STATE OF KUWAIT

Environment Public Authority

Kuwait's Initial National Communications under the United Nations Framework Convention on Climate Change

November 2012

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Foreword

It is a pleasure to present, on behalf of the State of Kuwait, this Initial National Communication (INC) under the United Nations Framework Convention on Climate Change (UNFCCC). Through this submission, Kuwait provides to the Conference of the Parties (COP) country-specific information for use within the climate change context. Kuwait recognizes that the global nature of climate change requires the utmost cooperation of all countries in response to the challenge.

Kuwait is vulnerable to the physical impacts of climate change on its ecology, human systems, and natural resources. Kuwait is also acutely vulnerable to climate change due to its total dependence on oil exports.

The State of Kuwait ratified the UNFCCC on 28 March 1995 and ratified the Kyoto Protocol on 11 March 2005. The INC summarizes efforts to establish the country's first greenhouse gas (GHG) emission inventory, the emission reduction benefits of mitigation measures in the energy sector, and the impacts of climate change on coastal zones and water resources. Other salient information is also included regarding national circumstances, future climate, as well as potential adaptation and mitigation measures.

Kuwait's national vision is the basis for the information provided in this INC. Through its focus on emission levels and how climate change challenges have been addressed, the INC seeks to make clear the specific areas and capacities that need improvement to ensure a healthier and more sustainable environment in Kuwait.

COP guidelines, as well as those of the Intergovernmental Panel on Climate Change (IPCC), have been followed in developing this report, which also reflects the best available information at this time. The INC's preparation has enhanced climate change-related awareness and knowledge, and is an important step in accounting for the challenge of climate change in national planning and policymaking.

The INC has enhanced data and information availability. It has also promoted a better understanding of local climate change impacts and has produced recommendations, which will be worked out in a National Action Plan in the Second National Communication. Implementation of this plan will enable the Government of Kuwait to contribute in achieving the noble goals of the UNFCCC and fulfill its commitments.

Finally, I would like to take this opportunity to thank His Highness the Prime Minister, **H.H. Sheikh Jaber Al-Mubarak Al-Hamad Al-Sabah** and the first Deputy Prime Minister of Interior and the Chairman of Higher Council of Environment, **H.E. Sheikh Ahmad Humoud Al-Jaber Al-Sabah**, for their continuous guidance and support. I also would like to thank the Global Environment Facility (GEF), the United Nations Environment Programme (UNEP) and its Regional Office for West Asia (UNEP/ROWA), Kuwait University, Kuwait Petroleum Corporation for their commitment and support throughout the INC preparation process. Thanks also go to the national experts and international advisors who have made this high quality report possible.

Chairman & Director General,
Environment Public Authority
Kuwait

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List of Acronyms

°C	degrees Centigrade
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BCM	billion cubic meters
BIPV	Building-integrated PV systems
CIS	Coastal Information System
CCCMA	Canadian Center for Climate Modeling Analysis model
CCS	carbon capture and storage
CDM	Clean Development Mechanism
CFP	Clean Fuels Project
CH_4	methane
CIS	Coastal Information System
CNG	Compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COP	Conference of the Parties
CSO	Central Statistical Office
CSP	Concentrated solar power
EE	Environmental Education
EIA	Energy Information Administration (USA)
eMISK	environmental Monitoring Information System of Kuwait
ER	Environmental Research
GCC	Gulf Cooperation Council
GCM	Global Circulation Model
GDEM	Global Digital Elevation Model
GDP	gross domestic product
Gg	Gigagrams (i.e., one billion grams)
GHG	Greenhouse gas
GIS	Geographic information systems
GW	gigawatt (billion watts)
GWh	gigawatt-hour (billion watt-hours)
GWI	Global Water Intelligence
HFC	hydrofluorocarbons
INC	Initial National Communication
HVAC	heating, ventilation and air conditioning
IPCC	Intergovernmental Panel on Climate Change
KEPA	Kuwait Environment Public Authority
KFAS	Kuwait Foundation for the Advancement of Sciences
Kg	kilogram
KISR	Kuwait Institute for Scientific Research
Km	kilometers
Km^2	square kilometers
KPC	Kuwait Petroleum Corporation
KU	Kuwait University
kWh	thousand watt-hours
l/cap/day	liters per capita per day

LEAP	Long-range Energy Alternatives Planning model
LPG	liquid petroleum gas
m	meters
MEW	Ministry of Electricity and Water
MHTL	Mean high tide level
Mm^3	million cubic meters
MSW	Municipal solid waste
N_2O	nitrous oxide
NGCC	natural gas combined cycle power station
NGO	Non-governmental organization
NHA	National Housing Authority
NMVOC	non-methane volatile organic compounds
NO_x	nitrogen oxides
O_3	ground-level ozone
PAAET	Public Authority for Applied Education and Training
PAAST	Public Authority for Applied Sciences and Training
PACI	Public Authority for Civil Information
PFC	perfluorocarbons
PM_{10}	particulate matter less than 10 microns in diameter
PV	photovoltaic (solar)
QSAS	Qatar Sustainability Assessment System
SEI-US	Stockholm Environment Institute – US Center
SLR	Sea level rise
SO_2	sulfur dioxide
TNA	Technology Needs Assessment
TSE	Treated sewage effluent
UAE	United Arab Emirates
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USGS	United States Geologic Survey
WEAP	Water Evaluation And Planning model

List of Contributors

Guidance and Oversight

Salah Mudh'hi Al-Mudh'hi, Director General, Kuwait Environment Public Authority (KEPA)
Captain Ali Haider, Deputy Director General, KEPA
Hasan A. Al-Sanad, Vice President for Research, Kuwait University (KU)
George Manful, Senior Task Manager, UNEP

Technical Manager

Abdul-Majeid Haddad, UNEP Regional Office for West Asia (UNEP/ROWA)

Project Coordination

Obaid Al-Otaibi, Assistant Vice President for External Research Collaboration, KU
Shareef Alkhayat, Assistant Project Coordinator, KEPA

Technical Teams

National Circumstances and other information:

Walid Chakroun, Kuwait University
Abbas A. Al-Mejren, Kuwait University
Shareef Alkhayat, KEPA
Abdullah Alsanad, Kuwait University
Manaf Behbehani, Kuwait University
Zamzam Hussain, Central Statistical Office
Haitham M.S. Lababidi, Assistant Vice President for Research, Kuwait University
Advisor: Abdul-Majeid Haddad, UNEP/ROWA

GHG Inventory and Mitigation Assessment:

Abdullatif Ben-Nakhi, College for Technology Studies
Gamal Al Sanoosi; Kuwait Petroleum Corporation (KPC)
Sana Al Ghareeb, Ministry of Electricity and Water
Haitham Al-Ali, Ministry of Electricity and Water
Rasha Abbas Maarafi, Kuwait Petroleum Corporation
Fathiaya Akroof, KEPA
Shareef Alkhayat, KEPA
Hanan Malallah, KEPA
Mohammed Jamal, Agriculture and Fisheries Authority
Yaqoob Al Maatooq, Ministry of Social Affairs
Fatima H. Taher; KEPA
Fatimah Al Shatti, Kuwait Petroleum Corporation
Advisors: GHG Inventory: Mohamed Alam, Consultant, Jordan
GHG Mitigation: Ibrahim Abdel Gelil, Arabian Gulf University, Bahrain

Vulnerability and Adaptation (Water Resources):

Meshari Al Harbi, Kuwait University
Fawzia Al-Ruwaih Kuwait University
Hamed Eidan, Ministry of Planning
Anwar Sarkhouh, Ministry of Electricity and Water
Abdulaziz Al-Shalabi, KEPA
Advisors: Waleed Al-Zubari, Arabian Gulf University, Bahrain
Alaa El-Sadek, Arabian Gulf University, Bahrain

Vulnerability and Adaptation (Sea Level Rise):
Mohammad Al Sahli, Kuwait University
Ahmad AlHasem, Kuwait University
Shaimaa Al-Saffar, KEPA
Eman Faisal, KEPA
Advisor: Sabah Al Jenaid, Arabian Gulf University, Bahrain

Climate and Climate Modeling:
Essa Ramadan; Department of Meteorology, Civil Aviation
Hassan Aldashti, Department of Meteorology, Civil Aviation
Mohammad Al-Shafi, Kuwait University
Advisor: Mansour Almazroui, King Abdulaziz University, Saudi Arabia

Compilation and Review:
Mona Radwan, Consultant, UNEP/ROWA

International Reviewer and Editor:
William Wallace Dougherty, Climate Change Research Group, Boston, USA

Administrative Support
Lorraine D'Almeida, UNEP/ROWA
Violet Al-Kassar, KPC
Talal Bunashi, Administrative Affairs, Kuwait University
Manal Ali, KEPA

Executive Summary

National Circumstances

The State of Kuwait is located at the northwestern end of the Arabian Peninsula between latitudes 28°30'and 30°5' North and longitudes 46°33' and 48°30' East. Total land area is approximately 17,818 km^2, consisting of a mainland where the capital Kuwait City is located and nine (9) uninhabited islands in the Arabian Gulf. From East to West, Kuwait is roughly 170 km across and 200 km from North to South. Kuwait shares a 495 km border with Saudi Arabia to the south and 195 km with Iraq to the north and west.

The government of Kuwait is a constitutional, hereditary emirate ruled by princes (Emirs) drawn from the Al-Sabah family. The Constitution of Kuwait, endorsed by the Constituent Council on 11 November 1962, has elements of a presidential and a parliamentary system of government. The country is administrated relative to six (6) governorates: Al Kuwait (capital), Al Jahra (largest), Al Ahmadi (several major oil refineries), plus governorates located close to the capital: Al Farwaniyah, Hawalli, and Mubarek Al-Kabeer.

Kuwait has an overwhelmingly urban population that has grown steadily over the past two decades. Between 1994 and 2011, total population grew about 4.1% per year on average. Over this time, the Kuwaiti population as a share of the overall population has remained fairly steady, between 32% and 37%, and has grown about 3.3% per year on average. In contrast, the expatriate work force has grown more rapidly over the same period - about 4.6% per year on average - while accounting for between 63% and 68% of total population.

Kuwait has a hyper-arid desert climate, hot and dry. Average rainfall typically varies from 75 to 150 millimeters a year. Minimum annual levels have been recorded as low as 25 millimeters while maximum annual rainfall has reached 325 millimeters. In summer months, average daily high temperatures range from 42°C to 46°C. From mid-August through September, humidity can exceed 95%. Dust storms are particularly frequent in the summer and can reach speeds up to 50 km per hour.

The economy is fairly small, comparatively rich, semi-open and highly dependent on oil exports. Petroleum accounts for the majority of gross domestic product, export revenues and government income. Since 1994, oil operations as a share of GDP have steadily increased, reaching 51% of the economy in 2010. As a result, Kuwait's economy continues to be highly vulnerable to changes in global oil demand, as well as international oil market price volatility.

Kuwait is one of the world's leading oil producers, an energy source upon which virtually every nation is dependent. It has the world's fifth largest crude oil reserves and is one of the ten largest global exporters of crude oil and oil products. Proven oil reserves are estimated to be about 101.5 billion barrels (bbl), just over 7% of the world total. Additional reserves of about 5 bbl are held in the Partitioned Zone, which Kuwait shares on a 50-50 basis with Saudi Arabia. Gross oil production levels reached about 2.7 million barrels per day in 2011. Natural gas reserves are small in comparison.

A highly water-stressed country, Kuwait relies on desalinated water and fresh groundwater to meet drinking water needs. Brackish groundwater and treated wastewater are used in agriculture and industrial applications. As of 2011, about half of water supply was provided by desalinated water. Overall water consumption reached 1,202 million cubic meters in 2011. Households and agriculture sectors dominate Kuwait's total water demand, with only a small share devoted to industrial applications. On a per capita basis, Kuwait has one of the highest water usage rates in the world.

Kuwait has developed a waste management system to process the country's solid and liquid industrial wastes. Municipal solid waste (MSW) quantities have increased substantially in the last decadeasa result of population growth, industrial development, and life style changes.

There is an extensive, modern and well-maintained network of road infrastructure. As of 2010, the total length of paved roads exceeded 6,600 km, representing just over 77 km^2 or 0.4% of the country's total land area. In coming years, government plans call for an additional 700 km of new paved roads.

The potential of agricultural development in Kuwait is very limited, as less than1% of the land area is considered arable. Moreover, only a portion of arable land area is actually cultivated due to a hyper-arid climate, water scarcity, poor soils, and a lack of relevant skills. Not surprisingly, agriculture's share of GDP is negligible, consistently less than 1%. As a result, Kuwait relies heavily on food imports, which account for 98% of cereals, 90% of milk and dairy products, 77% of fruits, 65% of fish, and 62% of meat.

Environmental Education is a national commitment and an essential and integral part of the education program at all levels. The goal is to develop a concern and awareness among students, as well as the overall population, about the value of environmental services. Programs also aim to increase an understanding of environmental challenges and enhance a commitment to work individually and collectively towards protection of the environment.

Since Liberation in 1991, a national policy has been adopted for giving priority funding for Environmental Research Projects, especially those dealing with the impacts of oil pollution and burning oil wells. Over US$ 30 million has already been spent on such projects. Within Kuwait, there are several institutions with substantial capacity for conducting environmental activities.

Kuwait is endowed with rich biodiversity of terrestrial flora and fauna. Desert areas contain many species of annuals, which make up about 90% of plant species of Kuwait. Kuwait is also endowed with rich marine biodiversity. Many endemic species can be found including crabs, which are found on biota-rich intertidal Sabkha zones.

Greenhouse Gas Emission Inventory

The Revised IPCC 1996 Guidelines in combination with the IPCC's Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000) were used to develop Kuwait's first greenhouse gas inventory. The inventory used 1994 as the base year. Table ES-1 summarizes Kuwait's overall GHG emissions profile. Total GHG emissions were 32,373 Gg CO_2e, which includes 30,855 Gg from energy; 668 Gg from industrial processes; 66 Gg from agriculture, and 784 Gg from waste. CO_2 sequestration by the forestry and land use sector amounted to 22 Gg. Net GHG emissions are estimated at 32,351 Gg CO_2e.

Energy-related activities accounted for the dominant portion of GHG emissions in Kuwait in 1994. Approximately 95.3% of all GHG emissions are associated with the combustion of fossil fuels and the release of fugitive emissions from oil and gas operations. Waste management accounted for 2.4% of all GHG emissions, followed by industrial process emissions with 2.1%. Agriculture accounts for 0.2% and managed tree plantations throughout the country sequestered less than 0.1% of GHG emissions.

Table ES-1: Total GHG emissions in Kuwait, 1994 (Gg)

GHG Sources & Sinks	CO_2e	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
1 Energy	30,855	28,856	92.69	0.17	113	544	522	320
2 Industrial Processes	668	668	0.00	0.00	0	0	0	0
3 Solvent & Other Product Use	0	0	0.00	0.00	0	0	0	0
4 Agriculture	66	0	2.70	0.03	0	0	0	0
5 Land-Use Change & Forestry	-22	-22	0.00	0.00	0	0	0	0
6 Waste	784	0	33.80	0.24	0	0	0	0
Total National Emissions	32,373	29,524	129.19	0.44	113	544	522	320
Net National Emissions	**32,351**	**29,502**	**129.19**	**0.44**	**113**	**544**	**522**	**320**

Vulnerability and Adaptation

Kuwait's vulnerability to climate was examined relative to two key sectors, coastal zones and water resources. As a basis for considering the adverse impacts of climate change, projections temperature and rainfall were first assessed. Modeling results show that average annual temperatures will increase in the future with average annual temperatures projected to reach a high of about 28.7°C in Kuwait during the 2010-2035 period. This represents about a 1.6°C increase over the average annual temperature of the past decades.

Average annual rainfall is projected to decline in the future, reversing past trends in Kuwait. Average annual rainfall levels are projected to be consistently below 70 mm per year over the 2016-2026 period, over 60 mm per year lower than the historical average. On average, rainfall in Kuwait is expected to decrease about 2 mm/year per decade through 2035, a potentially serious adverse impact to grazing areas of livestock herds. These projections also suggest the possibility for increased dust storms.

Kuwait's coastline spans about 350 km and is the region where most of the population and critical infrastructure is located. Climate change-induced sea level rise could lead to serious adverse impacts on future socioeconomic development. Rising seas in the Arabian Gulf are projected to flood low-lying urban infrastructure, threaten coastal lagoons and salt marshes, and contribute to the deterioration of groundwater quality. Using local elevation data, GIS analysis techniques, and a sea level rise scenario approach, the extent of inundated area is projected to be up to 542 km^2, with about 174 thousand people at risk. Table ES-2 provides a summary of results.

Table ES-2: Extent of inundated area and population at risk under the SLR scenarios

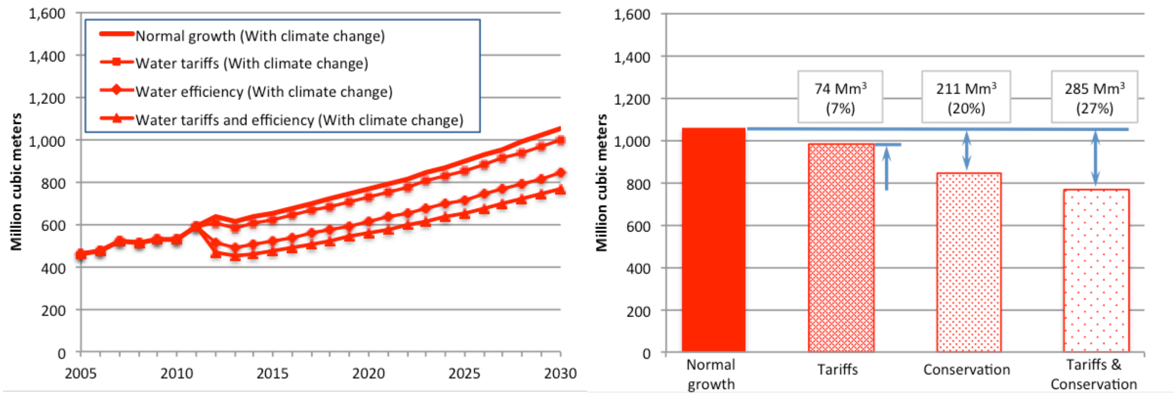
	Sea level rise scenario							
	Low (MHTL + 0.5 m)		Central-Low (MHTL + 1.0 m)		Central-high (MHTL + 1.5 m)		High (MHTL + 2.0 m)	
Coastal zone	Km^2	% of total	Km^2	% of total	Km^2	% of total	Km^2	% of total
Northern	199	1.1	408	2.3	416	2.3	419	2.4
Central	34	0.2	34	0.2	34	0.2	76	0.4
Southern	7	<0.1	7	<0.1	46	0.3	46	0.3
Total inundation	**241**	**1.4**	**450**	**2.5**	**496**	**2.8**	**542**	**3.0**
People at risk (thousand)	**65.1**	**1.8**	**65.1**	**1.8**	**125.8**	**3.5**	**173.7**	**4.8**

Water resource management is already a critical planning challenge for Kuwait. With climate change, it is expected that balancing water supply and water demand will become an even greater challenge. Using local water supply/demand data, a water planning software model, the temperature/rainfall projection discussed earlier and a population growth scenario approach, water consumption in Kuwait was found to exceed by 5% current expectations without climate change.

To assess the impact of water efficiency and conservation on future water consumption, several adaptation measures were considered. These included a water tariff system, greater use of water conservation technologies and a combination of both measures. The introduction of these adaptation measures would be significant, leading to water savings of up to 285 million cubic meters by 2030. Figure ES-1 summarizes the results of the adaptation analysis for the Normal Population growth scenario.

Figure ES-1: Impact of adaptation measures in the Normal Growth Scenario

a) Overall impact, 2012-2030 **b) Detailed impact, 2030**

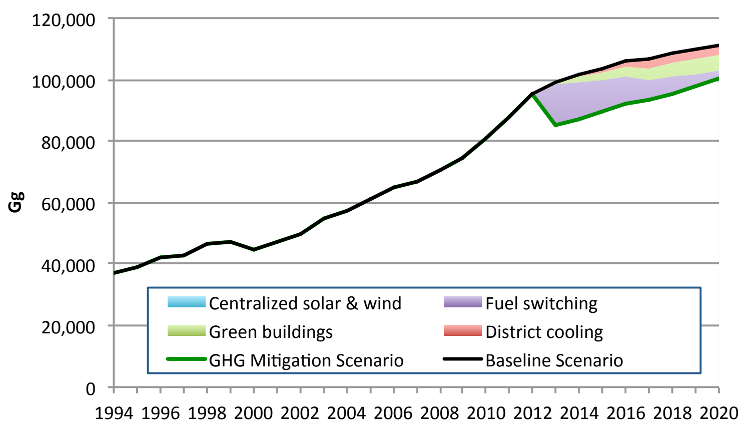


Greenhouse Gas Mitigation

An evaluation of key technology options to reduce GHG emissions was carried out to develop a better understanding within Kuwait of the potential synergies such options may enjoy with national development goals and priorities. These benefits include, but are not limited to, reduced air pollution levels, enhanced institutional environment for new technologies, diversified power supply, reduced road congestion, and job creation.

Four specific mitigation options were evaluated, district cooling, green buildings, fuel switching, and solar and wind power development. The implementation of these GHG mitigation options in Kuwait would lead to significant reductions in CO_2e emissions by 2020. A total of 10,284 Gg of CO2e would be avoided in 2020, roughly equivalent to 10% of the Baseline GHG levels in that year. Figure ES-2 provides a summary of results.

Figure ES-2: Impact of GHG mitigation options, 1994-2020



Technology Needs Assessment

A Technology Needs

Assessment was conducted to develop a better understanding of the range of technology options that could be harnessed to address the challenge of climate change in Kuwait. Key technologies were identified and ranked through a series of local stakeholder consultations.

Due to the prominence of energy production and consumption in Kuwait's GHG emission profile, the focus for mitigation technologies was on the energy sector. Specifically, technologies for electricity generation, as well as technologies that can reduce residential building energy consumption were targeted. A total of 16 priority mitigation technologies are recommended. For adaptation technologies, the focus was on coastal zones, water resources, and public health. A total of 15 priority adaptation technologies are recommended.

The priority technologies face a number of barriers for widespread adoption in Kuwait. Overcoming these barriers will involve engaging key stakeholders in government and the private sector; reforming/strengthening policies and measures; fostering the emergence of technology "champions"; developing market-based technology support systems; and strengthening technical capacity and education.

1 National Circumstances

This chapter includes a brief description of Kuwait's government structure, population, geography, climate, and economic profile. In addition, the chapter devotes several sections to describe current sectoral activities in energy, transport, water resources, waste management, and agriculture.

1.1 Geographic Profile

The State of Kuwait is located at the northwestern end of the Arabian Peninsula between latitudes 28°30′and 30°5′ North and longitudes 46°33′ and 48°30′ East (see Figure 1-1). Total land area is approximately 17,818 km^2, consisting of a mainland where the capital Kuwait City is located and nine (9) uninhabited islands in the Arabian Gulf. From East to West, the State of Kuwait is roughly 170 km across and 200 km from North to South. Kuwait shares a 495 km border with Saudi Arabia to the south and 195 km with Iraq to the north and west. The coastline is comprised of 325 km along the mainland and 175 km along the islands. Two distinct zones characterize country, as briefly described below.

Figure 1-1: Map of the State of Kuwait (source: Environment Public Authority EPA, Kuwait)

- *Northern zone:* This area includes Kuwait Bay and five islands: Warba, Bubiyan, Maskan, Failaka, and Ouha. Kuwait Bay is a shallow but very important marine habitat with high productivity and diversity. Its coastal zone accounts for nearly half of the country's shoreline. Bubiyan (888 km^2) and Warba (212 km^2) are highly pristine areas that are home to migratory birds and rich marine biodiversity. The northern half of Bubiyan Island is a designated marine protected area named Mobarak Al-Kabeer.

