0	0
D Other (please specify)	0	0	0	0	0	0	0	0

wastewater handling accounted for small amount of total waste-related emissions.

Emissions of PFCs, HFCs, and SF_6

According to the Revised IPCC Guidelines, the major emission sources of PFCs, HFCs, and SF_6 these gases are the following activities: replacement of ozone-depleting substances; HCFC-22 production; electric power transmission; production of primary aluminum; production of semiconductors; and production and processing of magnesium.

Only the third and fourth of the above activities occur in Bahrain (i.e., aluminum production and power transmission). PFCs and HFCs were not produced or imported/consumed as substitutes for ozone depleting substances in refrigeration and fire extinguishers because ozone-depleting substances were not banned in Bahrain in 2000.

The estimation of SF_6 emissions associated with electric power transmission proved to be a significant challenge due to data constraints and was assumed to be negligible.

Uncertainty Assessment

An uncertainty assessment was considered to be an essential element of the GHG emission inventory update to help prioritize efforts to improve the accuracy of future inventories. In Bahrain, uncertainties are associated with data access/constraints, potential unsuitability of generic emission factors, and an in complete understanding of the processes associated with emissions.

Some of the current estimates, such as CO_2 emission factors for energy production and consumption activities are considered to have

Table 2-5: Uncertainty assessment associated with Bahrain GHG inventory, 2000

		Uncertainty Assessment		Confidence in
Sector	Activity	emission factor	data quality	Inventory results
Energy	Public Electricity and Heat Production	low uncertainty	good quality	High
	Domestic Aviation	low uncertainty	medium quality	medium
	Road transport	low uncertainty	medium quality	medium
	Commercial/Institutional	low uncertainty	medium quality	medium
	Residential	low uncertainty	medium quality	medium
	Agriculture/Forestry/Fishing	low uncertainty	medium quality	medium
	International aviation (bunkers)	low uncertainty	medium quality	medium
Industrial processes	Cement production	Not applicable	Not applicable	Not applicable
	Lime production	Not applicable	Not applicable	Not applicable
	Limestone and Dolomite Use	Not applicable	Not applicable	Not applicable
	Soda ash production and use	Not applicable	Not applicable	Not applicable
	Production and use of miscellaneous mineral products	Not applicable	Not applicable	Not applicable
	Ammonia Production	medium uncertainty	good quality	medium
	Nitric acid production	Not applicable	Not applicable	Not applicable
	Adipic acid production	Not applicable	Not applicable	Not applicable
	Carbide production	Not applicable	Not applicable	Not applicable
	Production of other chemicals	Not applicable	Not applicable	Not applicable
	Iron/steel production	medium uncertainty	good quality	medium
	Aluminum production	medium uncertainty	good quality	medium
Agriculture	Enteric fermentation	Not applicable	Not applicable	Not applicable
	Manure management	Not applicable	Not applicable	Not applicable
	Agricultural Soils	Not applicable	Not applicable	Not applicable
LULUCF	Changes in Forest and Other Woody Biomass Stocks	Not applicable	Not applicable	Not applicable
Waste	CH4 emissions from SWD sites	medium uncertainty	poor quality	low
	CH4 emission from Domestic and Commercial Waste water	medium uncertainty	medium quality	Medium
	N2O emissions from human waste	medium uncertainty	good quality	Medium

minimal uncertainty associated with them. For some other emission factors that rely on local input such as per capita protein consumption, there is a lack of information that increases the uncertainty surrounding the estimates presented in this chapter. Many categories are not applicable to Bahrain.

Table 2-5 summarizes the uncertainty assessment for Bahrain GHG inventory. Based on expert judgment of specialists participating in the development of the inventory, the confidence in the results for each source/sink category was evaluated relative to the uncertainty associated with data quality and emission factor suitability. Less than 10% uncertainty was considered to be low; uncertainty between 10% and 50% was considered medium; and uncertainty greater than 50% was considered high.

Attention to two areas could help reduce uncertainty in Bahrain GHG inventory. First, enhancing the availability of detailed and high quality activity data will increase confidence in the inventory results. Although adequate methodologies have been developed to estimate emissions for some sources, problems arose in obtaining activity data at a level of detail in which aggregate emission factors can be applied. Addressing these areas through additional capacity strengthening and development of dedicated observation networks will enhance the quality and accuracy of future emission inventories.

Second, improving the accuracy of emission factors to calculate emissions from a variety of sources is vital. Most of the emission factors noted in the above table are classified as having medium uncertainty (i.e., uncertainty between 10% and 50%). For example, the accuracy of current emission factors for enteric fermentation by animals at low altitude and subject to high temperatures throughout the year remains uncertain in the absence of local sampling and testing activities.

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3

Vulnerability and Adaptation

The Kingdom of Bahrain, being located in an arid region, already experiences high climatic variability, which is typical of arid regions. With climate change, it is expected that future increases in climatic variability will lead to adverse impacts on a number of vulnerable sectors, systems, and livelihoods in the country. Indeed, recent scientific assessments of climate change impacts on Bahrain indicate that the country is increasingly vulnerable to current and projected changes. It is also clear that strategies for adaptation are essential to increase the nation's resilience.

During the past several years, the Kingdom of Bahrain undertook and completed a major climate change impact assessment that addressed four key sectors; coastal zones, water resources, human health, and biodiversity. The assessment has helped to develop a better understanding of climate change impacts and vulnerabilities to assist policymakers in the identification, design and implementation of potential adaptation measures. All of the assessments have been peer-reviewed by scientists, and government officials.

The results of the assessment have been shared with a wide range of stakeholders in Bahrain, including both the general public and private sector. It is now providing the basis for initial efforts to incorporate climate change into planning decisions made by policymakers, national agencies, and other stakeholders. As this chapter demonstrates, the motivation for adaptation is clear, and movement is underway to initiate and coordinate action. Some of the key findings are summarized in the sections below.

Coastal Zones

The Kingdom of Bahrain is a small island state where almost all of the population and development activities are located in close proximity to the coastline, with very limited capacity to adapt to sea-level rise (SLR). Most of the coastal areas of the islands do not exceed 5 meters above current mean sea level and it will be physically and economically difficult, if not impossible, to establish zoning setbacks for new development or for marine habitats to migrate toward higher land elevations. This is particularly true for Bahrain's main island as illustrated by the topographic contour map of Figure 3-1.

Bahrain's coastal zones support both a vibrant marine environment and an extensive built environment. The marine environment is an important natural resource for its people. However, these areas are already under intensive pressure from anthropogenic causes including pollution and extensive dredging and land reclamation activities. In recent decades, over 150 km^2 of marine habitats have been irreversibly lost due to land reclamation, putting increasing pressures on the biodiversity of the marine environment, especially coral reefs of which over 80% are endangered due to bleaching events and marine pollution and habitats for endangered green turtles.

Also under threat is the continued availability of fish stocks and viability of marine nursery functions that support green turtle and dugong populations. As marine ecosystems around Bahrain currently exist near their upper tolerances, future changes in water temperatures; salinity and mean sea levels will likely further exacerbate what is already a highly threatened marine environment.

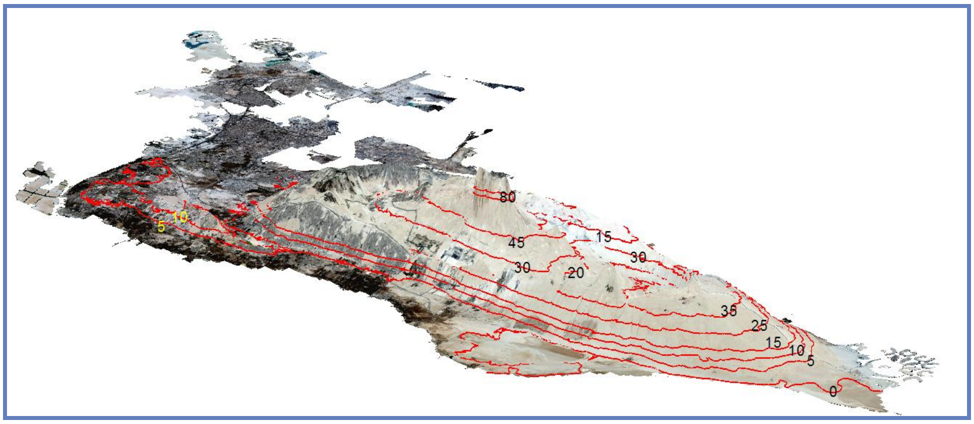
Bahrain's coastal built environment supports critical infrastructure such as roads, buildings, and telecommunications, as well as extensive commercial and industrial activities. Over the past decades, sea level rise in the Arabian Gulf has shown a trend between about 2.1 and 2.3 mm per year (Sultan et al., 1995 and Ayhan and Alothman, 2009, respectively), roughly consistent with the IPCC's global average estimates. Future sea level rise could potentially lead to large areas of Bahrain's built environment exposed to inundation, increased erosion, and other risks. The results of a quantitative assessment of these risks are summarized below based on a study by Aljenaidet al., 2010.

Methodological approach

In order to account for both near-term and long-term impacts associated with sea level rise, two methodologies were applied. A scenario-based inundation analysis was carried out to

Figure 3-1: Contour map of Bahrain's main island

Bahrain's coastal areas are highly vulnerable to sea level rise as elevations are typically between 0.5 to 2 m above mean sea level. Contour lines on the map below show the results of digital elevation modeling assembled from 350,000 spot elevations.



examine long-term impacts relative to the latest IPCC sea level rise projections in the Fourth Assessment Report (IPCC, 2007). To support near-term coastal zone planning, a vulnerability indexing approach was used, adapted from methods applied successfully elsewhere.

Both methods relied on a range of governmental sources including high-resolution digital satellite images, aerial photographs, analogue/digital maps, bathymetric data, soil/geology maps, regional scientific literature, and IPCC findings. These data were integrated into a GIS analysis framework to produce a set of 2-D maps of vulnerable areas.

The methodology for the scenario-based inundation analysis consisted of several steps. First, sea level rise scenarios that could be instructive for purposes of bracketing the potential threat were developed on the basis of literature review and stakeholder consultations. Three scenarios were developed that account for uncertainties associated with the rate of glacial ice melting and its impact on sea level rise projections. Two snapshot years were considered; 2050 and 2100. Table 3-1 summarizes the sea level rise scenarios used in the inundation analysis.

A digital elevation model was developed for the terrestrial built environmental of Bahrain and its major islands based on 350,000 terrestrial spot elevations. Interpolations were carried out using inverse distance weighted methods which resulted in a vertical resolution of about 30 cm. Eight (8) different land use cover types developed on the basis of satellite imagery were integrated into the digital mapping framework to provide details regarding specific land use types that would be impacted by rising sea levels. Figure 3-2 shows current built-up and industrial areas accounting for 245km^2 out of a total land area of 748km^2 (about 34%), and are located largely along the eastern coastline of Bahrain's main island.

Finally, the spatial extent of inundated area from the sea level rise scenarios was quantified by layering each climate change scenario onto the digital elevation model. Vulnerable areas subject to future inundation from sea level rise were identified and disaggregated by land use type.

The methodology for the near-term planning was based on a coastal vulnerability index (CVI) approach. The CVI approach combines coastal susceptibility to change with the ability of coastal systems to adapt to changing environmental conditions, yielding a quantitative relative measure of coastal areas where vulnerability to sea level rise may be high.

The entire coastline of the main islands (i.e., Bahrain, Muharraq, Sitra, and Nabiah Saleh) was evaluated relative to six variables, as briefly described in the six bullets that are shown below:

- *Geology*: This corresponds to the rock or soil types along the shoreline.

- *Coastal slope*: This corresponds to the slope of the shoreline, measured in degrees.

Table 3-1: Sea level rise scenarios

The scenarios below represent the projected sea level rise (meters) above historical mean sea level in the Arabian Gulf area around Bahrain. The scenarios are descriptive only, and not meant to be understood as actual sea level rise projections for the Arabian Gulf. Rather they are intended to support decision-making in the face of uncertainty.

Scenario No.	Scenario Name	2050	2100
1	No accelerated deglaciation	0.3	1.5
2	Low deglaciation rate	0.5	2.0
3	Extreme deglaciation rate	1.0	5.0

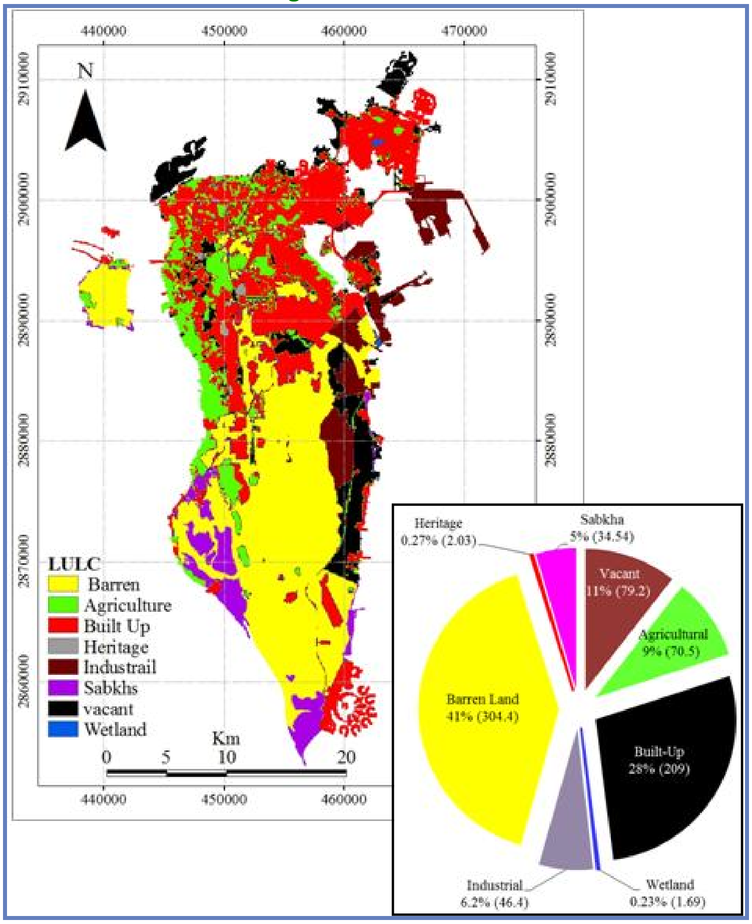
- *Geomorphology*: This corresponds to the type of landforms present (e.g., dunes, coastal structures).

- *Elevation*: This corresponds to land height above mean sea level, measured in meters.

