Bahrain's

Initial Communications to the United Nations Framework Convention on Climate Change

Volume I: Main Summary Report

Kingdom of Bahrain
General Commission for the Protection of Marine Resources, Environment & Wildlife

March 2005

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Preface

The Kingdom of Bahrain, along with over 150 countries, endorsed the UN Framework Convention on Climate Change at the Earth Summit in Rio de Janeiro, Brazil in June 1992. Taking into consideration the importance of the convention, Bahrain ratified the Framework Convention in December 1992.

At the time of preparation of National Communications, Bahrain has been engaged in discussions about ratification of the Kyoto Protocol, which is planned for imminent ratification.

The Kingdom of Bahrain is very pleased to present this initial National Communication in fulfillment and its obligations towards as a Party to the Framework Convention, and soon to the Kyoto Protocol.

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Volume I: Main Summary Report

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Volume II: Technical Annexes

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List of Abbreviations

AGU	Arabian Gulf University
CFL	Compact florescent light
CH_4	Methane
CC	climate change
CO	Carbon monoxide
CO_2	Carbon dioxide
CSC	Cost of saved carbon
CSO	Central Statistical Office
DSM	Demand Side Management
EA	Environmental Affairs
EF	Emission Factors
EIA	Energy Information Agency
ESCWA	Economic and Social Commission for West Asia
FAO	Food and Agriculture Organization
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GDPEW	General Directorate for the Protection of Environment and Wildlife
GEF	Global Environment Facility
GHGs	Greenhouse Gases
Gg	(10^9 grams) G
GJ	Gigajoules (10^9 Joules)
GWh	Gigawatt-hours (10^9 Watt-hours)
GWP	Global Warming Potential
Ha	Hectare
HFCs	Hydrofluorocarbons
IBA	Important Bird Area
ICZM	Integrated coastal zone management
IPCC	Intergovernmental Panel on Climate Change
km^2	Square kilometer
KOB	Kingdom of Bahrain
KSA	Kingdom of Saudi Arabia
kWh	kilowatt-hour (10^3 watt-hours)
LPG	Liquid petroleum gas
m^2	Square meter
MoWA	Ministry of Works and Agriculture
MW	Megawatt
NG	Natural gas
NGO	Non-governmental organization
NMVOCs	Non-methane volatile organic compounds
NO_X	Nitrous Oxides
O&M	Operation and maintenance
PV	Photovoltaic
SLR	Sea Level Rise
SO_2	Sulfur Dioxide
SO_x	Sulfur Oxides
TAR	Third Assessment Report
tC	tones of carbon
TOE	Tonnes of oil equivalent
tonne	10^3 kilograms
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
V&A	Vulnerability and Adaptation

1 National Circumstances

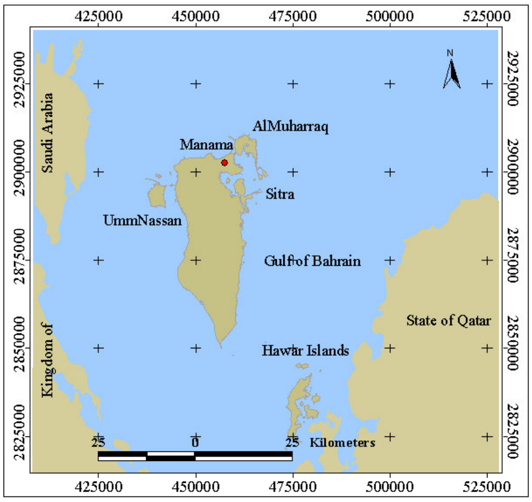
The State of Bahrain, an archipelago of 36 low-lying islands and shoals, is a nation of dynamic social and ecological systems as well as a plethora of accompanying climate-related challenges. In this chapter, the country's main characteristics are outlined in an attempt to provide readers with a sense of the context in which Bahrain's climate change challenges need to be seen.

1.1 Geographic Profile

The total land area of the Kingdom of Bahrain (KOB) in 1999 was about 706 square kilometers (km^2). It is located in the Arabian Gulf stretching between latitudes 25^0 32' N and 26^0 20'N and Longitudes 50^0 20'E and 50^0 50'E. There are approximately 534 km of coastline. The highest point in the country is *jabal Dukhan* at about 134 meters above sea level.

The capital city, Manama, is located on the largest island, Bahrain, which accounts for about 84 percent of the total area of the country. Other islands include Al Muharrah (4% of total land area), Sitrah (2%), Umm Nassan (3%), Nabih Saleh (0.1%) and Jiddah (0.05%). The southern chain includes Hawar, Sawad and other small islets (7%). Figure 1.1 shows a physical map of the country.

Figure 1.1 Kingdom of Bahrain



1.1.1 Land use

Land and freshwater resources in Bahrain, like many small islands, are subject to competing demands for urban development, agriculture, industry, and other uses. These two resources are vital for meeting basic human needs, economic growth and improved access to goods and services.

The total land area of Bahrain has been steadily increasing since the 1970's through land reclamation and dredging activities. Many sites along the northern and northeastern coastal areas were dredged and reclaimed for industrial, recreational and residential purposes. As a result, the country's total land area has increased from about 662 km^2 in 1975 to about 710 km^2 in 2000.

Although reclamation activities have significantly increased prime and suitable land for various development projects, they included a host of adverse social, economic and environmental impacts. In an effort to lessen the adverse impacts associated with future reclamation efforts, discussions are underway for Bahrain to adopt an integrated coastal area management approach for strategic planning.

Due to rapid urban and industrial development, valuable agricultural land in Bahrain has been increasingly lost. Arable lands have been converted to residential areas as demand has continued to increase for housing and recreational facilities. Moreover, high soil salinity resulting from the use of groundwater for irrigation has reduced the potential area that could be used for crop cultivations (FAO, 1997). At present, these irrigated areas consist of both annual crops and permanent tree-crops. Because of the low rainfall, poor soil and adverse climatic conditions, natural vegetation cover is sparse and forests do not exist in Bahrain.

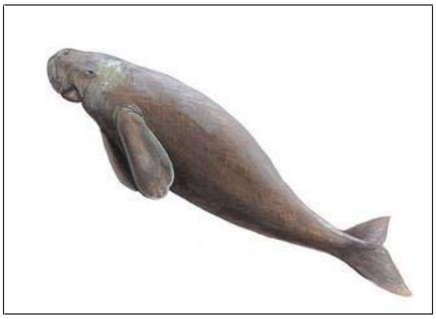
1.1.2 Ecosystems

Natural vegetation is of limited extent and is composed mainly of mangrove plantations, desert ephemerals, and halophytes (Abbas, 1999). Mangroves have important ecological functions in Bahrain for attenuating wave action, sheltering native species of flora and fauna and reducing seawater turbidity. They grow naturally in several coastal areas, support a wide variety of indigenous bird species, and are integral part of local biodiversity.

Local marine ecosystems are rich in fish stocks, sea grasses, and corals (Sheppard, et al, 1992). For example, there are 31 species of corals in the waters around Bahrain, which are nursery habitats for shrimp, crabs, and other sea creatures. Coral reefs thrive in the harsh Bahraini environment of high water temperatures, salinity levels and sedimentation. In addition, coastal salt marshes are sensitive ecosystems that contain quite, a large variety of native plant species. These areas are used as feeding and breeding sites for several kinds of birds and other species.

The Hawar island chain, located about 26 km southeast of the main island of Bahrain (Figure 1.1) is a sensitive wetland ecosystem area. The islands are home to the globally threatened dugon *Dugong dugon* (Figure 1.2) and possess rich inshore waters that support a variety of fish and other marine organisms. The islands are an important breeding area for resident and migrant sea birds and are internationally designated as an Important Bird Area (IBA).

Figure 1.2: Dugong dugon (top) and Western Reef Heron (bottom



source: University of Michigan Museum of zoology

source: www.digimages.info/

Within the Hawar chain, the islands of Rubud Al Gharbiyah and Rubud Ash Sharquiyah are breeding sites for the Western Reef Heron *(Egretta gularis schistacea)* (Figure 1.2) and wintering grounds for Slender Billed Gulls (*Larus genei*) and Greater Flamingos (*Phoenicopterus*). They are also a staging post for migrant waders. Box 1.1 illustrates the locations of sensitive breeding sites, nesting sites, feeding areas, and migration flyways for the islands.

1.2 Climatic Profile

Bahrain's climate is influenced by its location in a large arid zone, which extends from the Sahara northeastwards across the Arabian Peninsula, to the central Asian deserts. The climate of Bahrain is further

Box 1.1 Bird activity in the Hawar island group

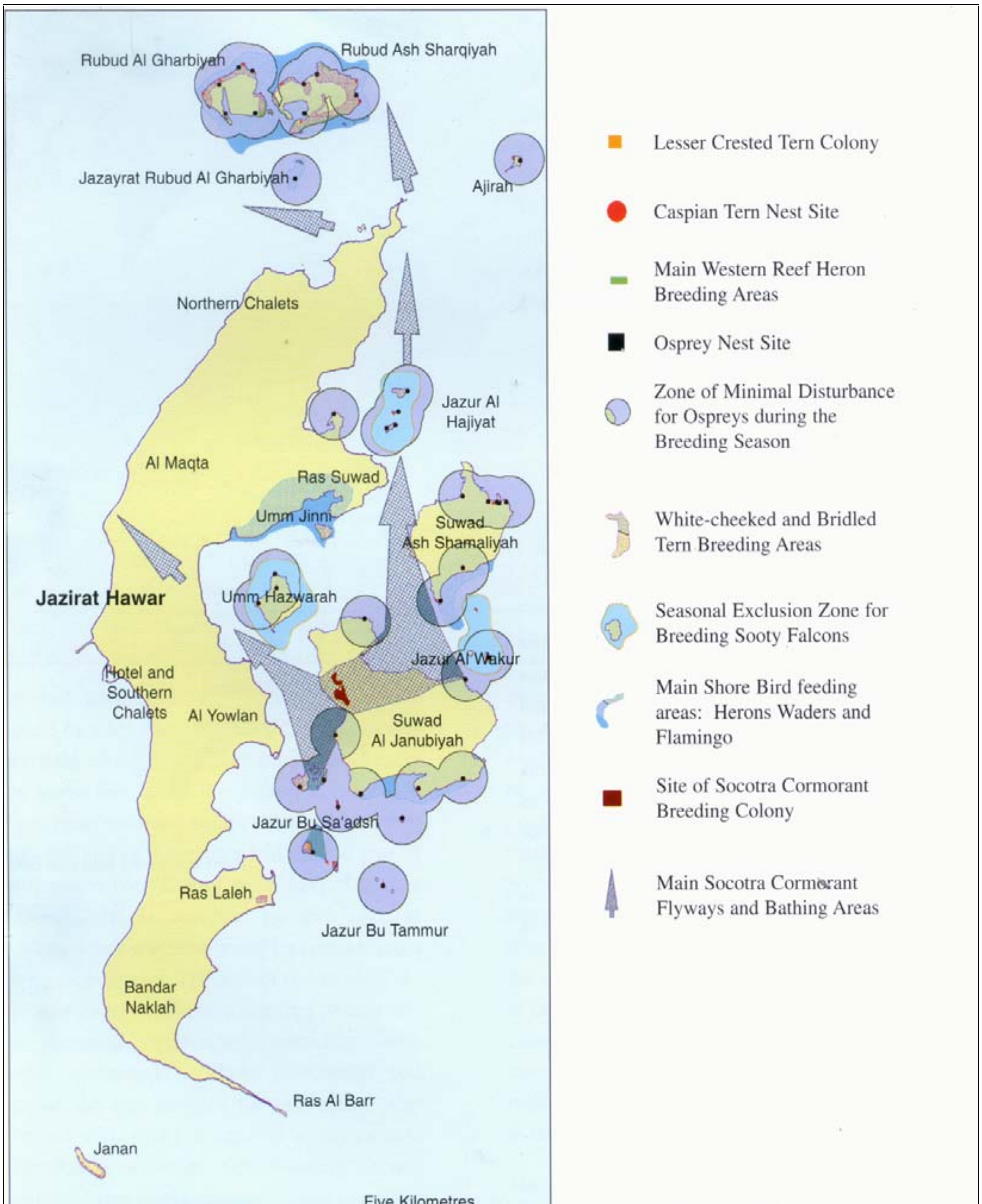


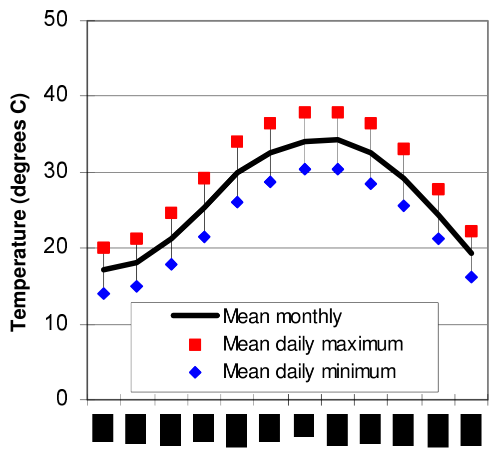
Figure 3.10 Ornithological Chart of Breeding Sensitivity and Feeding Activity

influenced by its proximity to tropical zones and being situated within the Arabian Gulf, a virtually land-locked sea bordered by arid landmasses. The predominant winds across the islands are northwesterly, locally known as *Shamal* and have average speeds of over 11 knots.