- *Southern zone:* The area extends from Ras Al-Ardh to the border area with Saudi Arabia. Its main features sandy and mixed shores and the coral reef islands of Kubbar, Qaruh and Um Al-Maradim. Many intertidal marshes, known as *sabkhas*, are also found, the largest being Al-Khiran Sabkha that is currently undergoing transformation into a large water front city. The southern region is a monotonous plain covered by sand. Al-Ahmadi hill, 125-m high is the sole exception to the flat terrain. Wadi Al-Batin and Ash-Shaqq are the only major valleys, portions of which lie within the western and southern reaches of the country, respectively. Rocks ranging in age from early Miocene (about 24 million years) to recent times are exposed within the boundaries of Kuwait.

1.2 Government Structure

The State of Kuwait is a constitutional, hereditary emirate ruled by princes (Emirs) drawn from the Al-Sabah family. The Constitution of Kuwait, endorsed by the Constituent Council on 11 November 1962, has elements of a presidential and a parliamentary system of government. The country is administrated relative to six (6) governorates: Al Kuwait (capital), Al Jahra (largest), Al Ahmadi (several major oil refineries), plus governorates located close to the capital: Al Farwaniyah, Hawalli, and Mubarek Al-Kabeer (see Figure 1-2).

His Highness Sheikh Sabah al-Ahmad al-Jabir al-Sabah is the Emir of Kuwait, head of state, and Commander-in-Chief of Kuwait's armed forces. The Emir, a member of the al-Sabah dynasty that has been ruling since approximately 1752, exercises his executive authority through the Prime Minister and the Council of Ministers. The Emir is constitutionally empowered to appoint the Prime Minister.

Figure 1-2: Governorates of Kuwait (source: http://mapsof.net)

Legislative power is vested in the Emir and the parliament (the National Assembly) which consists of fifty (50) members, who are chosen in direct elections that are held every four years. In accordance with the country's constitution, the fifteen (15) cabinet ministers are also members of parliament. Kuwait's parliament is not only the oldest legislative assembly among in Gulf Cooperation Council (GCC) states, but possesses the greatest political authority of any in the GCC. Since 2005, all Kuwaiti citizens, both male and female at least 21 years of age, are eligible to vote.

The Emir is empowered by the Constitution to dissolve the parliament and call for new elections, or in cases of national emergency can dismiss the parliament outright and/or suspend certain articles of the Constitution and assume supreme authority over the country. Either the Emir or the parliament can propose amendments to the constitution; a two-thirds majority of the members of the Assembly is required to adopt a change.

The nomination of a successor to the Emir is the prerogative of the ruling al-Sabah family, and is subject to parliamentary approval under the Constitution. If the nominee does not win a majority of votes of the Assembly, the parliament must vote on and approve another candidate for the post.

The Constitution allows for the establishment of political parties. At the current time, a law has not yet been enacted to regulate them. As a result, no political parties are operational in Kuwait in the formal sense. Nevertheless, several members of parliament identify themselves and function as de facto political parties on the basis of religious sect/belief, social class or tribe.

Kuwait has an independent judiciary system. Civil laws are based on a combination of British common law, French civil law, and Islamic religious law, the latter having a considerable role in personal and family matters. In each of the country's six governorates there is a summary court. There is also a court of appeals; a Cassation Court, which is the highest level of judicial appeal; and a Constitutional Court.

1.3 Demographic Profile

Kuwait has an overwhelmingly urban population that has grown steadily over the past two decades (see Figure 1-3). Between 1994 and 2011, total population grew from about 1.8 to 3.6 million (PACI, 2012), or about 4.1% per year on average. Over this time, the Kuwaiti population as a share of the overall population has remained fairly steady, between 32% and 37%, and has grown about 3.3% per year on average. In contrast, the expatriate work force has grown more rapidly over the same period - about 4.6% per year on average - while accounting for between 63% and 68% of total population (CSO, 2011).

Figure 1-3: Population composition (source: PACI, 2012)

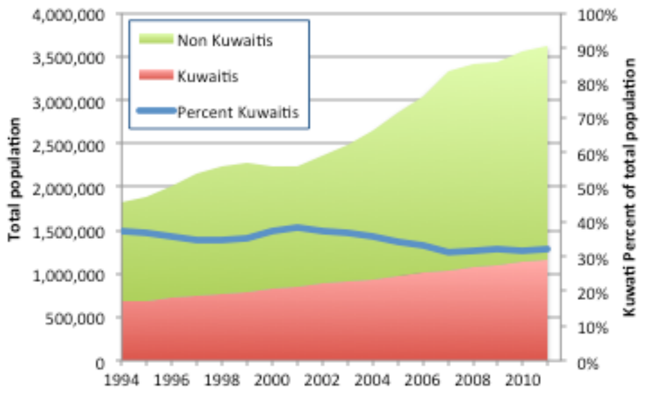
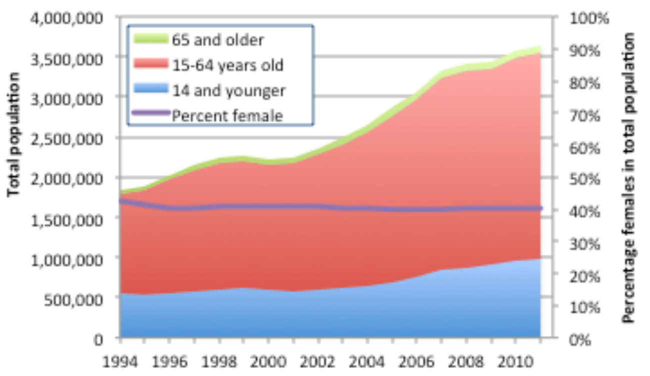


Figure 1-4: Population age and gender characteristics (source: PACI, 2012)



Between 1994 and 2011, most of Kuwait's total population has been between 16 and 64 years of age and roughly 60% male (see Figure 1-4). This is due in large part to the presence of a large number of expatriate workers in the country in that age bracket that are mostly male. In contrast, young Kuwaitis under the age of 20 accounted for the majority, about 51%, of the national population in 2005, the year of the last census. The gender distribution for the national population is roughly 50%-50% (CSO, 2011).

1.4 Climate

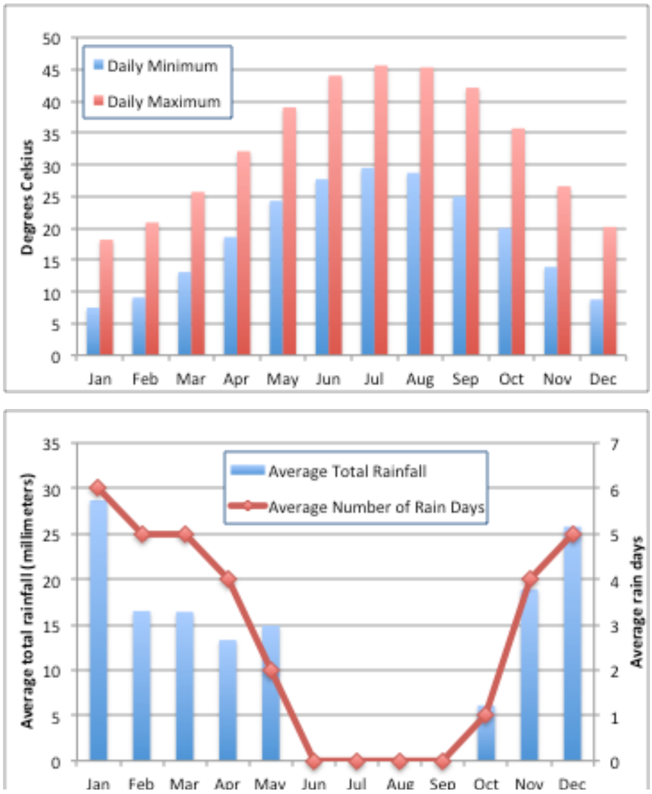
Kuwait has a hyper arid desert climate, hot and dry. Average rainfall typically is 116 millimeters a year across the country. Minimum annual levels have been recorded as low as 31.3 millimeters while maximum annual rainfall has reached 242.4 millimeters. In summer months, average daily high temperatures range from 42°C to 46°C, with the highest-ever recorded temperature of 53.5°C at Mitiriba meteorological station in the North West on August 3, 2011. The lowest temperature recorded was −4°C at Kuwait City in January 1964. Figure 1-5 illustrates average climatic conditions for temperature and rainfall at Kuwait airport over a 48-year period, 1962-2010. Three prominent features characterize Kuwait's climate, as described in the bullets below.

- *Humidity:* From mid-August through September, humidity can exceed 95%. This is due to high seawater temperatures coinciding with tropospheric temperature inversions. Relative humidity over the last 48 years (1962–2010) has average about 48%, with mean yearly maximums varying from 84% to 95%.
- *Evaporation:* Over the period 1994-2011, average evaporation rates vary from 3 to 13mm per day, with maximum levels ranging from 20 to 48 mm per day.
- *Dust storms*: While they can occur in any season, dust storms are particularly frequent in the summer and can reach speeds up to 100 km per hour (see Figure 1-6). Dust storms are aggravated by practices of overgrazing and citizen (uncontrolled) camping and are known to contribute to serious health impacts in Kuwait such as asthma incidence rates of 175 per day and road traffic accident rates that are over three times normal rates (Safar, 1985, KISR, 2012).

Kuwait's climate exhibits all four seasons. The winter season is considered to occur over a 2-month period between 6 December and 15 February. Low temperatures, clouds, rain and a cold northwesterly wind characterize this season. Two distinct climatic periods within the winter season are evident, as described below.

- *Murba'ania period:* This period corresponds to the first half of the winter season from 6 December to 15 January. Low temperatures can reach 3.3°C, especially during the night or when northwesterly winds are strong. Nevertheless, warm intervals are common and are due to a humid southeasterly wind with temperatures reaching up to 31.3°C.
- *Mild winter period:* This period corresponds to the latter half of the winter season from 16 January to 15 February. The presence of southeasterly winds result in overcast and rainy conditions. Such conditions are often followed by northwesterly winds which can bring much colder air, sometimes leading to dense fog and frost conditions when temperatures dip below 0°C.

Figure 1-5: Kuwait average monthly temperature and rainfall, 1962-2008 (source: Kuwait Meteorology Department)



The spring season is considered to occur a 3-month period from 16 February to 20 May and is characterized by moderate temperatures, rain, cloudy conditions and hot southerly winds. The climate during the spring is divided into two distinct climatic periods, as briefly described in the bullets below.

- *Cold moderate spring period:* This period corresponds to the first half of the spring season from 16 February to 8 April. Temperatures begin to increase due to a hot south wind (known as *Al-Suhily*) that lasts for several days at a time. Maximum temperatures may reach 41°C, well above the average for this period.
- *Warm spring period:* This period corresponds to the latter half of the spring season from 9April to 20 May. Thunderstorms (known as *Al-Sarayat*) are common during this period and typically develop in the late afternoon or evening. Severe dust storms can accompany these storms, with visibility dropping to zero. Temperatures gradually increase from about 30°Cduring the beginning of the period to 40°C at its end.

Figure 1-6: Dust storm approaching Kuwait City on 25 March 2011 (source: traveller blog photo, sv-ananda-cruising-blog.blogspot.com)

The summer season is considered to occur over a roughly 5-month period from 21 May to 4 November and is characterized by a significant increase in both humidity and temperature The climate during the summer is divided into three distinct periods, as briefly described below.

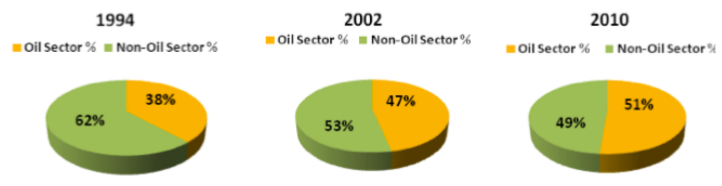
- *Transition period:* This period occurs from 21 May through 5 June and is the transition period between late spring and actual summer conditions. Skies are general clear of clouds and winds are variable in both direction and strength. Average maximum temperatures range from 40° to 44°C.
- *Dry summer period:* This period occurs from 6 June through 19 July and is characterized by a consistent hot and dry northwesterly wind (known as the *Semoom*) that contribute to strong dust storms where visibility can decrease to only few meters, especially at noon. Average maximum temperatures range between 42° and 46°C.
- *Wet summer period:* This period occurs from 20 July through 4 November and is characterized by light easterly and southeasterly winds that lead to high levels of humidity. Nevertheless, cloud cover is minimal and rainfall is rare during this period. Average maximum temperatures range between 45° and 46°C.

The autumn season is considered to occur over a single month-long period from 5 November through 5 December and is characterized by moderate temperatures, greater cloud cover, more frequent rain showers, and increasingly cold nights. (Al Kulaib, Abdulmalik A. 1984).

1.5 Economy

Kuwait's economy is fairly small, comparatively rich, semi-open and highly dependent on oil exports. Petroleum accounts for the majority of gross domestic product (GDP), export revenues and government income. Since 1994, oil operations as a share of GDP have steadily increased, reaching 51% of the economy in 2010 (see Figure 1-7). As a result, Kuwait's economy continues to be highly vulnerable to changes in global oil demand, as well as international oil market price volatility.

Figure 1-7: Breakdown in GDP between oil & other sectors 1994, 2002, and 2010 (source: CSO, 2011)



Both GDP and GDP per capita have shown overall strong growth over the period 1994-2011 (see Figure 1-8). Prior to the global economic recession of 2008, the average annual growth rate for Kuwait's GDP was about 5.0% per year on a purchase price parity (PPP) basis. Over the entire 1994-2011 period, growth still averaged over 4% per year on a PPP basis. Per capita GDP on a PPP basis rose from US$ 41,618 in 1995 to US$ 47,935 in 2011, equivalent to an average annual growth rate of 0.9% per year. This represents one of the highest per capita income levels in the world.

There are four major activities that contribute to the non-oil portion of Kuwait's GDP. These include social services, financial services, transport and manufacturing. Together, these sectors account for about 90% of the non-oil sector's contribution to GDP and 45% of GDP overall, with the remaining 4% of overall GDP accounted for by the agriculture, utilities, construction, and trade sectors. An overview of the major sectors is provided in the bullets below. Figure 1-9 shows their relative contribution to GDP in 2010.

- *Social services:* The contribution of this sector to GDP is in the form of government expenditures on basic services (e.g., health care). The overall contribution to overall GDP in 2010 was about 16%.
- *Financial services:* This sector plays a substantial role in the nation's economy. Dominated by the banking industry, its contribution to the GDP represented about 15% in 2010.
- *Transport:* Activities in this sector include development of the road, water, and air infrastructure. The overall contribution to overall GDP in 2010 was about 8%.
- *Manufacturing:* This sector consists primarily of petrochemical operations, electrical equipment industries, building materials, chemicals and steel. The overall contribution to overall GDP in 2010 was about 5.1%.

Figure 1-8: Kuwait trends in GDP and GDP per capita (source: World Bank, 2012)

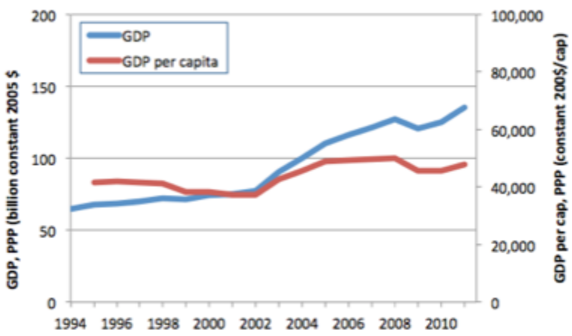
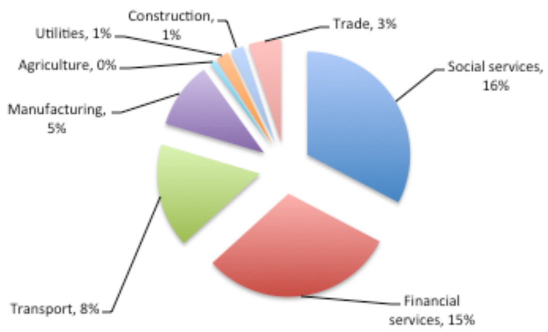


Figure 1-9: Breakdown in GDP for non-oil sectors, 2010 (source: CSO, 2011)



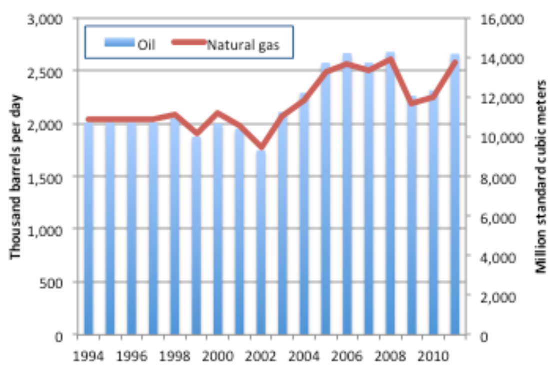
1.6 Energy

Kuwait is one of the world's leading oil producers, an energy source upon which virtually every nation is dependent. As a small country with negligible areas of land suitable for agriculture, Kuwait is dependent on international trade of its abundant energy resources for the provision of basic necessities, including food, clothing, and construction materials.

1.6.1 Oil

Kuwait, a member of the Organization of Oil Exporting Countries (OPEC), has the world's fifth largest crude oil reserves and is one of the ten largest global exporters of crude oil and oil products. The Ministry of Oil estimates the country's proven oil reserves at 101.5 billion barrels (bbl), just over 7% of the world total. Additional reserves of about 5 bbl are held in the Partitioned Zone, which Kuwait shares on a 50-50 basis with Saudi Arabia. Gross oil production levels reached about 2.7 million barrels per day in 2011 (see Figure 1-10).

Figure 1-10: Kuwait gross production of oil and natural gas, 1994-2010 (source: OPEC Annual Statistical Bulletins)



Much of Kuwait's reserves and production are concentrated in a few mature oil fields that were discovered in the early to middle decades of the past century. In recent years, a $90 billion expansion plan encompassing both upstream and downstream operations has been initiated by the Kuwait Petroleum Corporation (KPC). The plan, which is expected to boost gross oil production capacity to four million barrels per day by 2020, includes an upgrade of production and export infrastructures, expansion of both domestic and international exploration activities, and downstream facilities (EIA, 2012).

Only a small amount of oil is actually consumed in Kuwait. In 2011, consumption of refined petroleum products totaled 361 thousand barrels per day. However, domestic consumption has been steadily increasing recently - about 3.4% per year between 2007 and 2011 – partly as a result of increased oil-fired electricity generation. Power supply planning forecasts indicate that this trend will likely continue in the near term.

1.6.2 Natural gas

Kuwait had an estimated 1.8 trillion cubic meters (m^3) of proven natural gas reserves as of January 2011. Kuwait's reserves are not considered significant relative to global reserves and this has spurred an extensive drive in natural gas exploration. Vast discoveries of non-associated gas in the north of the country have been declared since 2006 and attracted interest from international oil companies but domestic political disagreement over development creates uncertainty about potential expansions of both reserves and production (EIA, 2012). Gross natural gas production levels reached about 13.8 billion m^3 in 2011 (see Figure 1-10).

Since 2009, Kuwait has been a net importer of natural gas. This is due to several factors including the declining rate of petroleum associated natural gas production; an increasing demand for natural gas for power, desalinated water, and petrochemical production; and an increased use of natural gas for enhanced oil recovery. In 2010, consumption of natural gas in Kuwait totaled 15.0 billion cubic meters, while gross production reached only 12.1 billion m^3, a deficit of 2.9 billion m^3, or about 23% (EIA, 2011)

1.6.3 Electricity

With Kuwait's hot summers comes sharply increased demand for electricity for space cooling, particularly during the dry and wet summer periods. In a country whose population and economy have been growing rapidly, this has posed serious planning challenges for meeting electricity demand requirements. This is evidenced by, as of the summer of 2010, Kuwait having an installed electric generation capacity of 11.3 GW, only slightly above peak summer demand of 10.9 GW. Such a low reserve margin has led to power shortages during the hot summer months when the demand for air conditioning is highest. In response, the Kuwaiti government has unveiled an extensive development plan that calls for an additional 10 GW of capacity by 2015, roughly doubling its current capacity.

Power is generated from five (5) natural-gas power stations. These plants use a combination of natural gas, heavy fuel oil, crude oil and gas oil, depending on boiler design. Priority is given to the use of natural gas within the limits of fuel availability constraints. The older plants can burn natural gas and diesel in case of emergency while the more modern units are capable of burning the four types of fuel (Beatonia, 2012).

Overall, electricity consumption has been growing at an average annual rate of about 6.1% per year over the period 1994-2010 (see Figure 1-11). On a per capita basis, there has also been significant growth over this period - from 10,655 kWh per person in 1994 to just over 14,000 kWh per person in 2010, or roughly 2%/year. Considered on a per capita basis, these levels confirm Kuwait to be one of the highest electricity consuming countries in the world.

1.7 Water resources

Kuwait is a highly water-stressed country, with few options for meeting socioeconomic development needs. Water supply relies on desalinated water, brackish groundwater, and treated wastewater. As of 2011, about half of water supply was provided by desalinated water, and the balance by a combination of mostly brackish groundwater, and treated sewage effluent (see column at left in Figure 1-12).

Overall water consumption in Kuwait reached 1,202 million cubic meters (Mm^3) in 2011. The domestic (i.e., households, commercial establishments) and agriculture sectors dominate Kuwait's total water demand, with only a small share devoted to industrial applications (see column at right in Figure 1-12).

On a per capita basis, roughly 907 liters per day are consumed in Kuwait, one of the highest rates in the world. Numerous efforts are underway to identify appropriate strategies for reducing water use (e.g., Al-Otaibi and Mukhopadhyay, 2005). The Ministry of Electricity and Water is coordinating programmes with the Ministry of Commerce to conserve water such as the promotion of import regulations mandating high efficiency water faucets (Arab times, 2012).

Figure 1-11: Kuwait electricity production and consumption, 1994-2010 (source: CSO, 2011)

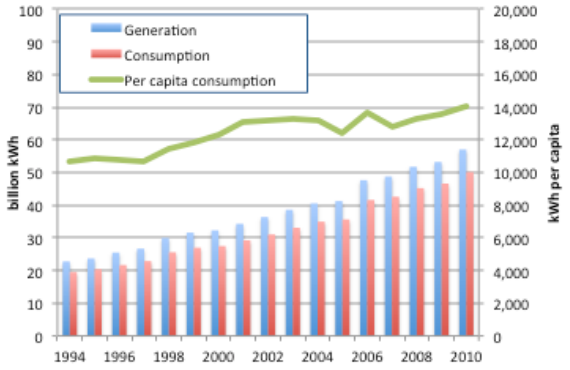
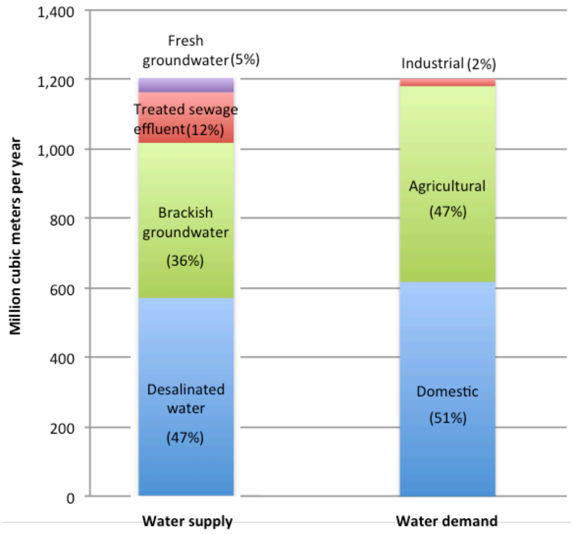


Figure 1-12: Kuwait water supply and demand, 2011 (source: Water Statistics)



1.8 Waste management

Kuwait has developed a waste management system to process the country's solid and liquid industrial wastes. As a small country undergoing high socioeconomic growth, several challenges remain regarding the future sustainable management practices to ensure the public health and the environment are suitably protected.

