Executive Summary
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

Feb2012

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.

Eng. Zahwa M.S. AL- Kuwari
Director of Environmental Assessment &Planning ,
N.F.P for UNFCCC
Public Commission for the Protection of Marine Resources, Environment and Wildlife
Manama, Bahrain

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	ManageAquiferRecharge

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-borne diseases
QAAET	Quality Assurance Authority for Education and Training
R&D	research and development
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

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 in

creased by almost 90 km^2as land reclamation policieshave been and continue to be pursued.

Climate.Bahrain has very hot summers and relatively mild winters. Mean air temperature fluctuates between 14°Cand 41°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. Work is on going to increase the Crude oil production to 100,000 bpd by 2017 from the current 40,000 bpd. 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 about4.4%/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 15years of age is compulsory and higher education is available through 2governmental 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 *Revised 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 22,374GgCO_2-equivalent, which includes 17,254 Gg from energy;2,515Gg from industrial processes; and 2,605 Ggfrom waste.

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	NM VOC	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**

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(SF6).

Energy-related activities accounted for the dominant portion of GHG emissions in Bahrain in 2000. Approximately77% 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 19,468 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 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 municipalsolid waste (MSW), municipal wastewater, and other wastes. MSW is the main source of GHGs and has been increasing at less than half the population annual growth rate. Municipal wastewater 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, 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 18 km^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, 418 km^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, 164 km^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 54 km, 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.

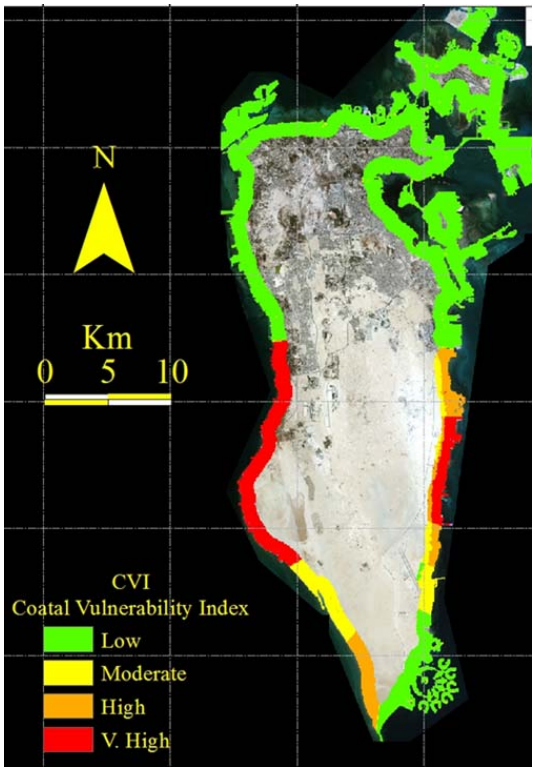
The remaining coastal areas are classified as low to moderate vulnerability. Comprising a total length of 630 km (88% of the total length of the coastline), these areas benefit from a combination of hard

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%

coastal protection structures and high rates of shoreline change (i.e., reclamation activities). Figure ES-1 summarizes the CVI assessment results.

Figure ES-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 intothe 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.

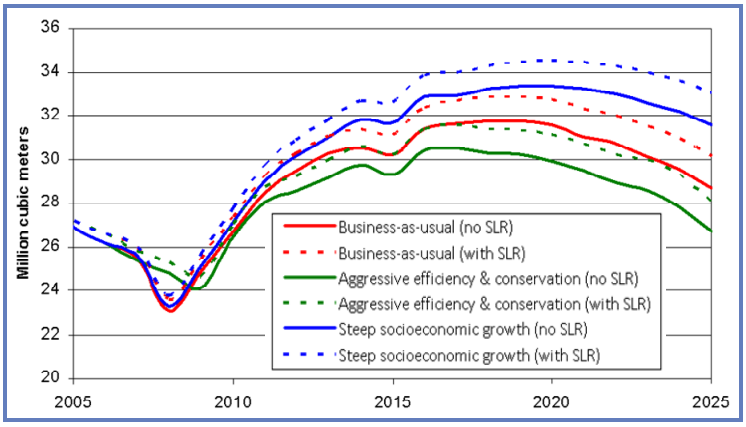
Bahrain relies on the Dammam aquifer for more than 30% of its water supply. However, the aquifer is now in a state of severe decline and quality deterioration due to decades of unsustainable use. Hence, the main water resource management challenge is how to balance decreasing water supply and increasing 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.

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



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.

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 landscapeto 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%.

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, rehabilitationof 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 aclear 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 milliontonnes of CO_2 by 2030, an increase of over 37 milliontonnes 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.

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 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.

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

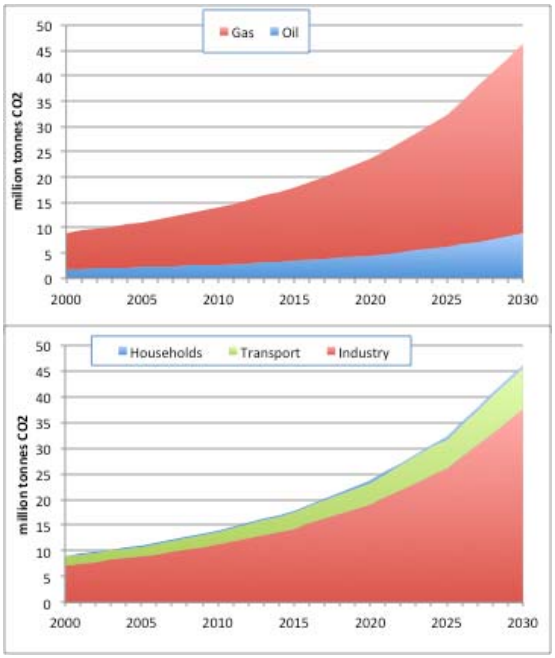


Table ES-3: Summary results of the assessment of the costs and benefits of GHG mitigation options

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

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 hotlines, 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.