Bahrain has two seasons: a very hot summer and a relatively mild winter. During the summer months, which extend from April to October, mean monthly temperature range from 24.5 to 34.2 degrees Centigrade. On the hottest summer days in July and August, afternoon temperatures can reach 48° C. Figure 1.3 provides a summary of temperature data for the period 1961-1994.

The small amount of rainfall that Bahrain receives is scant, erratic, and occurs during the cool winter season that extends from November to April. Average annual rainfall is about 74 millimeters spread across an average of 10 rainy days per year, none of which occur in the summer months. High relative humidity levels due to high seawater temperatures, as well as atmospheric temperature inversions characterize the islands of Bahrain throughout the year. Mean monthly relative humidity reached about 67% with mean daily maxima varying from 78% to 88%.

Figure 1.3 Average temperatures, 1961-2000



Source: CAD (Civil Aviation Directorate), 2000.

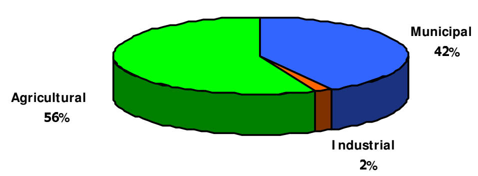
1.3 Water Resources

Bahrain has no natural fresh, surface water resources. Hence, groundwater and desalinated seawater are the only sources to meet water needs for households, industry and agriculture. Annual water consumption is nearly 320 million m^3. Figure 1.4 shows a breakdown of this amount by different sectors for the year 2001. Most of the water, nearly 60%, is consumed in the agricultural sector, which relies heavily on irrigation.

The average annual per capita consumption rate is about 490 m^3 per person and has been steadily increasing at the rate of about 2.5% per year. Current trends in sectoral water use are similar to earlier years, with only modest declines in water for use in agricultural relative to the other economic sectors.

The production of desalinated water continues to increase as the quantity and quality of underground water tends to decline and per capita consumption increases. In 2001, about 90 million m^3 of distilled water were produced using electric power stations. This represents a significant share of total water consumption (30%). In order to meet the increasing demand for water, plans are in place to increasing electric generating capacity over three phases. The initial Phase I, already in progress, adds sufficient electric capacity to enable the additional desalinization of 50 million m^3 of desalinated seawater per year.

Figure 1.4 Water Use, 2001



Source: W. K. Al-Zubari, 2003

By 2007, the goal is another 90 million m^3 of desalinated seawater per year.

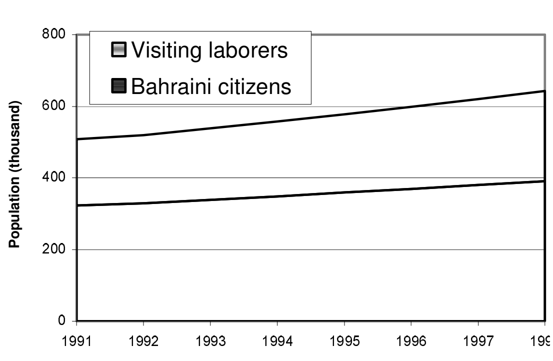
1.4 Population and Demographic Trends

Bahrain's total population was just over 508 thousand in 1991, the year of the last official census. The country has experienced large population growth over the years, with an annual national population growth of 3.6% per year rate during the period 1981-1991, making it one of the highest in the world. In fact, the total population has increased six fold to about 600 thousand people since the first official national census was carried out in 1941.

Population growth in Bahrain is influenced by two significant factors. Growth of the indigenous population as social, health and economic conditions improve and the rising number of foreign laborers as demand for new skills by various economic sectors increases. Behind the fast growth of both the Bahraini and non-Bahraini population was the discovery of oil in 1932, and the investment of its revenues in a range of national development projects and diversification of the economy.

Figure 1.5 summarizes population growth patterns for Bahrain for the period 1991-1998. In 1991, the native Bahraini population represented about 64% of the total population, dropping to about 62% by 1996. As the economy diversified demand for skilled labor increased, especially in the industrial and service sectors, the non-Bahraini population increased significantly - from 190,000 in 1992 to almost 251,000 in 1998, an increase of about 21%, or almost 5% per year.

Figure 1.5 Population growth, 1991-98



Source: CSO (1999)

Most of the population of Bahrain is concentrated along coastal zones particularly in the north and northeastern parts of the main island Bahrain. High population densities - approximately 731 persons/km^2 in 1991 and reaching about 880 persons/km^2 in 1997 - characterize these areas. This is due in large part to historically high urbanization rates, which have been intensifying in recent years. In 1941, 70% of the population resided in urban areas. This level increased to over 90% by 1994.

The overall (i.e., including native Bahraini and non-Bahraini segments of the population) literacy rate for individuals 10 years old and over in Bahrain was about 86% in 1991, the year of the last census taken. The overall literacy rate among males was almost 90%, and about 81% for females. For the native Bahraini population, literacy rate are quite high, ranging from about 83% for males to 76% among females). More recent estimates indicate that the literacy rate continues to improve for the overall Bahraini population, increasing to a little over 84% in 1993 (88% among the male population and 78% among the female population).

1.5 Human Health

Life expectancy increased from 51 years during the period 1950-1955, to 64 years during 1970-1975, and reached 72 years during the period 1990-1995, an excellent indicator of national achievements in the provision of health care services. The population of Bahrain is relatively young. The 1991 census results showed that about

32% of the population was younger than 14, and 66% between the ages of 15 and 65. Only 2% of the population was above 65 years of age.

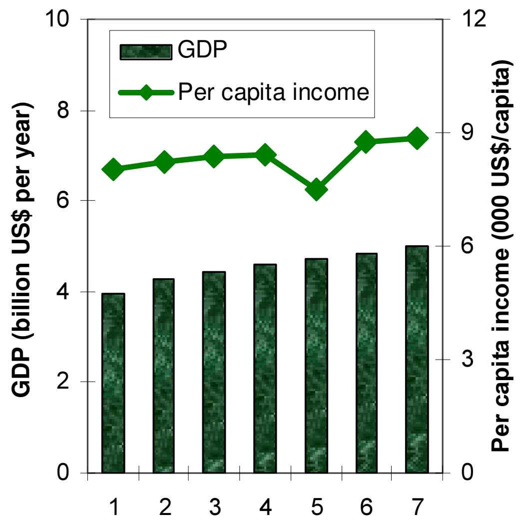
1.6 General Economic Profile

Bahrain is governed by a constitutional hereditary monarchy, and is composed of 12 municipalities. Prior to the discovery of oil in the early thirties the economy of Bahrain was dependent on pearl fishing, agriculture and regional trade. Since then, the major engine of economic growth in Bahrain has been the oil and natural gas industry.

The country gained its independence in 1971. Shortly afterward, socio-economic and restructuring of the economy took place at a rapid pace, boosted by the growing production of oil and gas and rising national revenues as oil prices increased in the world market, particularly after 1973. Because of the economic risks associated with oil price volatility, sustained policy initiatives were undertaken to diversify the national economy as a risk-hedging strategy. Industrialization became a focus, together with efforts to establish Bahrain as an international financial and service center located in the heart of the Middle East.

The Bahraini economy has shown steady growth over the 1990-1996 period (see Figure 1.6). The rates of growth during earlier periods 1982-1994 experienced wide variations. It declined from 7.87 percent in 1991 to 2.5 percent by 1994, and never exceeded 4 percent on average during the period 1992-1996. Per capita annual income ranged from a low of about US$7,500 in 1994 during a year of slows economic growth, to a high of about $8,858 in 1996.

Figure 1.6: GDP and Income trends, 1991-96

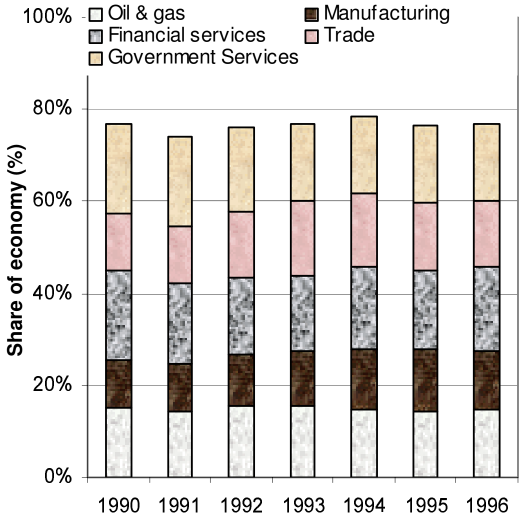


Source: Central Statistics Organization, 1999

The continued diversification of the Bahraini economy has been evident during the 1990's. There are five major sectors, which represent nearly 80% of activity in Bahraini economy. In addition to the oil & gas sector, these are trade, financial services, manufacturing, and government services. As illustrated in Figure 1.7, the oil and gas sector's share over the period 1990-1996 has been comparable to that of the other sectors. Overall, the oil sector (mining and quarrying in Figure 1.7 represents about 15% of overall economic activity over this period - even showing a slight decrease by 1996 – reflecting deliberate national policies of encouraging investments outside the oil sector in order to build a more diversified and resilient economy.

This is particularly evident in the manufacturing sector whose share of GDP steady increased from 10% in 1990 to almost 13% by 1996. The share of financial services, which was about 20% percent in 1990, has decreased slightly to 19% in 1996. Government services contributed about 19% in 1990 and 17% in 1996, indicating an expansion of the role played by the private sector in providing some of the services traditionally provided by the public sector.

Figure 1.7 Major economic sector shares, 1990-1996



Source: CSO (Central Statistics Organization) 1999

1.7 Energy

The turning point in the economic and social history of Bahrain was the discovery of oil in 1932. Since then, crude oil production, processing, distribution and consumption became major economic activities and significant sources of national income. Production of crude oil continues to increase to meet the growing demand for energy by all sectors of the economy. Most local crude production is consumed locally in refined oil products.