1.8.1 Solid waste

Municipal solid waste (MSW) quantities have increased substantially in the last decadeasa result of population growth, industrial development, and life style changes. The management of MSW (i.e., control, collection, processing, utilization and disposal)for the entire country is the responsibility of the Kuwait Municipality which oversees fifteen (15) sites of which only 5 sites - encompassing about 11 square kilometers - are currently operational (see Table 1-1). Half of the composition of MSW in Kuwait is food-related, with much of the balance consisting of paper products and plastics at 20% and 13%, respectively (Municipality of Kuwait, 2011).

Since 1994, MSW generation has consistently averaged between 1.4 and 1.5 kilograms per person per day in Kuwait, one of the highest rates in the world (Al-Yaqout and Hamoda, 2002). In an effort to manage these levels in a more sustainable manner, policies and programmes have been developed to encourage the private sector to participate in in recycling initiatives, particularly regarding industrial wastes (Municipality of Kuwait, 2011).

Table 1-1: Operational MSW sites in Kuwait (source: Municipality of Kuwait, 2011)

Name	Online Year	Waste type	Size (Km^2)
Sulaibiya	1980	Domestic/Commercial	1.2
Mina Abdullah	1992	Domestic/Construction	1.0
South 7th ring road	1992	Domestic – Sand	2.0
North 7th ring road	1986	Construction	6.0
Jahra	1986	Construction	0.6

1.8.2 Industrial wastewater

There are seven (7) industrial areas in Kuwait within which most industrial activity occurs. Since not all these industrial areas are connected to the central sewer system, a significant portion of industrial wastewater effluents are discharged without treatment directly to authorized landfills such as the Jahra site and the South 7th ring road site. In addition, it is widely known that some of these industries dispose of their wastewater to unauthorized open areas in violation of existing regulations.

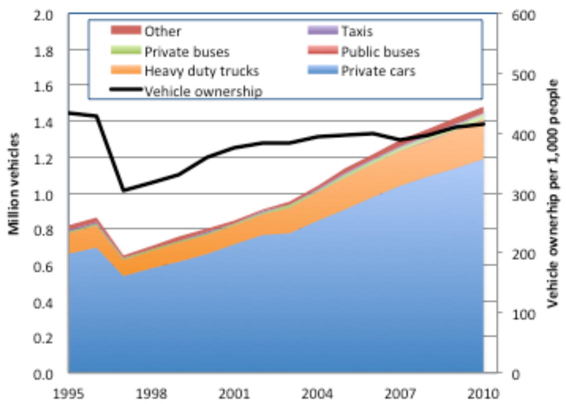
1.9 Transportation

Kuwait has developed an extensive, modern and well-maintained network of road infrastructure. As of 2010, the total length of paved roads exceeded 6,600 km, representing just over 77 km^2 or 0.4% of the country's total land area. In coming years, development plans call for an additional 700 km of new paved roads (State of Kuwait, 2010).

The total number of light and heavy duty road vehicles has been steadily increasing since1995 and reached about 1.5 million in 2010, nearly doubling in number over that period (see Figure 1-13). Since 1997, vehicle ownership has been growing at an average annual rate of about 2.4% per year, from 304 to 414 vehicles per thousand people in 2010.

While public transport bus services are available through the private sector as well as the state-owned Kuwait Public Transportation Corporation, private light duty vehicles are the overwhelming travel mode choice for personal mobility. In response to growing traffic congestions and accompanying air quality concerns, investment in public transport infrastructure has steadily emerged as a priority in national transportation planning. Current projects call for the construction of an US$11 billion rail network to be operational by 2020, and which will include a city metro (Reuters, 2008).

Figure 1-13: Registered vehicles in Kuwait by type, 1995-2010 (source: CSO, 2011)



Other vehicles include motorcycles, construction vehicles, governmental/diplomatic vehicles

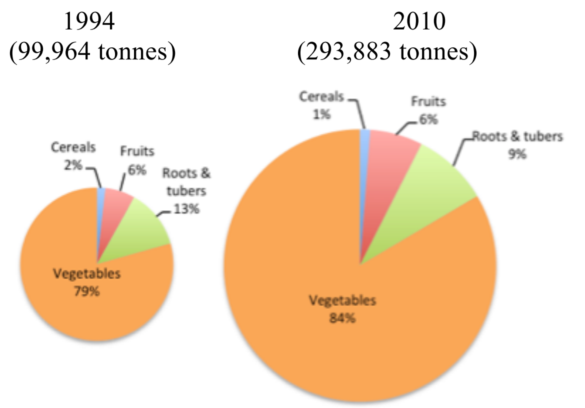
1.10 Agriculture

The potential of agricultural development in Kuwait is very limited, as less than 1% of the land area is considered arable. Moreover, only a portion of arable land area is actually cultivated due to a hyper-arid climate, water scarcity, poor soils, and a lack of relevant skills. Not surprisingly, agriculture's share of GDP is negligible, consistently less than 1%. Moreover, Kuwait relies heavily on food imports, which account for 98% of cereals, 90% of milk and dairy products, 77% of fruits, 65% of fish, and 62% of meat (AASY, 2012).

Nevertheless, a wide variety of crops are cultivated in Kuwait including tomatoes, fruits (dates, melons, strawberries), roots/tubers (potatoes, radishes), and many kinds of vegetables (cucumber, eggplant, cauliflower, sweet peppers, onions, and green leafy vegetables). As shown in Figure 1-14, production is dominated by tomatoes and overall production has increased nearly threefold from 1994 to 2010, thanks in part to a government policy of protected agriculture (Al-Nasser and Bhat, 1995).

Most crops are grown in greenhouses from Wafra, Kuwait's southernmost city near the border with Saudi Arabia to Abdally, its northernmost city near the border with Iraq. Other regions such as Jahraa and Sulaibiya near Kuwait City also have prominent agricultural activities. Some crops are also grown hydroponically for export.

Figure 1-14: Crop production in Kuwait by type, 1994 and 2010 (source: FAOSTAT, 2012)



In addition to crop production, there are many fairly large-scale dairy farms where milk production nearly doubled during the 1994 to 2010 period, from 30.0 to 57.4 thousand tonnes of milk, and average annual growth rate of about 4% per year. Over this same period, indigenous meat production showed similar trends, reaching nearly 57 thousand tonnes in 2010, an average annual growth rate of about 5% per year (see Table 1-2).

Table 1-2: Meat and milk production in Kuwait, 1994 and 2010 (source: FAOSTAT, 2012)

Name	1994	2010	Growth rate (%/yr)
Camel Meat	270	1,999	13%
Cattle Meat	689	2,428	8%
Chicken Meat	20,080	40,698	5%
Goat Meat	75	532	13%
Sheep Meat	3,038	11,127	8%
Subtotal meat:	24,151	56,784	5%
Milk production	30,040	57,444	4%

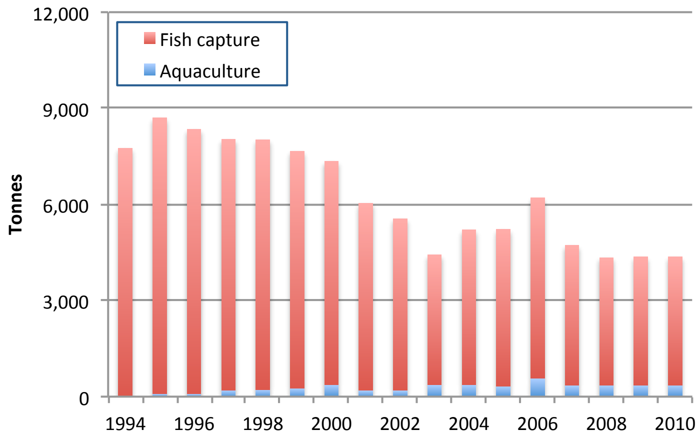
On the other hand, fishing is a leading commercial industry in Kuwait. In 2010, the quantity of captured fish from the Arabian Gulf totalled about 4,000 tonnes, with an additional 360 tonnes from aquaculture (see Figure 1-15). These levels are roughly half the levels in the 1990s, due on the one hand to overfishing but also due to inefficient methods, especially for those fishermen using small boats and traditional fishing methods (Elhendy and Alkatamni, 2012). Of overall production levels, shrimp and various types of fish are exported annually.

1.11 Environmental Education

Environmental Education (EE) is a national commitment and an essential and integral part of the education program in the State of Kuwait at all levels. The goal of EE is to develop a concern and awareness among students, as well as the overall population, about the value of environmental services. EE also aims to increase an understanding of environmental challenges and enhance a commitment to work individually and collectively towards protection of the environment.

There are several Government Institutions and private universities that have prominent roles in EE, as briefly described below in the bullets below. Box 1-1 summarizes the major environmental education programmes and/or courses that are currently available at these institutions.

Figure 1-15: Meat and milk production in Kuwait, 1994 and 2010 (source: FAOSTAT, 2012)



- *Ministry of Education:* The Ministry has integrated EE in textbooks at all levels from elementary to secondary education levels. Students are introduced to basic concepts of ecology such as ecosystem, food chains, energy flow, environmental balance, biodiversity, conservation and pollution. Emphasis is on local environmental conditions and problems such as life in the desert, excessive water consumption, waste disposal, water desalination, air pollution, depletion of marine living resources and threats to biodiversity.
- *Kuwait University:* At the undergraduate level EE is taught at the Faculty of Science, the College of Women, and the College of Social Sciences (see Box 1-1). Several courses are also taught in the Department of Civil Engineering at the Faculty of Engineering and Petroleum. At the Graduate level EE is taught at the College of Graduate Studies.
- *Public Authority for Applied Education and Training (PAAET):* Within the Department of Environmental Health of the Health Sciences College, several courses are offered at the undergraduate level within two programs: Industrial Hygiene and Applied Environmental Science. The courses include: Basics of Ecology, Desert Ecology and Marine Ecology.

Box 1-1: Higher learning programmes and courses in environmental education in Kuwait

Faculty of Science programs:

- Existing programs in Marine Biology and Desert Studies
- Forthcoming programs in Marine Science and Environmental Sciences
- Environmental courses for students majoring in Biology, Chemistry and Geology

Faculty of Science departmental courses:

- *Department of Biological Sciences:* Marine Sciences, General Ecology, Marine Biology, Marine Ecology, Desert Ecology and Environmental Biology
- *Department of Earth & Environmental Sciences (DEES):* Geological Oceanography, Marine Geology, and Environmental Science
- *Department of Chemistry:* Marine chemistry and environmental pollution

College of Women courses:

- Courses in Environmental Education aimed mostly towards enhancing the role of women in environmental protection.

College of Social Sciences courses:

- Department of Geography course called “Man and the Environment” for non-science majors.

Kuwait University program

- Joint Master’s Program in Environmental Sciences across Faculties of Science, Engineering and Law in College of Graduate Studies

- *Private Universities:* There are only a few private universities that have Environmental Education courses. But there is good potential for collaborative teaching in association with Kuwait University and PAAET.

Considerable space in EE programs is dedicated to global warming though it is addressed from a global/general perspective rather than a Kuwait-specific perspective. In the future, revisions to the EE curricula for climate change at all student levels should seek to address Kuwait's vulnerability to the impacts of climate change as well as actions that can be taken by individuals to reduce future emissions of greenhouse gases.

1.12 Environmental Research

Since the Liberation of the State of Kuwait in 1991, a national policy has been adopted for giving priority funding for Environmental Research (ER) Projects, especially those dealing with the impacts of oil pollution and burning oil wells. Over US$ 30 million has already been spent on such projects. Moreover, US$ 2.9 billion has been allocated by the United Nations as the compensation that is due from Iraq for remediation and restoration of Kuwait's natural environment. Within Kuwait, there are several institutions that have prominent roles as channels for ER funding, as briefly described below.

- *Kuwait University (KU):* Provides funding and management of all Research Projects including ER Projects through the Office of the Vice-President for Research. Major ER projects are done at The Faculty of Science and College of Engineering and Petroleum. The Geography Department at The College of Social Sciences also takes part in this effort dealing mostly with the demographic aspects of the environment. The College of Graduate Studies also provides funding for Environmental Research projects carried out by Master's and PhD students.

- *Kuwait Institute for Scientific Research (KISR):* KISR carries out contract and in-house ER projects mainly in applied fields. Non-contract ER projects are funded by various government and private agencies. Major projects have been undertaken to monitor the effects of the oil lakes on the desert ecosystem and the effects of oil pollution on the marine fauna and flora. Food Resources and Biodiversity and Conservation projects also receive considerable funding and priority.

- *Kuwait Environment Public Authority (KEPA):* The Authority basically conducts routine monitoring of the environmental parameters. Several ER Projects are also implemented. The main focus is on Air and Marine pollution. The Authority has several vessels of various sizes that are suitable for carrying out marine monitoring and oceanographic studies within the Kuwaiti waters. Additionally, KEPA provides funding for ER projects carried out by Kuwait University, KISR and PAAET Scientists.

- *Kuwait Foundation for the Advancement of Sciences (KFAS):* The Foundation is a major funding agency that has adopted a policy for giving priority funding for all types of Environmental Research projects. It supports ER projects submitted mainly by Kuwait University and KISR. It also provides support for Kuwaiti Scientists to present their findings in regional and international environment conferences. Additionally, KFAS provides prizes in recognition of ER and other types of basic and applied research. Students and young scientists are encouraged by KFAS for participation in contests dealing with environmental issues in which the winners are provided with monetary rewards and recognition.

- *Public Authority for Applied Education and Training (PAAET):* The Authority Staff Members and Scientists carry out basic and applied ER in various areas but teaching is a priority and research facilities are limited.

Although some of the ER projects touch upon climate change impacts in Kuwait, there is currently no serious commitment by scientists and institutions for conducting ER projects aimed towards assessing the adverse socioeconomic consequences of climate change on Kuwait. It is important that climate change be explicitly incorporated into future ER programmes. The advanced research facilities and highly qualified expertise, particularly at Kuwait University and KISR, are of great potential for examining the short- and long-term impacts of climate change on people and biota of Kuwait.

1.13 Biodiversity

Kuwait is endowed with rich biodiversity of terrestrial flora and fauna. Desert areas contain many species of annuals, which make up about 90% of plant species of Kuwait (see Figure 1-16a). Perennials such as *Rhanteriumeppaposum,* Kuwait's national flower (see Figure1-16b) also abound and support a wide variety of insects, such as the plain tiger butterfly (see Figure 1-16c), and birds such the bee-eater *Meropsapiaster*, which feed on these insects (see Figure 1-16d).

Figure 1-16: Examples of terrestrial biodiversity in Kuwait (sources: Louis-M Landry, al-sirhan.com, hawar.island.com)

a) *Vaccaricahispanica,* a native annual plant

b) *Rhanteriumeppaposum,* Kuwait's National Flower

c) Plain tiger butterfly *Danaus genutia* (rare)

d) Bee-eater, *Meropsapiaster*

Kuwait is also endowed with rich marine biodiversity. Many endemic species can be found including the crab *Leptochryseus kuwaitense* (see Figure 1-17a), which is found on biota-rich intertidal sabkha zones. Also found is the recently described isopod *Eurydice marzouqui.* Within the marine environment itself, three dozen coral species exist in Kuwaiti waters, most being reef-building species (see Figure 1-17b).

Migratory birds are annual visitors to Kuwait. The Al-Jahra Pool Nature Reserve located in northern Kuwait is a wet and green sanctuary area that attracts a wide variety of birds, both migrant and winterer species. To date, 220 bird species have been recorded in the Reserve (BirdLife International, 2012). Another site for migratory birds is Kubbar Island, located roughly 30 kilometers off the southern coast of Kuwait, and a breeding haven for three species of terns that come from early May to August (see Figure 1-18a). Finally, Bubiyan Island, Kuwait's large (about 888

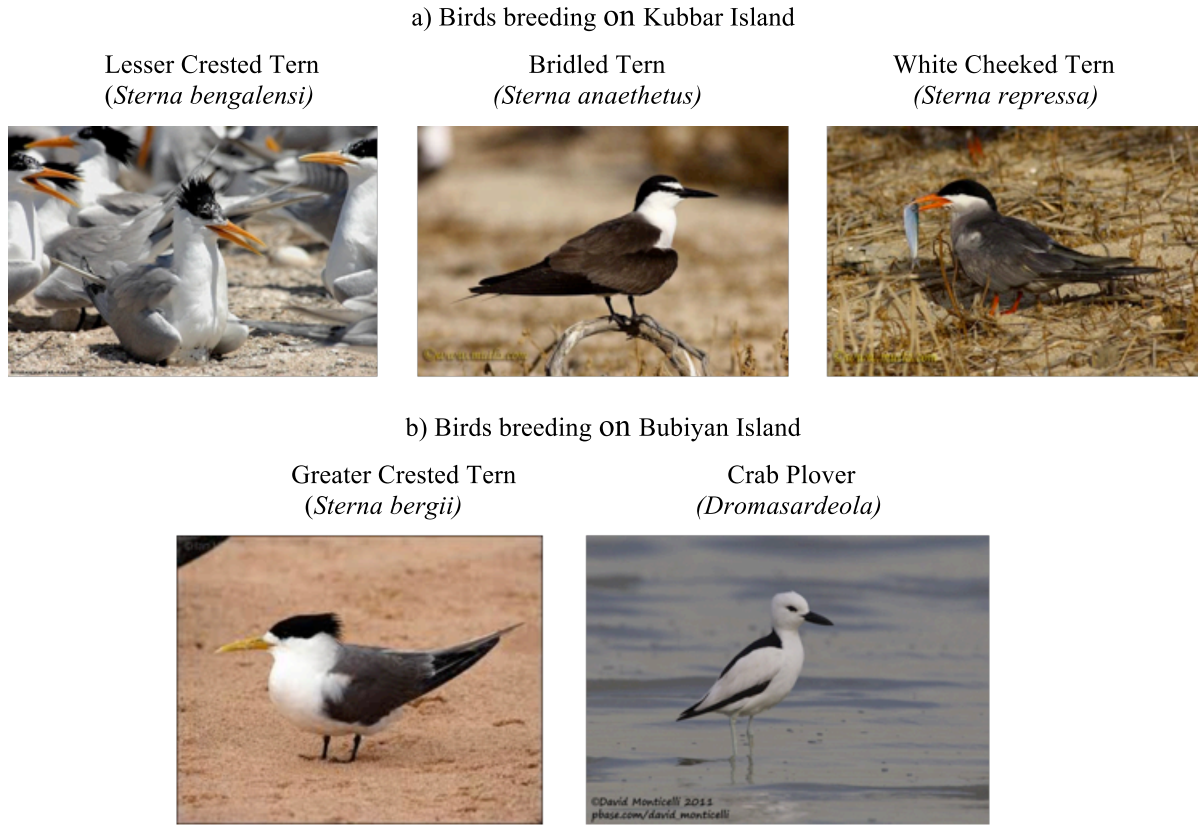
Figure 1-17: Examples of marine biodiversity in Kuwait (source: Ismail Ghareeb, Kuwait Diving Team)

a) *Leptochryseuskuwaitense,* an endemic intertidal crab

b) Local coral species, (bleached)

km^2) island that is separated from the mainland by a narrow channel is the breeding site for the Greater Crested Tern and the Crab Plover (see Figure 1-18b). The plover's population on Bubiyan Island is the largest recorded worldwide for this bird.

Figure 1-18: Examples of migrant and winterer birds in Kuwait (source: www.mutla.com)



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2 Greenhouse Gas Inventory

This chapter presents Kuwait's anthropogenic emissions by sources, and removals by sinks, of all greenhouse gases (GHGs) not controlled by the Montreal Protocol for the Base Year of 1994.

2.1 Introduction

This initial GHG Inventory has been prepared in fulfillment of Article 4, paragraph 1, and Article 12, paragraph 1 of the United Nations Framework Convention on Climate Change (UNFCCC). The requirement is that each signatory to the Convention to report to the Conference of Parties (COP) information on its emissions by sources and removals by sinks of all Greenhouse Gas Emissions (GHGs) not controlled by Montreal Protocol".

A team of 11 national experts representing relevant ministries and institutions prepared Kuwait's GHG inventory. The engagement of those stakeholders has facilitated data collection and analysis. In addition, the process helped to identify data gaps and provide a basis for future inter-sectoral cooperation and capacity building.

2.2 Methodology

The Revised IPCC 1996 Guidelines (IPCC, 1996) in combination with the IPCC's Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000) were followed. The inventory used 1994 as the base year and the IPCC's GHG inventory software for the 1996 Guidelines.

Both Reference and Sectoral (bottom-up) approaches were used to estimate carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions and removals in five categories, namely energy, industrial processes, agriculture, land use, land-use change and forestry (LULUCF), and waste. In accordance with the Guidelines, emissions from bunker fuels are reported as a memo item.

An overview of the process in the development of Kuwait's first GHG inventory is provided in Box 2-1. The subsections that follow report GHG emissions both in absolute units of carbon dioxide, methane and nitrous oxide emissions, as well as in units of CO_2-equivalent (CO_2e) by applying 100-year GWPs of 1 for CO2, 21 for CH4, and 310 for nitrogen oxide.

Box 2-1: Overview of Kuwait's GHG development process

- Hold inception/training workshop to agree on methodology
- Assess data availability/quality for all emission categories
- Identify/develop methods for overcoming data issues/gaps
- Select a suitable tier of the IPCC Guidelines
- Prepare work plan and collect national data
- Develop strategy to overcome data availability/access barriers
- Estimate emissions for emission/sink categories
- Assess uncertainty of emission/sink estimates
- Estimate missing data using several approaches
- Include information on indirect gases
- Assess need for country-specific emission factors
- Cross-check estimate results for quality control
- Develop recommendations for future inventories
- Prepare report and circulate for peer review

Default emission factors were adopted based on the 1996 IPCC Guidelines. Local Emission factors were used on a limited basis where available. Data on emissions-generation activities were mostly collected from secondary sources, such as published research, statistical reports, and oil company annual reports.

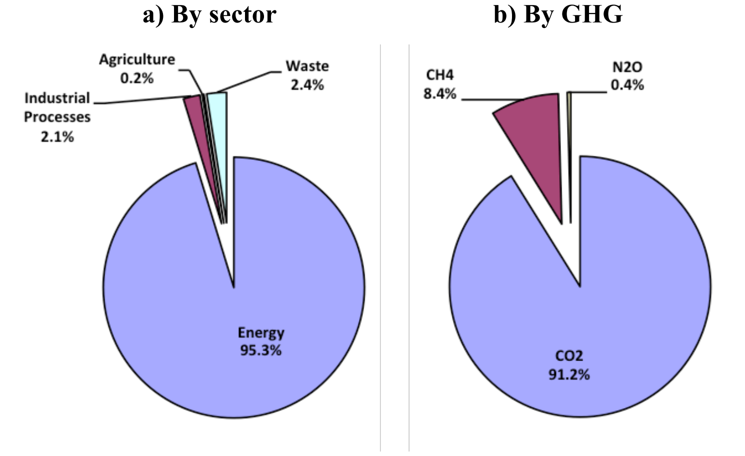
2.3 Total GHG emissions

Table 2-1 and Figure 2-1 summarize Kuwait's overall GHG emissions profile for the year 1994. Total GHG emissions were 32,373 GgCO_2e, which includes 30,855 Gg from energy; 668 Gg from industrial processes; 66 Gg from agriculture, and 784 Gg from waste. CO_2 sequestration by the forestry and land use sector in 1994 amounted to 22 Gg. Net GHG emissions are estimated at 32,351 Gg CO_2e. Emissions from perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulfur hexafluoride (SF6) in Kuwait were not estimated due to data unavailability. The Annex at the end of this Chapter provides detailed summaries of GHG emissions using the tabular format specified in COP Decision 17/CP.8.