- *Shoreline change*: This corresponds to historical erosion rates, measured in meters lost or gained per year.

- Rate of sea-level rise: This corresponds to historical rates of seal level rise, measured in mm per year.

Figure 3-2: Land use



These variables were evaluated for 5-meter by 5-meter grid cells covering 717 km of coastline (roughly 214km^2) for the main island. Each variable was characterized for each grid cell based on a linear scale from 1 (very low vulnerability) to 5 (very high vulnerability).

Some variables were readily characterized for the entire coastline due to the uniformity of physical conditions. For example, the rock type variable for all coastal segments was assigned high vulnerability (i.e., a value of 4) due to the prevailing sandy clay loams and sabkhs that exist throughout the coastal area; the sea level rise variable was assigned medium vulnerability (i.e., a value of 3) due to an assumed near-term rate of sea level rise of up to 2 mm per year, applicable to all coastal areas. Other variables showed more granularity. For example, coastal slopes of less than 6° were considered highly vulnerable (i.e., a value of 5), while slopes between 20° and 45° were considered to have low vulnerability (i.e., a value of 2).

Table 3-2: Results of the long-term inundation scenario analysis

The results below are based on the GIS mapping analysis. The values represent projected impact of permanent submergence of low-lying lands on the main islands of the Kingdom of Bahrain associated with the three sea level rise scenarios, disaggregated by land use type. Percentages in the rows corresponding to the eight land use types refer to the share inundated for those land types.

		No accelerated deglaciation				Low deglaciation rate				Extreme deglaciation rate			
		2050 *(SLR=0.3 m)*		2100 *(SLR=1.5 m)*		2050 *(SLR=0.5 m)*		2100 *(SLR=2.0 m)*		2050 *(SLR=1.0 m)*		2100 *(SLR=5.0 m)*	
Land use type	**Total area (km2)**	**Inundation (km2)**	**(%)**	**Inundation (km2)**	**(%)**	**Inundation (km2)**	**(%)**	**Inundation (km2)**	**(%)**	**Inundation (km2)**	**(%)**	**Inundation (km2)**	**(%)**
Built Up	209	10	5%	46	22%	10	5%	64	31%	46	22%	126	60%
Industrial	46	8	17%	29	63%	8	17%	32	69%	29	63%	38	82%
Vacant	79	5	7%	24	30%	5	7%	27	34%	24	30%	38	48%
Agriculture	71	5	7%	15	21%	5	7%	23	32%	15	21%	57	80%
Wetland	2	1	69%	1	77%	1	70%	1	80%	1	74%	2	100%
Barren	304	29	10%	52	17%	29	10%	68	22%	51	17%	122	40%
Heritage	2	0	0%	0	0%	0	0%	0	0%	0	0%	0	1%
Sabkhs	35	26	75%	33	97%	26	76%	34	98%	33	97%	35	100%
Total	**748**	**83**	**11%**	**200**	**27%**	**84**	**11%**	**248**	**33%**	**199**	**27%**	**418**	**56%**

Once all shoreline cells had been scored for each variable, the CVI was calculated as the square root of the product of the ranked variables divided by the total number of variables as per Gorntizet al (1997). CVI values ranged from about 7 to 35 and showed significant variation depending on the location of coastline segments.

Impacts

Table 3-2 summarizes the results of the long-term inundation analysis under each scenario for the years 2050 and 2100. As shown in the table, the Kingdom of Bahrain faces the prospect of severe land loss in the future from climate change induced sea level rise.

Even under the "no accelerated deglaciation" scenario, 83 km^2, or 11% of the total land area, would be lost by 2050 from a 0.3-meter increase in mean sea level. Approximately 18km^2 of built-up and industrial areas would be under water. These areas account for about 7% of these areas, about 2% of the country's entire land area, and a substantial portion of its socioeconomic activity.

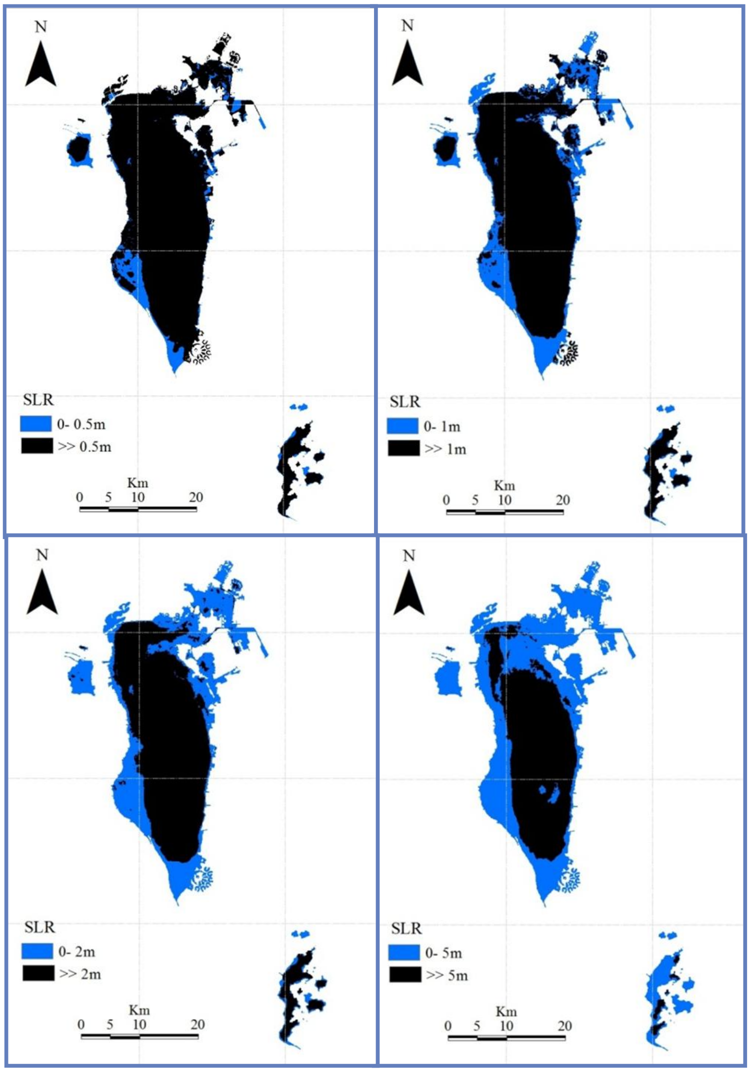
Under the "extreme deglaciation rate" scenario, 418km^2, or 56% of the total land area, would be lost by 2100 due to a 5-meter increase in mean sea level. Of this amount of inundated land, 164km2 would correspond to built-up and industrial areas, roughly 64% of these areas and about 22% of the country's entire land area.

Figure 3-3 provides a set of maps that spatially link the above inundation results to specific areas in Bahrain that are expected to be impacted under the lower and upper bounds of potential sea level rise scenarios.

For the lower bound of sea level rise, the map on the top left of Figure 3-3 shows that in 2050 the majority of the inundated area from a 0.3-meter sea level rise would mostly be in low-lying industrial areas in the northeast as well as in the southeastern region of the country where sabkh areas (i.e., uninhabited sand flats) are prevalent. In 2100, all coastal areas show substantial loss of land due to rising sea levels, with the built-up and industrial areas along the east of the main

Figure 3-3: Sea level rise impacts in Bahrain

The figures below represent the spatial range of inundation for Bahrain under the "No accelerated deglaciation" scenario (top) and "Extreme deglaciation rate" scenario (bottom). The maps on the left correspond to the year 2050; the maps on the right correspond to the year 2100.



island showing the greatest impact, as shown in the top right map of Figure 3-3.

For the upper bound of sea level rise, the map on the bottom left of Figure 3-3 shows that in 2050 the majority of the inundated area from a 1.0-meter sea level rise would completely submerge much of the low-lying built-up and industrial areas in the northeast as well as virtually all of the sabkh areas in the southeastern region of the country.

In 2100, all coastal areas show severe loss of land due to rising sea levels, with the extent of inundation in built-up and industrial areas along the northern portion of the main island reaching about 10 km inland, as shown in the bottom right map of Figure 3-3. Those lands that would remain above sea level in 2100 are barren and uneven rocky terrain of sharp topographic relief and are currently considered unsuitable for development.

Regarding near-term vulnerability, Figure 3-4 summarizes the CVI assessment results. To identify specific vulnerable hotspot areas, the entire coastline of Bahrain's main island was classified into one of four levels of vulnerability; low, moderate, high, and very high.

Bahrain's near-term vulnerable hotspots (i.e., classified as having very high vulnerability) are located along the central portions of the western and eastern coastlines. The vulnerability of these areas is mostly driven by their characteristically shallow coastal slopes, low elevations, and erosion-prone nature of the sandy soils present. These areas comprise a total of 54km, or about 8% of the shoreline and should be the priority focus of near-term adaptation planning.

Another 33km of coastline are classified as highly vulnerable (5%). As shown on Figure 3-4, these areas are located along the eastern coast adjacent to the vulnerable hot spots. In addition, the western coast of the southern tip of the main island is also a highly vulnerable area. For the purposes of adaptation planning, these areas are also considered priority vulnerable hotspots.

The remaining coastal areas are classified as low to moderate vulnerability. Comprising a total length of 630km (88% of the total length of the coastline), these areas benefit from a combination of hard coastal protection structures and high rates of shoreline change (i.e., reclamation activities).

Adaptation

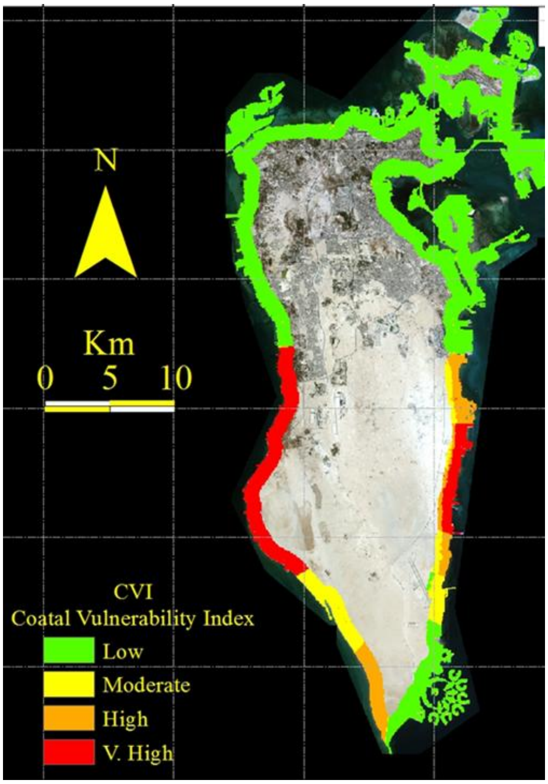
The major implication from the previous discussion is that mainstreaming adaptation to account for the impact of sea level rise needs to be integrated as soon as possible into the national policymaking process.

Adaptive measures to mitigate the impact of inundation and coastal erosion typically involve retreat, protection and accommodation. However, as a small island state, "retreat" is not an option for Bahrain as over 50% of its residential communities, resorts, industrial compounds, and other infrastructure are located on land less than 5 meters above sea level. Moreover, "accommodation" will likely prove prohibitive due to the heavy costs involved in dealing with a steady state of significantly higher sea levels.

Therefore, "protection" remains the only adaptation option for Bahrain in the long-run. This is particularly true given that coastal development and shore protection are interconnected and can be mutually reinforcing. As summarized in the bullets below, a mix of responses including capacity strengthening, integrated planning, local/regional stakeholder engagement, and hard coastal protection are core principles underlying a future climate change adaptation plan for Bahrain's built-up coastal areas.

Figure 3-4: Mapping of coastal vulnerability hot spots in Bahrain

Bahrain's coastal vulnerability based on the CVI range. Low vulnerability (green) corresponds to CVI values between 7 and 14; moderate vulnerability (yellow) for values between 14 and 21; high vulnerability (brown) for values between 21 and 28; and very high vulnerability (red) for values greater than 28. Coastal vulnerability hot spots are indicated in red.



Capacity strengthening

- Strengthen capacity regarding interactions between climate change induced sea level rise, urban planning frameworks, and risk assessment models at local and regional scales.

- Support research on coastal morph dynamic modeling to better understand sediment transport and land subsidence in the context of coastal development and sea level rise.

- Initiate a coastal monitoring program to observe and document changes in the terrestrial and marine coastal environment.

Integrated planning

- Revise the legal and administrative framework for reclamation activities in order to promote inundation resilience of public and private properties. To first order, reclaimed land elevations should be raised at least 40 cm.

- Develop enhanced planning frameworks capable of promoting sustainable rehabilitation and reclamation works in the face of sea level rise.

- Integrate enhanced environmental safeguards in the planning process for hard coastal protection structures like rock sills and breakwaters.

Stakeholder engagement

- Raise awareness among policymakers and the general public regarding the importance of sea level rise impacts and its implications for future socioeconomic development.

- Involve local communities and the private sector in developing priority adaptive responses to the threat of sea level rise.

- Promote regional cooperation among neighboring GCC countries to harmonize and share information regional impacts of development activities on sediment transport.

Hard coastal protection

- Deepen inlet/outlet water channels to increase channels capacity for absorbing storm surge and easing water flow in order to prevent stagnation of water.

- Reinforce existing coastal protection structures and adjust building codes to accommodate safe sea level rise in the near-term.

- Evaluate materials, designs, and construction processes used in reclamation activities and coastal protection structures to ensure stability under sea level rise.

For marine ecosystems, proactive adaptation should focus on increasing the resiliency of such systems. Essentially, this involves the design and implementation of an enhanced conservation policy to ensure protection and the rehabilitation of disturbed sites. As summarized in the bullets below, a mix of responses are core principles underlying climate change adaptation planning for marine ecosystems.

- Rehabilitate mangroves in the Tubli Bay areas where degradation is taking place at a rapid rate.

- Establish extended conservation zones for coral reefs which have been severely degraded and whose biodiversity is under threat.

- Promote resiliency of key endangered and/or threatened marine ecosystems through legal mechanisms that aim to reduce man made pressures such as pollution, reclamation, over fishing and dredging.

- Implement and enforce an integrated management plan for protecting sensitive marine ecosystems in the face of sea level rise, particularly mangroves.

- Intensify afforestation efforts for mangroves in suitable alternative areas with particular emphasis on areas of high risk of coastal erosion.

In conclusion, there are certain to be high costs associated with adaptation to future sea level rise in Bahrain, particularly if actions are delayed and no-regret options are ignored. Regardless of the specific adaptation measures taken, any comprehensive adaptation package should reflect both a strong national sense of urgency to confront the challenge of climate change, as well as the support of the international community to protect the way of life of small island states like Bahrain.