Production of crude oil reached a peak of 15.7 million barrels in 1988, dropping to 14.7 million in 1994 and continuing to drop slightly after that. Large quantities of crude are also imported from Saudi Arabia for processing in Bahraini refineries and eventual export to international markets.

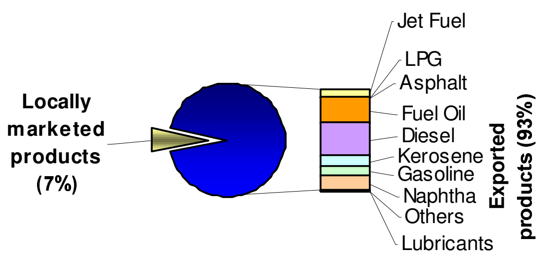
Bahrain's crude oil refining capacity has steadily increased over the past decades. The vast majority of refined oil products, over 93%, are exported to international markets (see Figure 1.8).

In recent years, natural gas has become more widely used, with consumption rising to 967 million cubic feet per day in 1994 and continuing to increase since then. Most of the natural gas consumed in Bahrain is used to generate electricity and to satisfy heat demand from the manufacturing industries, mostly in the aluminum industry.

Electric power generation has shown steady increase significantly over the years. Generated electricity increased by almost 5% between 1998 and 1999, (i.e., from 5,227 to 5,469 GWh). The installed available electric generating capacity in Bahrain in 1994 was 946 MW and consists of four publicly owned power stations (i.e., Manama, Muharraq, Riffa and Sitra). The annual output from these plants typically account for about 83% of total electricity generated, with the remainder (17%) imported from the power station of the aluminum smelting plant (ALBA).

The demand for electricity is relatively high compared to the region, as well as compared to the world.. Average annual per capita electricity consumption increased from 3,601 kWh in 1990 to 4,638 kWh in 1994, an overall increase of 29% (or 2.9%/year) increase during the same period. Total generation to satisfy rising industrial, household, and other demand increased from 3,000 GWh in 1990 to 5,469 in 1999, an overall increase of 82% (or 6.8% per year) Most of the electricity consumed is in the household sector which accounts for about 60% of total electricity demand. Figure 1.9 summarizes electric consumption patterns.

Figure 1.8 Refined oil products, 1994 (thousands of tonnes of oil equivalent)



Source: Oil Directorate, Ministry of Oil & Industry

1.8 Transportation

Rapid industrial and urban development has been accompanied by rapid increases in the number of private and public cars and service vehicles, particularly within the urban areas, causing problems of congestion and increased air pollutant emissions. Vehicle ownership has increased by about 5.4% per year over the period 1990-1995, from 130 to 169 thousand vehicles. It is expected that the number of cars per person will continue to rise from its level of 0.3 in 1995.

Fuel consumption has risen less rapidly than vehicle ownership thanks in part to rising fuel economies. Total fuel consumed in personal cars rose to 189 million liters in 1997 (126 million liters for diesel; 63 million liters for gasoline), an annual growth rate of about 2.1%. Over this same period, the annual rate of fuel economy improvement was 2.4%. However, in Bahrain the average fuel economy for the personal vehicle stock was low, ranging from about 2.9 liters per 100 km in 1990 to 2.5 liters per 100 km in 1997.

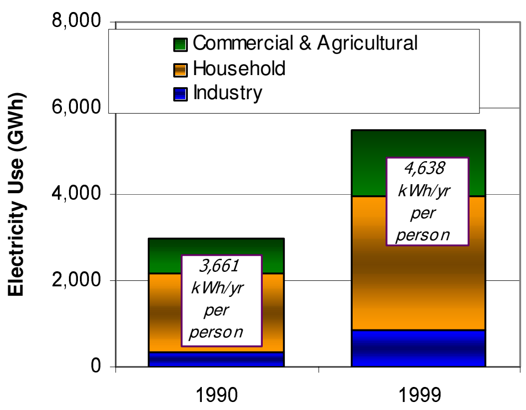
1.9 Industry

The industrial base in Bahrain comprises a number of industries, some mature, others only recently developed. Aluminum manufacturing is one of the main contributors to national wealth in Bahrain, following closely after oil and natural gas production. Aluminum Bahrain (ALBA), the national aluminum company produces about 450,000 tonnes of aluminum per year. Bahrain is a large consumer of petrol coke in the aluminum industry, consuming about 210,000 tonnes of petrol coke in 1994.

The chemical industry in Bahrain includes chemical industries, asphalt production, and cement production. There are two asphalt roofing plants in Bahrain (Arabian Company for Chemical Products and Bahrain Membrane Plant), producing a combined 1,550 tonnes of asphalt roofing materials per year. There are three plants producing road-surfacing asphalt (Bahrain Asphalt Co., United Gulf Asphalt and Construction, and Eastern Co.), producing a combined 340,686 tonnes. There is only one cement Packing Factory in Bahrain, producing about 147,000 tonnes per year

The main food processing industries in Bahrain include bread, poultry, cakes, biscuits, and animal feeds. A variety of goods, including flours, cakes and biscuits

Figure 1.9 Electricity use patterns, 1990 & 1999



Source: Central Statistics Organization, 1999 production are produced by the Bahrain Flour Mills Co, the national bakery company.

1.10 Agriculture

Arable and permanent crop areas totaled about 8,200 ha in 2000, or about 12% of the total land area of the country (Al-Madani, 2000). Most of the agricultural zones are located along the western coast of Bahrain island. Major commercial crops include date palms, assorted vegetables, and fodder crops.

Agriculture in Bahrain faces a number of challenges rendering it a relatively minor sector with currently little contribution towards national food self-sufficiency. It represents a small share of national GDP with only 2% of the labor force engaged in agricultural activities. The contribution of this sector (including fisheries and poultry) was about 0.9% in 1990 and did not exceed 1% until 1995.

The agricultural sector in Bahrain uses irrigation extensively and consumes a disproportionately high share of scarce water resources, relative to its share of GDP. In 1999, water use for agricultural activities accounted for about 57% of total available water in Bahrain. Moreover, agricultural activities are constrained by poor soils, limited supply of capital and skilled manpower and continued loss of agricultural land for urban, industrial, recreational and other services development.

Agricultural activities are undertaken on roughly 6% of the total land area of the country. Total cultivated land area increased from 3,920 hectares (ha) in 1991 to 4,100 ha in 1993 and continued at essentially the same level in 1994 and 1995 (see Table 1.1). Livestock has not changed much over the last few years.

Table 1.1: Area of cultivable and cultivated Land in Bahrain (1990-1996)

Year	Total Area (Km^2)	Cultivable land (ha)	Cultivated land (ha)
1990	693	4,050	3,010
1991	695	8,200	3,920
1992	695	9,300	4,100
1993	706	9,720	4,100
1994	706	10,400	4,100
1995	707	11,100	4,150
1996	707	11,100	4,130

Source: *GCC (Economic Report) 1997*

1.11 Waste

The high rates of economic growth during the last four decades have been associated with rapid growth in consumption, and increasing rates of municipal solid waste production. Annual levels of solid waste are about 244,185 tonnes. Daily per capita municipal solid waste generation is about 1.2 kg/person and 438 kg/person annually. The content of the waste is mostly percent organic matter with small fraction of paper, plastics, glass, metals, and other materials.

Management of municipal solid waste is relatively efficient in Bahrain. Some of waste is recycled, while the remainder is disposed of in sanitary landfills. The high organic matter content in the waste prompted the private sector to establish a composting plant that produces compost fertilizers and soil conditioners.

Management of municipal waste effluents has evolved considerably in Bahrain. During the 1960s and 1970s, Bahrain installed urban sewerage networks and sewage treatment facilities to handle the increasing volume of wastewater generated from domestic, commercial and industrial uses. In 1975, the main urban areas of Manama and Muharraq were provided with sewerage systems. At the end of 1993, approximately 380,000 inhabitants were connected to the main sewage pipeline system. The areas provided with pipeline networks is increasing every year, with the aim that by 2010 virtually all inhabited areas of Bahrain will be connected.

Wastewater treatment methods used in Bahrain are primary, secondary and tertiary treatment. The recycled water is used mainly to irrigate gardens, fodder crops and highway landscaping. Sludge is produced in both primary and secondary treatment plants. It is treated before being recycled as a soil conditioner used on the Ministry of Works and Agriculture farms. The method of wastewater handling in Bahrain is an aerobic system, which produces some methane (CH_4) because of the poor management of the aerobic systems.

Lastly, major industries, though few in number, produce relatively large quantities of liquid waste. These include petrochemical industries which produces 201 Mm^3 /year, the petroleum industry which produces 268 Mm^3/year and power stations which produce about 537 Mm^3 /year. Most of these amounts are treated at the primary level, then mixed with the thermal effluents, which are discharged directly to the sea. Though large amounts of BOD characterize industrial waste effluents.

1.12 Environmental Education and Outreach

Environmental awareness is increasing among various sectors of Bahraini society, thanks in part to increasing numbers of non-governmental organizations (NGOs). Environmental education is spreading and there are activities and environmental courses being incorporated in the various departments' curricula of Universities and colleges. Presently, at least two master programs in Environmental management and Sustainable Development are being offered by the University of Bahrain and Arabian Gulf University.

However, climate change and its related impacts have not yet publicly recognized as a national threat. Partly, this is due to a shortage in financial and human resources in the various responsible agencies. For example, the Bahrain Center for Scientific Research, which is one of the leading institutes for research and training in resource development and marine studies, lacks required financial resources to undertake a sustained research agenda related to sea level rise issues. In this context, updating knowledge on climate change in educational institutions and building public awareness is a challenge and new endeavor for concerned authorities and institutes in Bahrain.

2 Greenhouse Gas Inventory

2.1 Introduction

According to the Intergovernmental Panel on Climate Change (IPCC) assessment reports, there has been a discernable human influence on the global climate. Human activities in pursuit of development, such as fuel combustion, industrial processing, intensive agriculture, land-use change and forest utilization, have caused a substantial increase in Greenhouse Gas (GHG) emissions into the atmosphere, which contribute to climate change. Major GHG emissions linked to such activities include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O).

The Kingdom of Bahrain has undertaken, as of 1996, the task of compiling its first inventory of greenhouse gas emissions. These activities will create a GHG emission profile for Bahrain that could be used in the larger global context, will enable Bahrain to comply with its obligations under the United Nations Framework Convention on Climate Change (UNFCCC), and will assist the nation in formulating climate sensitive development goals and informed mitigation and adaptation policies.

The national GHG inventory was developed using the revised IPCC Guidelines (1996). GHG emissions have been determined for all of the source/sink categories identified in the different sectors, namely energy, industry, agriculture, waste management, and land-use change and forestry. The team of national experts formed to compile the greenhouse gases inventory were drawn largely from those sectors identified as sources and sinks for GHGs, including the Civil Aviation Directorate, the Ministry of Works and Agriculture, the Ministry of Oil & Industry, the Bahrain Electricity Directorate, as well as members of the private sector.

2.2 Methodology and Data Used

2.2.1 Methods

The year 1994 was selected as the base year for all sectors. In keeping with the revised IPCC guidelines, carbon dioxide (CO_2) methane (CH_4) and nitrous oxide (NO_2) were studied. Nitric oxides (NO_x), sulphur dioxide (SO_2), non-methane volatile organic compounds (NMVOCs), hydro fluorocarbons (HFCs), and carbon monoxide (CO) were also considered. To assess these gases the national inventory covered the sources/sink categories identified by the IPCC Guidelines in the energy, industrial processing, agriculture, land-use change and forestry, and waste management sectors. Specific methods related to each sector and associated sub-sectors are discussed in the sections below.

2.2.2 Data Sources, Coverage, and Reliability

Data on emissions-generating/sequestering activities were collected mainly from secondary sources, such as published research, statistical reports, related studies, publications of the FAO, the Arab Organization for Agricultural, and other international groups, and periodical government reports.