Table 2-1: Total GHG emissions in Kuwait, 1994 (Gg)

GHG Sources & Sinks	CO_2e	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
1 Energy	30,855	28,856	92.69	0.17	113	544	522	320
2 Industrial Processes	668	668	0.00	0.00	0	0	0	0
3 Solvent& Other Product Use	0	0	0.00	0.00	0	0	0	0
4 Agriculture	66	0	2.70	0.03	0	0	0	0
5 Land-Use Change & Forestry	-22	-22	0.00	0.00	0	0	0	0
6 Waste	784	0	33.80	0.24	0	0	0	0
Total National Emissions	32,373	29,524	129.19	0.44	113	544	522	320
Net National Emissions	**32,351**	**29,502**	**129.19**	**0.44**	**113**	**544**	**522**	**320**

Figure 2-1: Breakdown in GHG emissions in Kuwait, 1994



Energy-related activities accounted for the dominant portion of GHG emissions in Kuwait in 1994. Approximately 95.3% of all GHG emissions are associated with the combustion of fossil fuels and the release of fugitive emissions from oil and gas operations. Waste management accounted for 2.4% of all GHG emissions, followed by industrial process emissions with 2%. Agriculture has the lowest contribution with 0.2%. Managed tree plantations throughout the country sequestered less than 0.1% of GHG emissions in 1994.

Figure 2-1 also summarizes Kuwait's overall GHG emissions profile by GHG type for the year 1994. Carbon dioxide emissions amounted to 29,524 Gg CO_2e and accounted for about 91.2% of total emissions. Methane emissions amounted to 2,713 Gg CO_2e and accounted for about 8.4% of total emissions. Nitrous oxide emissions amounted to 136 Gg CO_2e and accounted for about 0.4% of total emissions.

2.4 Emissions by sector

The following sections provide an overview of GHG emission totals and characteristics by emitting and sequestering categories for the year 1994.

2.4.1 Energy

Table 2-2 summarizes GHG emissions associated with energy activity in 1994. Relative to overall anthropogenic GHG emissions, the 30,855 Gg CO_2e represented about 95% of total national emissions. Carbon dioxide emissions amounted to 28,856 Gg and accounted for about 93% of energy sector emissions, with the balance associated with methane emissions.

Table 2-2: GHG emissions from energy activities in Kuwait, 1994 (Gg)

GHG Source Categories	CO_2e	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
All energy emissions	**30,855**	**28,856**	**92.69**	**0.17**	**113**	**544**	**522**	**320**
A Fuel Combustion Activities	28,944	28,856	1.69	0.17	113	502	95	204
1 Energy Industries	23,255	23,210	0.36	0.12	63	7	2	204
2 Manufacture/construction	0	0	0.00	0.00	0	0	0	0
3 Transport	5,393	5,351	1.28	0.05	50	495	93	0
4 Other Sectors	296	295	0.05	0.00	0	0	0	0
B Fugitive Emissions from Fuels	1,911	0	91.00	0.0	0	42	427	115
1 Solid Fuels	0	0	0.00	0.0	0	0	0	0
2 Oil and Natural Gas	1,911	0	91.00	0.0	0	42	427	115
Memo Items	3,474	3,474	0.00	0.0	0	0	0	0
International Bunkers	3,474	3,474	0.00	0.0	0	0	0	0
CO2 Emissions from Biomass	0	0	0.00	0.0	0	0	0	0

Note: Numbers may not add up due to rounding

GHG emissions from energy activities are due to fossil fuel combustion and fugitive emissions from oil and gas exploration activities. Fuel combustion emissions are associated with the use of a variety of crude oil, petroleum products and natural gas. There is virtually no use of biomass in Kuwait.

Figure 2-2: Breakdown of GHG emissions associated with energy activities, 1994

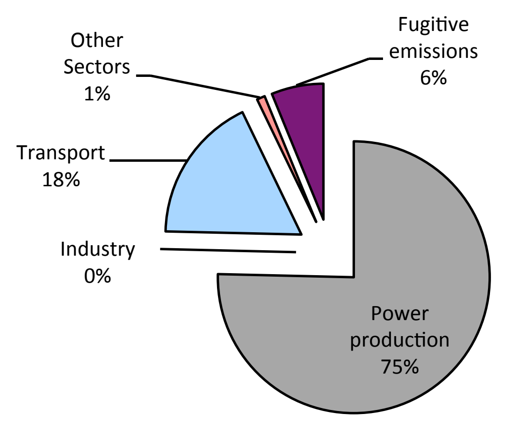


Figure 2-2 illustrates the breakdown in energy-related GHG emissions in 1994 by GHG-emitting activity. Power production is based overwhelmingly on the use of natural gas, with small amounts of crude oil, residual oil, and diesel, and accounted for about 75% of total emissions from all energy production and consumption activities in Kuwait.

Fugitive emissions of methane from oil and gas operations, a gas that has a high global warming potential, accounted for about 6% of all GHG emissions in the energy industries sector on a carbon dioxide equivalent basis, as Kuwait is a major supplier of the world's energy needs. Transport emissions for road transport and domestic civil aviation accounted for about 18% of total transport-related emissions in 1994.

Notably, there was no energy consumption within industrial operations for manufacturing (e.g., cement, iron and steel, aluminum production) and construction activities in 1994. As a result, there were no energy-related GHG emissions for these activities accounted for in this initial inventory.

2.4.2 Industrial Processes and other product use

Table 2-3 summarizes GHG emissions associated with industrial processes in 1994. This sector accounts for 668 Gg of CO_2e, or 2% of national CO_2e emissions in 1994.

Table 2-3: GHG emissions from industrial processes and other product use, 1994 (Gg)

GHG Source Categories	CO_2e	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
All industrial emissions	**668**	**668**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Industrial Processes	668	668	0.00	0.00	0.00	0.00	0.00	0.00
A Mineral Products	668	668				0.00	0.00	0.00
B Chemical Industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C Metal Production	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D Other Production	0.00	0.00			0.00	0.00	0.00	0.00
E Production of Halocarbons and Sulphur Hexafluoride								
F Consumption of Halocarbons and Sulphur Hexafluoride								
Total Solvent & Other Product Use	0.00	0.00		0.00			0.00	

There are only two sub-sectors that are sources of GHG's in the industrial processes sector, mineral production and food and drink manufacture. Mineral production mainly includes cement production and lime production and accounted for virtually 100% of industrial process GHG emissions. Food and drink manufacture includes production of bran, pasta, biscuits, bread, salt and oil/fats and account for 2% of industrial process GHG emissions.

2.4.3 Agriculture

Table 2-4 summarizes GHG emissions associated with agricultural activity in 1994. Relative to overall anthropogenic GHG emissions, the 66 Gg CO_2e represented about 0.2% of total national emissions.

Table 2-4: GHG emissions from agricultural activities, 1994 (Gg)

GHG Source Categories	CO_2e	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
All agriculture emissions	**66.0**	**0.0**	**2.7**	**0.03**	**0.0**	**0.0**	**0.0**
A Enteric Fermentation	52.5		2.5				
B Manure Management	4.2		0.2	0.00			0.0
C Rice Cultivation	0.0		0.0				0.0
D Agricultural Soils	9.3			0.03			0.0
E Prescribed Burning of Savannas	0.0		0.0	0.00	0.0	0.0	0.0
F Field Burning of Agricultural Residues	0.0		0.0	0.00	0.0	0.0	0.0

On a CO_2e basis, the majority of emissions from agriculture are associated with methane emitted during the domestic livestock enteric fermentation process, about 2.5 Gg, or 80% of agriculture emissions. Remaining emissions are associated with nitrous oxide emissions from soils, about 0.03 Gg, or 14% of agriculture emissions. This small amount is due to fertilizer inputs (about 60%) and the balance due to indirect nitrous oxide emissions associated with leaching and runoff.

2.4.4 Land Use, Land Use Change and Forestry

Table 2-5 summarizes GHG emissions associated with land use, land use change and forestry in 1994. The 22 Gg CO_2esequestered through managed plantations was roughly 0.1% of

Kuwait's overall anthropogenic GHG emissions. The small levels of sequestered carbon are due to the relatively small numbers of planted trees throughout the country.

Table 2-5: GHG emissions from LULUCF activities, 1994 (Gg)

GHG Source Categories	CO_2e	CO_2	CH_4	N_2O	NO_x	CO
All LULUCF emissions	**-22**	**-22**	**0**	**0**	**0**	**0**
A Changes in Forest & Other Woody Biomass Stocks	-22	-22				
B Forest and Grassland Conversion	0	0	0	0	0	0
C Abandonment of Managed Lands	0	0				
D CO2 Emissions and Removals from Soil	0	0				

2.4.5 Waste

Table 2-6 summarizes GHG emissions associated with waste management activity in 1994. Relative to overall anthropogenic GHG emissions, the 784 Gg CO_2e represented about 2% of total national emissions.

Table 2-6: GHG emissions from waste management activities, 1994 (Gg)

GHG Source Categories	CO_2e	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
All waste emissions	**784**	**0**	**33.8**	**0.2**	**0.0**	**0.0**	**0.0**
A Solid Waste Disposal on Land	710	0	33.8		0.0		0.0
B Wastewater Handling	74	0	0.0	0.2	0.0	0.0	0.0
C Waste Incineration	0	0			0.0	0.0	0.0

On a CO_2e basis, the majority of emissions from waste is associated with methane emitted at municipal solid waste disposal sites, about 710 Gg, or 91% of waste emissions. Remaining emissions are associated with nitrous oxide emissions from domestic wastewater management, about 74 Gg, or 9% of waste emissions. These emissions were estimated based on protein consumption per capita assumptions.

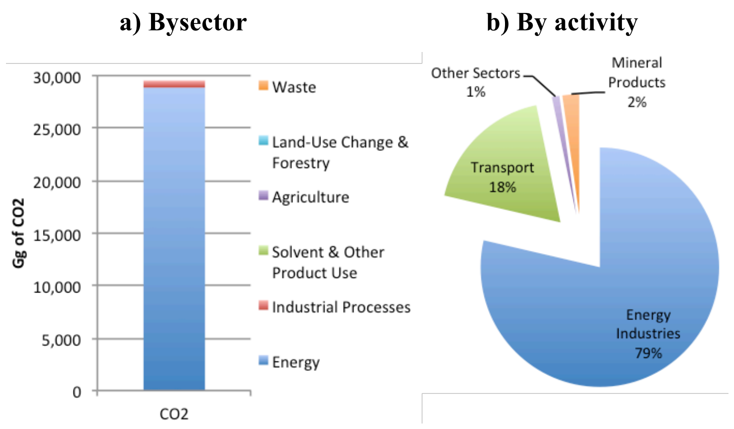
2.5 Emissions by greenhouse gas type

The following sections provide an overview of GHG emission totals by all GHG types for the year 1994.

2.5.1 Carbon dioxide

Net CO_2 emissions were estimated to be 29,502 Gg, or 91% of Kuwait's total greenhouse emissions in the year 1994. Figure 2-3 summarizes the contribution associated with CO_2 emissions at both the sector and activity levels.

Figure 2-3: Breakdown in CO_2 emissions in Kuwait, 1994



2.5.2 Methane

Methane had the second largest share of Kuwait's greenhouse gas emissions in 1994. CH_4

emissions were estimated to be about 129 Gg, or about 8.4% of Kuwait's total greenhouse emissions on a CO_2e basis.

Figure 2-4: Breakdown in CH_4 emissions in Kuwait, 1994

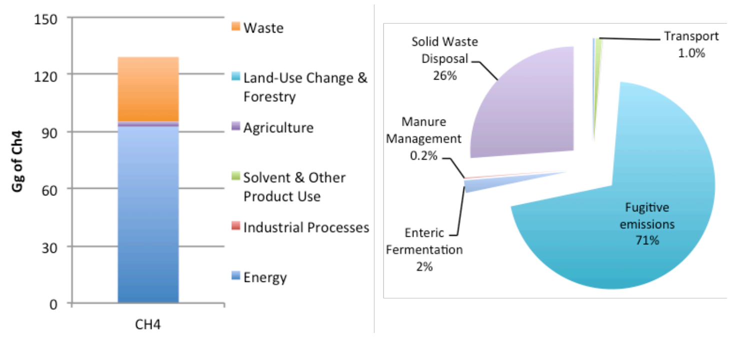


Figure 2-4 summarizes the contribution associated with CH_4 emissions at both the sector and activity levels. Fugitive emissions are the largest contributor to CH_4 emissions in the year 1994, about 71%. Remaining methane emissions are associated with solid waste disposal, 26%, enteric fermentation, 2% and fuel combustion in the transport sector, 1%.

2.5.3 Nitrous Oxide

Nitrous oxide emissions were very small in 1994 compared to other GHGs. N_2O emissions were estimated to be only about 0.44 Gg, or about 0.4% of Kuwait's total greenhouse emissions on a CO_2e basis.

Figure 2-5: Breakdown in N_2O emissions in Kuwait, 1994

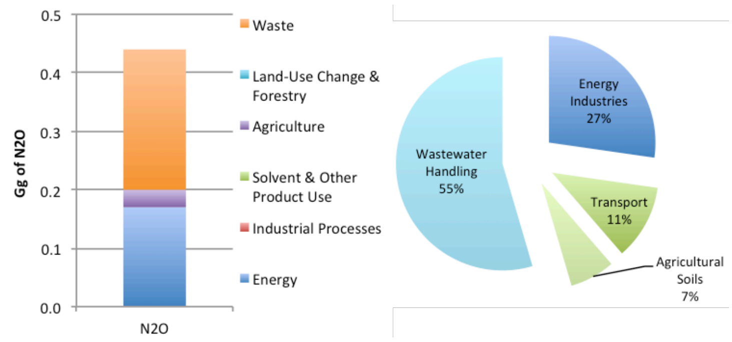
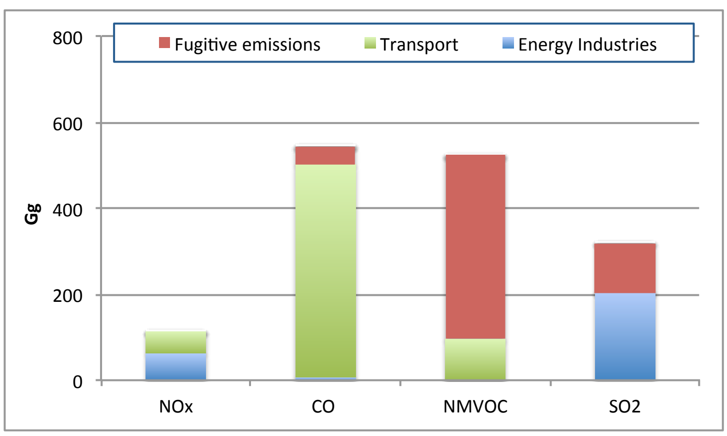


Figure 2-5 summarizes the contribution associated with N_2O emissions at both the sector and activity levels. Wastewater handling is responsible for largest share of N_2O emissions in the year 1994, about 55%. Remaining nitrous oxide emissions are associated with energy industries, 27%, fuel combustion in the transport sector, 11, and agricultural soils, about 7%.

2.5.4 Air pollutants

Emissions of nitrogen oxides (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC), and sulfur dioxide (SO_2) are associated with power generation, fugitive emissions from oil & gas operations, and transport. Figure 2-6 summarizes annual emissions levels in Kuwait for these pollutants in 1994. On a weight basis, SO2 emissions total quantities, accounting for 320 Gg.

Figure 2-6: Breakdown in air pollutant emissions in Kuwait, 1994



2.6 Energy sector CO_2 emissions using the Reference Approach

The IPCC's Reference Approach was also used to estimate CO_2 emissions for 1994 associated with energy consumption activities based on the Revised 1996 Guidelines. As recommended by COP Decision 17/CP.8, these results are compared to sectoral results in Tables 2-7. As can be seen in this table, the difference between CO_2 emissions for the Reference and sectoral approaches is 3,341 Gg, or about a 10% difference. This difference is readily explained by the exclusion of fuel used in the industrial sector due to the lack of data.

Table 2-7: Comparison of CO2 emissions from Reference and Sectorial Approaches, 1994 (Gg)

	Reference Approach	Sectoral Approach	Difference
Total	32,198	28,857	3,341

2.7 Uncertainty

There were uncertainties associated with estimating greenhouse gas emissions and removals in Kuwait. Primarily, these uncertainties are due to data gaps, quality issues, and inconsistencies across different sources. Other factors that contributed to the uncertainty of results include differing interpretations of source/sink categories, use of average emission factors instead of Kuwait specific factors, and an incomplete scientific understanding of the basic GHG emission and removal processes.

2.8 Challenges and Recommendations

There were several major challenges that needed to be overcome to complete Kuwait's initial GHG inventory. These included a poor institutional framework to address climate change, a lack of collaborative arrangements across agencies for data collection, and inadequate coordination among key stakeholders. Such challenges contributed to long delays in receiving feedback and data from concerned entities. Moreover, for many emission categories there were serious data unavailability and quality issues for the year 1994, with the earliest availability for data in some sectors being the year 2000.

Several recommendations have emerged on the basis of the experience gained by the national team in the development of Kuwait initial GHG inventory, as follows.

- Establish a national system to collect data required for updates to the inventory
- Establish a GHG inventory committee with high-level representation from key ministries/institutions, having clear oversight and coordination authority.
- Develop an integrated database of relevant information including annual statistical abstracts and annual reports from specific entities.

2.9 List of References

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IPCC, 2000. IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories.

IPCC, 2003.IPCC Good Practice Guidance on Land Use, Land Use Change and Forestry.

IPCC, 2006.Guidelines for National Greenhouse Gas Inventories.

Organization of the Oil Exporting Countries (OPEC), 2005.Annual Statistical Bulletin – 2005. Austria

Annex – Detailed GHG inventory tables

Table 2-8: Kuwait GHG inventory of anthropogenic emissions by source and removals by sinks of all GHGs not controlled by the Montreal Protocol and GHG precursors, 1994

	CO2 Emissions	CO2 Removals	CH4	N2O	NOx	CO	NMVOC	SO2
Total National Emissions and Removals	**29,524**	**22**	**129.19**	**0.44**	**113**	**544**	**522**	**320**
1 Energy	28,856	0	92.69	0.17	113	544	522	320
A Fuel Combustion (Sectoral Approach)	28,856		1.69	0.17	112	502	95	204
1 Energy Industries	23,210		0.36	0.12	63	7	2	204
2 Manufacturing Industries and Construction	0		0.00	0.00	0	0	0	0
3 Transport	5,351		1.28	0.05	50	495	93	0
4 Other Sectors	295		0.05	0.00	0	0	0	0
5 Other (please specify)	0		0.00	0.00	0	0	0	0
B Fugitive Emissions from Fuels	0		91.00		0	42	427	115
1 Solid Fuels			0.00		0	0	0	0
2 Oil and Natural Gas			91.00		0	42	427	115
2 Industrial Processes	668	0	0.00	0.00	0	0	0	0
A Mineral Products	668		0.00	0.00	0	0	0	0
B Chemical Industry	0		0.00	0.00	0	0	0	0
C Metal Production	0		0.00	0.00	0	0	0	0
D Other Production	0				0	0	0	0
E Production of Halocarbons and Sulphur Hexafluoride								
F Consumption of Halocarbons and Sulphur Hexafluoride								
G Other	0		0.00	0.00	0	0	0	0
3 Solvent and Other Product Use	0			0.00	0	0	0	0
4 Agriculture			2.70	0.03	0	0	0	0
A Enteric Fermentation			2.50					
B Manure Management			0.20	0.00			0	0
C Rice Cultivation			0.00				0	
D Agricultural Soils				0.03	0	0	0	
E Prescribed Burning of Savannas			0.00	0.00	0	0	0	
F Field Burning of Agricultural Residues			0.00	0.00	0	0	0	
G Other			0.00	0.00	0	0	0	
5 Land-Use Change & Forestry (2)	0		0.00	0.00	0	0	0	0
A Changes in Forest and Other Woody Biomass Stocks	0	22						
B Forest and Grassland Conversion	0	22	0.00	0.00	0	0		
C Abandonment of Managed Lands		0						
D CO2 Emissions and Removals from Soil	0	0						
E Other	0	0	0.00	0.00	0	0		
6 Waste		0	33.80	0.24	0	0	0	0
A Solid Waste Disposal on Land			33.80		0		0	
B Wastewater Handling			0.00	0.24	0	0	0	0
C Waste Incineration			0.00	0.00	0	0	0	0
D Other			0.00	0.00	0	0	0	0
7 Other	0		0.00	0.00	0	0	0	0
Memo Items		0						
International Bunkers	3,474		0.00	0.00	0	0	0	0
Aviation	1,050		0.00	0.00	0	0	0	0
Marine	2,424		0.00	0.00	0	0	0	0
CO2 Emissions from Biomass	0							

Table 2-9: Kuwait GHG emissions summary (by sector and gas), 1994

SHORT SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)									
GREENHOUSE GAS SOURCE AND SINK CATEGORIES		**CO_2 Emissions**	**CO_2 Removals**	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**	**SO_2**
Total National Emissions and Removals		29,523	22	129.19	0.44	113	544	522	320
1 Energy	Reference Approach	32,198							
	Sectoral Approach	28,856		92.69	0.17	113	544	522	204
A Fuel Combustion		28,856		1.69	0.17	113	502	95	204
B Fugitive Emissions from Fuels		0		91.00		0	42	427	115
2 Industrial Processes		668		0.00	0.00	0	0	0	0
3 Solvent and Other Product Use		0			0.00			0	
4 Agriculture				2.70	0.03	0	0		
5 Land-Use Change & Forestry		0	22	0.00	0.00	0	0		
6 Waste				33.80	0.24				
7 Other		0	0	0.00	0.00	0	0	0	0
Memo Items:									
International Bunkers		3,474		0.00	0.00	0	0	0	0
Aviation		1,050		0.00	0.00	0	0	0	0
Marine		2,424		0.00	0.00	0	0	0	0
CO_2 Emissions from Biomass		0							

Table 2-10: Total GHG emission in Kuwait, 1994

SHORT SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)							
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	**CO_2 Emissions**	**CO_2 Removals**	**CH_4**	**CH4 21 CO2 eq**	**N_2O**	**N_2O 310 CO2 eq**	**Total CO2 eq**
1 Energy							
A Fuel Combustion	28,856		1.69	35.5	0.17	52.7	28,944
B Fugitive Emissions from Fuels	0		91.00	1,911.0		0.0	1,911
Energy total							30,855
2 Industrial Processes	668		0.00	0.0	0.00	0.0	668
3 Solvent and Other Product Use	0			0.0	0.00	0.0	0
4 Agriculture	0		2.70	56.7	0.03	9.3	66
5 Land-Use Change & Forestry	0	22	0.00	0	0.00	0.0	-22
6 Waste			33.80	709.8	0.24	74.4	784
7 Other	0	0	0.00	0	0.00	0.0	0
Total	29,524	22	129.19	7,501	0.44	136.4	32,373

3 Vulnerability and Adaptation

This chapter provides an overview of the potential adverse impacts of climate change on key sectors in Kuwait, together with an overview of adaptation options. The chapter begins with a review of climate change projections for the country regarding temperature and rainfall. The bulk of the chapter is a summary of vulnerability and adaptation studies regarding Kuwait's coastal zones and water resources.

3.1 Climatic conditions

Kuwait's climate, past and future, was characterized relative to temperature and rainfall patterns. The results of this analyze formed the basis by which to conduct the vulnerability assessments described in this chapter.