Water Resources

Bahrain is a water-scarce country characterized by an extremely arid environment, high average annual temperatures, erratic and scanty rainfall, high evapotranspiration rates, and no perennial rivers. The average annual rainfall is less than 80 mm, while the potential evapotranspiration averages about 1,850 mm/year (Zubari, 2006), leading to high deficit in the natural water supply budget.

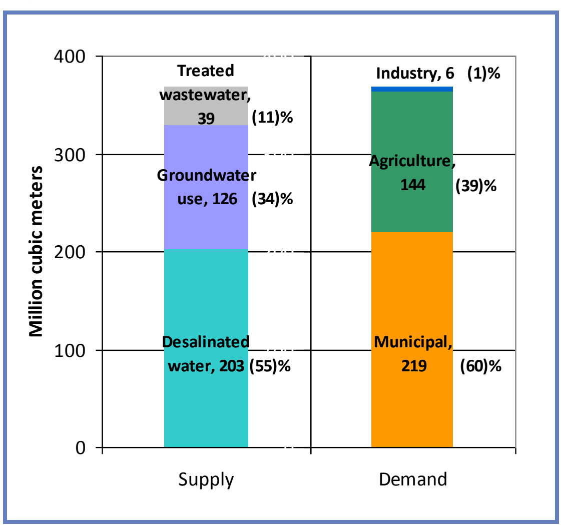
Over the last four decades, rapid population growth and urbanization, coupled with the expansion of irrigated agriculture and industrialization have led to very high water demand and increasing vulnerability of water supply. The Kingdom's water requirements are met primarily by desalination plants, followed by groundwater and treated domestic wastewater. In 2009, water use totaled 368 Mm^3, or around 450 m^3 per capita, and was comprised of municipal, agricultural and industrial demand. Supply and demand characteristics are summarized in Figure 3-5 for the year 2009.

Groundwater represents the only natural relatively freshwater source available to Bahrain. It is obtained from the Dammam aquifer, a large transboundary groundwater system that extends from central Saudi Arabia, where the aquifer crops out and where its main recharge area is located, to the Arabian Gulf waters, including Bahrain, Kuwait, southern Qatar, UAE and Oman.

Within Bahrain, there are two major zones within the Dammam aquifer. The upper "Alat" zone (15-25 meters thick) has limited hydraulic properties and currently experiences high levels of salinization, and is being used at local scales by farmers. The lower "Khobar" zone (40-49 meters thick) is developed in highly fractured limestones and dolomites and provides most of groundwater supply for Bahrain. Underlying these zones is the Rus-Umm ErRadhuma brackish/saline water zone (see Figure 3-6).

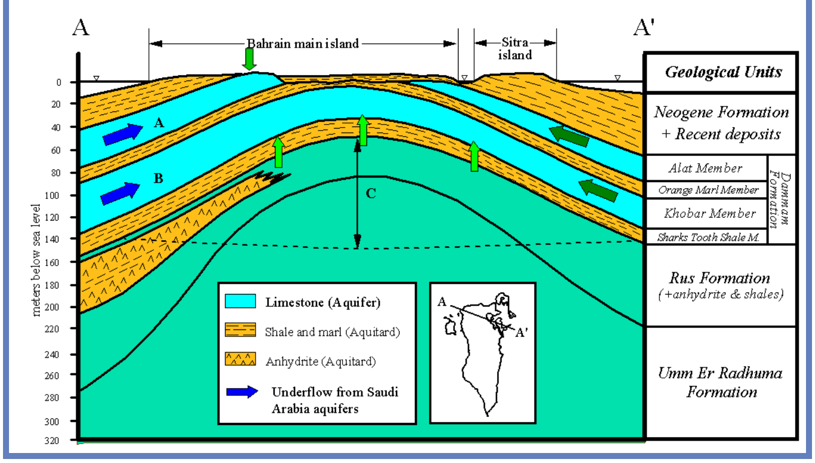
Groundwater resources, particularly for the development of the agricultural and municipal sectors, have been used unsustainably for the past several decades. As shown in Figure 3-7, groundwater abstraction rates have been significantly above sustainable yield levels since the mid-1960s, a pattern that has resulted in a severe decline in groundwater levels, with most of the original groundwater reservoir being lost to saltwater intrusion from the Arabian Gulf.

Figure 3-6: Bahrain water supply & demand, 2009



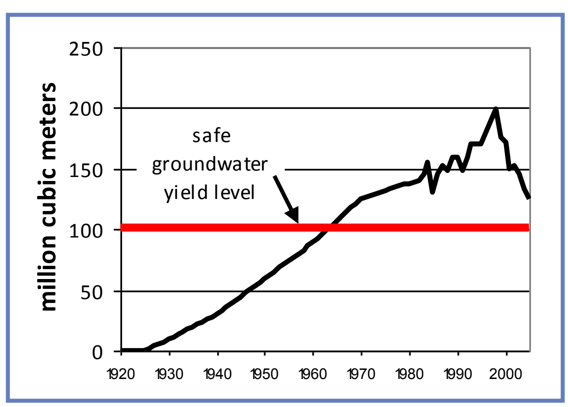
Continuing this unsustainable pattern of groundwater use is both dangerous and alarming. Unless proper groundwater management and intervention measures are considered now, the whole aquifer could be lost, imposing costly alternatives on water authorities in Bahrain to compensate for the lack of this natural resource, in addition to the loss of its strategic reserves in the cases of emergencies.

Figure 3-5: Bahrain's Groundwater aquifer system



Hence, the main water resource management challenge facing Bahrain is how to balance decreasing water supply and increasing water use (i.e., the supply-demand gap) on a long-term sustainable basis while promoting national development with the least social, economic, environmental and other costs.

Figure 3-7: Groundwater abstraction levels



With climate change, this challenge becomes even more urgent and pressing. On the supply side, rising sea levels in the Arabian Gulf would shift the position of the freshwater/saline water front inland, further deteriorating the quality of the aquifer and reducing freshwater supply. Moreover, with potentially lower rainfall in the main recharge areas of central Saudi Arabia due to climatic changes, future groundwater recharge rates of the Damman aquifer could decrease.

On the demand side, climate change will lead to substantially higher annual average temperatures in Bahrain. This could lead to even higher levels of groundwater use in the agricultural (i.e., plants and crops) and municipal (i.e., households, business) sectors. With higher temperatures in central Saudi Arabia, a similar impact on water demand can be expected, further constraining down-gradient groundwater availability in Bahrain.

Future sea level rise represents a major threat to Bahrain's increasingly scarce groundwater resources. Coupled with its potential adverse impact on Bahrain's built environment due to inundation and increased erosion, a quantitative assessment of sea level rise impact on groundwater characteristics was undertaken. The results of the study are summarized below based on a study by Zubari, et al., 2010.

Methodological approach

The objective of the groundwater vulnerability assessment study was to forecast aquifer hydraulic response to different development scenarios impacted by sea level rise, specifically the rate of seawater intrusion into the aquifer.

A 3-part methodological approach was adopted. First, an appropriate groundwater mathematical model was researched and selected. This involved an extensive literature review of hydrogeologic studies related to groundwater systems in Bahrain and Eastern Saudi Arabia, including those studies that dealt with aquifer characterization, monitoring, abstraction, modeling, and management.

On the basis of this literature review, the most relevant and representative mathematical models of groundwater systems in Bahrain and Eastern Saudi Arabia, were identified. Each model was then evaluated relative to the computer source code used, conceptual approach, time frame for analysis, input hydraulic parameters, boundary conditions, and level of detail for results.

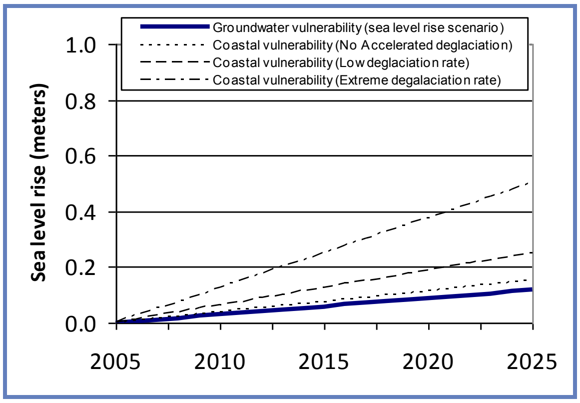
The second step in the methodological approach was to select the most appropriate groundwater model from the models reviewed. The selected model used MODFLOW, a leading groundwater modeling tool. This model was then re-constructed to be consistent with known groundwater conditions in Bahrain (i.e., hydraulic parameters, abstraction rates, and observed water levels) as well as with spatial representation of boundary conditions. The model was then recalibrated to achieve a satisfactory match between observed and calculated conditions.

Finally, quantitative predictions of aquifer behavior were made using the re-constructed and calibrated model. This involved establishing three socioeconomic development scenarios associated with future groundwater consumption levels, as follows:

- *Business-as-usual*: Continuation of groundwater use at the average levels of the past 10 years;
- *Aggressive efficiency & conservation*: A decrease in the growth rate of groundwater use by 25% by 2025; and
- *Steep socioeconomic growth*: An increase in the growth rate of groundwater use by 25% by 2025;

The above socioeconomic scenarios were analyzed with and without sea level rise. A single climate change scenario was assumed based on the IPCC's projection of maximum sea level rise of 0.59 meters by 2100. This scenario is most similar to the "No accelerated deglaciation" scenario analyzed as part of the coastal vulnerability assessment (see Figure 3-8).

Figure 3-8: Sea level rise scenario



Impacts

Underlying the effects of sea level rise on the behavior of the Khobar zone of the Dammam aquifer are four key processes. As groundwater is withdrawn, the following takes place:

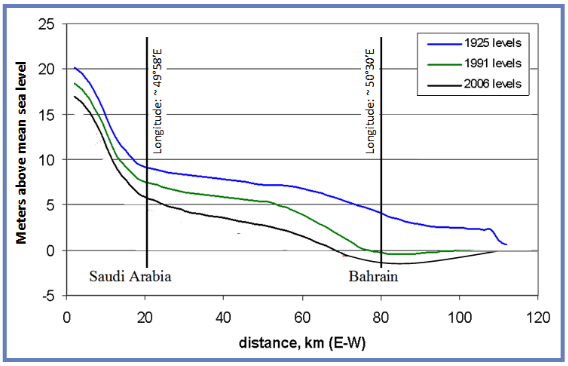
- *Recharge*: The amount of groundwater from eastern Saudi Arabia increases;
- *Intrusion*: Seawater intrusion from the Arabian Gulf occurs and mixes with upper groundwater zones;
- *Migration*: Upward migration of water from the underlying Rus-Umm ErRadhuma brackish/saline zone into the Damman aquifer; and
- *Storage*: Quantities in Dammam aquifer remain constant due to seawater intrusion and brackish/saline upward migration.

Saltwater intrusion from the Arabian Gulf as well as brackish/saline intrusion from underlying groundwater zones pose important water resource management challenges for Bahrain.

Seawater intrusion (i.e., the second bullet above) has likely been occurring in Bahrain since around 1990. Prior to that year, there has been a net discharge from the Khobar zone of the Dammam aquifer to the Arabian Gulf. In 1990, however, this situation was reversed due to the accumulated impact of decades of intensive groundwater withdrawal in Bahrain. There is now a significant net inflow of seawater from the Arabian Gulf to the Khobar zone of the aquifer. This is represented as the seawater inflow/outflow curve crossing the aquifer storage line in Figure 3-9. This is an important indicator of the unsustainable nature of groundwater use in Bahrain.

Brackish water intrusion from the underlying Rus-Umm ErRadhumazone (i.e., the third bullet above) has also been underway for some time and has led to the degradation in water quality of the Khobar zone of the Dammam aquifer. Since 2005, the Khobar zone of the Dammam aquifer has been losing freshwater to the lower Rus-Umm ErRadhuma brackish/saline zone. This is due to the reversal of hydraulic heads between the two zones due to water withdrawals from the Rus-Umm ErRadhumazone for reverse osmosis desalination. This situation is represented as the lower level exchange curve crossing the aquifer storage line in Figure 3-9.

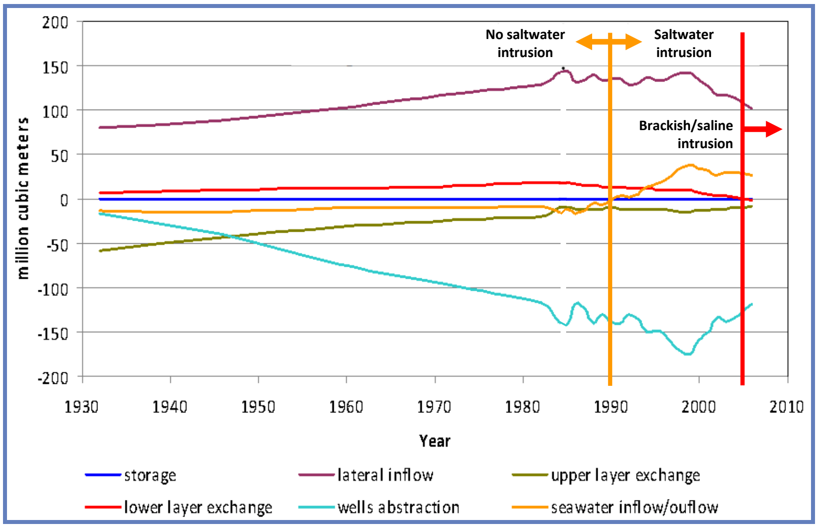
Figure 3-9: Dammam aquifer groundwater levels



In conclusion, the Khobar zone of the Dammam aquifer, on which Bahrain relies for more than 30% of its water supply, is now in a state of severe decline due to decades of unsustainable use. This historical trend, one that is largely independent of climate change, is further evidenced by the drop in groundwater levels in the Dammam aquifer over the period 1925-2006, as shown in Figure 3-10. Groundwater levels have dropped more than 5 meters from 1925 to 2006, an average rate of about 0.5 meters/year, and are now below mean sea level in Bahrain.

With sea level rise, there will be additional pressure placed on already stressed groundwater resources. As shown on Figure 3-11, the amount of seawater intrusion is greater (dashed lines) than the levels in the three scenarios without sea level rise. Even under the Aggressive efficiency & conservation scenario, the impact of sea level leads to an additional 1 million cubic meters of seawater annually entering the aquifer by 2025, relative to Base Year levels.