Data was often available in formats that suit government planning purposes, but do not cover all the information required by the IPCC methodology. This highlights a future need for establishing reliable databanks within each sector, to provide complete and standardized information. Emissions and default factors were taken chiefly from

IPCC default values and conversion coefficients.

2.2.3 Uncertainties

Uncertainties are inherent in any estimate of national emissions. Commonly, uncertainties and limitations arise from different interpretations of source/sink categories, use of average values (especially default emission factors), and incomplete scientific understanding of the basic GHG emission and removal processes. Some of the sector-specific uncertainties that were encountered by the national inventory team are elaborated in the sections that follow.

2.2.4 Assumptions and Justifications

A number of assumptions were made in the application of the methodology and default data to the Bahraini context. Similarly, assumptions were made in order to justify the use of locally derived values, intended to represent the explicit local conditions of Bahrain as outlined in the sections that follow.

2.3 Energy Sector Inventory

In Bahrain, the only primary sources of energy are natural gas and refined oil products. There is virtually no use of biomass as a fuel source.

Energy consumed during the 1994 inventory year is estimated to be 281.8 thousand TJ. About 85% of this amount (or 238.6 thousand TJ) was in the form of natural gas, 8% (22 thousand TJ) in the form of refined petroleum products, and 7% (21 thousand TJ) in the form of crude oil. Greenhouse gases emitted from the energy sector are mainly CO_2, CH_4, and NO_x. CO is also emitted but to a lesser degree.

The process used to develop the GHG inventory estimates relied on the step-by-step Tier 1 methodology for calculating GHG emissions using the Reference Approach (for primary fuels), main source categories (for secondary fuels), and fugitive methane emissions (from oil and natural gas production activities). Definitions of activity/source categories were based on those provided in the IPCC Reporting Instructions (Volume 1).

Default GHG emissions factors were used for the carbon content of locally produced fuels, and of those main fuel combustion activities (source categories). Stored carbon, wherever available, was deducted from the calculated carbon emissions. Energy data was derived mainly from the Central Statistics Organization and private companies. Alternative emission factors were used occasionally to calculate GHGs, but on a limited basis, and are noted where they apply.

Table 2.1 shows the calculated GHG emissions in the energy sector. As can be seen in this table, carbon dioxide emissions are dominated by power supply , mostly in the form of electricity production from public power stations and heat production. Substantial levels of carbon dioxide are also emitted by the transport sector consisting mostly of on-road transportation.

Table 2.1: Greenhouse gas emissions, 1994: energy sector (Gg)

GHG Source & Sink Categories	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Total energy	**14,633**	**26.50**	**0.04**	**57.45**	**121.12**	**23.07**	**1,177**
Energy Industries	13,320	0.30	0.03	45.27	6.04	1.51	0
Fugitive emissions from fuels	0	25.88	0.00	0.00	0.00	0.00	0
Transport	1,291	0.30	0.01	12.01	116.26	21.86	1,177
Other Sectors (commercial, agricultural, residential, forestry, fishing)	22	0.02	0.00	0.18	0.04	0.01	0

Small amounts of carbon dioxide are emitted by other sectors (i.e., residential) for miscellaneous end uses. In addition, methane emissions are dominated by fugitive emissions associated with leakage from natural gas transport.

2.4 Industrial Processes Inventory

The contribution of the industrial sector to Bahrain's GDP is substantial. Many of the industrial activities described by the IPCC methodology are implemented in Bahrain including cement production, chemical production, food and beverage production, aluminium production, and halocarbon use. Accordingly, greenhouse gas emissions in this sector are primarily CO_2, NMVOC, HFCs, CO, CH_4, and SO_2. In addition, certain processes contributed to emissions of CF_4 , C_2, and F_6,

Data used in this assessment was obtained from reliable, official statistical record sources including the Central Statistics Organization, private companies, and records from various factories. In this sector, only GHGs emissions from physical and chemical transformation processes were considered.

GHG emitted in this sector, as summarized in Table 2.2 are mainly CO_2, NMVOC and CO. Some methane and SO_2 are also emitted. Not surprisingly, the most important GHG in this sector is CO_2, 96% of which is produced by the chemical and aluminium industries. NMVOC emissions are attributed almost solely to road paving with asphalt, while CO emissions are solely produced by aluminium production. Small levels of SO_2 are emitted from all industries except for food and beverages.

2.5 Agricultural Sector Inventory

GHG emissions in this sector come from several sources, including livestock, and agricultural soils. Major GHGs are CH_4, N_2O, NO_x and CO. Agriculture is a small sector in Bahrain's economy. In the year of the inventory, its share of GDP reached about 1%. Bahrain possesses sizeable numbers cattle, sheep, and poultry.

Data was collected from several sources and

Table 2.2: Greenhouse Gas Emissions, 1994: industrial sector (Gg)

Greenhouse Gas Source and Sink Categories	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	SF_6	CF_4	C_2F_6
Total Industrial Processes	1,850	2.1	0	0	180	110	0.62	0	0.02	0
A-Mineral Products										
Cement Production	73	0	0	0	0	0	0.04	0	0	0
Asphalt Roofing	0	0	0	0	**	0.0056	0	0	0	0
Road Paving with Asphalt	0	0	0	0	0	109	0	0	0	0
B-Chemical Industry										
Ammonia Production	616	0	0	0	**	**	**	0	0	0
Carbide Production	486	2.1	0	0	0	0	0	0	0	0
Others (Sulfuric Acid)	0	0	0	0	0	0	0.18	0	0	0
C-Metal Production										
Aluminum Production	675	0	0	0	180	0	0.41	0	0.02	0
SF6 Used in Aluminum & Magnesium Foundries	0	0	0	0	0	0	0	0	0	0
D-Others										
Food and beverages	0	0	0	0	0	0.73	0	0	0	0

**The IPCC (1996) default figures were used throughout.*
*** Negligible amounts*

Table 2.3: Greenhouse gas emissions, 1994: agricultural energy sector (Gg)

Greenhouse Gas Source and Sink Categories	CH_4	N_2O
Total Agriculture	0.84	0.09
A-Enteric Fermentation and Manure Management		
Cattle	0.44	0.0
Sheep	0.11	0.0
Goats	0.09	0.0
Camels	0.06	0.0
Horses	0.05	0.0
Poultry	0.09	0.0
B-Manure Management		
Solid storage and dry lot	0	<0.001
Pasture range & Paddock	0	<0.001
C-Agricultural Soils		0.09

Default values used throughout.

converted to match the IPCC Guideline worksheets. Data Sources included the Central Statistics Office. Calculations of GHG emissions covered a number of source activities, including CH_4 (emissions from enteric fermentation and manure management, while N_2O emissions were calculated from manure management.

As shown in Table 2.3, GHG emissions from the agriculture sector are small and consist mostly of CH_4 (0.84 Gg). Livestock enteric fermentation constitutes all of the agricultural CH_4 emissions.

2.6 Land Use change and Forestry Inventory

This category does not apply in Bahrain as there are no forests or grasslands that could be converted to alternative uses. There are large amounts of palm trees and while the monitoring of palm tree areas have typically been neglected, it is well established that they are not destroyed when land is are converted to residential or commercial areas. Rather, they are relocated to other areas and replanted. As a result, this is not considered a land conversion activity.

2.7 Waste Management Inventory

This section deals with the estimation of GHGs especially methane (CH_4), emitted from various handling methods of municipal solid waste (MSW) and wastewater treatment in Bahrain, closely adopting the methodologies elaborated in IPCC 1996 Guidelines. No attempt was made to calculate the amounts of methane emitted from industrial wastewater and sludge handling, because of lack of specific data. Though large amounts of BOD characterize the industrial waste effluents, the handling systems do not allow calculation of methane emissions.

Data sources include the Ministry of Works and Agriculture (wastewater and management systems) and reports of the municipalities of Bahrain (total amounts of MSW) and the Central Statistics Organization (total population). IPCC default figures were used throughout. Table 2.4 provide a summary of emissions.

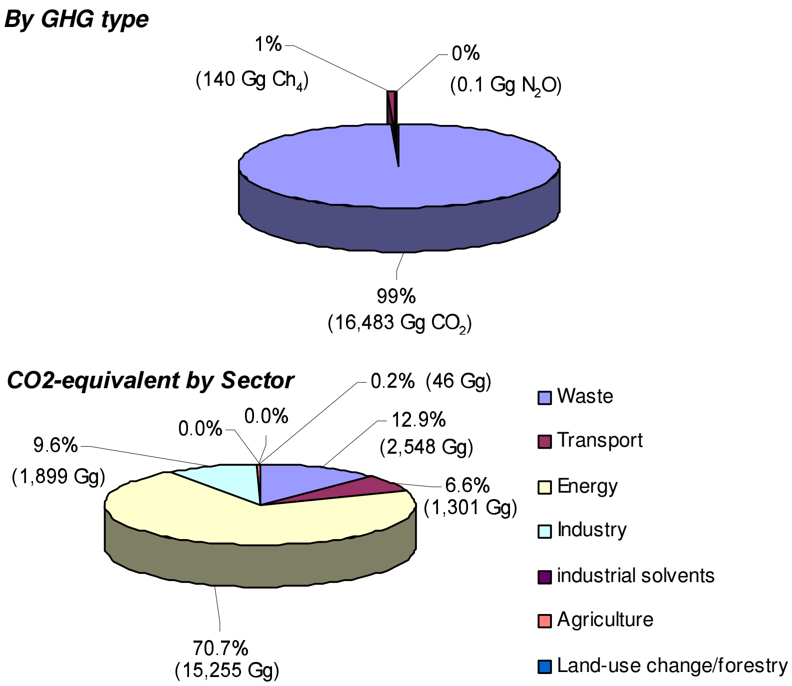
Table 2.4: Greenhouse gas emissions, 1994: waste management (Gg)

GHG Source and Sink Categories	CH_4	N_2O
TOTAL	110.8	0.0
Solid waste Disposal on land	0	0
Managed waste disposal on land	18.8	0.0
Wastewater Handling	0.0	0.0
Domestic and	92	0.0

2.8 Summary of Inventory Results

Figure 2.1 shows the total emissions of GHGs for 1994 in Bahrain's broken out by GHG type, and by sector on a carbon dioxide-equivalent basis. Different GHGs are known to contribute differently to the total greenhouse effect. This contribution is expressed as Global Warming Potential (GWP) – the ratio of GHG radiative forcing

Figure 2.1: Total GHG emissions by GHG type and by Sector, 1994 (Gg)



(ability to trap infrared radiation) of 1 kg relative to 1 kg of CO_2 over a specified period of time (usually 20, 100 or 500 years – the 100-year GWP was chosen for the Bahrain GHG inventory). GHG emissions can be expressed as CO_2 equivalent.

The main gas emitted is carbon dioxide (16,483 Gg), which constitutes 99% of the total, followed by methane (140 Gg). N_2O, and other GHGs though are emitted in very small amounts.

The main GHG-emitting sector is energy, which account for about 71% of total emissions on a carbon dioxide equivalent basis. Waste, industry, and transport account for 13%, 10%, and 7% respectively. On a per capita basis, CO_2-equivalent emissions are emitted at the rate of 0.035 Gg per person.

2.9 Recommendations for Enhancing the Quality of Bahrain's GHG Inventory

A program to enhance the accuracy of Bahraini national GHG emissions inventory is necessary and important. A reliable and verifiable greenhouse gas emissions database is a prerequisite for compliance with the Framework Convention, and is relevant to Bahrain's ability to identify opportunities for achieving emission reductions. Based on the experience gained in developing the first national greenhouse gas inventory there are several efforts that should be carried out as described below.