3.1.1 Factors influencing Kuwait's climate

There are several key factors that have a large influence on Kuwait's past and future climate. First, the sun's angle of altitude affects the amount of solar energy received. Kuwait's latitude is about 29°N so the sun's highest angle is 84° above the horizon at the beginning of summer (i.e., 21 June). The lowest angle is 37° above the horizon at the beginning of winter (i.e., 22 December). Daylight duration is also affected by this location – summer daylight hours are 14.0 hours and winter daylight hours are about 10.3 hours (Al-Yamani, et al. 2004). By virtue of its location, Kuwait's climate is strongly affected by a hot subtropical climate.

Secondly, elevation has a pronounced effect on climate. Since Kuwait has a flat topography, with the highest elevation about 287.5 meters at the Al Salmy meteorological station to the west, elevation does not have significant effect on Kuwait's climate. However, the neighboring Zagros mountains to the east in Iran has an great effect during the summer "Albwarh Winds", which are influenced by the orographic-lifting "Foehn Effect". Typically, this effect raises wind temperature blowing toward Kuwait.

Thirdly, continental air masses influence local temperature, precipitation, and humidity: Several air masses influence Kuwait at different times of the year (Al Kulaib, 1981, 1984). These are briefly described in the bullets below.

- *Polar Continental Air Masses (cP):* This air mass originates in northern Asia, and consists of cool and dry air.
- *Polar Maritime Air Masses (mP):* This air mass originates in the north Atlantic with its cool waters, and reaches the region behind the western depression.
- *Tropical Continental Air Masses (cT):* This air mass originates in the Arabian Peninsula, and consists of hot and dry air.
- *Tropical Maritime Air Masses (mT):* This air mass originates in the Arabian Gulf, and consists of warm and humid air.
- *Tropical Continental Air Masses (cT):* This air mass originates in northwest India, and consists of hot and dry air that greatly influence summer weather in Kuwait.

Finally, dust storms are a typical phenomenon in hot, dry desert regions. The main factors that contribute to the formation of dust storms exist in Kuwait. These factors include high wind speed during the dry season; loose sand and dusty surfaces, lack of soil moisture, and lack of vegetation. The number of days with dust storms increases during the summer dry season.

3.1.2 Baseline climate

According to the Koppen system, Kuwait's current climate is classified as "BWh", which means tropical, dry, desert and hot climate (Koppen, W,1936). The letter "B" in the classification corresponds to areas where potential evaporation exceeds the precipitation; the letter "W" corresponds to desert regions; and the letter "h" corresponds to areas where the average annual temperature is 18 C or greater (Lutgens and Tarbuck, 2010).

To further characterize Kuwait's baseline climate relative to key indicators such as temperature and rainfall, climatic data were obtained from the Kuwait International Airport Station (KIAS). Data have been systematically recorded at this meteorological station since around the 1960's. As a result the climate baseline is based on the 53-year period, 1957-2010. Box 3-1 provides an overview of the nature of the climatic data available from this station. To develop estimates of weather phenomena such as dusty days, low visibility days, and rainy days, statistical tools such as Meteorological Data Processing system software were used.

Box 3-1: Key features of KIAS data

- *Data record:* The 1960 to 2010 period covered, sufficient for establishing a climatic baseline
- *Urban based:* The meteorological station is based proximate to most population/infrastructure
- *Representative:* A single station in a small country is capable of reflecting countrywide conditions
- *Comprehensiveness:* A complete record of climate data exists without any gaps
- *Data quality:* There is more confidence on the accuracy of data this station than others in Kuwait
- *Scope:* The data record covers both daily and monthly observations
- *Continuity:* represents the most continuous data record of any others available in Kuwait

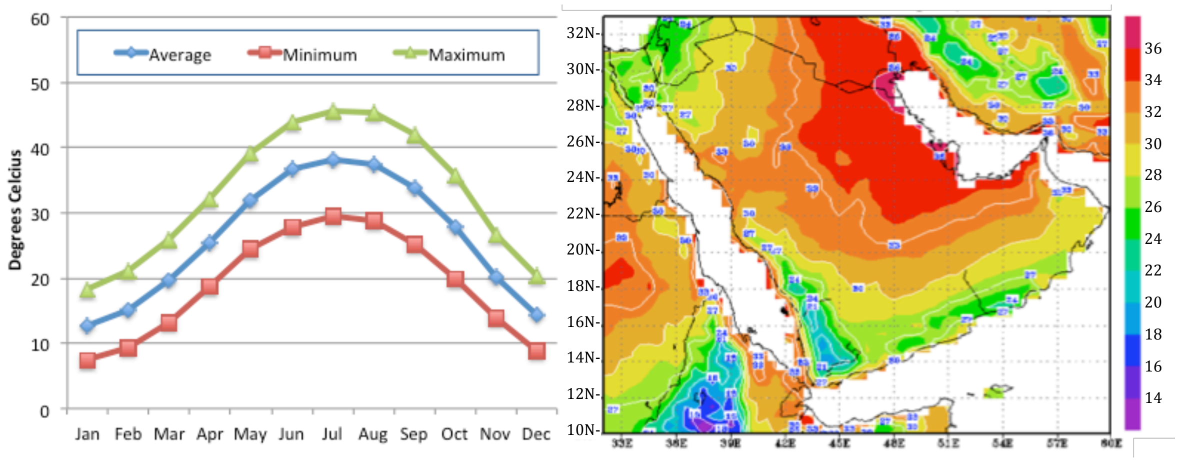
Temperature trends

Based on temperature observations over the 1957-2010 period, the average annual temperature in Kuwait is 26.1°C. On a monthly basis, substantial variation exists, as illustrated in Figure 3-1a and summarized in the bullets below.

Figure 3-1: Monthly average, maximum, and minimum temperatures in Kuwait, 1957-2010

a) Monthly average, maximum, and minimum temperature in Kuwait, 1957-2010

b) HadCM3 mean observed July temperatures at 2 meters above ground level, 1961-1990



- *Summer:* During the month of July, which is the peak of the hot summer months, the average temperature is 38.2°C. Average maximum temperature is significantly higher during this month, 45.6°C, which is about 16°C hotter than the average minimum temperature during July.

- *Winter:* During the month of January, which is the peak of cool winter months, the average temperature is 12.7°C. Average minimum temperature is considerably lower during this month, 7.5°C, which is about 11°C cooler than the average maximum temperature during January.

Regional climatic temperature maps produced by the HadCM3 model show reasonably good agreement with Kuwait historical data. For example, Figure 3-1b shows HadCM3 July temperatures in the Arabian Peninsula, averaged over the period 1962-1990. On this map, HadCM3 model outputs for July show Kuwait's average temperature to be between 36°C and 38°C. This compares well to the 38.2°C, which was averaged over a longer period. It is important to note that the band showing the highest July temperature (i.e., greater than 36°C) has been roughly limited to Kuwait during the region's baseline climatic conditions.

Despite significant inter-annual variations, there is a strong signal for increasing average annual temperatures in Kuwait over the 48-year period, 1962-2010 (see Figure 3-2). Based on a linear regression analysis, temperatures in Kuwait have risen about 1.6°Cover this entire period, which is very similar to published international values. This trend seems too large to be attributed merely to natural variation and/or the heat island effect. Moreover, these temperature trends are also in evidence for the other countries in the region (Kuwait Meteorological Department, 2012).

Figure 3-2: Average annual temperature trend in Kuwait, 1962-2010

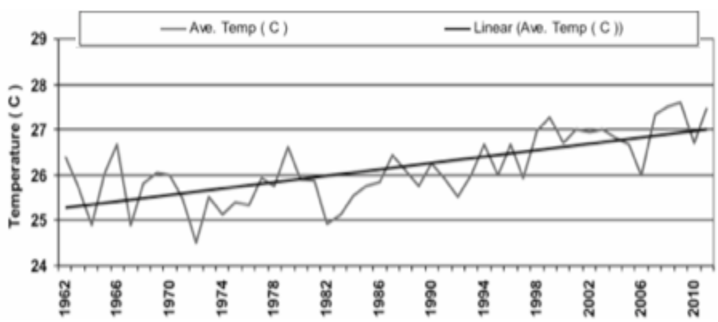
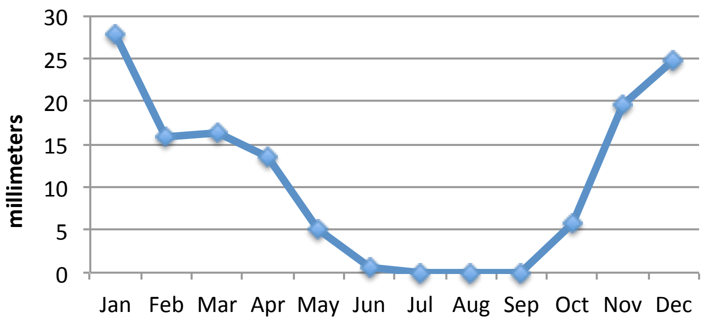


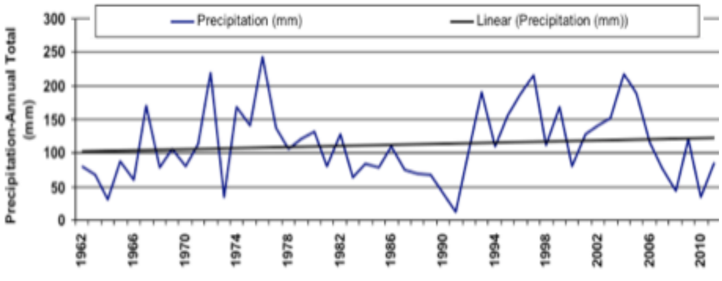
Figure 3-3: Average monthly rainfall in Kuwait, 1957-2010



Rainfall trends

The average annual rainfall in Kuwait is 116 mm per year. On a monthly basis, rainfall is concentrated in the winter and spring months (see Figure 3-3). During the peak of winter in January, the average rainfall is 27.8 mm. During the summer months from July through September, the average condition is zero rainfall.

Figure 3-4: Average annual rainfall in Kuwait, 1962-2010

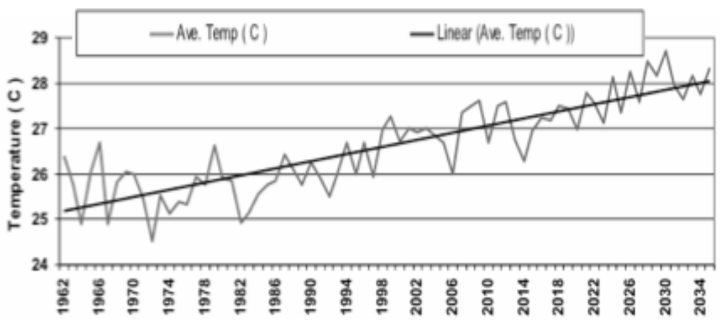


Inter-annual variations are even more prominent for rainfall (see Figure 3-4). For example, annual rainfall in 1973 was less than 50 mm while in 1974 annual rainfall reached nearly 170 mm, a difference of about 120 mm. Intra-annual variation can also be quite large. For example, in January 2004 rainfall levels reached 126.3 mm, roughly close to the average for a typical year. Based on a linear regression analysis, rainfall in Kuwait has increased by about 10 mm per year over the 1962-2010 period. Given the large inter-annual and intra-annual variations, it remains unclear if these trends are more than natural variation.

3.1.3 Future climate

To assess future temperature and rainfall projections, the outputs from two global circulation models were examined. The HadCM3 Climate Model was used to develop long-term (i.e., through 2099) climatic forecasts for Kuwait and surrounding Arabian Peninsula. The CCCMA, Canadian Center for Climate Modeling Analysis model, was used to develop mid-term (i.e., through 2035) temperature and rainfall projections for Kuwait only. Data homogenization was carried out using the RClimDex software (Kuwait Meteorological Department, 2010). Using historical Kuwait values over the 1962-2010 baseline period, these climate models were evaluated for a mid-term forecast period, 2010 to 2035 (RCB4.5 IPCC's emission scenario).

Figure 3-5: Projected average annual temperature in Kuwait, 1962-2035



Temperature projections

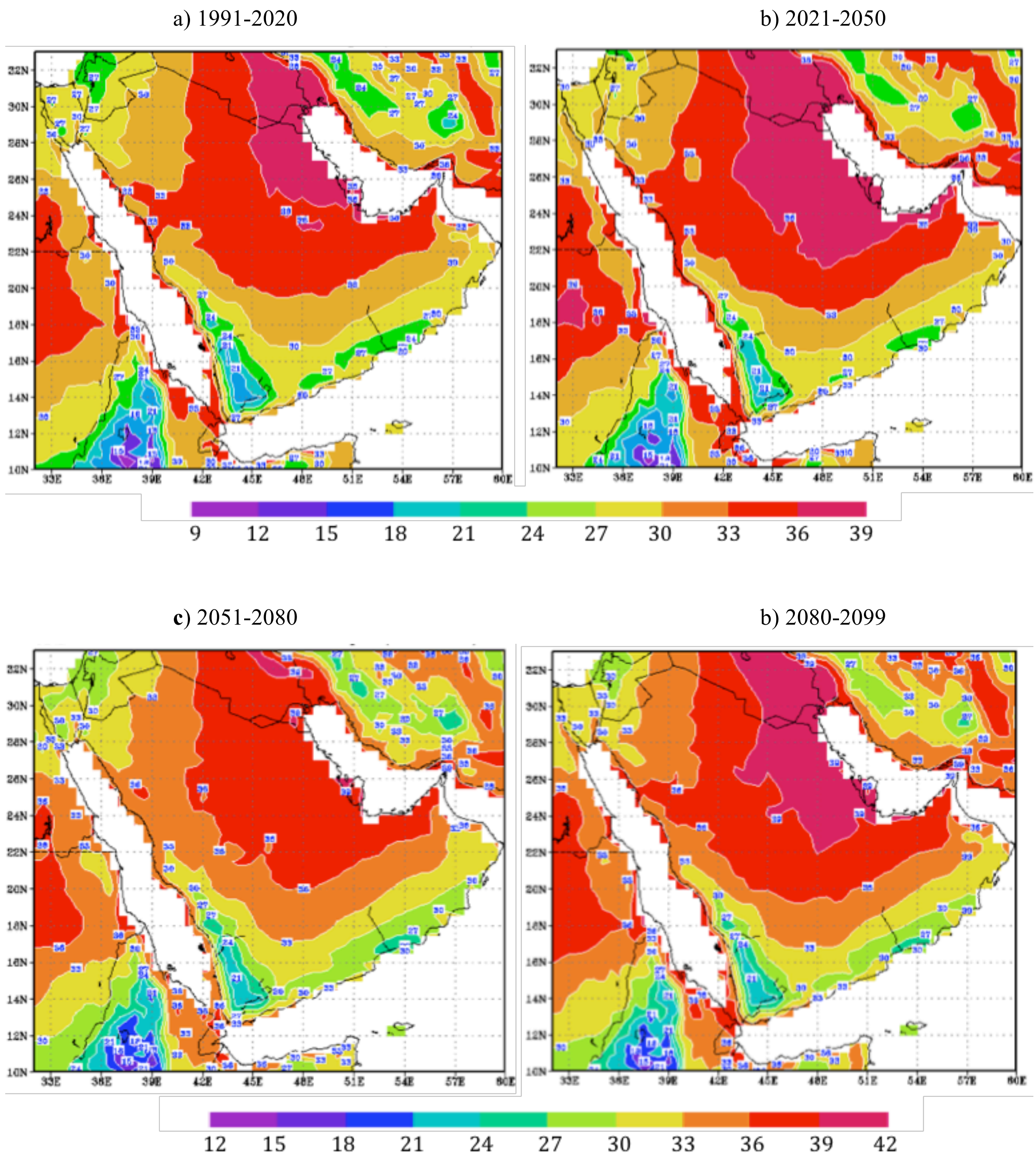
The CCCMA modeling results show that average annual temperatures will continue to increase in the future in Kuwait. Average temperatures are projected to reach a high of about 28.7°C during the 2010-2035 period (see Figure 3-5). This represents about a 1.6°C increase over the average annual temperature under Kuwait's baseline climate. Based on a linear regression analysis, temperatures in Kuwait are expected to rise about 0.4°C per decade over the coming years. These modeled projections clearly reinforce the temperature trends found in the historical period and suggest a potentially serious hazard to terrestrial and marine biodiversity.

The HadCM3 modeling results show that the Arabian Peninsula is projected to experience a gradual enlargement of the land area where Kuwait's July-like temperatures can be found (see Figure 3-6a through d). During the near-term projection period, 1991-2020, the land area showing the highest July temperature (i.e., greater than 36°C) expands from just around Kuwait (i.e., see Figure 3-1b) to encompass southern Iraq, western Iran near the Arabian Gulf, and parts of eastern Saudi Arabia. This trend continues through the mid-term projection period ending in 2050, with average July temperatures above 36°C projected for most of Iraq, and much of Saudi Arabia. By the end of the long-term projection, the year 2099, all of Kuwait and much of Iraq and Saudi Arabia are projected to experience average July temperatures that exceed 39°C.

Rainfall projections

The CCCMA modeling results show that average annual rainfall will decline in the future, reversing the increasing trend of the baseline climate (see Figure 3-7). Average annual rainfall levels are projected to be consistently below 70 mm per year over the 2016-2026

Figure 3-6: HadCM3 projected mean temperature in July at 2 meters above ground level

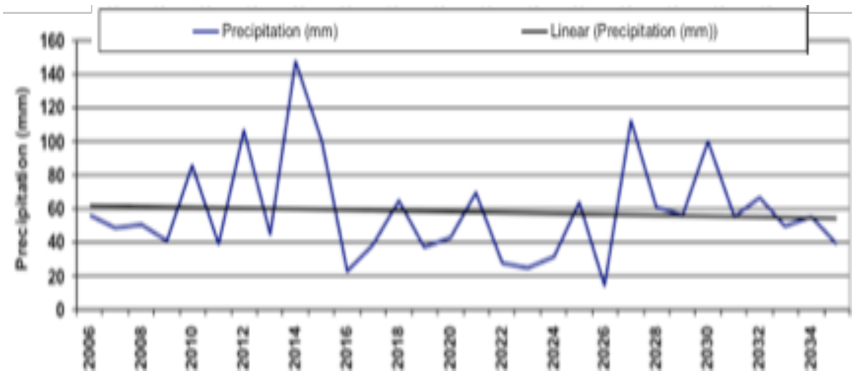


period, over 60 mm per year lower than the historical average. Moreover, for all years except 2014, average annual rainfall levels are projected to be less than the historical average. Based on a linear regression analysis, rainfall in Kuwait is expected to decrease about 2 mm/year per decade through 2035, a potentially serious adverse impact to grazing areas of livestock herds. These projections also suggest the possibility for increased dust storms.

3.2 Coastal zones

Kuwait's highly productive marine environment provides seafood and seawater for desalination. The coastline spans about 350 km and is the region where most of the population and critical infrastructure is located (Al-Bakri and Kittaneh, 1998). The crucial role that marine and coastal environments have in Kuwait suggests that climate change-

Figure 3-7: Projected average annual rainfall in Kuwait, 2006-2035



induced sea level rise (SLR) could lead to serious adverse impacts on future socioeconomic development. There is ample evidence from the international research literature that rising seas will likely flood low-lying urban infrastructure, threaten coastal lagoons and salt marshes, and contribute to the deterioration of groundwater quality. The rest of this section summarizes the results of a study to assess the impacts of future SLR on Kuwait's coastal zones, subject to a set of plausible SLR scenarios. The study's twofold aim was to establish the spatial extent of inundated areas and the magnitude of the risk to the population.

3.2.1 Baseline conditions

Most of Kuwait's urban areas lie within 20 km of the coast. These are areas where key infrastructure such as residential and commercial buildings, port facilities, oil support industries, road networks, and recreational facilities has expanded markedly over recent decades. A brief overview of the major features of the coastal zone is provided in the subsections below.

Physical setting

The stable Arabian shelf, the delta of Shatt Al-Arab and Quaternary sea level changes are the primary processes that have determined the long-term general character of the coast of Kuwait. Hydrodynamic factors such as tides, waves and currents are secondary processes that have modified the character of coast in the short term, namely the past few decades.

For assessment purposes, the coastal zone is divided into two main units; the northern and the southern zone, as shown in Figure 3-8 (Khalaf, 1988). Table 3-1 provides a breakdown in the variety of sediments found along the entire coastline.

The northern coastal zone extends from the Al-Subiya tidal channel to

Figure 3-8: Main zones along Kuwait's shoreline

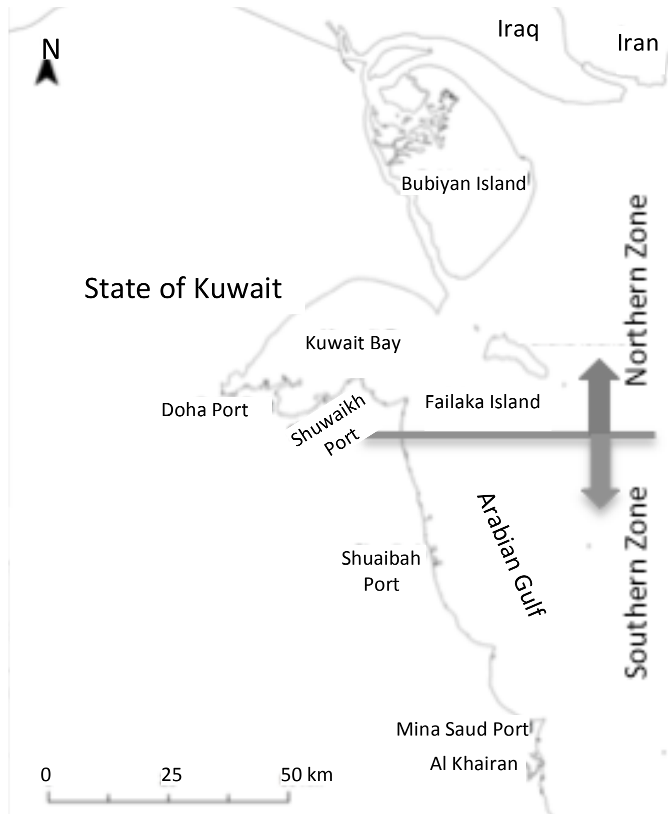


Table 3-1: Key features of Kuwait's shoreline

Sediment type	Coastline share	Key features
Soft mud tidal flats	57%	Found on Kuwait Bay, the Khiran area, Al-Subiya tidal channel and around Bubiyan Island
Sandy beaches underlain by rock	17%	Found south of Kuwait Bay from Ras Al Ardh to Ras Az-Zor; high wave energy; currents flow from south to north
sandy-rocky tidal flat	9%	Found in western part of southern coast of Kuwait Bay, along the southern coast of Bubiyan Island and in Ras Al-Subiya; nursing area for shrimp and fish
Coral reefs	9%	Found off the southern islands
Artificial sandy beaches	5%	Reclaimed tidal flat land around Kuwait City for recreational purposes
Oolitic limestone beaches/cliffs	3%	Found along southern coast; cliffs are 2-8 meters in height and separated from the sea by narrow beaches bound seaward by 700 m of wide rock tidal flats, partly covered with coarse sand

the southwest coast of Kuwait Bay. This coast is predominantly composed of clastic sediments originating from aeolian deposits and the Shatt Al-Arab estuary (Al-Sarawi *et al*., 1985). Its sediments are composed mainly of terrigenous material (quartz, feldspars and clay minerals), with smaller amounts of carbonates (Al-Bakri and El-Sayed, 1991).

In some parts of Al-Subiya tidal channel and along the western coast of Kuwait Bay, oyster banks are found at the surface of the upper and lower intertidal flats. The mud in this zone varies in thickness from a few centimeters to a few meters and is underlain by discontinuous beach rock ranging in thickness between 0.5 and 1.0 m (El-Sayed and AlBakri, 1994). The northern coastal zone is also a low-energy accretional coast with an extensive intertidal zone that varies in width from 200 to 1,500 m and covered mostly by muddy sediments.