Figure 3-10: Water balance for the Khobar zone of the Dammam aquifer



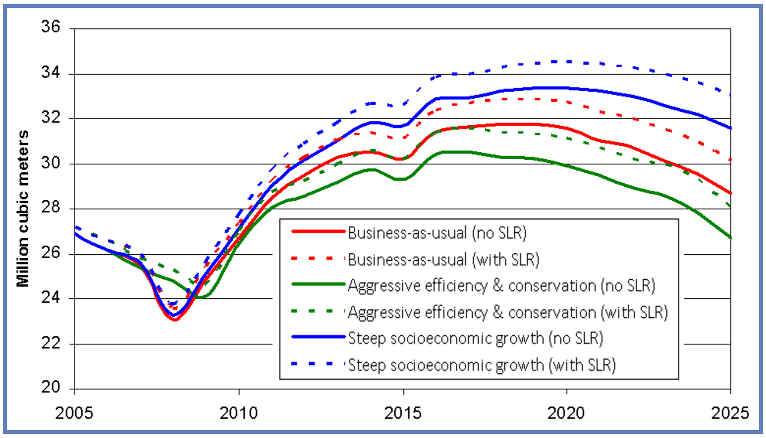
In short, sea level rise makes an already dire groundwater supply situation in Bahrain even worse. Moreover, if sea level rise proceeds in a manner more consistent with the assumption of the Low deglaciation rate scenario applied in the coastal zone vulnerability assessment, seawater intrusion levels would probably double or more by 2025, and the downward seawater intrusion trend in the post-2020 period would likely disappear.

Figure 3-11 shows the magnitude of seawater intrusion into the aquifer up through 2025 for the scenarios, based on modeling results. Without considering the impact of sea level rise, the amount of seawater intrusion increases under each of the three scenarios (solid lines). All scenarios show higher seawater intrusion levels in 2025 than in the Base Year (2005).

This trend is most evidenced in the Steep *socioeconomic growth* scenario which shows that seawater intrusion levels in 2025 nearly reach 32 million cubic meters, about 17% more than Base Year levels. This indicates that despite the expansion of desalination during 2005-2008, the aquifer is expected to experience further serious deterioration in water quality as well as a continuing decline in actual fresh groundwater levels.

Finally, groundwater vulnerability to climate change would be larger still if it accounted for indirect impacts in up-gradient areas (i.e., in eastern Saudi Arabia). The aquifer is already affected by municipal and agricultural activities in and around the recharge area on the Arabian Peninsula. In the future, the aquifer will likely be adversely impacted by the combination of temperature and rainfall changes in eastern Saudi Arabia, as well as the intensification of groundwater development activities there. This is why reducing groundwater use to sustainable levels in Bahrain alone would not necessarily promote recovery of the Dammam aquifer – much depends on groundwater development along the central and eastern regions of Saudi Arabia and the emergence of a mechanism for collaborative transboundary management of this vital resource.

Figure 3-11: Seawater intrusion in the Bahrain aquifer, with and without sea level rise



Adaptation

Several key aspects emerge from the results of the above vulnerability assessment regarding water resource adaptation in Bahrain. These focus on the establishing of an adaptation planning framework, the prioritization of adaptation options, and the technical evaluation of the highest priority option. Each aspect is briefly outlined in the paragraphs below.

Adaptation planning framework

At a broad adaptation planning level, it will be important for Bahrain to establish an effective aquifer management framework that can promote recharge, enhance storage, reduce demand, protect quality, and limit discharge (i.e., equivalent to reduced water demand).

An important step in this direction has already been taken through the establishment of a National Water Resources Council in 2009 (Royal Decree No. 36). This decree/law reactivated the High Water Council, seen as the most suitable organizational framework to ensure efficient levels of water resources management in the Kingdom. The responsibilities of the Council are as follows:

- *Strategies*: This involves the formulation of water resources policies and strategies, including setting up new institutional and legislative frameworks, as needed;
- *Institutional coordination*: This involves coordination of government water policies and ensuring integration of these policies across relevant institutions; and
- *Implementation*: This involves prioritization and follow-up for implementing policies, strategies and programs.

The above mandate represents a workable framework for the development of a clear and comprehensive national water resources management policy reform that is based on integrated water resource management principles. The formation of the Council represents the first step forward in a long intricate path to sustainable water management in the Kingdom under conditions of socioeconomic development and climate change.

Adaptation strategies

At a more detailed adaptation planning level, it will be important to identify, prioritize, and assess potential adaptation measures that can increase the resilience of groundwater resources in a climate changed world.

While climate change poses many challenges to water resources management in the Kingdom, it can also lead to important opportunities, such as new capacity investments, rehabilitation of existing systems, and the introduction of efficient technologies to optimize processes and operations. Specifically, the following strategies have been identified as priorities for future evaluation.

- *Promote artificial recharge/storage*: This involves the introduction of technological interventions (e.g., infiltration basins, treated effluent disposal, diversion of excess irrigation) to store excess water for aquifer rehabilitation and/or later use.

- *Reduce demand*: This involves the introduction of demand side management programmes (e.g., tariffs, regulation, conservation) to reduce groundwater use in the municipal and agricultural sectors.

Of these, the promotion of artificial recharge/storage has been identified as the highest priority near-term strategy and was analyzed in a follow-up study.

Managed aquifer recharge

Managed aquifer recharge (MAR) involves building infrastructure and/or modifying the landscape to intentionally enhance groundwater recharge. It forms one of the 'managing aquifer recharge' adaptation responses and is increasingly being considered for improving the security of water-scarce regions(Gale, 2005).

MAR has several potential benefits, including: storing water for future use, stabilizing or recovering groundwater levels in over-exploited aquifers, managing saline intrusion, and enabling reuse of treated wastewater or storm water. The implementation of MAR requires suitable conditions, all of which are met in Bahrain. These include falling groundwater levels, hydrogeologic suitability, and the availability of surplus unused treated sewage effluent (TSE) for aquifer recharge.

Notably, TSE is readily available in Bahrain and has in fact been aggressively exploited since 1984 to meet rising agricultural and municipal water demand. Even after municipal and agricultural use, Bahrain still discharges about 16,055 m³/day of TSE to the Arabian Gulf, with an annual value of US$ 0.66 million. Hence, this is an important potential resource for recharging the Bahrain aquifer.

To explore the feasibility of using TSE for aquifer recharge, a 3-step methodology was applied that involved developing and applying site selection evaluation criteria, conducting simulation modeling of selected sites, and assessing the environmental and health risks associated with the use of TSE.

As shown in Figure 3-12, two sites were determined to be suitable for artificial recharge based on satisfactory hydraulic properties and pre-specified ranking criteria that included the location and capacity of TSE storage tanks, availability of emergency wells for abstraction/injection, proximity of domestic water supply well fields and agricultural lands.

Figure 3-12: Proposed TSE injection sites

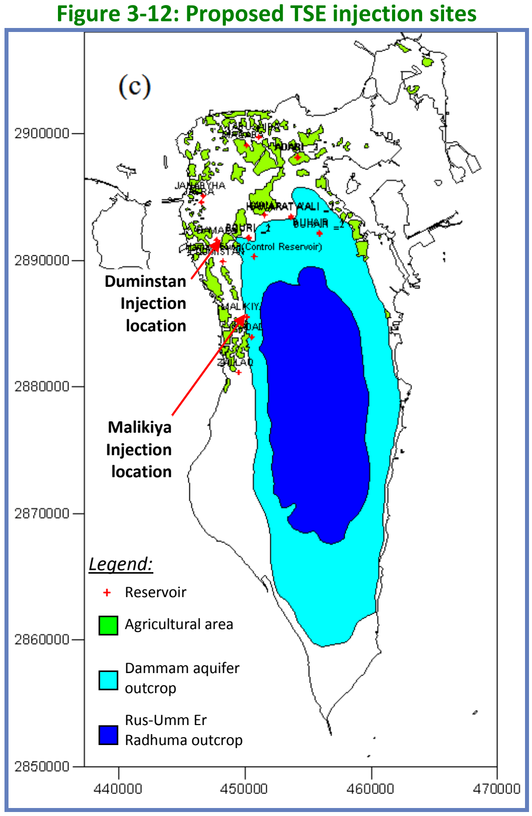


Table 3-3 summarizes the main results of the analysis regarding groundwater height and salinity levels. For the Dumistan site, groundwater levels were raised after the 5-year period by an average of about 5 meters in the case where all 77 million cubic meters are used to recharge the aquifer; 3 meters in the case where only the surplus 35 million cubic meters are used for recharging. Average aquifer salinity levels dropped by about 50% for both recharge scenarios.

Table 3-3: TSE recharge modeling results

Recharge site	Total TSE recharge (Mm3)	Groundwater level increase (meters) Start of 5-year period	End of 5-year period	Drop in salinity levels
Dumistan	77	8.0	5.0	50%
	38	2.5	3.0	
Malikiya	77	4	2.5	50%
	38	1.2	1.5	

For the Malikiya site, the modeling showed that groundwater levels also increased significantly. Levels increased by 2.5 and 1.5 meters, respectively, for the two recharge scenarios. Average aquifer salinity levels also dropped by about 50% for both recharge scenarios.

The potential health risks posed by TSE injected into underground aquifers depends upon the chemical and microbiological composition of the TSE; the physical, chemical, and biological conditions within the aquifer; the attenuation rate of contaminants; and the retention time of TSE within the injection zone.

The distribution of pathogens and nitrates within the aquifer was also modeled using the same analytical framework. The results of the assessment indicate that health risks exist for any injection sites that are located close to farmer wells if used for drinking. However, the Dumistan site has a high probability of uptake of recharged water by a domestic water supply well field. Hence, the Dumistan site would be unsuitable. It is concluded that the Malikiya recharge site could be adequate provided awareness and risk minimization programs are implemented.

Human health

In Bahrain, climate change is understood by governmental and other stakeholders to pose a potentially significant threat to public health. Increased exposures to thermal extremes, changing disease vector dynamics, an increased incidence of food-related and waterborne infections are likely to be experienced throughout the Bahraini population, with the elderly, patients with pre-existing medical conditions, and children, likely among those hit the hardest.

At present, there is a paucity of environmental heath information in Bahrain that could be used in a vulnerability assessment regarding the impacts of climate change on human health. Unlike the previous assessments for coastal zones and water resources for which a substantial amount of information and data were readily available for analysis, no such baseline level of data was available for the human health sector, limiting the extent of vulnerability analysis that could be conducted.

Therefore, the human health assessment focused on the identification, synthesis, and analysis of pertinent baseline data that could serve as inputs to future vulnerability assessment of climate change impacts on human health in Bahrain. Specifically, systematic databases were developed and analyzed to examine the influence of climate in six human health areas: morbidity, expatriate laborer health, children's health, food-borne diseases, hospital discharges, and mortality. It is expected that such baseline information could be used both to inform future health impact assessments as well as begin to fashion adaptive responses. The results of the baseline data gathering effort is summarized below based on a study by Hamadeh, et al., 2010.

Morbidity

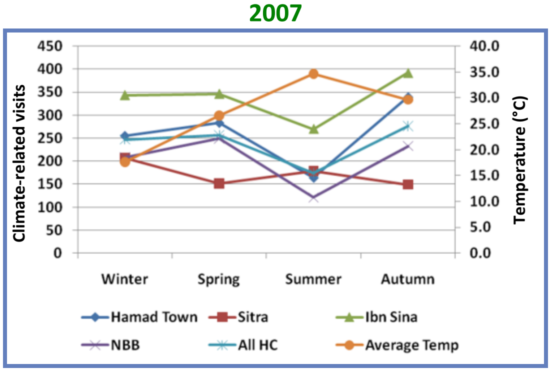
This study was a retrospective cross-sectional study of medical records of all those who attended health centers serving a population of

30,000 during 2007. Health centers from four governorates were included, namely IbnSina in the Capital Governorate, Hamad Town in the Northern Governorate, National Bank of Bahrain (NBB) in the Muharraq Governorate and Sitra in the Central Governorate. The aim of the study was to provide baseline data on climate-related diseases in health centers in Bahrain.

A 5% random sample of medical files was selected. Overall, a total of 1,235 records were analyzed relative to four potentially climate-related diseases, namely respiratory ailments, allergic reactions, dermatological diseases, and non-specific gastrointestinal diseases. Data collection was performed by a group of 3rd year Arabian Gulf University (AGU) medical students.

The results of the study showed that one quarter of the primary health care center visits were climate-related with children below the age of 10 having the highest prevalence rate (about 35%). There was seasonal variation exhibited in overall morbidity with the highest rates occurring in autumn and lowest in summer (see Figure 3-13).Visits due to respiratory conditions accounted for the majority of the health center visits and showed a similar pattern across all centers.

Figure 3-13: Seasonal variation of climate-related diseasesamong patients at the Health Centers, 2007



Air quality showed a significant relationship with health center visits. In autumn, when the concentrations of SO_2 were highest; the respiratory disease rates were highest as well.

On the other hand, a counterintuitive relationship emerged between average temperature and the rate of the climate-related disease. In summer, where the temperatures were highest in Bahrain, respiratory related visits were lowest. It is also worth noting that the average humidity was lowest in summer, where the respiratory disease rates were lowest.

Expatriate laborer health

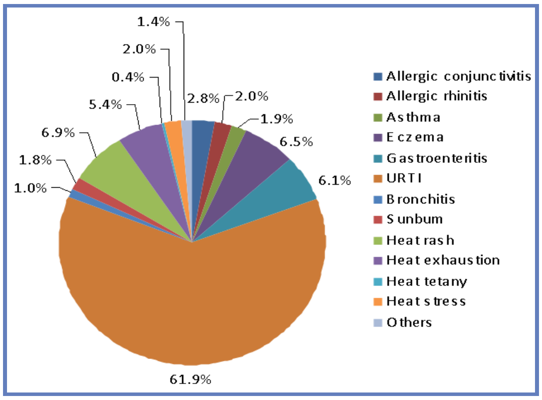
This cross-sectional study focused on expatriate workers who were registered and attendedAl Razi Health Centre during the period from 1-14August 2008. The Al Razi Health Centre is one of the Ministry of Health's centers devoted mainly to the expatriate workforce. The aim of the study was to provide baseline data on climate-related diseases among expatriate workers in Bahrain.

Expatriate workers who were diagnosed by the attending physicians to have climate-related disease during the study period were interviewed by a group of 3rd year AGU medical students. The variables included in the questionnaire were age, gender, nationality, occupation, work setting, diagnosis, chronic diseases, medications prescribed, and sick leave length.