In the near-term - and to facilitate the preparation of future communications - high priority objectives are strengthening the institutional structure for carrying out future GHG inventory assessment, and developing local emissions factors that better represent Bahraini conditions. Within these braod objectives, there are several specific recommendations, as outlined below:

- *Institutional strengthening:* It is essential to establish a permanent Secretariat within the General Commission for the Protection of Marine Resources, Environment and Wildlife in order to coordinate periodic updates of the national inventory. Moreover, a national system for GHG data collection monitoring, reporting and verification is necessary in order to ensure that an inventory updating system is both sustainable and meets high standards.
- *Improvement of local emission factors:* Nationally developed and authenticated GHG emission factors should be used in place of the IPCC default values in future updates. Scientific research should be conducted regarding specific sources of emissions – particularly nitrous oxides from soils and emission factors associated with in-situ agricultural and vegetation waste incineration.

In the mid-to long-term, the highest priority is to address some of the gaps in the available data. Efforts to improve data availability and quality could be principally targeted at the following sectors:

- *Energy:* It is recommended that national surveys be conducted to better represent consumption levels and patterns of various subsectors of the economy. In particular such survey should focus on marine and aviation bunker fuels, fugitive emissions, and new modes of public transport.
- *Industry:* Scientific research should be conducted to better understand and represent energy consumption patterns in small industries and factories, as well as to improve overall data availability from these emission sources.
- *Agriculture:* Data should be collected regarding crop residue disposal systems, the quantity of fertilizers and pesticides used by the agriculture sector, and the number of locally owned and imported livestock.
- *Waste:* Data should be collected regarding the quantities of solid waste and wastewater produced by small rural communities and their waste disposal systems.

3 Vulnerability and Adaptation Assessment

3.1 Introduction

The low-lying nature of Bahrain's islands, coupled with significant land reclamation investments and extensive industrial, commercial, and residential activity in coastal zones, emphasize the country's acute vulnerability to climate change-induced sea level rise (SLR). In the face of this threat, an assessment of vulnerability and adaptation options to sea level rise is a critical component of Bahrain's response to climate change. The specific focus, as discussed in this Chapter, has been to identify vulnerable sectors, regions, and resources and to assess the degree of future risk posed by SLR. The results of this work are expected to provide clearer indications of Bahrain's coastal zone management challenges, as well as provide insights into national strategies for proactive adaptation.

3.2 Approach

The purpose of a vulnerability and adaptation assessment is to illuminate the potential impacts of climate change on critically important sectors. In the case of Bahrain's coastal zones, this involves an estimate of the spatial extent of future inundation from projected SLR, together with an assessment of its impact on human settlements, agriculture, and natural ecosystems. It also implies the identification of strategic adaptation options.

This process requires that a scenario be created of what Bahraini coastal areas might look like in a future without climate change, and that this scenario be compared with a parallel vision of what coastal zones would look like under predicted conditions of climate change. In order for this to be done, two climate scenarios must be created: a baseline scenario, aimed at representing a future *in the absence of climate change* and a climate change scenario, aimed at representing a future under increased greenhouse gas concentrations and the resulting changes in sea level.

3.2.1 Baseline Scenario

A baseline scenario was constructed using geographic information systems (GIS) and remote sensing techniques (Al-Jeneid and Abido, 2004). The approach involved creating a digital elevation model for the five major islands (i.e., Bahrain, Muharraq, Sitrah, Jiddah, and Um Na'asan) as well as the Hawar group islands using 1995 satellite imagery.

These islands were chosen for strategic importance. The five major islands represent 93% of the total land area (not including the Hawar group islands) and are zones of intense economic activity and population growth. Inundation from sea level rise could lead to serious displacement of people and commercial activities. The Hawar group islands represent protected areas that are surrounded by coral reefs and shallows. They are uninhabited and declared as national protected areas. Inundation from sea level rise could lead to loss of biological diversity and adverse impacts on the diverse populations of birds, corals and fish.

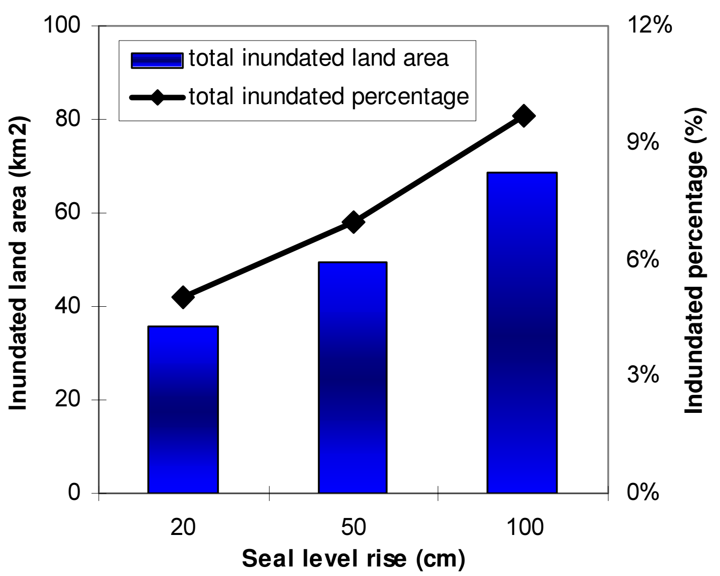
To facilitate the analysis, it was assumed that these islands' coastal zone geography and economic activity levels in 2100 would be similar to what they were in 1995. This is a conservative assumption in that it is far likelier that coastal zones will have been further developed by 2100 (for example, more land reclaimed, greater economic activity) and the resulting impacts from SLR of greater magnitude.

3.2.2 Climate Change Scenarios

Three climate change scenarios – low, moderate, and high - were developed to examine the impacts from sea level rise on the selected islands. The low SLR scenario assumed a 0.2-meter rise above current sea level, the moderate scenario assumed a 0.5 meter rise, and the high scenario assumed a 1.0 meter rise in sea level. A digital elevation model was developed for each climate change scenario and vulnerable areas were then identified – by sector and land use class - by overlaying the satellite imagery over the digital elevation models.

This multiple SLR approach to the analysis was important to offset data limitations and to account for uncertainties associated with topographic perturbations. (i.e., regional subsidence/uplifting). The latter is a particularly important issue in Bahrain as land surface and seabed topography are continually undergoing changes due to the extensive resource extraction activities (i.e., oil, natural gas, groundwater) that are expected to at least continue at their current pace, and possibly intensify over time.

Figure 3.1 Inundated areas due to sea level rise, 2100



3.3 Sea Level Rise Impacts

The findings of this first vulnerability assessment give cause for concern for Bahrain's security in the face of a changing climate. As described below, the assessment results suggest that under even small changes in sea level, Bahrain faces threats in terms of land area inundated, and a variety of adverse impacts on population settlements, aquatic resources, crop productivity, coastal erosion, and biological diversity.

3.3.1 Inundation Levels

The total land area that would be inundated under the various climate change scenarios is substantial. As shown in Figure 3.1, even the low sea level rise scenario results in an inundation of about 5% (36 km^2) of the total land area of the total land area of Bahrain by 2100. This level increases to about 10% of total land area (69 km^2) for the scenario where sea level rises 1 meter above current levels.

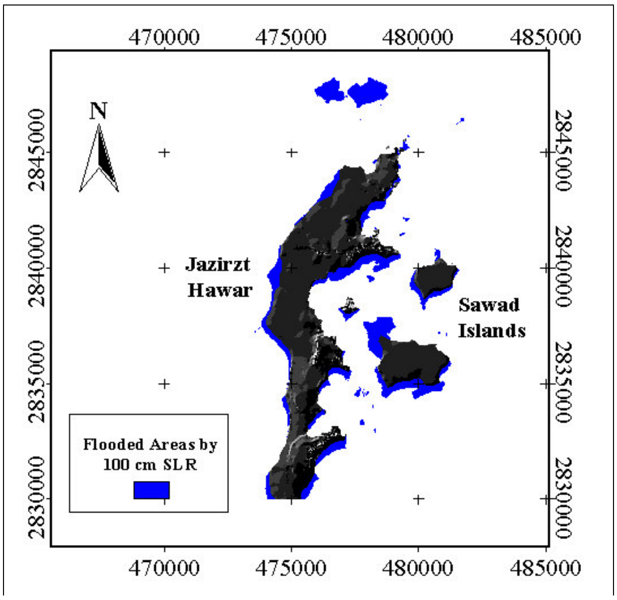
Inundation will unevenly affect Bahrain's vulnerable infrastructure. For the main islands of Bahrain, Muharraq, Sitrah, Jiddah, and Um Na'asan - where the majority of socioeconomic activities are concentrated - inundation would adversely affect cities, roads, agricultural areas, as well as beaches and salt marshes. Of a total inundated area of about 57 km^2, about a quarter of the total (14 km^2), would occur in the productive zones taken up by cities, roads, and agricultural lands.

The extent of inundation on the Hawar Islands, given their status as wetlands of international importance, is particularly noteworthy. The islands in this chain are even more low lying than the main islands. Jazirat Hawar, the largest in the island chain, has a maximum elevation of 12.5 meters, and a mean elevation of 0.5 meters above sea level. Were sea levels to rise by one meter, about 22% (11 km^2) of the combined land area of these pristine islands would be inundated. Figure 3.2 illustrates the spatial extent of this inundation. It is important to note that these inundated areas significantly overlap the sensitive bird breeding and nesting sites (refer to Box 1.1 in Chapter 1).

3.3.2 Impacts on Human Settlements and Infrastructure

The total population affected by a 1 meter sea level rise by 2100 is expected to be low. This is in part thanks to national policies that have historically encouraged the siting of human settlements away from coastal zones so as to promote commercial development in these areas. On the other hand, coastal zones are currently where extensive economic infrastructure is located that includes highway networks, tourist centers, and commercial establishments. Roads networks, for example, would likely be hard hit, with an estimated 8.8 km2 of highways and major roads submersed under a 1 meter sea level rise. This represents a significant share of total coastal roads in Bahrain.

Figure 3.2 Inundated areas of Hawar islands due to a 1-meter rise in sea level, 2100



3.3.3 Impacts on Agriculture

Although its contribution to the national economic accounts is less than one percent, the agricultural sector plays an important role in the livelihood of Bahraini society. The agriculture sector relies on heavy irrigation and currently provides job opportunities to more than 3,400 people and contributes to national food security goals.

The loss of agricultural land due to a 1 meter rise in sea level is likely to be around 5 km^2, or about 11% of the total arable land in the country. Other impacts from the inundation of agricultural lands include damage to drainage systems, an increase in water logging problems, and higher groundwater tables. These impacts are likely to contribute to adverse impacts on crop production levels, particularly date palms which are highly susceptible to groundwater salinity levels.

3.3.4 Impacts on Corals and Fishing Industry

The effect of SLR on coral reefs is difficult to quantify due to the uncertainties related to regional subsidence due extraction of groundwater, oil and natural gas. Nevertheless, there are several possible impacts that are important to identify as areas of future investigation, as follows:

- *Reduced light penetration:* Siltation from coastal erosion may lead to reduced light penetration that can adversely impact the rate at which various species of corals grow.
- *Sea temperature rise:* An increase in climate change-induced sea temperature may contribute to an increase in the incidence of severe coral bleaching, and eventually the death of corals.
- *Coral calcification:* It is likely seawater with higher levels of carbon dioxide will adversely affect the coral calcification rate. This could reduce the density of coral carbonate skeletons and lead to accelerated coastal erosion.

There are currently about 6,000 people employed in the fishing industry. Annual fish yields are approximately 12 metric tones, of which coral fishes (e.g., shrimp, crab) account for about 28% of the total annual catch. Deterioration of coral reef habitats from climate change would negatively affect associated fauna and fish stocks, and eventually threaten the viability of the fishing industry.