The southern coastal zone extends from Ras Al-Ardh, just south of Kuwait Bay's entrance, to the southern border of the state near the Al-Khairan area. Carbonates, belonging to the northern-most marginal sector of the shallow Arabian shelf dominate this zone (Al-Sarawi *et al*., 1985) which also includes terrigenous minerals (chiefly quartz), and feldspars (Al-Bakri and El-Sayed, 1991).

Extensive and gently sloping mudflats characterize the shoreline of the southern zone. This zone is also bounded by extensive supratidal sabkha flats. Offshore, there is a relatively steep drop-off and the intertidal zone is narrow and covered mainly by sand deposits. The southern coastal zone is also a moderate- to high-energy erosional coast, with a rather steep profile and a narrow intertidal flat, not exceeding 500 meters in width except in the Al-Khairan area where it is about 2 km in width. In general, sand deposits cover this zone.

Tidal features

Kuwait's tidal range increases from south to north. On the southern coast, the average tidal range is approximately 1.8 m, while on the northern coast it varies between 3.5 and 4.0 m. Extreme tidal ranges occur in Spring when the tidal range reaches order of 4.3 m, not including wind effects (Jones, 1986; Al-Sarawi *et al*., 1985). Prevailing winds can significantly affect the tidal range. Northwesterly winds lower the tidal range and southeasterly winds have the opposite effect (Kuwait Ports Authority, 1996). This phenomenon is due to the fact that northwesterly winds blow in the opposite direction of flood currents, and in the same direction as the ebb currents. The converse is true for southeasterly winds (Al-Hasem, 2002).

Wave features

Wave heights along the coastline of Kuwait generally increase southwards. Along the southern coast, wave heights typically reach about 4 m with 9-second periods. Within the naturally protected Kuwait Bay, waves are much smaller, typically reaching only 1.5 meters with a period of 3 to 5 seconds (Abou-Seida and Al-Sarawi, 1990). Waves arriving on the coast of Kuwait are of two types. First, swell waves originate in the southern Arabian Gulf under the influence of prevailing southeasterly winds. Second, locally generated wind waves originate in the Kuwaiti offshore zone during periods of winds with a northerly component (Hayes *et al*., 1986). Under the same wind velocity, the southeasterly winds generate larger waves than the northerly winds because of the greater fetch.

The effect of wave action increases with high tide. At low tide, intertidal flats separate most wave and current action from the shoreline. For this reason the influence of waves is slight along the northern coast because of its shallow offshore depth and broad intertidal flat. Waves usually break far from the shoreline and when they reach the beach most of the energy has been dissipated. The effect of wave action is greatest along the southern coast because of the narrow intertidal flat and steep offshore topography.

3.2.2 Methodology

A brief overview of the major elements of the methodological approach that was applied to examine Kuwait's vulnerability to sea level rise is provided in the subsections below.

Scenario framework

A scenario framework was chosen to estimate the spatial extent of potential inundated areas and number of people at risk. Specifically, four SLR scenarios were developed for the analysis, as briefly described in Table 3-2.

Table 3-2: Scenarios evaluated in the coastal zone assessment

Scenario name	Baseline sea level	Assumed change in sea level due to climate change (meters)	Assumed future sea level (meters)
Low SLR	Mean High Tide Line (MHTL), based on historical average along Kuwaiti coastline	0.5	High tide + 0.5
Central-Low		1.0	High tide + 1.0
Central-High		1.5	High tide + 1.5
High SLR		2.0	High tide + 2.0

The scenario framework used the highest potential water levels (i.e., occurring at high tide), as the basis to develop estimates of potential inundated areas relative to increasing sea levels in the Arabian Gulf. Land areas with elevations below future sea level and which have connectivity with the Arabian Gulf were considered as inundated areas. The number of people at risk was then estimated by multiplying *current* population density by the area of inundation.

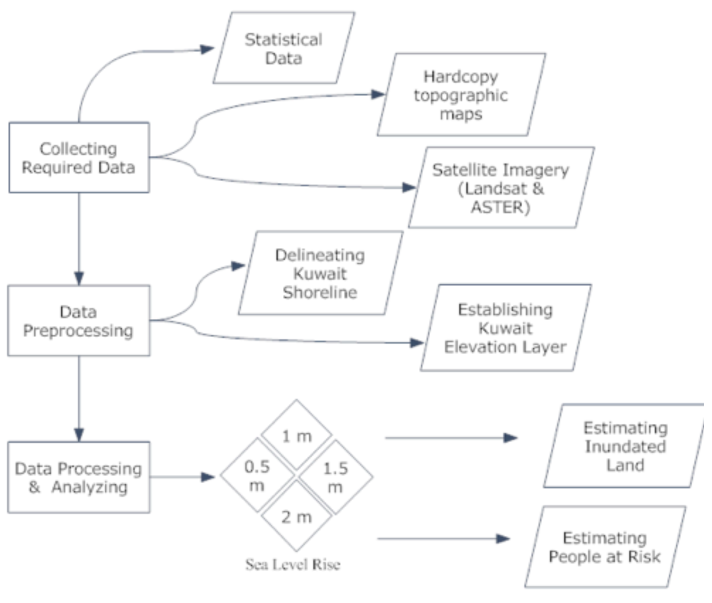
Overall analytic process

A small team of national experts representing relevant ministries and institutions prepared the coastal zone analysis. The engagement of key stakeholders facilitated data collection. Figure 3-9 provides an overview of technical steps involved in this study, which included acquisition of statistical data, topographic maps, and remote sensing data.

Shoreline delineation

The Kuwait shoreline was delineated using the most recently available topographic maps and satellite imagery. Several hardcopy topographic maps produced by the Defense Ministry of Kuwait (1994) at scales varying from 1:25,000 to 1:100,000 were scanned and georeferenced with root mean square error less than 1 meter. Georeferenced topographic maps were then used to delineate most of Kuwait shoreline.

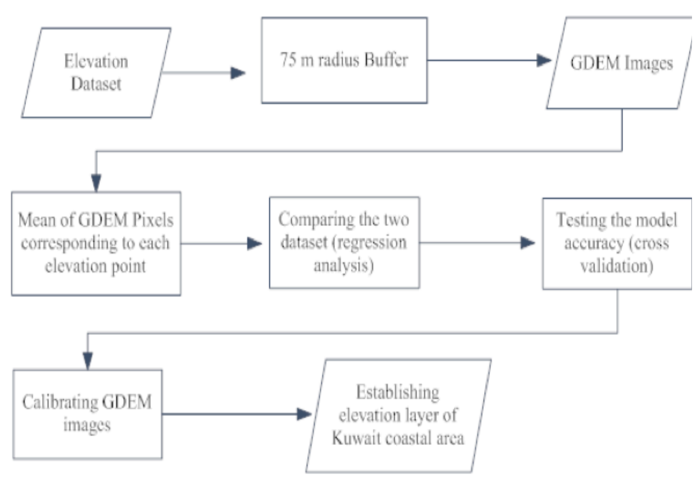
Figure 3-9: Overview of the analytic process



For coastal areas and islands not covered by available topographic maps, such as southeastern BubiyanIsland, the shoreline was delineated using a Landsat 4 image acquired on 27 August 1992 (USGS, 1992). The satellite image date was acquired during high tide in the same period of those data used to produce the topographic maps so that shoreline changes over time should be negligible.

The southern area of Kuwait coast, specifically Al-Khairan area, is experiencing extensive urban developing that significantly altered the shoreline of this area. Thus, the shoreline in this area was delineated using a 15-meter panchromatic band of Landsat 7 obtained on 12 March 2009 (USGS, 2009).

Figure 3-10: Overview of the GDEM image and elevation dataset matchup process



Elevation data

To develop elevation characteristics of the Kuwaiti shoreline, key data were assembled and compared. As a starting point, a database of 793 elevation points along the coastline was developed on the basis of the Defense Ministry's topographic maps. Each point was identified relative to its latitude, longitude, and vertical distance above mean sea level. Alone, however, these elevation points were insufficient to fully characterize the elevation of potentially inundated areas. Therefore, they were coupled with publicly available digital elevation models in a process to produce a robust and detailed characterization of Kuwait's coastal elevations. Figure 3-10 provides an overview of the elevation data comparison and calibration process, with additional details below.

The digital elevation model is based on version 2 of the Global Digital Elevation Model (GDEM) released in October 2011 by the United States Geologic Survey (USGS, 2011). A total of six GDEM images, each representing a 60 km by 60 km area of Kuwait, were downloaded and used in the process. GDEM elevations are expressed as the distance in meters above mean sea level.

Using a GIS framework, each of the 793 topographic elevation points was spatially aligned with the GDEM images. All GDEM elevation values within a 75-meter radius of each topographic elevation point were averaged. This yielded an average GDEM elevation point that could be directly compared to each topographic elevation point. Regression analysis was then carried out and indicated that there was very good correlation between the topographic and averaged GDEM elevation sets (i.e., a coefficient of determination of 0.98).

The model derived from the regression analysis (i.e., elevation (in meters above mean sea level) = $-0.0012 * GDEM^2 + 1.2058 * GDEM - 5.9763$) was then tested for robustness and consistency using cross validation techniques, as discussed in Camstra and Boomsma (1992), D'alimonte and Zibordi (2003) and Jonathan *et al* (2000). Essentially, this involved dividing the GDEM elevation dataset into four segments. Three of these segments were selected to rebuild the digital elevation model. The remaining segment was used to validate the accuracy of the model. This procedure was repeated four times by switching among the four segments. The result of the process was a fully characterized and robust digital elevation model of the Kuwait coastal zone, with a spatial resolution of 30 meters by 30 meters layer.

Analytic steps

GIS techniques were used to estimate the extent of inundated area for each of the scenarios, based on the approach by Bhadra *et al.,* (2011). Key analytic steps are summarized in the bullets below.

- Each point in the calibrated GDEM was assigned a numeric value relative to its inundation under each SLR scenario. A value of zero (0) was assigned to points that are below projected sea level; a value of one (1) was assigned to points above projected sea level.
- A seawater connectivity test was conducted for each point in the calibrated GDEM layer below projected sea level (i.e., having a value of zero from the above step). Only points that are below projected sea level and having seawater connectivity are considered inundated.
- Inundation area relative to each SLR scenario was computed by simply summing the area associated with the inundated points.

GIS techniques were also used to estimate the population at risk from each of the sea level rise scenarios. Key analytic steps are summarized in the bullets below.

- Urban population density was computed based on data from the 2011 census (Kuwait Census, 2011) together with detailed spatial information regarding the location and land area where this population lives. Since population at the time of future sea level rise would likely exceed that of 2011, urban population density estimates are considered to be a lower bound.
- Urban population density was apportioned to each of the points, as appropriate, in the calibrated GDEM layer's 30- by 30-meter grid.
- For each inundated grid point, the total population at risk was calculated as the product of the apportioned population density, the number of grid points, and the grid area.

3.2.3 Impacts of sea level rise

The calibrated GDEM images were used to estimate the extent of inundation and the population at risk under the SLR scenarios. Three specific coastal zones – northern, central, and southern – were considered. The spatial extent of inundation in these zones and other details are described in the sections that follow. Tabular results for each zone relative to each SLR scenario are provided in Table 3-3.

Table 3-3: Extent of inundated area and population at risk under the SLR scenarios

	Sea level rise scenario							
	Low (MHTL + 0.5 m)		Central-Low (MHTL + 1.0 m)		Central-high (MHTL + 1.5 m)		High (MHTL + 2.0 m)	
Coastal zone	Km^2	% of total	Km^2	% of total	Km^2	% of total	Km^2	% of total
Northern	199	1.1	408	2.3	416	2.3	419	2.4
Central	34	0.2	34	0.2	34	0.2	76	0.4
Southern	7	<0.1	7	<0.1	46	0.3	46	0.3
Total inundation	**241**	**1.4**	**450**	**2.5**	**496**	**2.8**	**542**	**3.0**
People at risk (thousand)	**65.1**	**1.8**	**65.1**	**1.8**	**125.8**	**3.5**	**173.7**	**4.8**

As can be seen in this Table, between 241 km^{2}and 542 km^2 of Kuwait would be inundated under the SLR scenarios, representing between 1.4% and just over 3% of the total land area. As described in the subsections below, rising seas will not only result in land inundation but would also adversely affect sediment transport, wave height, storm surge, tidal dynamics, coastal erosion. Combined, these changes could seriously undermine biodiversity support systems in the entire coastal zone as well as development plans for certain coastal locations.

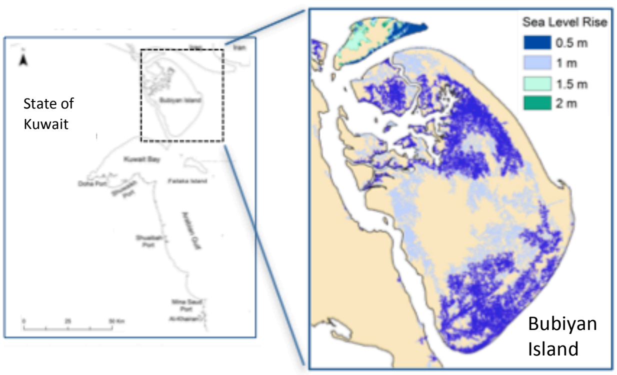
Rising seas also pose a serious threat to the numerous coastal communities and businesses located in the vicinity of the shoreline. In total, the lower bound estimate of the number of people that would be vulnerable to rising seas between 65 and 174 thousand, depending on the SLR scenario. The overwhelming majority of those who would be impacted inhabit the coastal area around Kuwait Bay, the heart of socioeconomic activity in the country.

Northern zone

The northern zone comprises areas north of Kuwait Bay, including the northern islands, and is considered part of inland marine system with numerous tidal channels (see Figure 3-11). Under the smallest SLR scenario, the northern islands of Kuwait, especially Bubiyan Island, would be highly impacted, with about 22% of the island under water. Under the largest SLR scenario, most of the island would be inundated with only the eastern coastline and central areas still above sea level. Aside from some small isolated areas, the mainland coastline is not impacted by inundation from sea level rise.

In total, up to 419 km^2 of current land area would be inundated in the Northern zone. This corresponds to over 2% of the total land area of Kuwait and nearly 80% of the inundated area in the highest SLR scenario. Nearly all of the inundation, about 97%, would take place from sea level rise of up to 1 meter.

Figure 3-11: Extent of coastal zone inundation, Northern zone



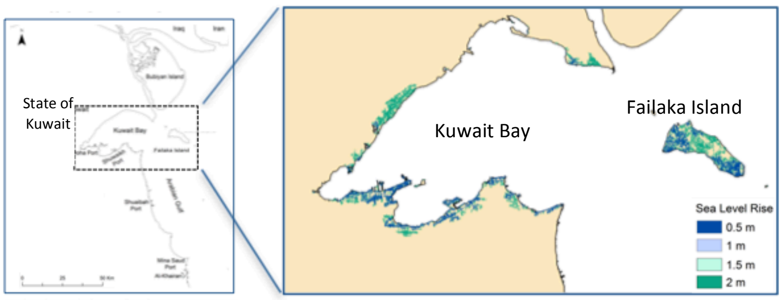
Tidal processes are the dominant influence on the hydrodynamic regime and sediment transport dynamics in the Northern zone, Other studies have shown that rising levels in the Arabian Gulf could increase the total tidal prism and current velocities in the channels, thereby adversely affecting suspended sediment concentration, erosion and deposition (Chappell *et al*., 1995).Moreover, rising seas could impact the rate of tidal wave propagation that cause a modification of flood/ebb dominance ratio, resulting in unpredictable coastal behavior (Boon and Byrne, 1981; Thom and Hall, 1991; Cowell *et al*., 1995; Pethick, 1996; Al-Hasem, 2002).

Almost all of the inundated land in the Northern zone consists of sabkha areas on the islands, which are critically important in support of local biodiversity. Since the islands in the Northern zone are currently largely uninhabited, the population at risk is expected to be small. The inundation of inland coastal depressions and supratidal sabkhas would convertthese drylands to wetlands or water, depending on the SLR scenario. Such an outcome would adversely impact future coastal zone development plans, particularly along the northern coast of Bubiyan Island where the several development projects are planned.

Central zone

The Central zone comprises the entire area around Kuwait Bay (see Figure 3-12). This is the region where much of the country's population and infrastructure are located. Under the smallest SLR scenario, extensive areas in the southern coast of Kuwait Bay would be under water, particularly the Doha and Shuwaikh Ports. Under the largest SLR scenario, significant areas on the northern coast would also be inundated, as well as almost all of Failaka Island.

Figure 3-12: Extent of coastal zone inundation, Northern zone



In total, up to 76 km^2 of current land area would be inundated in the Central zone. This corresponds to just under 0.5% of the total land area of Kuwait and just over 14% of the inundated area in the highest SLR scenario. About half of the inundated area in the Central zone would take place under the smallest SLR rise scenario, a serious concern as almost all of this land is heavily populated and filled with commercial enterprises that contribute greatly to the Kuwaiti economy.

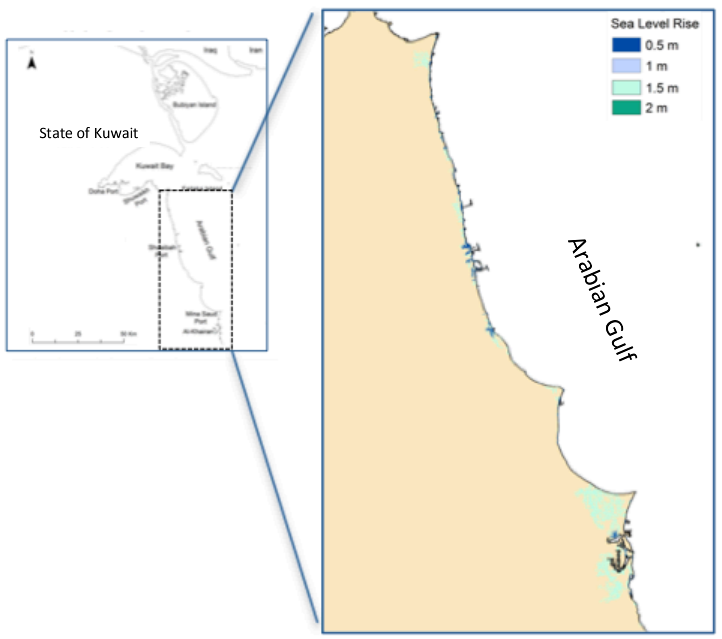
Southern zone

The southern zone comprises all coastal areas south of Kuwait Bay (see Figure 3-13). Relatively steep coastal plains characterize the near-shore profile of this coastline. Hence, inundated areas are small in comparison to the Northern and Central zones for most of the scenarios. Exceptions are the Shuaibah and Mina Saud port areas, as well as the Al-Khairan region, which show extensive inundation as seas rise to 1.5 meters.

In total, up to 46 km^2 of current land area would be inundated in the Southern zone. This corresponds to just under 0.3% of the total land area of Kuwait and just below 9% of the inundated area in the highest SLR scenario.

Of the three zones considered in the analysis, the Southern zone is expected to be most vulnerable to changes in coastal morphodynamics and stability accompanying sea level rise. Wave processes and storm surges will likely become more intense with rising sea levels, leading to higher and more destructive waves as well as new sediment transport patterns that result in increased coastal erosion along many parts of the coast.

Figure 3-13: Extent of coastal zone inundation, Southern zone



3.2.4 Conclusions and recommendations

These results suggest that adaptation planning should be pursued to ensure that Kuwait's capacity and resilience is strengthened to be able to cope with these impacts. In the near-term, a twofold adaptation-planning framework is recommended that focuses on enhancing coastal information systems and the development of adaptation planning and design strategies, as briefly described in the bullets below.

- *Enhancing coastal information systems:* Data collection and information development are prerequisites for coastal adaptation. The more relevant, accurate, and up-to-date the data and information available to coastal planners, the more targeted and effective adaptation strategies can be. Enhanced information systems should include data and information on coastal characteristics and dynamics and patterns of human behavior, as well as an understanding of the potential consequences of climate change. It is also essential that there be a general awareness among the public, coastal managers and decision makers of these consequences and of the possible need to take appropriate action.

- *Developing adaptation planning and design strategies:* Strategies to protect Kuwait against sea-level rise can be implemented either reactively (i.e., after sea level rise) or proactively (i.e., before sea level rise). Given the findings discussed earlier, it is essential for Kuwait to actively develop a strategic adaptation planning capacity because most desirable adaptation options are best implemented in an anticipatory manner. The comprehensive range of appropriate adaptation options available to Kuwait should be systematically relative to criteria such as cost-effectiveness, environmental sustainability, cultural compatibility, and social acceptability.

3.3 Water resources

Water resource management is already a critical planning challenge for Kuwait. With climate change, it is expected that balancing water supply and water demand will become an even greater challenge. Therefore, it is essential to better understand the options and strategies available to reduce Kuwait's vulnerability to climate change. The rest of this section summarizes the results of a study to assess the impacts of future changes in temperature and rainfall on Kuwait's water resources, subject to a set of plausible development scenarios. The study's twofold aim was to quantify incremental water requirements under climate change to meet socioeconomic development needs and to evaluate the impact on future water use from the implementation of a set of adaptation measures.

3.3.1 Baseline conditions

As noted in Chapter 1, Kuwait's daily per capita water use levels are very high compared to global patterns. This is due in large part to a hyper-arid climate, strong population growth, and a thriving economy. Most of Kuwait's water supply resources are constrained and likely to become more so in the future. A brief overview of the major features of historical water supply and demand patterns is provided in the subsections below.

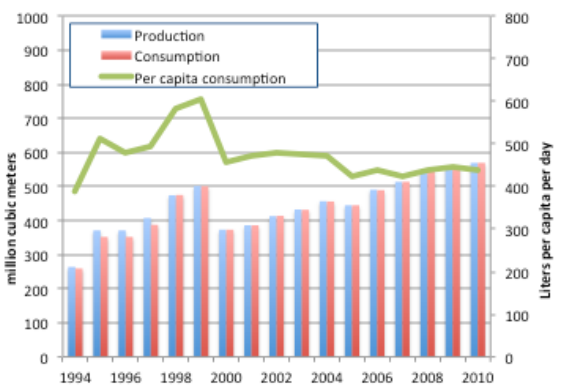
Desalinated water

Desalinated water is considered Kuwait's only reliable future option to meet the needs of its growing population and economy. Desalinated water is coproduced at several power plants, namely the Shuwaikh, Shuaiba North, Shuaiba South, Doha West, Az-Zor South, and Sabiya stations. Together, these desalination plants represent a substantial portion of desalination capacity in the Gulf, as well as the world.

As of 2011, total installed capacity for desalinated water supply was about 2.1 million cubic meters per day (GWI, 2012). All of this capacity relies on seawater from the Arabian Gulf. While various desalination technologies are used in Kuwait, most of the desalinated water is produced using multi-stage flash technology, which requires extensive amounts of process heat.

Over the period 1994-2010, desalinated water consumption has been growing at an average annual rate of about 5.0% per year, with desalinated plants running at nearly full capacity (see Figure 3-14). On a per capita basis, however, there has been significant improvement in water use since 1999 when desalinated water consumption reached about 600 liters per person per day. In 2011, desalinated water use was about 429 liters per person per day, or nearly a 30% decrease from 1999 per capita consumption levels.