Data collection was obtained during the morning and evening shifts of the health center. Respondent age ranged from 18 to 62 years and most of them were in the age group 26-35 years. About 76% of the patients were Indians, 9% Bangladeshi, 7% Pakistani, 4% Nepalese, 3% East Asian and the remainder from other nationalities. About three quarters of the patients worked in the morning and the others were evening shift workers. The majority of patients with climate related diseases were outdoor workers.

The results of the study showed a high percentage of heat-related and upper respiratory tract ailments among the expatriate labor force. As shown in Figure 3-14, heat stress accounted for nearly 62% of total visits, while asthma/bronchitis accounted for about another 10% of visits.

Figure 3-14: Breakdown in climate-related diseases among expatriate patients at the Al-Razi Health Center



In comparison to the health cent visit records of other health centers, as discussed in the previous section, the incidence of these types of health issues is much higher among the expatriate worker community than the overall population. This is likely due to the fact that other groups typically do not work outdoors and are therefore much less exposed to heat and other climate related factors on a daily basis.

In conclusion, the prevalence of climate-related diseases, particularly heat-stress related, is quite high for expatriate groups. This contributes to a loss of productive hours which ultimately affect the country's economic welfare. In addition, the high visit rate results in associated direct costs for prescription medications. No association could be found with age, nationality or place of work of expatriate workers.

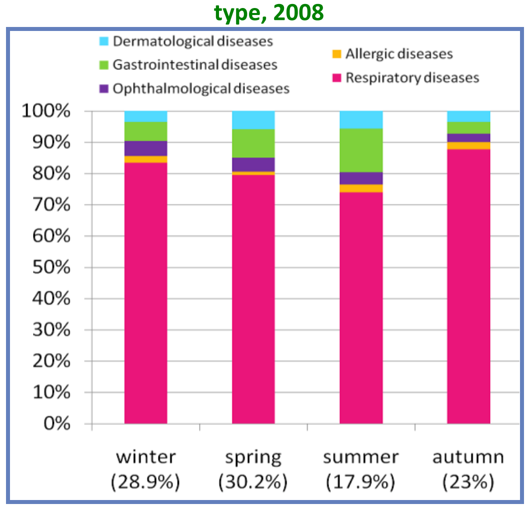
Pre-school children's health

This cross-sectional study focused on children aged 6 years or younger who were admitted to primary healthcare centers during 2008. A 1% stratified random sample comprising 1,039 records was developed from four regional health centers (Muharraq, Naim, Isa Town and Hamad Town) in proportion to the number of visits per center. Data was collected by a group of 3rdyear AGU medical students. The aim of the study was to provide baseline data on climate-related diseases among preschool children in Bahrain.

While there were little differences between the four health centers in the proportion of climate-related diseases in children under the age of 2,there were marked variations in those aged 3 to 4 years old. It was highest in Naim and Hamad Town health centers. The highest proportion of families with a family size of 6 or more was in Hamad Town health center (about 37%) illustrating the high rates of climate-related diseases in this region.

Overall, over half of the total health center visits by pre-school children were climate related. Of these, most were respiratory–related, as shown on Figure 3-15. Respiratory diseases (e.g., asthma, bronchitis) accounted for between 75% and 88% of all climate-related visits, with the highest share evident in the autumn months. Gastrointestinal diseases in the very hot summer season accounted for about 15% of these visits. Most of the visits occurred in the winter/spring seasons (about 60%); visits during the hot summer months account for less than 18% of annual visits, perhaps related to extended time spent outside Bahrain during vacation periods.

Figure 3-15: Seasonal variation of pre-school children health center admissions by ailment type, 2008



The percentage of climate-related diseases was highest among children aged 3-4 years. These differences may reflect the fact that children under the age of 2 years are less likely to be outdoors but this would not explain the lower percentage evidenced in the 5-6 year old range. There were statistically significant differences between preschool children by family size and nationality but not by gender.

Food-borne diseases

This study focused on food-borne reported diseases in Bahrain during the period 2001-2008. Information was collected based on personal communication from the Disease Control Section of the Public Health Directorate of the Ministry of health. The aim of the study was to provide baseline data on the seasonal variation of the incidence rates of food-borne diseases in Bahrain.

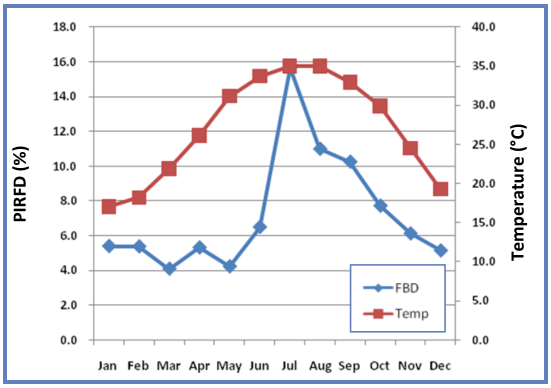
Of the total number of reported diseases in Bahrain, six were classified as foodborne and climate related (amoebias is, food poisoning, shigellosis, typhoid fever, paratyphoid fever and other salmonella infection).Average proportional incidence rates of food-bornediseases (PIRFD)for each year, as well as all years combined, were calculated for these six diseases. The average monthly temperatures during the study period were also collected and compared to incidence rates in order to assess whether any climatic-based patterns could be detected.

There were a total 14,990 reported cases of food-borne diseases during the 8-year period. A clear correlation with temperature emerged from the analysis of these data, as shown in Figure 3-16. That is, average temperatures throughout the period have a bell shaped distribution with peak temperatures occurring in July and August. When compared with PIRFD results averaged over the entire study period, a similar pattern emerged with the highest incidence rates occurring in July and August, 16% and 11%, respectively. The analysis of individual years yielded very similar patterns and in some years the correlation is even greater.

These results confirm that food-borne diseases are more prevalent in hot weather in Bahrain. With even higher temperatures predicted in the summer months due to climate change, this represents an important finding that can guide subsequent adaptation planning.

Finally, the data show a decrease in the overall incidence rates of food-borne diseases in Bahrain during the study period. From a value of 10% in 2001, the average annual incidence rate for food-borne diseases dropped to about 7% in 2008.

Figure 3-16: Average temperature and food-borne incidence, 2001-2008



This finding correlates well with the timing of government programmes to raise public awareness about proper food handling and storage, as well as governmental and non-governmental efforts in monitoring the safety and hygienic processing of food supplies. Future efforts will examine how such effective efforts could be expanded to account for climate change.

Hospital discharges

This study focused on discharge patterns from the Salmaniya Medical Complex (SMC) to assess whether patterns are evident that can be linked to climatic factors. The aim of the study was to provide baseline data on a potential relationship between climate change and hospital discharges in Bahrain.

SMC is the largest governmental hospital in Bahrain, with 56,004 discharges in 2008, representing about 57% of discharges in Bahrain (HID, 2009). Thus, discharge patterns from SMC are believed to be able to provide insights regarding national patterns.

A list of climate related disease groups with their International classification of diseases (ICD-10) codes was first identified. These disease groups included asthma, ischemic heart disease, certain cerebrovascular diseases, certain cardiovascular diseases, dermatitis, eczema and diaper rash, disorders of conjunctiva, and intestinal infectious diseases.

The Health Information Directorate provided the lists of discharges from SMC for these disease groups for the period 1998-2007 via personal communication. The available figures of the total population for Bahrain for each year during the study period were obtained from the Central Informatics Organization (CIO, 2010) for the calculation of incidence rates.

The study concluded that asthma, dermatitis, eczema and diaper rash demonstrated strong seasonal pattern while none could be detected in the other diseases. The lack of such an association might be explained by the use of discharges as a morbidity indicator instead of incidence and prevalence data. For the purpose of a baseline association, the study concluded that there appears to be a potential relationship between climate and asthma, dermatitis, eczema and diaper rash that should be further explored in future studies.

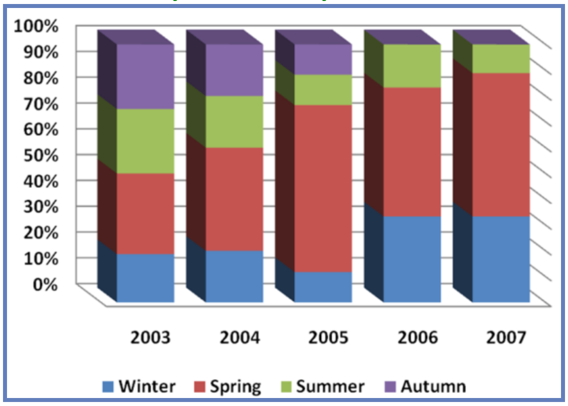
Mortality

This study focused on mortality rates to assess whether patterns may be evident that can be linked to climatic factors. The aim of the study was to provide baseline data on a potential relationship between climate change and mortality in Bahrain.

A list of climate related disease groups with their corresponding ICD-10 codes were identified. The study focused on asthma, ischemic heart disease, and other types of cerebrovascular diseases. The Health Information Directorate provided the total deaths for each year and deaths attributed to these disease groups for the period 2003-2007 via personal communication. Analyses by season and month were performed for the total period combined and compared with the average temperatures. Annual cause-specific death rates were calculated for each disease.

In general, there were few seasonal patterns noted in the number of deaths attributed to climatic factors. One exception was asthma where there were evident patterns of mortality rates during spring months that are more than double those of other seasons (see Figure 3-17). This may be partially explained by the fact that a prevalence of allergens during this season in Bahrain is known to exacerbate asthma.

Figure 3-17: Deaths attributed to asthma in Bahrain by season and year, 2003-2007



Another potential exception was ischemic heart disease. There were noteworthy declines in the cause-specific death rates of such diseases and cardiovascular diseases during winter seasons for the study period. This may be partially explained by milder temperatures in the winter months.

For the purpose of a baseline association, the study concluded that a strong case could not be made, on the basis of the data assembled and analyzed, that extreme temperatures in the summer months are a significant contributor to mortality in Bahrain. Nevertheless, this is a critical issue that should be revisited in future, more comprehensive studies.

Adaptation

Several conclusions have emerged from the above studies that have a strong bearing on the formulation of a comprehensive climate change adaptation strategy for human health in Bahrain. These conclusions are summarized below and represent an important basis for next steps in this area.

- Climate contributes substantially to morbidity in Bahrain. This suggests that an adaptation action plan to increasing climatic risks should be a focal point of future work.

- Children represent a particularly vulnerable population to climate related diseases. This suggests that the need to design future adaptation strategies that focus particularly on building resilience in children's health to climate change impacts. Areas of potential focus could include decreasing in-utero vulnerability, assessing impacts of different diets, and evaluating the effect of time spent outdoors during summer months.

- Expatriate laborers represent a vulnerable population for climate related diseases, particularly for respiratory diseases. This suggests that a further review of measures to prevent heat-related conditions should be integrated into an adaptation action plan.

- The potential for food borne diseases are highest during the summer months. This suggests that a further review of public awareness programs about proper food handling, storage, as well as governmental food monitoring actions should be integrated into an adaptation action plan.

- There is an apparent relationship between ambient air pollution concentration and climate related diseases. This suggest that a future study to assess the public health impacts from ambient air pollution concentrations associated with various climate change and socioeconomic scenarios will make a valuable contribution to the development of adaptation strategies.

Biodiversity

Biodiversity in Bahrain is strained by a number of economic and social factors. Industrial development and urbanization have taken a toll on biodiversity as coastal development activities such as dredging, land reclamation, pollution, housing and careless recreational activities have degraded important biodiversity habitats.

The terrestrial landscape in Bahrain is predominately arid desert with virtually no inland waters. On the other hand, its marine environment is very diverse and includes extensive sea grass beds, mudflats, coral reefs as well as offshore islands. Sea grass beds are important foraging grounds for some threatened species such as dugongs and the green turtle.

With climate change, these and other features of biodiversity in Bahrain will experience additional stress. While no biological modeling was conducted to assess the impact of climate change on key species and habitats in Bahrain, a biodiversity inventory and what could be potential biodiversity vulnerability hotspots were assembled in an effort to inform and guide any such modeling in the future. The results of the biodiversity inventory and hotspot review are summarized below (Protection of Marine

Resources, Environment and Wildlife, 2006).

Marine and coastal habitats

There are sixteen (16) different marine habitats in Bahrain (Geomatec, 2009). Of these, there are six (6) for which a strong consensus exists within Bahrain to consider as priority systems for any subsequent climate change adaptation action planning. These are briefly described in the sections below.

Algae Beds

More than 90 species of marine algae have been recorded in the water around Bahrain, as has been reported by several researchers (e.g., Vousden, 1985; Basson et al 1989). They are present in the main groups of algae, namely green, red and brown algae, (see Figure 3-18 for a picture of a green algae colony). Various surveys and reports showed that the main algae-dominated habitats occur in the eastern intertidal and subtidal areas of Bahrain Main Island and around Hawar Island (Al Zayaniet l., 2009).

Figure 3-18: Green algae habitats near Hawar Island

Coral Reefs

Around 30 species of corals have been reported around Bahrain (Vousden, 1985). According to Al Zayani et al (2009), the most healthy and diverse coral reefs in Bahrain waters are located north to Hayr Bulthama (see Figure 3-19). This reef became legally protected in 2007.

Corals are present throughout the coastal water around Bahrain. However, the average coverage is less than 5% of the available reef areas in Fasht Al Adham, Fasht Al Jarim and Khor Fasht.

According to Sheppard (2009), the coral reefs around Bahrain are currently in poor condition. Most reefs which are located within 20-30 km of Bahrain Island are in a state of ecological disorder as a result of various development activities.

Figure 3-19: Coral reef near HayrBulthama

Seagrass beds

Only three species of seagrass are recorded in Bahraini waters. Dense seagrass beds are present around the islands but mainly in the eastern and western subtidal waters (see Figure 3-20; top). Seagrass bed is considered as important breeding and feeding grounds for many fish species like *Siganuscanaliculatus*, prawns (*Penaeussemisulcatus*), and the globally threatened green turtle (*Cheloniamydas*) as well as the endangered dugong (*Dugong dugon*) whose population in the Arabian Gulf is the second largest in the world (see Figure 3-20, bottom).

Figure 3‑20: Seagrass meadow near Hawar Island (top); green sea turtle (lower left); herd of dugong seen from the air (lower right)

Oyster beds

There are few famous oyster beds located mainly in the north and North West of Bahrain. Oyster beds are normally occurring in hard flat rocky seabed in location where water depth exceeds 10 meter. Density of the pearl oyster (*Pinctadaradiate*) varies in such locations depending on many environmental factors (Nayar and Al Rumaidh, 1993).