3.3.5 Impacts on Mangrove and Salt Marshes

Mangrove areas are already under high stress due to land reclamation activities. In the event of sea level rise, major portions of mangrove ecosystems would be inundated and, in theory, lead to a gradual retreat of plantations to areas inland. However, in view of land reclamation and associated commercial land development pressures, it is unlikely that there will be suitable areas to accommodate the gradual retreat of mangrove plantations. The total area of mangrove plantations affected, though not directly quantified in the sea level rise vulnerability assessment, is expected to be quite high.

Coastal salt marshes in the main islands will be among the hardest hit areas due to rising sea levels in terms of the extent of impact. Home to unique and sensitive ecosystems, the total area that would be affected by a 1 meter rise in sea level is about 32 km^2. This represents about 55% of all the submersed areas, and about 5% of the total land area of the main islands.

3.3.6 Impacts on Coastal Erosion

Most of Bahrain's coastal plains have heights less than 5 meters above sea level and are erosion prone. The wave-induced movement of sand along the western and eastern beaches is primarily southward and consequently heavy transport of sediments occurs toward the southernmost parts of islands, and especially along the Ras Al Barr sandbar at the lower end of Bahrain Island. This process is likely to be exacerbated under conditions of sea level rise, with increases in effective wave heights and intensification of littoral transport along the western and eastern coasts. Furthermore, higher sea levels coupled with erosion may lead to sea penetration inland in particularly low lying areas less than 5 cm above sea level.

3.3.7 Impacts on Hydrology and Water Resources

With the increases in population and economic growth of recent decades, Bahrain has substantially increased its demand for fresh water. About 75% of freshwater demand is met by groundwater withdrawals, resulting in a sever decline of the groundwater table through saltwater intrusion. At present, over half the volume of the original groundwater reservoir has been lost to salinization, sharply reducing its availability for municipal and agricultural purposes.

A rise in sea level will further aggravate a serious problem. One possible impact of sea level rise would be a regression in the position of the freshwater/saline waterfront leading to further saltwater intrusion and deterioration of the aquifer. Moreover, SLR would lead to a new line of contact further inland between salt marsh areas and groundwater which would likely lead to more seepage of salt water into the groundwater reservoir. There are also indirect impacts from climate change in general as higher temperatures might lead to higher levels of water consumption in agricultural activities and households, further depleting scarce freshwater supplies.

3.4 Adaptation Action Plan

The findings of this first vulnerability assessment raise serious issues of great national concern. Currently heavily reliant upon its coastal ecosystems and resources that are, in many cases, already fragile or degraded, the population of Bahrain can ill afford the added challenge of increased ecological stress that climate change would surely bring.

Adaptation to sea level rise in Bahrain will likely need to be a multi-stage and iterative process that includes information acquisition, raising public awareness, mainstreaming SLR into the policy context, implementing adaptation measures, and monitoring and evaluation. While there are several types and forms of adaptation, the approach outlined below focuses on a mix of strategies and measures that are tailored to fit Bahraini local conditions, and take into account existing constraints and opportunities. Two broad elements of an adaptation strategy are essential for Bahrain to adapt to future sea level rise, as discussed below.

3.4.1 Policy Mainstreaming Initiatives

Adaptation policy initiatives are needed to protect investments in vulnerable areas, minimize coastland loss of vulnerable low-lying areas, conserve natural ecosystems, control coastal erosion, and protect groundwater resources. In this respect, adaptation policies are needed that are anticipatory and ensure continued protection amidst the development of coastal resources, alleviating SLR damages incurred to date, and developing a comprehensive understanding of strategic responses. The Environmental Affairs (EA), given its current role in facilitating the integration of environmental concerns within Government development plans, is to take the leadership role in the process of developing a national strategic response and coordinate stockholder involvement throughout the planning process. Specific initiatives it would address are summarized below.

- *Integrate SLR considerations into national development policies:* This approach is principally aimed at introducing shift in the consideration of formulating policies and national development plans. Since SLR is a gradual process, it is still possible to consider adaptation measures now that can render future infrastructure investments less vulnerable to SLR. Experience has shown that policy makers, planners and managers (i.e. Ministry of Housing) are eager to address SLR vulnerability into the planning process. A variety of action items are needed as summarized in Table 3.1.
- *Strengthen stakeholder capacity:* There is a need for capacity building to enable the EA, as a principal environmental authority, to play a major role in planning, coordinating and implementing adaptation programs of action. EA capacity needs to be strengthened in terms of human, financial, technical and technological resources. Moreover, the capacity of

scientific institutions, related government agencies, NGOs and other entities that have a clear stake in SLR should also be strengthened. A variety of action items are needed as summarized in Table 3.1.

- *Prioritize near-term coastal protection:* Vulnerable coastal areas contain industrial compounds, recreational facilities and human settlements. These areas are of high priority and public investment. The current coastal erosion threat can be addressed by near-term engineering measures and proper maintenance of coastlines. However, protection as a mean of adaptation is costly and it may have limited long-term effectiveness. Several initiatives should be pursued, as outlined in Table 3.1, that can help to systematically minimize the likely effects of SLR along vulnerable coastal zones.

3.4.2 Ecosystem Protection Initiatives

Wetlands and marine resources are under continuous stress and their ecosystems are being disturbed. Many of the sensitive wetlands in Bahrain are currently subject to pollution, over-exploitation, and adverse effects of coastal envelopment projects that require extensive dredging and land reclamation. Further disturbance as a consequence of SLR will slowly degrade major functions of these systems, thus adversely affecting biodiversity. The following paragraphs highlight major adaptation action needed to limit ecosystem deterioration.

- ***Mangrove and other wetland (Sabkhas) areas:*** Mangrove plantations are experiencing formidable threats reclamation and infilling activities that threaten their existence. Mangrove stands are also vulnerable to SLR having no capacity for inland retreat. A variety of action items are needed as summarized in Table 3.1.
- *Coral reefs and other marine resources:* Coral has already experienced bleaching events. Other types of damage due to mismanagement are evident such as pollution from point sources and from tanker traffic. A variety of action items are needed as summarized in Table 3.1.
- *Groundwater Resources:* The importance of groundwater resources in Bahrain cannot be overemphasized. Groundwater resources are experiencing severe pressures from over-extraction practices. SLR will likely intensify seawater intrusion into the aquifer leading to a continuous salinization and rapid deterioration of its quality. A variety of action items are needed as summarized in Table 3.1.

Planning an effective response to SLR will require aggressive pursuit of the above options. The anticipatory initiatives discussed in the Action Plan – both policy mainstreaming and ecosystem protection initiatives - will promote sustainable coastal development by accounting for the likely effects of SLR and current maladaptive practices. Careful consideration and selection of adaptation policies and strategies is critical for Bahrain, a small and highly vulnerable country.

Table 3.1: Specific measures in the Adaptation Plan

Integrate SLR considerations into policies:	*Prioritize near-term coastal protection:*	*Strengthen stakeholder capacity:*
• AccomZmodate SLR in the design of new policies regarding building codes and coastal structures, • Formulate sector specific development guidelines (tourism, industry, etc) to highlight for investors the potential problems arising from SLR, • Formulate a comprehensive policy framework for integrated coastal and marine resources management, and • Formulate guidelines and legislation for the implementation of integrated coastal zone management.	• Identify and delineate critically vulnerable coastal areas, • Reassess coastal area vulnerability to SLR, including economic valuation of endangered properties, establishments, and resources, • Create a GIS-based coastal database management system for facilitating decision-making regarding coastal areas, • Investigate the feasibility of new coastal structures (e.g., dikes, levees, etc..) and maintenance measures (e.g., periodic beach nourishment) to protect high priority areas. • Establish and maintain effective agricultural drainage systems, • Rehabilitate endangered ecosystems with special emphasis on coral reef areas, mangroves, and important bird nesting areas, • Raise public awareness on climate change issues in general, and SLR in particular, • Actively enforce legislation regarding coastal areas and marine resources, • Formulate an integrated water resource management plan to rationalize water use and protect aquifers from salinization, • Accommodate SLR in the design of new policies regarding building codes and coastal structures, and ongoing projects, • Review and update legislations related to water usage.	• Strengthen national capacity (marine authorities) for monitoring SLR dynamics and trends through upgrading and networking existing monitoring stations. • Develop legal, institutional and human resources capacity for the EA and national research institutions. • Conduct training programs in CC/SLR information management, vulnerability, risks assessments and adaptation planning • Strengthen the capacity of farmers to adapt to new techniques in farming and management of salt affected soils. • Strengthen regional cooperation and networking among countries in the region to facilitate exchange of data and information on CC/ SLR issues.
Mangrove ecosystems	***Coral ecosystems***	***Groundwater resources***
• Establish a protective buffer zone around Mangrove plantations. • Reforest mudflats & other locations along beaches. • Revive traditional agricultural systems around mangroves using treated sewage effluent. • Launch a national campaign to raise public awareness among various sectors of the society.	• Rehabilitate corals in key sites, • Aggressively enforce of legislation regarding marine resources.	• Formulate an integrated water resource management plan to rationalize water use and protect aquifers from being excessively salinized. • Legalize and institutionalize reuse of sewage treated water.

4 Greenhouse Gas Mitigation Initiatives

This chapter summarizes a national-level analysis of a set of options and opportunities for reducing GHG emissions in Bahrain. Each of the initiatives was evaluated relative to several selection criteria: capital investment required, achievable GHG reductions, cost of saved carbon (CSC), and social acceptability. Particular emphasis was placed on options that are low or zero-cost, can substantially reduce GHG emissions, and will contribute positively to the national development priorities

While the measures discussed in this chapter will focus on the potential of various technologies and practices, it is clear that to achieve the results laid out in this chapter will also involve a certain number of parallel institutional, regulatory, and financial initiatives. The following discussion lays out viable measures that could be implemented in the near to mid-term in Bahrain for achieving enduring greenhouse gas reductions, followed by an outline of an action plan for implementing the conclusions.

Two scenarios were considered: a "Base Case" assuming business-as-usual assumptions, and a "Mitigation Case", with a set of initiatives described below that have the potential to reduce GHG emissions. The period considered in the assessment was from 1995 through the year 2015.

4.1 Business-as-Usual GHG Emissions in Bahrain

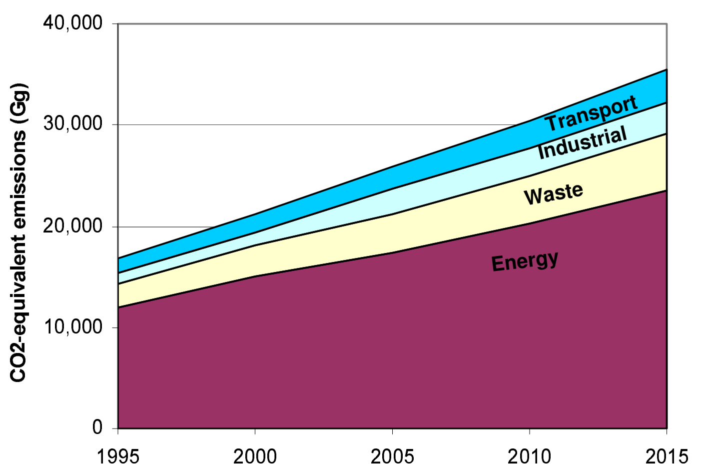
Based on the results of the GHG inventory, the major contributing sectors to GHG emissions in the State of Bahrain are summarized as follows:

- ***Energy supply:*** GHG emissions from energy supply are primarily associated with electric power generation, as well as certain large industrial applications (i.e., aluminum, petrochemicals, refineries). Total carbon dioxide-equivalent (CO2-equivalent) emissions from this sector were 13,954 Gg in 1994.
- ***Waste management:*** GHG emissions from waste management are primarily associated with two types of wastes, namely municipal solid waste and sewage effluents. Total CO2-equivalent emissions of from this sector were 2,548 Gg in 1994.
- ***Industrial processes:*** GHG emissions from industrial processes in Bahrain are primarily associated with mineral, chemical, metal and food & beverage production. Total CO2-equivalent emissions of from this sector were 1,899 Gg in 1994.
- ***Transport:*** GHG emissions from transportation in Bahrain are associated with the amount of fuel consumed in cars, trucks, and buses. Total CO2-equivalent emissions of from this sector were 1,301 Gg in 1994.