Figure 3-14: Kuwait desalinated water production and consumption, 1994-2010 (MEW, 2010)

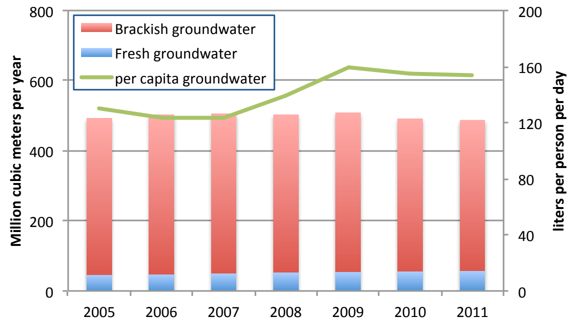


Groundwater

There are two types of groundwater in Kuwait. Brackish groundwater accounts for the dominant share of groundwater use, about 90% over the 2005-2011 period (see Figure 3-15). Brackish groundwater possesses high salinity levels (i.e., 3,000–10,000 mg/liter) and is extracted from the Dammam aquifer, a transboundary groundwater resources recharged from Saudi Arabia and Iraq. The Dammam aquifer underlies all of Kuwait and consists of 200–300 meters of soft, porous, chalky limestone and hardy crystalline dolomitic limestone with nummulitic and green shale at the base.

Fresh groundwater possesses low salinity levels (i.e., 600–1,000 mg/liter) and is available from deep subsurface lenses at Al-Rawdatain and Umm Al-Aish in the Northern part of Kuwait. These resources are renewable in nature and are recharged over time by annual rainfall in the region. In comparison to other water supply sources, there are very limited fresh groundwater resources in Kuwait, and consumption takes up a very small share of the annual water budget, typically below 5%.

Figure 3-15: Kuwait groundwater use, 1994-2010 (MEW,2010)



Groundwater is typically blended with desalinated water to make it useable for irrigation and landscaping plus household purposes, livestock watering, and construction. The use of brackish groundwater supply has been decreasing at an average annual rate of 0.6% per year since 2005. On the other hand, freshwater groundwater use has been rising about 3.6% per year since 2005. On a per capita basis, total groundwater consumption levels have increased from 131 to 154 liters per person per day (see Figure 3-15), or by at an average annual rate of about 2.7% per year since 2005.

Treated wastewater

Driven by the high costs of desalination, increasing attention has focused on wastewater reuse in recent years. The wastewater collection and treatment system in Kuwait City and its suburbs has been well established since the 1970s and consists of 4,700km of gravity sewers and 1,600km of pressure mains (El-Essa, 2000). Municipal and wastewater is pumped through this intricate network by 17 major pumping stations and 52 secondary pumping stations. Collected wastewater is then transferred to four wastewater treatment plants in the Kuwait City vicinity.

As of 2011, wastewater treatment capacity in Kuwait was 0.72 Mm^3/day and treated sewage effluent (TSE) levels were about 0.55Mm^3/day. About half of Kuwait's TSE is produced at the Al-Sulaibiya plant which came online in 2004 and uses an advanced reverse osmosis (RO) and ultra-filtration (UF) membrane-based purification system resulting in treated effluent characterized by less than 1 mg per liter for both total suspended solids (TSS) and biological oxygen demand over a 5-day period. On average, between 50% and 60% of TSE is used for irrigation while the rest is routed into the Arabian Gulf (MPW, 2010).

3.3.2 Methodology

The focus of the study was on domestic water demand, with both vulnerability and adaptation options considered. The domestic sector was selected for analysis because it currently accounts for the majority of water consumption, 51% of total water demand in 2011 (see Figure 1-13), and is expected to grow rapidly under business-as-usual conditions. The domestic water sector relies on desalinated water and fresh groundwater supplies.

The vulnerability of Kuwait's domestic water demand and supply system was defined as the additional future amount for urban water supply that would be needed due to climate change. Potential adaptation measures were evaluated relative to their effectiveness in reducing future water demand under climate change. The key features of the methodological approach to the analysis are briefly described in the subsections below.

Climatic Conditions

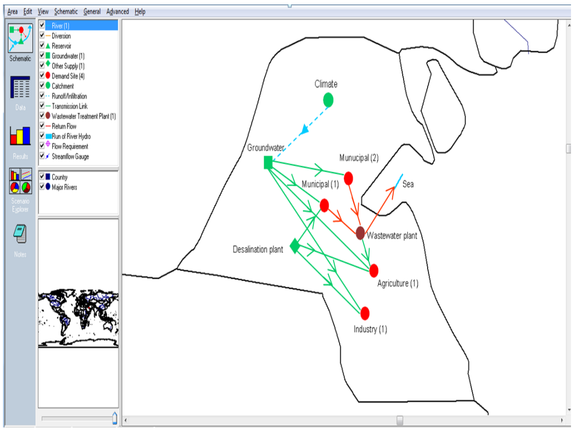
Higher temperatures are a key driver for changes in future water consumption patterns in the domestic sector. As temperature increases in the future due to climate change (see Figure 3-5, as discussed earlier), water production will also increase due to greater need of water for a variety of domestic activities (e.g., watering lawns and trees) and industrial activities (e.g., cooling purposes), especially in the hot summer months. Based on an analysis of historical patterns, for each increase of 1°C due to climate change, an additional 30 Mm^3 increase in freshwater demand is expected.

Reduced rainfall is a key driver for changes in fresh (i.e., renewable) groundwater characteristics. As annual rainfall levels decrease due to climate change (see Figure 3-7, as discussed earlier), recharge rates and depths of renewable groundwater could be adversely affected. On the other hand, it is possible that groundwater recharge in Kuwait could increase under climate change if there is a greater frequency of high-intensity rainfall. Runoff from such precipitation events would be able to infiltrate the ground before evaporating. At present, however, information regarding the current groundwater recharge rates in Kuwait is poor and the future frequency of high-intensity rainfall events is not well understood. Hence, additional climate modeling and groundwater characterization would be needed before the vulnerability of renewable groundwater can be evaluated.

Modeling framework

The Water Evaluation And Planning (WEAP) model, developed by the Stockholm Environment Institute – US Center (SEI-US), was used to evaluate water supply and demand balances under climate change, with and without adaptation strategies. WEAP is an integrated water accounting framework capable of exploring the long-term impacts of user-defined assumptions and scenarios regarding development paths, water demand management strategies, and environmental quality constraints (SEI-US, 2007). Kuwait's water supply and demand system was modeled within WEAP by representing its major elements in a spatial schematic (see Figure 3-16), as briefly described below.

Figure 3-16: Kuwait's water supply/demand system, as modeled in WEAP



- *Water supply:* These elements include rainfall (green circle), groundwater aquifers (green square), desalination plants (green diamond) and wastewater plants (dark red circle).
- *Water demand:* These elements include water demand sectors (light red circles) corresponding to the domestic, agricultural and industrial sectors. Domestic water demand is separated into two municipal sectors for greater resolution.
- *Water transmission:* These elements include links between supply sources and demand sectors (green lines), between rainfall and groundwater (dashed blue line), and between demand sectors and either treatment or the sea (orange lines).

Each element in the WEAP representation was also characterized quantitatively using historical data. For example, desalination plants were represented as a single water supply source having a production capacity equal to the sum of the individual capacities of all plants; annual water consumption was assigned to each demand sector in units of Mm^3.

Calibration and validation

The aim of developing the spatial and quantitative WEAP representation described above was to establish a basis to predict future water supply/demand behavior under climate change. However, in order to ensure that the WEAP representation of the Kuwaiti water supply/demand system would be a valid basis for making projections, a calibration and validation process was carried out. This involved inputting historical data for the 2005-2008 period and using the WEAP representation to project water consumption for the years 2009-2011. The resulting projections were then compared to the actual observed values for these years. After a process of adjustment and iteration concerning various parameters within the model, projected values using the WEAP representation converged on the actual observed values, within an acceptable error bound.

Scenario framework

The calibrated WEAP model was used to estimate future freshwater demand with and without climate change. Using a planning period from 2005 to 2030, two plausible baseline scenarios (i.e., without climate change) for Kuwait were considered, as briefly described in the bullets below.

- *Normal Growth, no climate change:* This scenario assumes an average annual population growth rate of 3.2% per year from 2012 through 2030. This is roughly three quarters of the average annual growth rate during the period 2005-2011. Under this scenario, total population in Kuwait grows from 3.63 million in 2011 to 6.6 million people in 2030. Per capita water consumption levels are assumed to be equal to the historical average.
- *High Growth, no climate change:* This scenario assumes an average annual population growth rate of 4.7% per year from 2012 through 2030. This is slightly greater than the average annual growth rate during the period 2005-2011.Under this scenario, total population in Kuwait grows from 3.63 million in 2011 to 8.7 million people in 2030.Per capita water consumption levels are assumed to be equal to the historical average.

The impact of climate change accounted for the combined effect of population growth and increased per capita water consumption. Two climate change scenarios for Kuwait were considered, as briefly described in the bullets below.

- *Normal Growth, with climate change:* This scenario assumes the normal population growth rate (i.e., 3.2% per year from 2012 through 2030) and per capita water consumption rates increase from 440 liters per capita per day (l/cap/day) in 2005 to 443 l/cap/day in 2030.
- *High Growth, with climate change:* This scenario assumes the high population growth rate (i.e., 4.7% per year from 2012 through 2030) and an increase in per capita water consumption rates from 440 liters per capita per day (l/cap/day) in 2005 to 551 l/cap/day in 2030.

The impact of adaptation measures on domestic water consumption was accounted for the combined effect of population growth and reduced per capita water consumption. Three adaptation scenarios for Kuwait were considered, as briefly described in the bullets below.

- *Water tariffs:* This scenario assumes that a block-tariff system would be implemented to reduce domestic water demand. At monthly household consumption rates up to $36 m^3$, a base water tariff would be in place. For consumption levels between 37 and 55 m^3 per month, the tariff is increased by 56.3% over the base tariff. For consumption levels above

55 m³ per month, the tariff is increased by 87.5% over the base tariff. The tariff levels are assumed to begin in 2012.

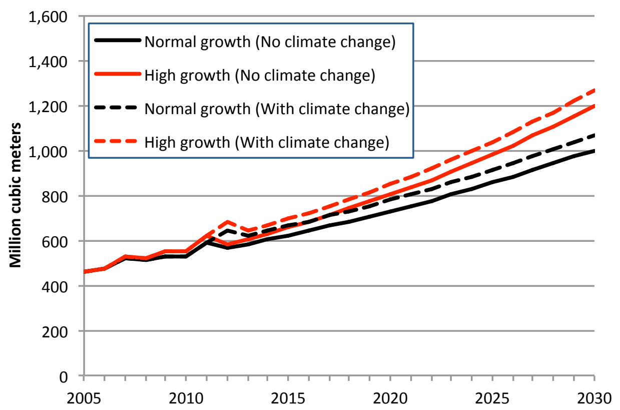
- *Water conservation:* This scenario assumes the widespread penetration of water-saving devices in households and businesses in order to increase the efficiency with which water is used. These devices include low-flow showerheads, faucet aerators, and others. Such devices would not only conserve water, but also reduce utility bills and increase the average home's energy efficiency. The water conservation measures are assumed to be completely installed in all existing and new buildings in 2012.
- *Water tariffs and water conservation:* This scenario assumes that water tariffs and water savings devices are implemented together in 2012.

3.3.3 Impacts of climate change

The calibrated WEAP model was used to estimate the vulnerability of water resources to climate change (see Figure 3-17). The results of the analysis are briefly summarized in the bullets below.

- *Baseline scenarios without climate change:* Total domestic sector water consumption in 2030 reaches 1,000 Mm^3 and 1,200 Mm^3 in the Normal and High Growth scenarios, respectively. These levels show more than a doubling in water consumption relative to 2005 levels.

Figure 3-17: Impact of climate change on domestic water consumption



- *Climate Change scenarios:* Total domestic sector water consumption in 2030 reaches 1,050 Mm^3 and 1,260 Mm^3 in the Normal and High Growth climate change scenarios, respectively. These levels show about a 5% increase in annual water consumption relative to the baseline scenarios.

3.3.4 Adaptation to climate change

In Kuwait, water is considered to be a precious resource that will become even more valuable as the population continues to grow and the climate becomes hotter and potentially drier. In the face of groundwater resources declining in both quantity and quality, and the costs of seawater desalination and treatment continually rising, adaptation to climate change is not merely an option for Kuwait but an imperative.

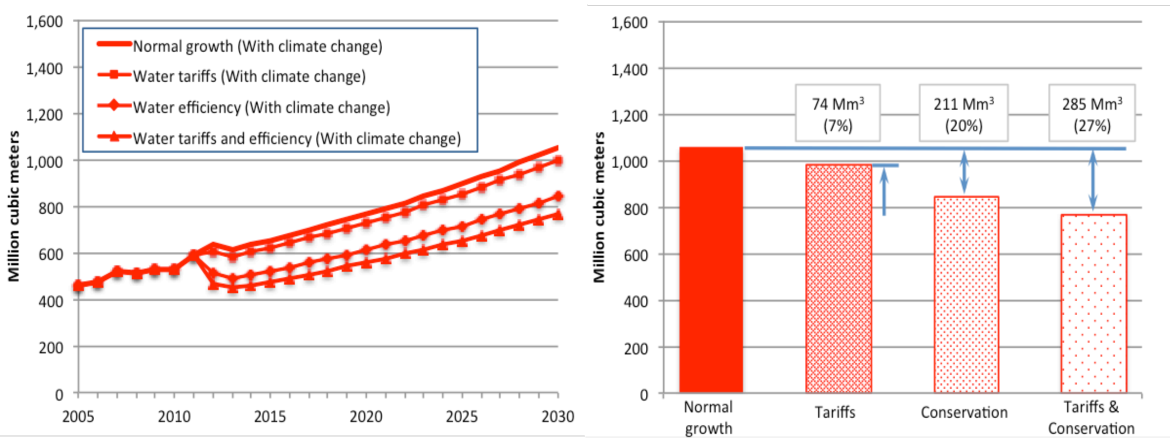
While adaptation to climate change within Kuwait's domestic sector can be expected to occur reactively in response to market signals, there is a clear understanding that it is important for Kuwait to be proactive in the development of the information, skills, infrastructure, and institutions that can increase the country's adaptive capacity. This is true despite Kuwait's current capacity to meet freshwater demand by virtue of its strong economy and financial/energy resources. An adaptation planning framework is needed that can simultaneously promote efficiency, conservation, and sustainability within water resource management practices and Kuwait's national development priorities.

Water consumption implications

In the Normal Growth Scenario, the impact of adaptation measures would be significant (see Figure 3-18), as briefly described in the bullets below.

Figure 3-18: Impact of adaptation measures in the Normal Growth Scenario

a) Overall impact, 2012-2030 **b) Detailed impact, 2030**



- *Water tariffs:* Adaptation in the form of water tariffs would have the effect of lowering domestic sector water consumption by about 74 Mm^3 in 2030 relative to what levels would otherwise be in that year. The reduction is about 7% and would bring water consumption to just below levels without climate change. Per capita consumption would decline from about 438 to about 412 l/cap/day.

- *Water Conservation:* Adaptation in the form of water conservation technologies would have the effect of lowering domestic sector water consumption by about 211 Mm^3 in 2030 relative to what levels would otherwise be in that year. The reduction is about 20% is about three times what can be achieved with tariffs alone. Per capita consumption would decline from about 438 to about 355 l/cap/day.

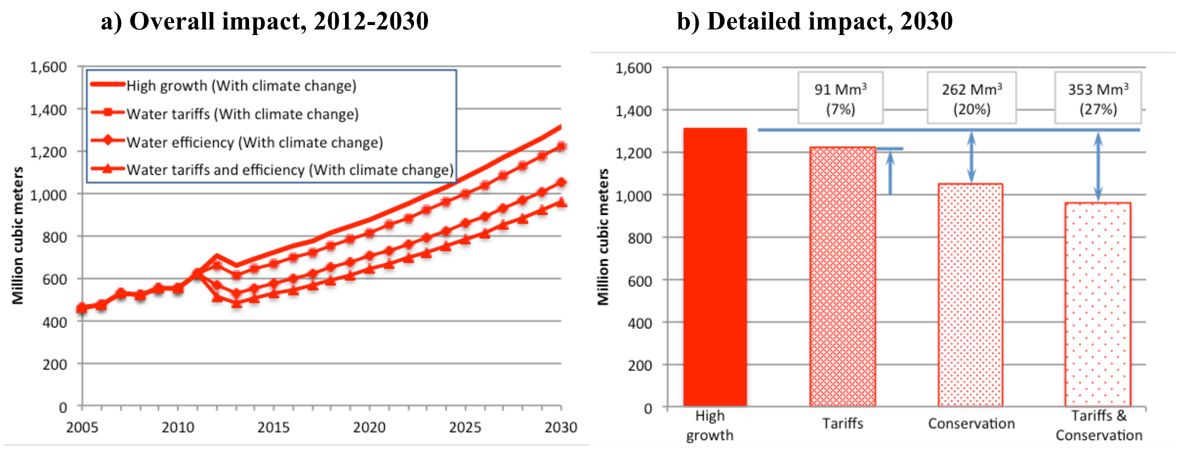
- *Water tariffs and conservation:* Adaptation in the form of combining water tariffs and water conservation technologies would have the effect of lowering domestic sector water consumption by about 285 Mm^3 in 2030 relative to what levels would otherwise be in that year. The reduction of about 27% assumes there are no synergies between pricing- and technology-based adaptation strategies. Per capita consumption would decline from about 438 to about 324 l/cap/day.

In the High Growth Scenario, the impact of adaptation measures would be even more significant (see Figure 3-19), as briefly described in the bullets below.

- *Water tariffs:* Adaptation in the form of water tariffs would have the effect of lowering domestic sector water consumption by about 91 Mm^3 in 2030 relative to what levels would otherwise be in that year, a reduction of about 7%. Per capita consumption would decline from about 551 to about 512 l/cap/day.

- *Water Conservation:* Adaptation in the form of water conservation technologies would have the effect of lowering domestic sector water consumption by about 262 Mm^3 in 2030 relative to what levels would otherwise be in that year. The reduction is about 20% and would bring water consumption to levels to about what they would have been in the

Figure 3-19: Impact of adaptation measures in the High Growth Scenario



Normal Growth Scenario without climate change. Per capita consumption would decline from about 551 to about 441 l/cap/day.

Water tariffs and conservation: Adaptation in the form of combining water tariffs and water conservation technologies would have the effect of lowering domestic sector water consumption by about 353 Mm^3 in 2030 relative to what levels would otherwise be in that year. Per capita consumption would decline from about 551 to about 402 l/cap/day.

Cost implications

The savings in freshwater demand due to the implementation of adaptation strategies would yield significant cost savings. Currently, the average cost to produce 1m^{3}of fresh water is about US$ 2.64 (MEW, 2010). Assuming this price remains constant over the planning period, the cost savings in 2030 would range from US$ 0.20 billion to US$ 0.93 billion, depending on the adaptation scenario (see Table 3-4). Liberating such financial resources could yield sustainable development benefits as these savings are used promote greater resilience to climate change impacts in Kuwait.

Table 3-4: Cost impacts from the implementation of adaptation measures for freshwater consumption in the domestic sector in Kuwait (billion US$)

	Normal Growth Scenario				High Growth Scenario			
Impact	Climate change	Tariffs	Conservation	Tariffs & conservation	Climate change	Tariffs	Conservation	Tariffs & conservation
Costs	2.78	2.58	2.22	2.03	3.45	3.21	2.76	2.52
Savings	**-**	**0.20**	**0.56**	**0.75**	**-**	**0.24**	**0.69**	**0.93**

Greenhouse gas emission implications

The savings in freshwater demand due to the implementation of adaptation strategies would also yield significant greenhouse gas reductions. Depending on the plant, the range in CO_2 emissions from desalination in Kuwait is between 10 and 20 kg for each 1m^{3}of fresh water produced (Sommariva, 2010). Assuming the lower bound in this range, the emission reductions would range from 0.6 million tonnes to 3.5 million tonnes, depending on the adaptation scenario (see Table 3-5). Moreover, there will also be emission reductions from the reduction of treated wastewater.

Table 3-5: CO_2 emission impacts from the implementation of adaptation measures for freshwater consumption in the domestic sector in Kuwait (billion US$)

	Normal Growth Scenario				High Growth Scenario			
Impact	Climate change	Tariffs	Conservation	Tariffs & conservation	Climate change	Tariffs	Conservation	Tariffs & conservation
Emissions	10.6	9.8	8.4	7.7	13.1	12.2	10.5	9.6
Reductions	-	**0.6**	**2.2**	**2.9**	-	**0.9**	**2.6**	**3.5**

3.3.5 Conclusions and recommendations

Developing and maintaining a continuous supply of freshwater is a national security issue in Kuwait given its importance to the country's socioeconomic development plans. Hence, the development of new water management policies that can help Kuwait to become more resilient to climate change should be a high priority. In the near-term, a twofold adaptation planning framework is recommended that focuses on the elements below.

- *Awareness raising:* This involves increasing people's awareness about climate change impacts on water resources and the environment. This could be accomplished via media, newspapers, visiting schools and universities.
- *Institutional support:* This involves ensuring financial and political support for the implementation of adaptation strategies.
- *Capacity strengthening:* This involves the development of a program to raise technical capacity at key institutions. Training workshops would be needed to match the scientific message to participant background, education level, knowledge level, experiences, and role of consumers.
- *Policy development:* This would involve the assembly of information that can be used in the analysis of adaptation policies and incentives.

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4 Greenhouse Gas Mitigation

This chapter provides an overview of potential greenhouse gas emission reductions of a set of priority GHG mitigation opportunities. As a non-Annex I signatory to the UNFCCC, the state of Kuwait is not obliged to take on emission reduction commitments. Nevertheless, an evaluation of key technology options to reduce GHG emissions will provide a better understanding within Kuwait of the potential synergies such options may enjoy with national development goals and priorities. These benefits include, but are not limited to, reduced air pollution levels, enhanced institutional environment for new technologies, diversified power supply, reduced road congestion, and job creation.

4.1 Baseline conditions

The baseline conditions for GHG emissions in Kuwait have been discussed in the GHG inventory (see Chapter 2). The inventory year, 1994, represents the Base Year of the mitigation analysis. The underlying physical characteristics associated with the emission results reported for 1994 are used to establish baseline conditions. Table 4-1 provides the consumption levels in 1994 by fuel type for those fuels associated with combustion.

Table 4-1: Key baseline conditions regarding fuel consumption, 1994

Fuel	Units	Amount
Natural gas	thousand standard cubic feet	116,667
Liquid fuel	thousand barrels	21,981
Gasoline	thousand barrels	11,621
LPG	thousand barrels	820
Diesel	thousand barrels	1,159
Bitumen	thousand barrels	427
Kerosene	thousand barrels	2,570
Lubricants	tonne	61,373

4.2 Methodological approach

A 26-year planning period was chosen for the evaluation of potential GHG mitigation options, 1994 through 2020. While typically a Base Year for the planning would be chosen that is closer to the present day, the use of 1994 as the Base Year was necessary due to the availability of quality-controlled data that emerged from the GHG emission inventory development process.

The focus of the GHG mitigation analysis was the energy sector, both on the energy supply side and energy demand side. The energy sector was selected for analysis because it accounted for the overwhelming majority - nearly 98% - of all GHG emissions in the Base Year (see Figure 2-1). Given the rapid socioeconomic growth rates projected for Kuwait in the coming year, energy use is expected to also grow rapidly and result in increasing levels of GHG emissions under baseline conditions.

Finally, the analysis focused on GHG reductions only. Because of a variety of constraints, the incremental costs associated with achieving the emission reductions were not considered. Since some of the mitigation options, particularly on the demand side, may result in cost savings in addition to GHG reduction – "win-win" options – this aspect of the analysis is a priority for future work.

4.2.1 Scenario framework

Two scenarios were developed as a way of understanding the impacts of mitigation strategies on national GHG emissions. These are briefly described below.

- *Baseline Scenario:* This scenario assumes that past trends will continue in the absence of specific policies to reduce GHG emissions. Under this scenario, total population in Kuwait grows at an average annual rate of 3% per year. Base year energy production and consumption levels are consistent with the GHG inventory. Future levels of energy production and consumption are assumed to grow consistent with recent past trends.
- *Mitigation Scenario:* This scenario assumes that a priority set of GHG mitigation options are implemented during the planning period. Target levels for the penetration of mitigation technologies are set relative to their technical feasibility in the Kuwaiti context and are independent of any emission reduction targets.