Mangrove forests

Balck Mangrove (*Avicennia marina*) is the only forest species present in Bahrain. The natural location of this tree is Tubli bay, however, some plantation activities have been carried out in other places around Bahrain. In Tubli Bay, mangroves play an important role as shelter and nursery sites for shrimp and some fish species (see Figure 3-21). Dense patches of mangrove attract other animals including birds to breed or feed.

Figure 3-21: Tubli Bay mangrove protected area

Mudflats (Sabkhs)

Mudflats are areas within the intertidal zone. They cover large areas along the eastern shores of Bahrain Island and also in Muharraq and Hawar Island. During high tide, many types of fish come with the tide to feed in the mudflat areas due to the rich food available in the sediment. As water recedes during low tide, many resident and migratory birds utilize the vast mudflat to feed (see Figure 3-22). More than 40 different species of wading birds have been reported around Bahrain to feed at low tide (Mohamed, 1998).

Salt marshes and coastal dunes

In the upper zone of the shoreline, there are two main coastal habitats salt marshes and coastal dunes. Salt marshes can be seen around the eastern shores of Bahrain Island and also around Hawar Island. They are supratidal zones found in sand or mixed mud and sand substrate. Halophytic vegetation grows in the seareas and includes species such as *Arthrocnemummacrostachyum*, *Halopeplisperfoliata*, *Limoniumaxillare* and *Suaedavermiculata*(Al-Eisawi, 2003).Coastal dunes are found around coastal lowlands in southwestern areas of the main island of Bahrain. Some small sand dunes are present with halophytic vegetation.

Figure 3-22: Mudflat around Hawar Island

Species diversity

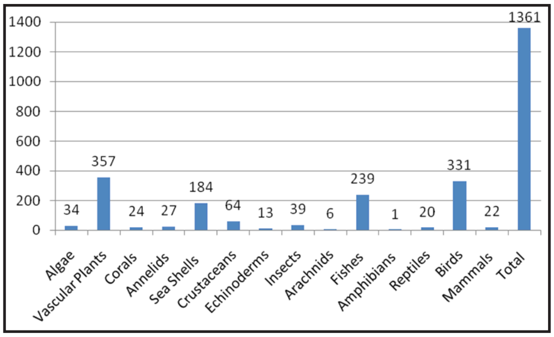
Several surveys have been conducted over the past three decades to identify species in different groups in Bahrain. This information has been compiled and summarized in Figure 3-23 (PCPMREW, 2006). This information is continually in the process of being updated to fill data gaps.

Of these, species, 30 are classified as being *vulnerable to critically endangered* by the IUCN. Two species, the hawksbill turtle and the, are classified as being *critically endangered;* dugongs are classified as an *endangered species*, and the Socotra cormorant is classified as *vulnerable*. A key concern for future adaptation planning in Bahrain is the tolerance of these species toward projected changes in the marine environment (e.g., increased water temperature, declining salinity levels).

Vulnerability hotspots

As the demand for the services that biodiversity provides, climate change will increasingly exacerbate the human-induced pressures, potentially causing a progressive decline in biodiversity in Bahrain. Potential changes in the structure, function and composition of ecosystems will have an overall impact on health of these entities.

Figure 3-23: List of species by major groups



For example, increased thermal stratification in coastal areas due to climate change could lead to oxygen deficiency, loss of habitats, redistribution of species, and impact the entire ecosystem components (Rabalais et al., 2002). Coral reef mortality in the face of warming Arabian Gulf waters is a particular concern given recent bleaching events (Sheppard et al. 2010).

Therefore, an effort was made to identify systems that may be under the greatest threat from climate change as a way to prioritize future vulnerability risk assessment and adaptation planning activities. These vulnerable hotspots include fish stock levels, coral reefs, mangroves, coastal date plantations, and migratory birds. Each is briefly described below.

Fish stocks

The eastern, northern and western regions of Bahrain are prominent fishing areas. Many families in Bahrain depend on fish stocks as a source of free protein, revenue and income generation. In 2008, fishermen numbered nearly 7,000 while Bahrain's average per capita fish consumption was about 9.1 kg/yr, in 2007 (FAO, 2011), down from about 17 kg/yr in 1995. This pattern coincide with local fish catch data which shows that annual levels steadily dropped from 1,722 tonnes in 1998 to 925 tonnes in 2002, to 556 metric tons in 2008, a decline of nearly 7% per year (Public Authority for the Protection of Marine Resources, Environment and Wildlife, 2009).

As a result of these trends, there is now a broad consensus within Bahrain that fish stocks are being harvested unsustainably. The most two affected species are *Epinepheluscoioides*, *Acanthopagrusbifasciatus*, *Siganusjavus* and *S. canaliculatus*. As population grows, the demand for seafood is expected to continue. The observed declines of fish stocks will likely intensify leading to potentially serious implications for food security and nutrition for some communities in Bahrain.

Coastal date palm plantations

Coastal date palms are an important part of Bahrain's agro-biodiversity system. However, groundwater salinization is an ongoing threat to these systems. One of the clear near-term outcomes is the salinization of soil which is leading to the gradual desiccation and destruction of coastal date palm plantations (see Figure 3-24).

Moreover, future sea level rise will make this situation even worse. This is because irrigation systems in Bahrain are traditionally comprised of channel networks linked to the sea to provide drainage and help to decrease salinity. With sea level rise, coastal date palm areas will be vulnerable to inundation and infection by *Rhynchophorusferrugineus*. Irrigation water will also likely become scarcer due to aquifer depletion, constituting a major constraint for agro-biodiversity in Bahrain.

Mangroves
Although limited in extent, mangrove ecosystem forms a major component of natural vegetation in Bahrain. However, mangrove forests are experiencing formidable threats that endanger their presence in Tubli Bay (Abido and Mohammad, 2001).

Climate change-induced sea level rise will adversely impact mangroves in Bahrain. Given the country's acute spatial constraints, inland migration will likely not be possible due to the ubiquitous presence of urban infrastructure. Many of the associated plants like *Salicorniasp.*, *Suaedas*p., *Tamarixs*p., *Hammadas*p., *Phragmitesaustralis* and *Juncuss*p. will be adversely affected.

Figure 3-24: Desicciation & destruction of coastal date palm plantations due to aquifer degradation

Migratory and other birds
Increased temperatures and sea level rise are likely to adversely affect the size, distribution and reproductive timing of many coastal and marine bird population including the Socotra cormorant, an endemic species to the region which is classified as *vulnerable* by the IUCN (see Figure 3-25). There are several breeding colonies in Bahrain including on the Hawar Islands and the low island of Suwad al janoubiah, the latter considered to be the largest colony in Bahrain (King, 1999).

Figure 3-25: Socotra Cormorants, Hawar Island

In addition, nearly 45 species of waterfowls have been recorded in mangrove areas, including breeding populations of Moorhen (*Gallinulachloropus*) and Black-Winged Stilt (*Himantopushimantopus*) that rely on swampy habitats in Tubli Bay. With sea level rise, such communities will experiencet increasing disruptions.

Adaptation
Several key aspects emerge from the results of the above review of regarding biodiversity adaptation in Bahrain. These focus on the establishing a set of core principles to guide adaptation planning and the prioritization of specific actions for near-term implementation. Each aspect is briefly outlined in the paragraphs below.

Core principles

There are six (6) key principles that should underlie the development of a future adaptation planning framework in Bahrain, as follows.

- *Conserve existing biodiversity*: This involves the conservation of a) protected areas and other high quality habitats; b) range and ecological variability of habitats and species, and c) of agrobiodiversity system such as the coastal palms.

- *Minimize socio-economic activity impacts on key ecosystems and species*: This involves the reduction of pressures such as overfishing, dredging activities, careless recreation, and illegal hunting through new laws and regulations.

- *Maintain and restore biodiversity*: This involves ensuring that landscapes remain varied, with space for physical processes to take place naturally through a) enhancing local biological variation within sites and habitats; and b) making space for the natural development of coastlines as sea levels rise.

- *Establish ecological networks through habitat protection, restoration and creation*: This involves creating new habitats, restoring degraded ones, developing corridors, or reducing the intensity of management of some areas between existing habitats.

- *Apply an integrated ecosystem management approach*: This involves the adoption of an evidence-based approach which recognizes that biodiversity is constantly changing and the development of better database systems and capacity building in analysis tools and methods.

- *Mainstream biodiversity in decisions made across sectors, departments and economic activities*. This involves the development of a policy framework acknowledging linkages between climate change, biodiversity and economic activities to enable planning agencies to develop concrete ecosystem based adaptation action plans.

Key actions

There are eight (8) key actions that should be undertaken in the near-term in support of the long-term adaptation planning process described above.

- Share knowledge across civil society and government about the linkages between biodiversity, development, and climate change.

- Raise public awareness about the importance of biodiversity, the threats of climate change, and the potential for adaptive responses.

- Establish a national program of research on the impacts of climate change on key biodiversity components and ecosystem processes in Bahrain.

- Develop and empower the existing network of protected areas with effective management plan. Focus on specific habitats that need a link through wildlife corridors which will allow key species like the gazelles to move around in a larger range.

- Rehabilitate and protect sensitive habitats like the Tubli Bay mangrove forest and coastal vegetation strips while developing a plan to address data gaps and institutional capacity needs.

- Maintain and properly manage habitats threatened and vulnerable species like the hawksbill sea turtle, the dugong and the Socotra cormorant.

- Increase artificial coral reef areas in deeper water while also putting in place a process to develop a long term plan for artificial reef.

- Develop programmes and plans to reduce anthropogenic stress on the mudflats around the islands of Bahrain.

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4

Greenhouse Gas Mitigation

Greenhouse gas (GHG) emissions in the Kingdom of Bahrain consist mostly of carbon dioxide arising from the combustion of oil and gas. A small island nation situated in the Arabian Gulf, Bahrain's annual GHG emissions represent a very small amount relative to annual global emissions, less than 0.1%.

Nevertheless, despite physical and economic constraints that limit potential mitigation options, there are a number of activities underway to assess and promote sustainable energy alternatives for reducing the growth of GHG emissions in coming years. Such measures have led to improving performance regarding energy and carbon intensities.

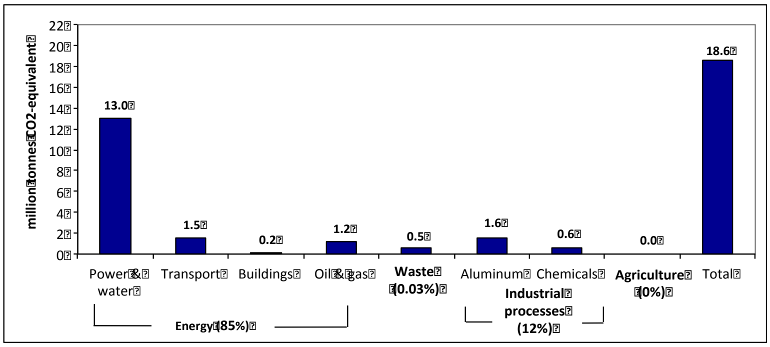
The rest of this chapter provides an overview of GHG mitigation potential based on review of the country's energy and carbon emission context, as well as an assessment of GHG mitigation choices that are appropriate for the Kingdom of Bahrain, given current barriers and opportunities. After first providing context showing gradual and consistent improvement in energy and carbon emission intensities, a brief overview is provided regarding the potential role for energy efficiency and renewable energy in the Kingdom, together with some of the initiatives underway to promote their integration into the overall economy.

Energy intensity

Most GHG emissions in Bahrain are associated with energy use activities. For both the 1994 and recently completed 2000 National GHG inventories, energy represented over 85% of all emissions, somewhat more than the global average. A breakdown in shares associated with major emitting sectors is shown in Figure 4-1 for

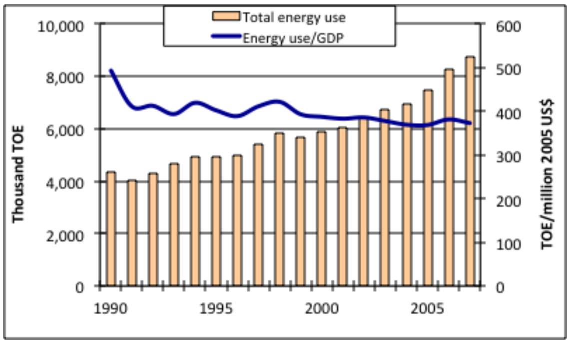
the national GHG inventory of 2000. The clear implication is that GHG mitigation activities in Bahrain should focus on energy-consuming activities.

Figure 4-1: Breakdown of Bahrain's direct GHG emissions in 2000



Since about 1990, Bahrain has steadily improved its energy intensity – that is, energy use per unit of gross domestic product (GDP). Energy intensity is a measure of how efficiently energy is used in the overall economy; a decreasing value over time indicates that energy is being consumed more efficiently. Figure 4-2 shows this to be the case in Bahrain; in 1990, it took about 500 tonnes of oil equivalent (TOE) to produce one million US$ of GDP in Bahrain but by 2007, it took only about 370 TOE to produce the same level of economic output, an improvement of nearly 25% during a period in which total energy use doubled.

Figure 4-2: Historical energy consumption and intensity in Bahrain, 1990-2007 (WRI, 2011)



Nevertheless, in 2007, the latest year for which international statistics are available, Bahrain significantly lagged behind European Union (EU) countries where the average energy intensity was about 125 TOE/million 2005$ (WRI, 2011). GHG mitigation activities, inasmuch as they focus on improving efficiency of resource use, will help to push energy intensity in Bahrain closer to European Union (EU) countries over time, while also leading to increasing fuel cost savings.

Carbon intensity

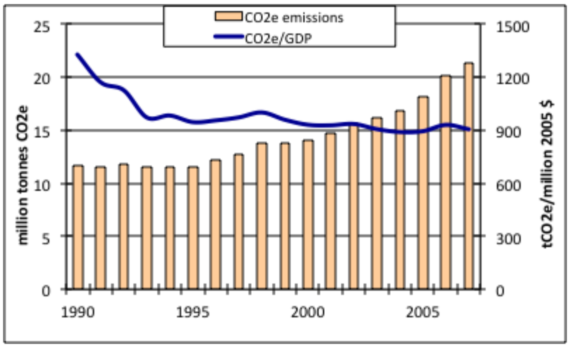
Bahrain's contribution to global GHG emissions of major GHGs - carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) - has steadily increased over the 17-year period 1990-2007, from 11.7 to 21.3 million tonnes of CO_2-equivalent (tCO_2e) with a corresponding increase in the national share of global emissions from 0.06% to 0.08% (WRI, 2011). On a per capita basis, Bahrain's carbon dioxide emissions are amongst the highest in the world at about 28.0 tCO_2e per person in 2007. This is over double per capita emissions in Annex 1 (13.9 tCO_2e/cap) and OECD (13.5 tCO_2e/cap) countries.