The three other sectoral categories in Bahrain's GHG inventory - solvents and other product use, agriculture, and land-use change and forestry – contribute negligible amounts to national GHG accounts (i.e., less than 0.2% of the total in 1994) and were not considered to be suitable sectors for considering GHG mitigation options.

To estimate the GHG emission trajectory of the energy supply, waste management, industrial processes, and transport, an analysis was carried out that accounted for population growth, economic activity, and several other expected trends that can affect the level of future GHG emissions (AL-Qahtani, 2001). Figure 4.1 illustrates the expected growth in GHG emissions under business-as-usual assumptions, highlighting the expected major contributions of the energy supply sector to overall emission

Figure 4.1: GHG emissions in the Business-as-usual scenario



levels, about 70% of total emissions over the 1995 to 2015 period.

4.2 Mitigation Initiatives Analyzed

There are several mitigation measures that have been analyzed to determine their GHG reduction potential and associated costs. Given the prominence of energy supply, all of these options are focused on this sector. The paragraphs below summarize the options considered.

4.2.1 Energy Efficiency of Power Generation

The overwhelming majority of GHG emission in the energy supply sector is from the combustion of natural gas for electric power generation. The Bahraini electric power supply system is characterized by numerous small and large units operating at low efficiencies. Replacement or upgrading to achieve greater combustion efficiencies would considerably reduce annual natural gas consumption levels.

While several options were considered, the mitigation assessment focused on upgrading existing systems with a combination of combined cycle units and co-generation (power and heat for water desalination). As part of a mitigation scenario, it was assumed that combined cycle units achieving at least 50% combustion efficiency would be introduced at eight inefficient single cycle power stations and cogeneration was introduced at one station. These changes would annually reduce emissions of carbon dioxide by 2.7 million tonnes.

There are no major cost, institutional, or social barriers envisioned for a more widespread use of energy efficient technology in electricity supply. The cost of saved carbon for implementing this option at 9 stations is negative (i.e., –$19.6/tonne of carbon dioxide avoided) indicating its attractiveness from an economic perspective. Moreover, direct surveys among a range of individuals confirm the attractiveness from a social perspective.

4.2.2 Renewable Energy Systems for Power Supply:

This initiative involves adding zero-carbon, renewable resources to the electric system. Bahrain is well endowed with solar energy with an annual average solar insolation level of about 400 W/m2, making it one of the highest in the world. Wind energy is less attractive as average wind speeds are well below 5 meters per second for large periods of the year over large portions of the country. Tidal energy is also not considered an attractive option due to land use required for the installation of turbines and the resulting adverse ecological impacts.

The mitigation assessment focused on solar thermal combined cycle systems to meet about 5% of electric demand. This would involve the installation of one 150 MW solar thermal station (with no natural gas backup), and would annually reduce emissions of carbon dioxide by 1.4 million tonnes.

The cost of saved carbon for implementing this option is negative (i.e., –$5.0/tonne of carbon dioxide avoided) indicating its attractiveness from an economic perspective. However, using substantial levels of intermittent renewable energy technologies in Bahrain would represent a departure from business as usual requiring new coordination among different institutional entities. Indeed, one of the key technical issues was how intermittent resources can be integrated in the electric system given system interfacing, stability, and operability concerns. While these issues will require further review for the specific circumstances posed by the Bahraini electric system, it is unlikely that they represent unsolvable technical problems.

4.2.3 Demand Side Efficiency Measures

Air conditioning and lighting are significant electricity end-uses in Bahraini households. Lighting efficiency measures— including automatic controls for exterior lighting, higher-efficiency fluorescent lighting fixtures, ballasts, lamps, and controls, and compact fluorescent lamps (CFLs) in place of incandescent bulbs—can significantly reduce lighting energy and peak power use. High efficiency air conditioning, including higher-than-standard efficiency compressors, heat-exchangers, fans, control systems, and other associated equipment also has great potential to reduce space cooling power requirements, which represents almost half of the total power generation in Bahrain.

The mitigation assessment focused on the introduction of CFLs and high efficiency air conditioners in the context of the existing electric supply system. For both measures, this would involve a complete replacement of existing inefficient technology, phased-in over a 10-year period. The combined effect of these measures would result in a combined reduction in carbon dioxide emissions by 2015 of about 1.2 million tonnes (0.95 million tonnes for air conditioners and 0.21 million tonnes for CFLs).

The cost of saved carbon for implementing this option is negative (i.e., –$33.0/tonne of carbon dioxide avoided) indicating its attractiveness from an economic perspective. The major impediments to implementation of high efficiency technology in Bahrain are likely to be the current low electricity tariffs, the high initial cost of many of the technologies relative to the less costly alternative, and current lack of availability of the efficient products themselves. Moreover, the introduction of lighting and space cooling efficiency measures require supply and demand for the technologies to be built up at the same time.

4.3 Other Mitigation Initiatives Considered

In addition to the measures discussed above, several other measures were considered though not analyzed due to data limitations and other uncertainties. The subsections below briefly summarize the options considered.

4.3.1 Road Traffic Management And Control

In Bahrain, growth in vehicle ownership is expected to double by 2015 to about 340,000 vehicles. The existing road infrastructure is becoming increasingly congested, especially during rush hours, leading to costly traffic delays. Redesigning the transport system to promote public transit, high-speed lanes, better vehicle fuel economy, and the use of alternative fuels could substantially reduce annual GHG emissions from the transport sector. Further investigation is needed on future traffic management policies and plans to better understand how certain measure can lead to lasting reductions.

4.3.2 Interconnection Of The Electric Transmission Grid

The Bahraini electric transmission system is currently not connected to region networks and is characterized by relatively high line losses. Integrating the transmission grid with that of the neighboring Gulf Cooperation Council (GCC) countries is potentially attractive for reducing GHG emissions because it could mean the operation of larger power generation station with better electric system carbon emission rates (i.e., tC/MWh), as well as being able to tap into transmission networks which on aggregate have lower line losses. Further investigation is needed on the carbon emitting characteristics of regional electric systems.

4.3.3 Landfill Gas And Utilization In Power Generation

This option can reduce greenhouse gas emissions by preventing the direct release of methane to the atmosphere. Since the Bahrain electric supply sector overwhelmingly uses natural gas, there is no net gain in the carbon content of electricity on the grid. The amount of methane that can be captured annually from large sanitary landfills is about 12,000 tonnes. The cost associated with methane recovery is much higher than the cost of natural gas, which is available in Bahrain at relatively low cost. Further investigation is needed on site-specific characteristics of the landfills, as well as the additional pipeline costs for the transport of methane to local power stations.

4.4 Impact of Mitigation Initiatives

If implemented, the combined effect of the initiatives analyzed can reduce overall emissions of carbon dioxide in Bahrain by about 5 million tones, or about 15%, by 2015 as shown in Figure 4.2. Notably, the costs for implementing the measures are negative, meaning that they represent "no-regret" options that are able to yield GHG reduction while saving money. This is primarily due to the fact that capital costs are more than offset by reductions in fuel costs over the measure's lifetime.

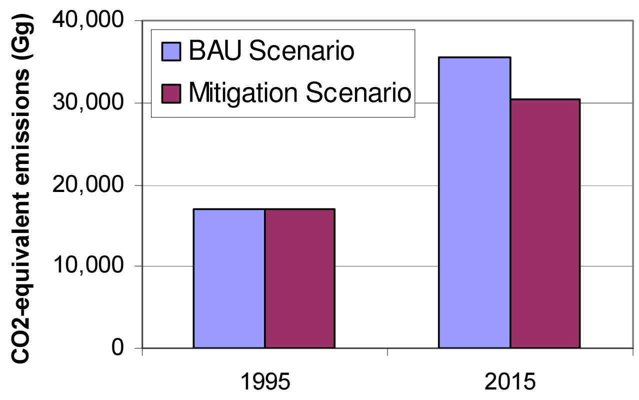
4.5 Mitigation Action Plan

There are several measures, techniques and policies that could be implemented to reduce national GHG emissions. In Bahrain, there is a variety of economic and social factors that influence GHG emission levels, as well as the cost effectiveness of mitigation options and plans.

Based on Bahrain GHGs emission inventory and projections in this section, it is clear that natural gas as well as other petroleum products is the major sources of energy and GHGs emissions. Therefore, significant mitigation of GHGs emissions could be achieved if more efficient generation was introduced, as well as conservation practices were implemented. Other strategic mitigation options for Bahrain include upgrading technologies in transport (e.g., bus and truck fleets) and buildings (e.g., more efficient air conditioning and home electric appliances).

There are three essential elements of a national mitigation plan of action that

Figure 4.2: GHG emissions in the Business-as-usual and Mitigation scenarios



should be considered for near-term action, as outlined below.

- *Replace inefficient power stations with new combined cycle units:* The mitigation analysis shows that it is economically feasible to upgrade or replace existing, inefficient power stations with high-efficiency natural gas combined cycle units over a 10-year period. Annually, this would result in about 2,000 Mm3/year in natural gas savings.
- ***Utilize solar energy technologies:*** Despite abundant levels of solar insolation available in Bahrain, there is no serious initiative to utilize solar energy technologies. Based on the mitigation analysis, solar troughs are a particularly relevant mitigation option for Bahrain that could lead to over 1,400 Gg in annual GHG savings, as well as provide a number of other benefits.
- *Promote efficient air conditioning and lighting:* There are several strategic demand side opportunities that should be promoted through national public awareness programs. In particular, energy-efficient air-conditioners and compact fluorescent lighting should be actively incentivized.

Supporting such action requires confronting and overcoming certain challenges and barriers. Specifically, it is necessary to build national technical capacity for mitigation assessment, and strengthen inter-ministerial links for information sharing. A program of action is outlined below.

- *Integrate mitigation options into national planning:* As many of the elements of a mitigation assessment in Bahrain cut across traditional ministerial boundaries, it is not clear, from an institutional coordination perspective, how all of the various elements of a mitigation plan, were one to be developed, could be implemented. The national climate change committee at the General Commission for the Protection of Marine Resources Environment and wildlife could be entrusted to coordinate implementation of the plan.
- *Strengthen technical capacity:* For aggressive Demand Side Management (DSM) programs to be successful in Bahrain, training in a number of different areas should be implemented. Training of Bahraini professional and other workers will be required to understand the opportunities for energy savings beyond air conditioning and lighting applications. National educational institutions can provide training in the field of climate change.
- *Develop energy information networks:* There is currently only modest information regarding energy end-use in Bahrain homes, businesses, institutions, and industries. In order to inform many elements of future mitigation assessments, as well as for many other forms of energy planning, it is essential to better understand how energy is used in Bahrain. To that end, it will be important to plan and implement a number of comprehensive end-use surveys in a range of different sectors, complemented by a combination of end-use meeting and energy audits for larger buildings and for industrial facilities. The climate change committee should coordinate such surveys and disseminate its findings.