Carbon intensity follows a similar trend as that of energy. Since about 1988, Bahrain has steadily improved its carbon intensity, or carbon emissions per unit of GDP. Carbon intensity is a measure of the efficiency of economic activity with respect to the resulting carbon emissions; a decreasing value over time indicates that the carbon footprint relative to productive activities is becoming smaller.

Figure 4-3 shows this to be the case in Bahrain. In 1990, one million dollars of GDP was achieved at the expense of about 1,325 tonnes of carbon dioxide equivalent (CO_2e) emitted to the atmosphere. By 2007, only 905 tonnes of CO_2e were emitted to produce the same level of economic output, an improvement of about 32% during a period in which total CO_2e emissions nearly doubled.

Nevertheless, in 2007, the latest year for which international statistics are available, Bahrain significantly lagged behind EU countries where carbon intensities in averaged about 490 tCO_2e per million \$. GHG mitigation activities, in as much as they focus on both improving efficiency of resource use as well as fuel switching to low carbon-emitting alternatives, will push carbon intensity in Bahrain closer to that of EU countries over time. while also potentially leading to substantial fuel cost savings.

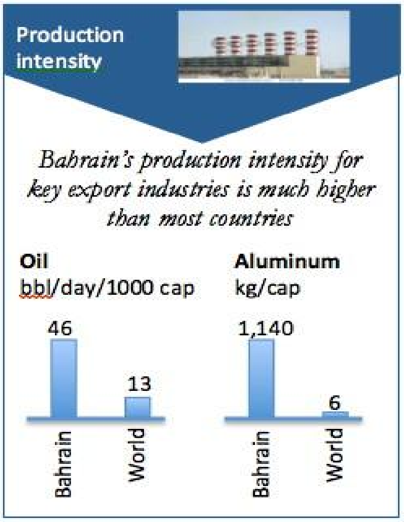
Figure 4-3: Historical carbon dioxide equivalent emissions and intensity in Bahrain, 1990-2007 (WRI, 2011)



The above patterns can be explained in large part by the intensity of Bahrain's key exports (see Figure 4-4). Export-oriented energy-intensive industries are the backbone of the Bahraini economy. Oil production is about 46 barrels per day for every thousand inhabitants, compared to a global average of only 13 barrels per day for every thousand people (EIA, 2011). Also, Bahrain produces about 1,140 kg/cap of aluminum per year, compared to a world average of only about 6 kg/capita per year (USGS, 2011).

In addition, Bahrain has experienced sustained and rapid growth. Over the period 1990-2007, the economy grew by nearly 170%, or about 6%/year on average. Public transport options remain few with attendant high use of cars and light trucks. Bahrain also has a very hot and arid climate and scarce fresh water resources. As a result, the nearly year-round demand for space cooling is very high compared to most countries. And, a high percentage of the water used comes from energy-intensive seawater desalination.

Figure 4-4: Key factors contributing to Bahrain's historic GHG emission trends



Sustainable energy initiatives

Driven by strong economic and population growth, energy consumption is projected to increase significantly in the coming years in Bahrain. At the same time, a general commitment to sustainable systems of production and consumption as an integral component of the energy mix is gradually emerging. Energy efficiency and renewable energy technologies, which can help meet Bahrain's current needs without compromising those of its future generations, are increasingly regarded as fundamental to a sustainable energy future. The sections below review some of the major initiatives underway in Bahrain to promote sustainable energy legislation, as well as major pilot projects for energy efficiency and renewable energy.

Legislative

At present, the National Economic Strategy (2009-2014) identifies energy efficiency and renewable energy as two strategic options to achieve a reduction in GHG emissions. While a clear action plan is not yet in place, there are a number of separate initiatives underway to promote sustainable energy legislation in Bahrain. Major activities include:

- Development of the *Economic Vision 2030 for Bahrain*, a comprehensive strategy document that outlines a set of policies and measures to improve energy and water efficiency, and develop renewable energy resources, while setting a target to reduce GHG per capita emissions by nearly two-thirds by 2014;

- Implementation of several industrial energy efficiency projects among the nation's largest energy consumers, by major energy consumers (e.g., Aluminum Bahrain (ALBA), Bahrain Petroleum Company (BAPCO), and the Gulf Petroleum Industries Company (GPIC)).

- Increasingly stringent enforcement of the 1999 building codes for insulation in new buildings to reduce air conditioning electricity requirements;

- Establishment of an Electricity & Water Conservation Directorate within the Electricity & Water Authority (EWA) to promote sustainable energy initiatives such as awareness campaigns, energy audits, load management studies, power factor corrections, and promoting compact fluorescent lighting (CFL);

- Promotion of high-efficiency district cooling strategies though the launching of Tabreed, a private-sector joint venture;

- Establishment of ad hoc sustainable energy committees, namely the Energy Conservation Committee at the National Gas & Oil Authority (NOGA) and a Renewable Energy Committee at EWA; and

- Establishment of the Supreme Energy Committee chaired by His Royal Highness, the Crown Prince to promote sustainable energy development, optimize use of available resources and assess appropriate alternatives to meet Bahrain's energy demand.

Each of the above initiatives is intended to facilitate the eventual development of comprehensive sustainable energy legislation in Bahrain. Such legislation is widely recognized as essential to promote increased energy efficiency and renewable energy at the national level.

While still in process, future legislation will establish a strategic energy vision, assign institutional roles/responsibilities, and enact regulatory and market-based instruments and policies. Comprehensive energy legislation will codify current public efforts; ensure better coordination of the various actions and measures than can be achieved by ad hoc committees; and provide a favorable planning context for policymaking.

Energy efficiency

Until recently, the preferred approach to meeting increasing electricity demand has been to build more power stations. However, this approach has led to accelerated depletion of indigenous hydrocarbon reserves, reduction in export revenues, deterioration of environmental quality, and disproportionate investments in power supply expansion relative to other priority investment areas. Increasingly, demand-side energy efficiency strategies are increasingly considered as a way of meeting power needs, while enhancing economic efficiency, promoting sustainability, and reducing risks.

Several market drivers are being introduced to facilitate the inclusion of energy efficiency strategies and measures. First, restructuring is underway in the energy sector in order to attract private investment. In addition, there are some state-owned enterprises that are in the process of being privatized, while low carbon development has risen higher on the agenda of private investors. Underlying these developments is the realization that Bahrain's diminishing oil and gas supplies will eventually need to be offset with other resources.

Thus, energy efficiency has become increasingly understood as essential for Bahrain's sustainable economic development. Indeed, there is now a widespread perception among policymakers that promoting energy efficiency in Bahrain can be economically beneficial by increasing oil supply available for exports, extending indigenous gas resources, enhancing industrial competitiveness in world markets, creating new jobs, improving environmental quality, and reducing GHG emissions.

Renewable Energy

Bahrain's future energy situation necessitates an urgent review of the potential development and use of renewable energy resources. Average annual solar radiation available in Bahrain is quite high, around 2600 $kWh/m^2/year$ and the technical potential for electric generation using solar thermal technology is about 33 TWh per year, or roughly 3 times current national electric generation levels (DRL, 2006). Bahrain's Economic Vision 2030 declared the need for alternative energy resources and as a result, there have been strategic initiatives by NOGA, EWA, and other public agencies to promote renewable energy technologies. Specifically, there have been some noteworthy pilot renewable energy projects as summarized in the bullets below.

- Three wind turbines on the World Trade Center in Manama, which meets about 13% of the building's electricity requirements, on average;

- A national assessment of wind energy potential, undertaken by NOGA in collaboration with a Japanese company;

- A pilot renewable power station implemented by EWA that will generate between 3 and 5 MW of power through renewable energy, both solar and wind;

- A pilot street lighting project using solar photovoltaic technology, implemented by EWA;

- The Petra Solar Project of NOGA to install 20MW of grid-Connected PV panels; and

- The Princess Sabeeka Park renewable energy educational project of BAPCO.

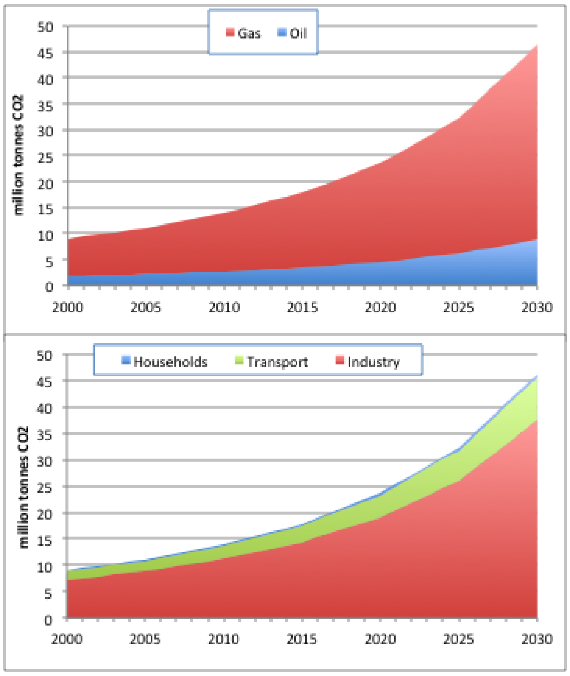
It is important to note that the above activities are being implemented as independent activities. Future legislation is needed so that such activities are outputs of an integrated and coordinated policy and institutional framework with appropriate incentives and mechanisms to promote robust private-sector investments.

Future carbon emissions

Future energy sector GHG emissions were estimated through 2030 assuming that historical trends would continue into the future, and that no additional new policies to mitigate GHG emissions would be implemented. The Long Range Energy Alternatives Planning system (LEAP), a widely used modeling tool for energy policy analysis and GHG mitigation assessment (Heaps, 2008), was used for the assessment. Specifically, the LEAP model was employed to construct a baseline scenario of future emissions based on the acquisition of wide range of data for major energy-consuming sectors (i.e., households, industry, transport) and energy supply (power plants, oil & gas), based on a study by Gelil (2010).

Figure 4-5 shows baseline GHG emissions for Bahrain between 2000 and 2030 by fuel and by sector. By 2030,annual GHG emissions from the energy sector are projected to increase to about 46 million tonnes of CO_2, an increase of over 37 million tonnes from levels in the year 2000, or a growth rate of about 5.6% per year.

Figure 4-5: Baseline GHG emission projections for the energy sector by fuel (top) and by sector (bottom) (Source: Gelil, 2010)



The combustion of natural Gas represents about 80% of GHG emissions in 2000, and this share is expected to continue in the future, even increasing slightly (see top curve of Figure 4-5). The industrial sector is the major energy intensive economic activity in Bahrain, and the overwhelming contributor to future growth in GHG emissions (see bottom curve of Figure 4-5). This is mainly due to the presence of ALBA, one of the world largest aluminum smelters.

The transport sector is the second largest emitter of GHGs, accounting for about 18% of energy sector emissions throughout the period through 2030. In the absence of public transport infrastructure and options, and the lack of policies to promote greater fuel economy in the light and heavy duty vehicle stock, emissions from cars, sport utility vehicles, light trucks and buses/trucks are expected to grow at an average annual rate of 5.6% per year, roughly double the population growth rate.

The share of GHG emissions from the household sector was small in 2000 - about 2% - and remain a small contributor to future emission levels. Household GHG emissions are associated with fuel consumption, primarily liquefied petroleum gas (LPG) for cooking. Emissions from electricity consumption are accounted for in the industrial sector.

There are several promising technologies and strategies for reducing the growth of GHG emissions in Bahrain that have been identified through a consultative process. For the power sector, the following represent the most attractive strategies:

- *Solar thermal technologies*: This would involve exploiting Bahrain's extensive solar energy potential by the introduction of concentrated solar power technology (i.e., parabolic trough, parabolic dish, tower plant);

- *Advanced natural gas combined cycle technology*: This involves shifting from oil-fired steam power plants and single cycle gas turbines to advanced natural gas combined cycle with combustion efficiencies around 55%.

- *Nuclear technology*: This would involve the development of civilian nuclear pressurized water reactors, an important option for relatively carbon-free electricity.

For the household and commercial sector, the following represent the most attractive strategies:

- *Efficient air conditioning*: This would involve the replacement of current system having an energy efficiency rating (EER) of 7.1 with higher-efficiency models having an EER of 10. Due to Bahrain's hot and arid climate space cooling is one of the most energy intensive services and would be significantly reduced.

- *Compact fluorescent lighting (CFL)*: This would involve the gradual phasing out of incandescent lighting and replacement with CFLs which show highly favorable cost-benefit ratios;

- *Solar hot water heaters*: This would involve the development of a solar hot water industry to promote switching from electricity for water heating. Given the high year-round solar insolation levels, such systems have very favorable economics.

For the industrial sector, GHG mitigation measures would first include detailed energy audits to identify a suite of technologies for investment. These would include CFLs, efficient motors and pumps, waste heat recovery, and combustion efficiency improvements, greater use of combined cycle technology to replace single cycle power generation, switching away from oil products to lower carbon intensity natural gas, and PFC reduction activities in the aluminum smelting industry.

Using cost and performance characteristics assembled from Ministries and other public agencies, a first-cut assessment of the incremental costs and GHG reduction benefits of the above technologies was conducted on a head-to-head basis using the LEAP model (El Gelil, 2010). A summary of the results of the assessment is provided in Table 4-1.

Overcoming barriers

In Bahrain, there have historically been a set of barriers that have put renewable energy and energy efficiency projects at an economic, regulatory, or institutional disadvantage relative to other forms of energy. Major local policy barriers are summarized as follows:

- *Lack of targets*: Both the National Economic Strategy (2009-2014) and the Economic Vision 2030 for Bahrain are silent on specific national targets or strategies for promoting energy efficiency and renewable energy;

- *Competitive disadvantages*: Energy and electricity markets favor traditional fossil-fired supply side investments. Access to the electric transmission and distribution system is unevenly provided to renewable energy technologies, or to independent power producers (IPPs); and

Table 4-1: Summary results of the assessment of the costs and benefits of GHG mitigation options

Sector	Option	Potential GHG Emission Reductions by 2030	Cost per Tonne	Priority for follow-up analysis
Power supply	Solar thermal	H	H	H+
	Advanced NG combined cycle	M	M	H
	Nuclear power	H	H	L
Household & commercial	High efficiency space cooling	H	L	H+
	Compact fluorescent lighting	H	L	H+
	Solar hot water heaters	H	L	H+
Industrial	Energy audits	NA	NA	H
	Efficient motors/pumps	M	M	M
	Waste heat recovery	M	M	M
	Combined cycle technology	H	L	H+
	Fuel switching	H	L	H+
	PFC reduction in aluminum industry	L	H	L

DEFINITIONS

Potential GHG Emission Reductions by 2030:
L = less that 0.1 million tCO2e; M = between 0.1 and 0.5 million tCOO2e; H = greater than 0.5 million tCO2e

Cost per Tonne avoided:
L = less than $0/tCO2e; M = between $0/tCO2e and $40/tCO2e; H = greater than $40/tCO2e

Priority for follow-up analysis:
L = low priority; M = medium priority; H = high priority; H+ very high priority

- *Low government priority*: There are currently very limited government expenditures on domestic research and development (R&D) programs, particularly an assessment of the country's range of renewable energy potential.