5 Strategy to Raise Public Awareness

This chapter summarizes a national-level strategy for raising awareness about climate change issues. Such a strategy is essential for moving toward a better understanding of both the potential impacts on Bahrain from a changed climate, as well as what its youth, civil society groups and government agencies can do in mobilizing adaptation activities.

As the previous chapters have sought to highlight, Bahrain has limited natural resources, a fast growing population, and rapid rates of urbanization and industrialization. In the face of the additional risks posed by a changing climate, the transition to sustainable development practices is not merely an option, but an imperative choice for Bahrain's economic and social prosperity (Khalil, 2004).

A key step towards meeting the challenges posed by a changing climate is to initiate a national dialogue to raise awareness among key policymakers, civil society organizations and NGOs about causes and potential consequences. A shared understanding among these individuals and institutions is essential, not only for mobilizing public support, but also for undertaking the range of participatory activities that will undoubtedly be needed.

5.1 Context for Action

An existing commitment to sustainable development and environmental protection is a key national premise for formulating an overall awareness building strategy for the Kingdom of Bahrain around climate change issues. This commitment is evident through ongoing outreach, training and education efforts undertaken by the Government, civil society organizations, academic and research institutions, industry and the media on environmental protection and resource conservation. In fact, several institutions and NGOs are already engaged in a variety of ongoing activities for raising public awareness and enhancing research of environmental problems confronting the country.

It is important to note that climate change and its potential negative impacts and consequences have only recently yet begun to be publicly perceived as a national challenge. A considerable lack of awareness still exists in Bahrain regarding how climate change may threaten national development activities. This is due primarily to a lack of information.

There is therefore a need to both elevate public sensitivity to climate change issues and involve a wide range of groups in developing strategic responses. Together, these actions should help to foster a sense of national responsibility and greater motivation and commitment towards meeting the challenge of climate change.

Finally, the effectiveness of awareness raising and education for climate change issues (mitigation and adaptation) and sustainable development in Bahrain should ultimately be measured by the degree to which they change the attitudes and behaviors of the people in carrying out their collective responsibilities as citizens.

5.2 Strategic Objectives and Approach

Thanks in large part to a September 2004 national workshop to seek public input on how to build public awareness around climate change issues, there has been a broad level of public participation concerning the strategic aims of such a process. Organized by the Desert and Arid Zones Sciences Program of the Arabian Gulf University, the workshop was attended by representatives from government, NGOs, scientific research and training institutes, the private sector, and media outlets. The outcome of this gathering was broad acceptance around a goal to enhance public awareness regarding climate change that can lead to specific actions to reduce emissions, proactively adapt, and protect the management (Khalil, 2004).

Within this overall goal, there is now a growing national consensus in Bahrain around a number of key public awareness objectives. These objectives, summarized in Box 5.1, essentially dictate and underlie a threefold approach to addressing climate change issues, namely engagement of civil society, strengthening of national capacity, and promotion of community-based initiatives. Each of these dimensions of the public awareness strategy is summarized in the subsections below. An overview of the specific target groups, objectives, key messages, and activities implied by the approach is provided in Table 5.1.

Box 5.1: Key objectives of Bahrain's Public Awareness Strategy on Climate Change

- Identify and increase levels of environmental awareness among key segments of Bahraini society
- Protect the environment, rationalize natural resource use, and reduce resource depletion rates
- Inculcate in the younger generation a set of values and ethical standards that will lead to proactive attitudes and behavior toward climate change and environmental protection
- Facilitate public participation and support for resource conservation
- Enhance institutional capacities of various government departments, civil society, industrial and economic organization relevant to climate change, environmental management, and resource conservation
- Establish networks for influencing social, economic and environment policies to be more conducive to sustainable development
- Target influential private and civil society groups for raising awareness campaigns regarding specific adaptation, mitigation and vulnerability reduction policies and measures that could be effectively implemented

5.3 Civil Society Engagement

Engaging Bahraini civil society is a fundamental aspect of the public awareness strategy. It should be an interactive process in which different parties are identified, approached and then involved in a dialogue around climate change issues. Each group will need to understand their particular roles, responsibilities and ways for making their voices heard, and for building consensus for social action. For policy makers and other interested groups, the ultimate aim is to channel new social norms and attitudes that emerge toward concrete actions that can address climate change.

There are several types of civil society groups that will be engaged. First and foremost, these include children, youth and teachers who together represent the best hope of a new generation of an environmentally sensitized citizenry. Governmental policy and decision makers also have an important role to play in shaping of new policies, together with a range of non-governmental and civil society organizations that can bring their perspectives on new legislation or policies needed.

The media – television, radio, and print - should also be engaged as a way of harnessing the way the climate change message is communicated to the general public.

Other key groups include the scientific and academic community with the potential for developing new environmental curricula, religious leaders who can stress that conservation and environmental protection are civic as well as religious duties, and the private sector (primarily industrial facility operators) which has such a role to play in achieving significant GHG emission reductions.

Table 5.1: Specific Measures in the Public Awareness Strategic Plan

Target Groups	Objectives	Message	Ranked Programs & Activities
Legislature ▪ Government Officials ▪ Members of Parliament & Consultative Council ▪ Members of Municipal Councils	▪ Develop advocacy networks ▪ Enact legislation on emissions, cleaner production, and coastal infrastructure standards; allocate necessary funds ▪ Apply "polluter pays" principle ▪ ICZM and take precautionary measures against SLR ▪ Address transport and emission problems ▪ Promote energy conservation ▪ Encourage scientific research & information dissemination	▪ Bahrain highly impacted by climate change (sea level rise and temperature increase) ▪ Highlight economic and health costs ▪ Imperative to take appropriate measures to alleviate impacts, implement adaptation policies, and lower emissions	▪ *Type 1 Activities:* visit decision makers, meet Parliament Committee members, write letters to decision makers ▪ *Type 2 Activities:* convene special symposium for decision makers ▪ *Type 3 Activities:* prepare technical reports on climate change with particular emphasis on costs
Industry ▪ Government Officials ▪ Private sector	▪ Reduce energy consumption and lower emissions ▪ Adopt cleaner production and clean technologies ▪ Encourage landscaping and greening activities (sinks)	▪ Energy conservation and cleaner production technologies increase competitiveness ▪ Tree and shrub planting can lower emissions around factories and in Bahrain in general	▪ *Type 1 Activities:* visit factories to introduce CC, discuss roles to address CC, encourage service ▪ *Type 2 Activities:* coordinate symposium for factory owners with Chamber of Commerce
Public ▪ Citizens ▪ Expatriate groups	▪ Raise awareness of CC among the public at large ▪ Demonstrate the importance of lowering consumption in emission reductions and resources conservation ▪ Develop national technical capacity for adapting to CC	▪ Rationalization and conservation helps to address adaptation to CC ▪ Tree and shrub planting can reduce pollution and absorb GHG emissions ▪ Water/electricity conservation is essential	▪ *Type 1 Activities:* conduct public seminars ▪ *Type 2 Activities:* conduct media campaigns (newspapers, TV, radio, road signs, etc.) ▪ *Type 3 Activities:* arrange exhibitions at public events, festivals, and shopping malls
Youth ▪ Elementary students ▪ University students	▪ Create an environmentally aware and active generation ▪ Build wise environmental behaviors in the next generation ▪ Increase participation of youth in environmental issues ▪ Increase influence of youth in society at large as activists and advocates for environmental protection	▪ Environmental protection and resource conservation are national responsibilities	▪ *Type 1 Activities:* incorporate climate change issues in school curricula and activities ▪ *Type 2 Activities:* conduct leadership workshops ▪ *Type 3 Activities:* hold competitions ▪ *Type 4 Activities:* involve/support youth in conferences, workshops, meetings on CC
Trainers, Advocates ▪ Educators ▪ Religious leaders ▪ Celebrities ▪ Media & Intellectuals	▪ Create and raise awareness and understanding of CC among this group ▪ Convey messages and information to the public about importance of addressing climate change issues	▪ Resource conservation & environmental protection is both a civic and religious duty ▪ Improving energy/water consumption patterns reduces wastes and pollution	▪ *Type 1 Activities:* conduct training workshops for trainers and advocates ▪ *Type 2 Activities:* hold awareness building workshops for educators, religious leaders, celebrities, media & intellectuals
Civil society groups ▪ Political NGOs ▪ Environmental NGOs ▪ Labor unions	▪ Raise awareness of the problem of CC ▪ Work together in raising awareness and mitigating impacts & adaptation ▪ Monitor compliance in emission reductions	▪ Let us work together	▪ *Type 1 Activities:* hold meeting with civil society groups to discuss local CC impacts ▪ *Type 2 Activities:* meet with representatives of the General Union of Bahrain Labor ▪ *Type 3 Activities:* Meet with NGOs & leaders ▪ *Type 4 Activities:* hold public seminars on CC

The types of methods and tools to be used to engage civil society groups will depend on the nature of the particular group. It will include awareness campaigns, publications, films and videos, internet sites, conferences, and so forth.

5.4 Strengthen National Capacity

The strengthening of national capacity is essential for sustaining actions that emerge from the awareness building strategy. In particular, strategic training programs are considered a constituent of individual capacity building as well as the most appropriate tool to develop human resources and facilitate the transition to a more environmentally sustainable world. Hence, education, on-the-job training, and formal and informal skill development are core requirements for any proper capacity strengthening process. Their aim is to fill gaps in knowledge and skills that would help Bahraini individuals and communities to be actively and effectively involved in climate change issues.

Training activities in Bahraini training institutes and centers are sectoral in their orientation with a clear job-specific focus. Vocational training, on job training and re-training programmes are widespread. A number of government ministries and the private sector have established a series of vocational training centers designed specifically to address certain needed expertise in industry, commercial and financial business. These

In fact, there is no lack of training institutions in Bahrain that could be adapted and/or mobilized to address climate change concerns, However, a reorientation of their programmes to integrate climate change issues is a necessary step towards understanding practical implications of the intersections between national development and climate change.

The specific areas recommended for capacity strengthening are as outlined below:

- *Environmental Affairs Agency*. This section of the Public commission for the Protection of Marine Resources, Environment and Wildlife has the stated mission of creating a critical mass of sufficiently trained national experts in all areas related to climate change, and to play an active and major role in planning, coordinating and implementing programmes of action.
- *Scientific institutions and NGOs.* These contribute to scientific knowledge and to convey information on issues per training to climate change and its impacts on the Kingdom of Bahrain, yet are presently highly constrained with regard to climate change issues.
- *Vocational training institutions.* Local training institutions will need to reorient their training curriculums to include climate change issues and to initiate training activities and workshops on GHG inventories, vulnerability and adaptation assessments and GHG abatement options. There is also a need for training in monitoring of climate change and its impacts, use and interpretation of predictive models and formulation of climate change project proposals.
- *On-the-job training.* There is a need for young researchers, analysts, engineers and others to receive training as part of the typical work experience. When combined with train-the-trainer program, there should be a multiplier effect for the rest of Bahraini society.

5.5 Encourage Community-based Initiatives

Community development, knowledge sharing and grass-roots communication for urban, sub-urban and village communities are important initiatives that should be nurtured as part of a national public awareness strategy.

There are many NGOs in the Kingdom of Bahrain that have formulated plans to strengthen the adaptive capacity of local communities to various stresses including climate variability. These plans have typically included community-based education, training, public awareness and demonstration projects. Such efforts extended to address climate change could help promote local community resilience to climate stresses and other environmental pressures. It should also enhance local capacity building for participatory decision-making and collective action.

These initiatives, suitably interwoven with future plans and programmes of grass-roots NGOs, will enhance understanding of the climate change issues, and its implications for the Kingdom of Bahrain. It should also lead to the design and implementation of effective GHG mitigation and climate change adaptation measures.

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