- *External costs ignored*: External costs to Bahraini society associated with heavy reliance on fossil fuels (e.g., impacts on local environment, human health, infrastructure, and fisheries) are not accounted for in decision-making.

Major local market-related policy barriers are summarized as follows:

- *Low capacity*: There is low institutional capacity for the management and dissemination of information about market opportunities of energy efficiency and renewable energy technologies;

- *Low public awareness*: There is a low level of consumer awareness regarding demand-side opportunities to reduce electricity use, leading to low market demand for energy efficient technologies;

- *Inadequate continuing education programs*: Professionals have few training options to augment their knowledge the fast-changing sustainable energy field;

- *Poor investment infrastructure*: The local banking sector is not geared to support investments in energy efficiency and renewable energy leading to a lack of proper financing schemes; and

- *Fossil energy subsidies*: Heavy energy subsidies favoring oil and gas remain in force and increase risks for investments in sustainable energy technologies having higher initial capital costs.

Overcoming the above barriers is a priority in order to promote the integration of sustainable energy technologies within Bahrain's economy. The following represents actions that need to be advanced in the near-term.

- *Promote awareness*: This involves the development of suitably designed information, databases, and other materials to build awareness among the general public, energy planners, and decision-makers regarding sustainable energy costs and benefits;

- *Develop suitable financing mechanisms*: Given the typically high initial capital costs of renewable energy technologies, suitably designed financial mechanisms need to be developed to ensure that long-terms benefits are considered;

- *Build local expertise*: At present, there are no training programs available that could promote the development of energy service companies. Such capacity building programs should be developed to keep pace with emerging trends and technologies; and

- *Undertake institutional reforms*: At present, renewable energy and energy efficiency activities are carried out on an ad hoc basis within a varied set of high-level committees. Such activities should be brought under an integrated institutional umbrella to promote coordination, priority-setting, and the development of needed legislative initiatives.

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5

Steps to Implement the Convention

In 1992, the Kingdom of Bahrain signed the United Nations Framework Convention on Climate Change (UNFCCC), which was ratified two years later. Since then, there have been numerous initiatives and strategies to implement the Convention consistent with the Kingdom's overall vision that "…economic growth must never come at the expense of the environment and the long-term well-being of our people: no effort will be spared to protect our environment and preserve our cultural heritage…"(KOB, 2011).

Summary of recent achievements

Today, Bahrain's steady commitment to environmental protection underlies a range of activities to promote the principles of the UNFCCC. These include efforts to overcome fragmented planning frameworks to better understand climate change risks and threats; build awareness among civil society and the private sector; and better coordinate mitigation and adaptation priorities among national agencies. Major initiatives over the past several years include the following:

- The *Economic Development Strategy* recommended a 5-year plan (2009-2014) to reduce emissions of nitrogen and sulphur oxides, protect biodiversity, reduce waste, and minimize adverse impacts of land reclamation and dredging activities (2000).

- Bahrain submitted its *Initial National Communication* (INC), thereby fulfilling an obligation under the UNFCCC (2005), and has been a participant at the annual COPs and other climate meetings (i.e., SBSTA, SBI).

- Bahrain's Council of Ministers approved the National Environmental Strategy (Edict No. 02–1902) that declared as key development principles i) improvement of environmental quality, ii) application of the precautionary principle, iii) imposition of a "polluter pays" program, and iv) development of partnerships for promoting sustainable development (2006).

- An agreement was reached between Bahrain and the United Nations Environment Programme (UNEP) for support in the preparation of Bahrain's Second National Communication (SNC) under the oversight of a National Climate Change Joint Committee (CCJC) responsible for national climate change policymaking (2007).

- Bahrain ranked well in the Human Development Report by raising its Human Development Index (HDI) from 0.820 in 2000 to 0.895 in 2009, thanks in large part to the initiatives implemented during the decade (2009).

Framework for action

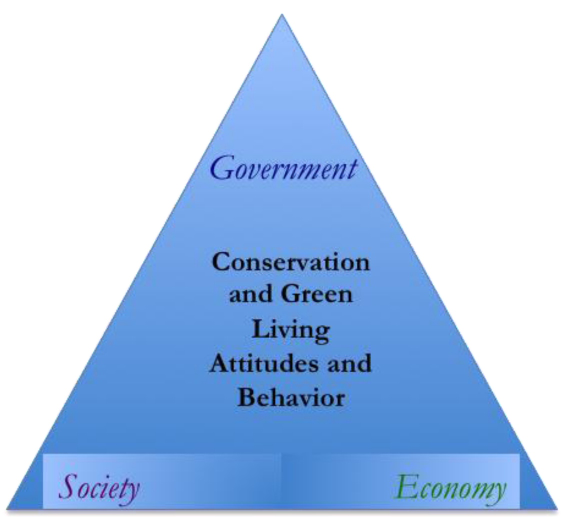
As a point of departure for action to implement the Convention, the Kingdom of Bahrain is in strong agreement with the conclusions reached by the Intergovernmental Panel on Climate Change (IPCC) that the global climate is changing due to increasing concentrations of GHGs from human activities. The adverse impacts of climate change are already being experienced in Bahrain and will affect all nations, industrialized and developing, in the coming decades.

Bahrain's ongoing national response to climate change is focused on the development of strategic partnerships for effective action among government institutions, private sector organizations, and civil society groups. This is considered fundamental in order to integrate emerging climate change risks and threats into new programmes, practices, and plans. Specifically, three main aspects underscore Bahrain's strategy to implement the Convention, awareness-raising, GHG mitigation, and adaptation.

Awareness-raising

In Bahrain, awareness-raising activities are considered a fundamental activity to ensure that decision-makers and the general public are informed about the challenge of climate change. At the national level, they have involved the design and implementation of public campaigns and educational. In the future, a key strategy for awareness-raising activities will be to try to coordinate initiatives across sectors and stakeholders through an integrated action plan that effectively builds awareness among educators, policymakers, vocational trainers, legislators, regulators, researchers, citizens, and the business community. The success of any such awareness-raising action plan will depend on supportive national leadership reflected in new legislation, regulations and adequate operational budgets.

Figure 5-1: Key pillars and aim for implementing the Convention



GHG mitigation

GHG mitigation involves greater governmental emphasis on renewable energy and energy efficiency as an approach to limiting growth in national GHG emissions. At the planning level, this consists of setting targets for the penetration of renewable energy technologies and other strategies to reduce emissions associated with energy production. At the individual citizen level, GHG mitigation consists of simple energy conservation measures to reduce electricity consumption, as well as the purchase of more efficient appliances, vehicles, and water use equipment.

Adaptation

Adaptation involves efforts to identify and implement practical and sustainable strategies to reduce vulnerability to the impacts of climate change, with a particular emphasis on changing consumption-oriented habits. At the citizen level, past awareness-raising activities have stressed that many of these strategies are already well-known to individuals and communities. They include, among others, recycling, avoiding unnecessary shopping, eliminating the use of plastic bags/bottles, and wasting less food. Inasmuch as the individual-level mitigation strategies identified in the subsection above can conserve local water and energy resources, they serve a complementary adaptation function. At the sectoral level, specific recommendations have been proposed for coastal zones, water resources, and ecosystems.

Strategy formulation

Bahrain's National Economic Development Vision 2030 declares that "… At the heart of the economic vision lie the aspirations for our economy, government and society in accordance with the guiding principles of sustainability, competitiveness and fairness…" These three entities - government, economy and society – are key pillars to raise awareness regarding climate change threats. As illustrated in Figure 5-1, these pillars are critical components for promoting conservation and green living attitudes and behavior in Bahrain (Es'haqi, 2009), and will enhance compliance with the Convention's objectives.

Strategy formulation to implement the Convention also involves coordination across multilateral agreements to which Bahrain is a signator. The biodiversity and desertification Conventions, as well as Kyoto Protocol Article 6, Agenda 21, and the Millennium Development Goals (MDG) need to be embraced synergistically in order to effectively strengthen national objectives, targets, and plans for combating overlapping climate change threats discussed in Chapter 3.

Bahrain considers that strategy formulation to implement the Convention is more of a journey than a destination. It involves vision setting from which long-term strategies and plans emerge to achieve the vision. It also involves the implementation of near-term objectives, pathways, and initiatives to ensure success in meeting long-term goals. In particular, synchronization between short and long-term objectives is essential. Moreover, overcoming fragmented planning, a key challenge for Bahrain, remains a priority in order to meet the objectives of the Convention.

Vision

Bahrain's vision for the ongoing implementation of the Convention was established through an extensive consultative process in order to define a clear vision for values, goals, implementation modalities, and achievement indicators (Es'haqi, 2010).

What emerged from the consultations was the need to develop a coordinated national awareness program to address key gaps in the implementation of the Convention. Specifically, four strategic elements - public engagement, educational reform, institutional coordination, and technical capacity building – underscore Bahrain's approach going forward to implement the Convention.

Public engagement

All segments of Bahraini society need to become engaged in addressing climate change in appropriate ways. That is, the government's aspiration is that all people living in Bahrain - whatever their age, nationality, level of education, or occupation - become engaged on the climate change issue, a global phenomenon that threatens everyone.

A key initial strategy for promoting public engagement is the development of a set of "Climate Change Best Practice Guides". The aim of these guides is to inform stakeholders of practical conservation measures (e.g., recycling), concrete ways to reduce carbon footprints (e.g., energy efficient appliances), and simple strategies to increase resilience to climate change impacts (e.g., multiple uses of scarce freshwater supplies).

These guides will be tailored to the perspectives, informational requirements and languages of major societal groups such as the trades (farmers, fishermen, and construction), children (i.e., kindergarten, primary school), households, businesses, and health professionals. Simple, clear and positive language will be used to promote group-specific understanding of key issues, options, and actions.

Educational reform

There are several educational reform initiatives that will be implemented to enhance climate change awareness-raising. Specifically, a four-part strategy, as described below, will be developed, implemented reviewed regularly, and modified/updated as needed.

First, Education for sustainable development (ESD) principles will be better integrated in the primary school study curricula overseen by the Ministry of Education (MOE). This will include a greater emphasis on environmental topics such as recycling, green schools, school auditing, and energy and water conservation throughout curricula for science, math, social studies, geography, and religious studies. This initiative supports Article 3 of the national 'Educational Law Project' that advocates building "…an awareness of the environmental features and human heritage and the means of conserving and utilizing them..." (MOE, 2011). Moreover, educational reform will be harmonized with Agenda 21 recommendations to help preserve the rights of future generations in Bahrain to its natural resource heritage.

Second, the scope of the Quality Assurance Authority for Education and Training (QAAET) will be expanded to address climate change. This authority, established by the Government in 2001 for education reform, will seek to augment the educational system with 'fit-for-purpose' climate change programs to equip future generations with the skills and knowledge to confront climate change and build sustainable communities. Specifically, teacher training will be the key near-term strategy to build such programs.

Third, an environmental auditing system will be established at the primary school level. The aim of the system is to monitor patterns relative to water use, energy conservation, and solid waste management. The need for such a system became evident from school visits during the consultative process. The results of the program should help to raise student awareness on climate change threats as well as identify schools/areas where progress may be lagging in the promotion of conservation and sustainability perspectives.

Finally, a hands-on approach to climate change will be promoted at all educational levels. This will involve introducing field-based educational techniques such as the creation of eco-clubs, support for student-led conservation campaigns and other ideas that collectively engage students around climate change issues and concerns. Similar programs, in principle, could also be developed in support of NGO's, companies, research centers, and policymakers.

Institutional coordination

Coordination of climate change awareness-raising activities across governmental and non-governmental institutions is both a challenge and necessity in Bahrain. These entities are essential to effectively engage households, decision-makers, and the private sector on concrete actions such as conservation, recycling, green energy and building options.

Key future initiatives to be undertaken are as following:

- *Community advisory services*: This involves creation of an advisory office on climate change for the community within the Public Commission for Protection of Marine Resources, Environment and Wildlife (PCPMREW).

- *Telephone hotline*: This involves the establishment of a central toll-free telephone number for information on practical measures to reduce energy consumption.

- *Civil society support*: This involves development of an enabling environment for the creation of new civil society groups interested in molding public opinion in support of environmental and sustainable development goals.

- *Information exchange*: This involves Bahrain becomes a regional hub for conferences and workshops on emerging technologies and trends regarding green technology and clean energy, as well as the creation of an official website promoting such information exchanges as well as providing climate change literature for the public in Arabic.

- *Media engagement*: All forms of media (i.e., television, print, radio) should be enlisted in promoting awareness-raising. Media support is crucial and should be creative and attractive for achieving the targeted objectives of raising people awareness towards climate change and sustainable development.

Technical capacity building

The final strategic element in Bahrain's vision for implementing the Convention is technical capacity building. This involves training workshops to ensure that policy-makers, civil society, trade groups, and the private sector have simple and straightforward access to climate change information. It also involves a number of proposed future initiatives as briefly described below:

- *Research and development*: Government investments should increase in research and development (R&D) and manpower development in clean technology and waste management.

- *Technology transfer*: Bahrain should prioritize the creation of enabling environments that can facilitate clean technology transfer as well as the introduction of climate change risk evaluation methods and tools.

- *Incentives development*: New incentive regimes need to be formulated to encourage investments in clean technologies, sustainable practices, and innovative research to reduce Bahrain's carbon footprint in key sectors and productive activities.

- *Niche markets*: The business community should be encouraged to develop and exploit emerging niche markets for energy services (audits, renewable energy technologies, high-efficiency appliances). New regulations and incentive regimes should to be developed to facilitate the emergence of such niche markets.

- *Partnership-building*: New public-private partnerships should be established to catalyse the technical capacity building initiatives indicated above. Such networks can help create strong and organized effective systems for building community capability to cope with climate change threats through risk-sharing.

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