4.2.2 Modelling framework and key assumptions

The Long-range Energy Alternatives Planning (LEAP) model, developed by the Stockholm Environment Institute – US Center (SEI-US), was used to evaluate GHG mitigation strategies. LEAP is an integrated energy accounting framework capable of exploring the long-range implications of user-defined assumptions and scenarios regarding development paths, energy demand management strategies, electric capacity expansion and environmental quality constraints (SEI-US, 2006). Kuwait's energy supply and demand system was modeled within LEAP by characterizing its major elements and key assumptions, as briefly described in the subsections below.

Energy demand

Energy demand refers to consumption within end use sectors (i.e., transport, industrial, agricultural, domestic, and commercial). Energy demand was disaggregated based on fuel type consumed. In Kuwait, the only energy sources consumed are electricity, gasoline, residual fuel oil, LPG, gas/diesel oil, bitumen, kerosene, and lubricants. Given the lack of data, fuel consumption could not be further disaggregated by sector. Key assumptions regarding future demand and emission factors for each fuel is summarized in Table 4-2.

Table 4-2: Key energy demand assumptions for the GHG mitigation analysis, 1994-2020

Parameter		Units	Natural gas	Liquid fuels	Gasoline	LPG	Diesel	Kerosene	Lubricants	Electricity
Growth, 1994-2020		%/year	7.8%	2.6%	4.1%	3.8%	9.9%	5.3%	2.5%	7.0%
GHG emission factor	CO_2	tonne/TJ	55.78	76.5	68.56	17.2	73.28	70.736	36.275	NA
	CH_4	kg/GJ	0.1 - 6	0.9	0.012	0.001	0.004	0.002	2	NA
	N_2O	kg/GJ	<0.001	0.3	0.003	0.003	0.002	0	0.6	NA
Pollutant emission factor	NO_x	kg/GJ	190-250	73.9	0.222	0.148	0.677	0.29	200	NA
	CO	kg/GJ	18-46	15	4.833	0.326	0.319	0.12	10	NA
	NMVOC	kg/GJ	0	0	0.932	0.410	0.107	0.018	5	NA
	SO2	kg/GJ	<0.001	512.8	0.0	0.0	0.0	0.0	0.0	NA

Energy transformation

Energy transformation refers to the various stages in the fuel cycle from extraction to delivery to end-users. Transformation accounts for how energy is converted into alternative forms, for example, crude oil into refined oil products or natural gas combustion for electricity generation. The energy transformation process was sorted into four distinct stages, namely oil/gas extraction, oil refining and petrochemical production, electricity and desalinated water generation, and fuel distribution to the consumer. In Kuwait, oil and gas activities dominate energy transformation. The oil/gas extraction stage is particularly noteworthy due to the high levels of fugitive emissions associated with these activities. Key assumptions regarding Base Year extraction levels of crude oil and natural gas, corresponding fugitive emission factors, and projected average annual growth rates up through 2020 are summarized in Table 4-3.

Table 4-3: Key energy transformation assumptions for the GHG mitigation analysis, 1994-2020

				GHG emission factor				Pollutant emission factor			
	Extraction characteristics			CO_2e	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO2
Fuel	Quantity in 1994	Units	Growth, 1994-2020	kg/bbl	kg/GJ	kg/GJ	kg/GJ	g/GJ	g/GJ	g/GJ	g/GJ
Crude oil	732,411	thousand bbl	1.9%/yr	7	NA	NA	NA	NA	NA	NA	NA
Natural gas	371,669	thousand ft^3	1.5%/yr	NA	1.6	20	0	4.1	1	11	2

Non-energy activities

In order to be able to provide a comprehensive accounting of all productive activities that contribute to national GHG emissions, LEAP also includes a non-energy category. Non-energy activities refer industrial processes, land use change and forestry, agriculture, and waste management. Due to data unavailability, only cement production, solid waste and wastewater were integrated in the LEAP model for Kuwait. Key assumptions regarding Base Year activity levels, their corresponding fugitive emission factors for GHGs and air pollutants (CO_2, CH_4, and SO_2 available only), and projected average annual growth rates up through 2020 are summarized in Table 4-4.

Table 4-4: Key non-energy transformation assumptions for the GHG mitigation analysis, 1994-2020

			Available emission factors		
	Production		CO_2	CH_4	SO2
Activity	Quantity in 1994 (million tonnes)	Growth, 1994-2020	Kg per tonne	Kg per cap	Kg per tonne
Cement production	1.5	4.0%/yr	0.4985	NA	0.3
Wastewater treatment	590	6.7%/yr	0.87	NA	NA
Solid waste disposal	480	6.2%/yr	NA	5.5	NA

4.3 Baseline Scenario GHG emissions

The assumptions discussed above regarding energy use, growth rates, non-energy activity levels, and emission factors were used to develop an estimate of GHG emissions for the Baseline Scenario. Figure 4-1 provides a comparison of GHG emissions developed in the GHG inventory discussed in Chapter 2 and GHG emissions developed by use of the LEAP modeling framework.

As can be seen in the Figure, the modeling framework is well calibrated to inventory results. The total level of CO_2e emissions using LEAP is 36,932 Gg, which is about 14% more than the 32,373 Gg estimated in the GHG inventory. For the purposes of the GHG mitigation analysis, this deviation was considered acceptable.

Figure 4-1: Comparison of GHG inventory and GHG mitigation results for the Base Year, 1994

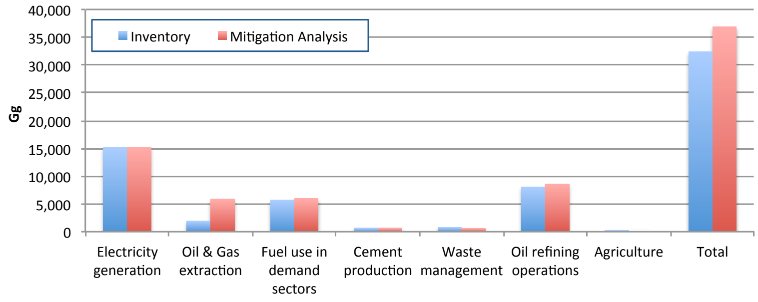
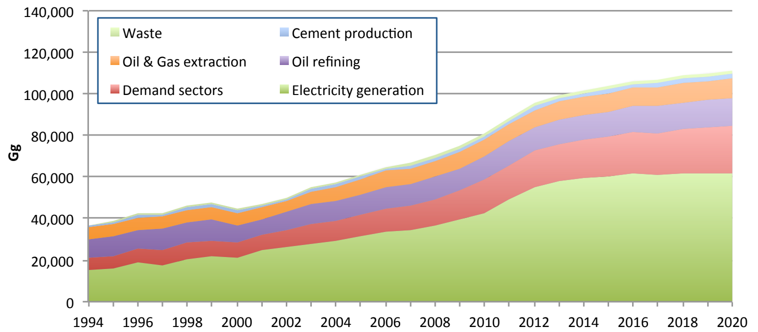


Figure 4-2 provides a projection of GHG emissions up through 2020. Overall, CO_2e emissions increase from 36,932 Gg in 1994 to 111,011 Gg in 2020. This corresponds to an average annual growth rate of about 4.3% per year, about 1% per year greater than assumed population growth.

Figure 4-2: Baseline Scenario CO_2e emissions in Kuwait, 1994-2020



The largest component of the GHG emission profile throughout the planning period corresponds to electricity generation, which grows from 41% of total CO_2e emissions in 1994 to 56% of total CO_2e emissions in 2020. On the other hand, the share of emissions from oil and gas extraction and oil refining operation decrease substantially over the planning period, from 16% to 8% for oil and gas extraction, from 23% to 12% for oil refining operations.

4.4 GHG mitigation options

A separate project by the Kuwait Environment Public Authority (KEPA) was the basis for the selection of priority GHG mitigation strategies for analysis. This project, involving the World Bank, identified potential short-term activities for the Clean Development Mechanism (CDM) and developed a National Strategy and Action Plan for GHG mitigation over the longer term. Some of the members of the GHG mitigation team participated in the KEPA project and provided a link to key data and assumptions.

4.4.1 Potential GHG mitigation options

Major GHG mitigation options identified by the KEPA project as technically feasible in Kuwait are summarized in the bullets below.

- *Electricity and desalinated water generation:* Electricity generation for retail electricity use and desalination accounted for nearly 60% of national GHG emissions in 2012. In part, this is due to a large share of liquid fuel for power generation, roughly 80% in that year, although this share declines to less than 20% by 2020 in the Baseline Scenario. Potential mitigation options include improvement of combustion efficiency at existing plants, fuel switching from liquid fuel to natural gas, development of wind and solar power plants, and carbon capture at existing/new power plants and storage in long-term reservoirs.

- *Oil and gas production:* Oil and gas operations accounted for about 16% of national GHG emissions in 1994. Potential mitigation options include gas recovery and utilization through reduced flaring, leakage reduction in natural gas transmission and storage, and carbon capture and storage through enhanced oil recovery.
- *Transport:* Emissions from cars, buses, and trucks accounted for a substantial portion of the 16% of the demand sector's 16% of national GHG emissions in 1994. With high projected growth rates in car ownership and limited public transport options, potential mitigation options include fuel efficiency improvements for light duty vehicles, use of alternative fuels (e.g., compressed natural gas), introduction of travel demand management systems (e.g., advanced traffic management systems, smart growth land use planning).
- *Buildings:* Emissions from residential and commercial buildings accounted for the remaining portion of the demand sector's 16% of national GHG emissions in 1994. With high projected space cooling requirements using electricity and most existing buildings not compliant with building codes, potential mitigation options include strengthening/ enforcing building energy codes, as well as adopting appliance efficiency standards.
- *Waste management:* Emissions from water management accounted for about 2% of national GHG emissions in 1994. Potential mitigation options include landfill gas capture and use at MSW sites, solid waste separation and recycling, and biogas capture and use at wastewater treatment plants, and increased use of treated sewage effluent for agriculture.

4.4.2 Priority GHG mitigation options

Selection criteria were applied to the above options in order to develop a subset of priority GHG mitigation strategies for analysis. This was necessary due to data and other resource constraints. Specifically, four criteria were considered: sectoral contribution to national GHG emissions, near-term potential for implementation, ease of implementation and the magnitude of potential reductions. Given the prominence of electricity generation emissions in national totals, this sector was selected as the highest priority sector. Within this sector, four specific mitigation options were evaluated, as briefly described in the bullets below.

- *District Cooling:* A comprehensive feasibility study for the National Housing Authority (NHA) and MEW showed that the use of a district cooling system for residential buildings in sectors A5 and B of Jaber Al-Ahmad City could reduce peak power demand by nearly 30 MW and electricity consumption by about 80 GWh per year compared to conventional space cooling system (Sebzali et al., 2008). Another study by the MEW estimated that peak power demand could be reduced by about 1,360 MW by a district cooling system installed in the cities of Sabah Al-Ahmad, Al-Khiran, and Mutlaa (Marafi, 2012). These installations were represented within the LEAP modeling framework as coming online over the period 2014-2018, with annual electricity reductions reaching 4,000 GWh by 2018.
- *Green buildings:* Making Kuwaiti buildings more energy efficient is the focus of many research projects funded by MEW and undertaken by KISR. Residential buildings account for about 64% of total electrical energy consumption in Kuwait (Hajiah, 2006). Energy audit studies conducted by KISR in the Kuwait Port Authority building and in KISR's main building (Maheshwari, 1997) showed that simple energy-efficient operation and maintenance strategies were able to achieve between 21% and 25% reduction in annual electricity consumption (Al-Ragom, *et al.*, 2002; Al-Ragom, 2002). Another study in Kuwait reported a 12% reduction through the implementation of energy auditing

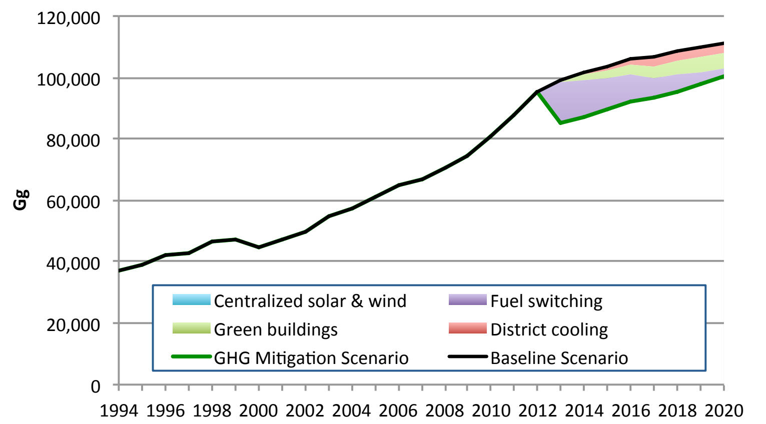
measures (Hadban, *et al*., 2010). The results of these studies were represented within the LEAP modeling framework as the implementation of energy audit requirements stating in 2012. It was assumed this strategy would lead to a gradual improvement in building thermal performance, reducing electricity consumption building by 10% by 2020.

- *Fuel switching:* This option involves fuel switching from liquid fuels to natural gas in all power plants starting in 2013. The combination of recently discovered natural gas reservoirs in Kuwait and regional imports are adequate to satisfy additional natural gas requirements. Combustion efficiencies in the natural gas-fired repowered stations are assumed to be the same as for the existing liquid fuel-fired stations.
- *Solar and wind power development:* Renewable energy is a topic of increasing importance in Kuwait. This option involves the installation of wind turbines and solar photovoltaic farms for power generation. It was assumed that the first installations would be operational by 2015 and be capable of displacing 2% of national electricity consumption. Moreover, the renewable share of generation is projected to reach 5% and 10% in 2018 and 2020, respectively.

4.5 Impact of GHG mitigation strategies

The introduction of priority GHG mitigation options in Kuwait would lead to significant reductions in CO_2e emissions by 2020 (see Figure 4-3). A total of 10,284 Gg of CO_2e would be avoided in 2020, roughly equivalent to 10% of the Baseline GHG levels in that year.

Figure 4-3: Impact of GHG mitigation options, 1994-2020



In the early part of the implementation period, most of the reductions are from fuel switching in the power sector. These reductions gradually decline over time due to the gradual displacement of liquid fuels by natural gas in the Baseline Scenario. By 2020, reductions from the Green Buildings and District Cooling options reach 5,300 Gg and 3,100 Gg, respectively. By comparison, CO_2e reductions from the last GHG mitigation option, centralized solar photovoltaic and wind farms, are negligible, reaching only about 5 Gg by 2020.

4.6 Conclusions and recommendations

The strategies described in this chapter are part of a visioning process for the manner in which long-term energy development could proceed in Kuwait. Such a process is important for getting a better understanding of ways to harmonize Kuwait's voluntary commitment to mitigate its GHG emission with the unique needs of a developing, oil-dependent economy. Kuwait should build its mitigation assessment capacities especially those related to human resources. Additionally, in order to improve the quality of mitigation assessment, there is an urgent need to develop a national database for monitoring and reporting information related to GHG emissions and mitigation projects. In the next and final chapter of this

Communication, an overview is provided about some of the additional steps being taken to implement the Framework Convention in Kuwait.

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5 Technology Needs Assessment

This chapter provides an overview of a technology needs assessment for climate change. Both mitigation and adaptation technologies were considered. The technologies considered encompass “hard” technologies, such as equipment and infrastructure, as well as “soft” technologies, such as management practices and institutional arrangements.

5.1 Methodology

UNDP’s Technology Needs Assessment (TNA) methodology was used to develop an understanding of the range of technology options that could be harnessed to address the challenge of climate change in Kuwait (UNDP, 2010). The TNA methodology essentially involved the development of a set of multi-criteria evaluation matrices for potential technologies to either reduce future GHG emissions or reduce Kuwait’s vulnerability to the impacts of climate change.

Key technologies were identified through a series of local stakeholder consultations. Stakeholders included individuals from the Kuwait Foundation for the Advancement of Sciences (KFAS), the Kuwait Institute for Scientific Research (KISR), local universities, the Kuwait Environmental Public Authority (EPA), the Ministry of Electricity and Water (MEW), and relevant professional societies. These stakeholders participated actively in every stage of the TNA process.

Technologies that were identified during initial stakeholder consultations were then assessed in a collaborative fashion among stakeholders relative to a set of four (4) evaluation criteria. Each technology was evaluated qualitatively relative to each criterion and assigned a score of either high, medium, or low. Brief descriptions of the criteria are provided in the bullets below.

- *Potential for GHG mitigation or building adaptive capacity:* For mitigation technologies, this involved an assessment of the potential magnitude of the GHG reductions that could be achieved in Kuwait in the near- to mid-term. For adaptation technologies, this involved an assessment of the increased resilience to known adverse climate change impacts.
- *Resources available in Kuwait:* This involved an assessment of the ease with which the technology could be implemented in Kuwait. Specifically, the current availability of a critical set of technology-related resources - financial, institutional, and infrastructural - were considered.
- *Cost-benefit ratio:* This involved an assessment of the performance of the technology in terms of its costs (i.e., capital investment, operation and maintenance costs) relative to the potential benefits (i.e., emission reductions, reduced impacts) achieved.
- *Contribution to Kuwait development priorities:* This involved an evaluation of the extent to which the technology was consistent with national development objectives and constraints.

5.2 Mitigation technology assessment

Due to the prominence of energy production and consumption in Kuwait’s GHG emission profile, the focus of the TNA was exclusively on the energy sector. Specifically, technologies for electricity generation, as well as technologies that can reduce residential building energy consumption were targeted. An overview of the results of the assessment is provided in the subsections below.

5.2.1 Advanced fossil technologies for electricity generation

Advanced fossil technologies for electricity generation refer to options that have either higher operating efficiencies or lead to sharply lower GHG emissions when compared to current technologies in use in Kuwait. Some of these technologies are already in limited use in Kuwait. Examples include high efficiency natural gas combined cycle units and district cooling. Others have yet to be introduced and represent potentially significant contributors for achieving future GHG emission reductions. A brief overview of these priority technologies is provided in the bullets below. Table 5-1 summarizes the results of the evaluation of these technologies.

- *Carbon capture and storage (CCS):* This technology prevents up to 90% of CO_2emissions associated with power generation from being released into the atmosphere. CCS separates CO_2 emissions from the process and transports compressed CO_2 to secure geological storage locations, such as Kuwait's abandoned oil fields and deep saline formations. Several methods are becoming commercially available: post-combustion, pre-combustion, and oxy-fuel combustion, each offering different strengths and weaknesses, depending on the nature of the investment.
- *Natural gas combined cycle (NGCC):* This technology is able to operate more efficiently by harnessing the large amount of heat emitted by a primary gas turbine for generating steam in a second turbine. Whereas a well-maintained conventional steam plant typically achieves combustion efficiency between 30% and 33%, advanced NGCC units can achieve combustion efficiencies equal to about 45%.
- *District cooling:* This technology uses the thermal energy from electricity generation, which would otherwise be wasted, to drive absorption chillers for air conditioning. In Kuwait's urban landscape, district cooling can be developed in new neighborhoods, providing a more efficient central cooling plant, rather than inefficient air conditioning units that contribute to stress on the electricity transmission and distribution infrastructure.
- *Fuel switching:* This refers to switching from high-emitting liquid fuels such as residual oil or diesel to natural gas. Fuel switching from oil to gas can reduce CO_2 emissions by 10-30% an input basis. This technology is suitable for Kuwait because a large portion of the world's gas reserves is located in nearby countries in the Arabian Gulf region, despite the fact that Kuwait's own natural gas reserves are minimal.
- *Low-sulfur oil refining:* This technology refers to the production of low-sulfur fuels at Kuwaiti refineries. Two initiatives for implementing such technology are already underway in Kuwait, the Clean Fuels Project (CFP) and New Refinery Project (NRP). The use of low-sulfur fuels results in lower SO2 emissions, which are an indirect greenhouse gas that is included in the national GHG inventory.

Table 5-1: Mitigation technology evaluation valuation results for advanced fossil technologies for electricity generation

Technology	Mitigation Potential	Resources Available in Kuwait	Cost Benefit	Contribution to development priorities	Currently Implemented (or in process)
Carbon Capture and Storage	High	High	Medium	High	No
Combined Cycle Gas Turbines	Medium	Low	Medium	Medium	Yes
District Cooling	Medium	Medium	High	High	Yes
Natural Gas fuel switching	Low	Low	Low	Medium	Yes
Reduced Sulfur Oil Refineries	Low	High	Medium	High	Yes

5.2.2 Renewable technologies for electricity generation

Renewable technologies for electricity generation refer to options that rely on non-emitting energy resources such as solar and wind. While renewable technologies are not currently in use in Kuwait, the Public Authority for Applied Sciences and Training (PAAST) has plans to construct the country's first solar power station by the end of 2013. Several renewable technologies represent potential opportunities for ready integration in the energy system of Kuwait. A brief overview of these priority technologies is provided in the bullets below. Table 5-2 summarizes the results of the evaluation of these technologies.

- *Centralized solar photovoltaic (PV):* This technology involves the large-scale use of photovoltaic panels that use the sun's rays to induce a difference in charge, or voltage, across two materials and thereby produce an electric current. Mirrors may be used to concentrate sunlight onto a solar cell and tracking —both single and double axis — devices may be installed to maximize a direct line as the sun moves across the horizon. Since Kuwait's daily electricity peaks are coincident with the solar energy profile, centralized solar power is potentially highly viable.
- *Building-integrated PV systems (BIPV):* This technology involves the small-scale use of photovoltaic panels within parts of a building's envelope such as its roof or facades.
- *Solar thermal:* This technology encompasses a range of small- and large-scale options that harness solar thermal energy for domestic water heating.
- *Solar ponds:* This technology uses temperature gradients within pools of salt water to collect thermal energy. The salinity gradient causes a density gradient that traps warmer water near the bottom layer. This technology was first considered in Kuwait in the later 1980s.
- Wind energy: This technology harnesses the wind kinetic energy into electrical power. The primary requirement for feasibility of this technology is available wind resources. A site is considered economically feasible with wind velocities of 5.6 m/s at an altitude of 10 meters—also known as class 3 wind speeds. Initial studies show that annual average wind speed in Kuwait is only 5.5 m/s—just below the class 3 wind speed limit for economic feasibility (Al-Nassar 2005).

Table 5-2:Mitigation technology evaluation valuation results for renewable technologies for electricity generation

Technology	Mitigation Potential	Resources Available in Kuwait	Cost Benefit	Contribution to development priorities	Currently Implemented (or in process)
Centralized Solar PV	High	High	High	High	Yes
Building-integrated PV	High	High	High	High	No
Solar Thermal Energy	Medium	High	High	High	Yes
Solar Ponds	High	Medium	Medium	High	Yes
Wind Energy	High	Low	Low	High	No

5.2.3 Residential building technologies to reduce electricity consumption

Technologies to reduce electricity consumption in residential buildings refer to a range of options that improve building performance from an energy perspective. Building performance is dependent on several factors including envelope design and materials; heating, cooling, ventilation and lighting systems; occupancy density, site topography, and behavior of the building's inhabitants. Some energy efficiency and conservation measures are already being implemented in Kuwait to minimize electricity consumption. Other measures represent new and potentially viable opportunities for improving residential building performance in Kuwait. A brief overview of these priority technologies is provided in the bullets below. Table 5-3 summarizes the results of the evaluation of these technologies.

- *Advanced controls:* This technology involves the installation of advanced control systems to reduce solar heat gain in buildings. These systems operate by sensing direct sunlight through building windows. When the daylight intensity reaches some pre-set threshold, daylighting controls are triggered that automatically dim lights or close window shades. When combined with occupancy sensors that automatically manage cooling needs, the efficiency and functionality of living spaces can be enhanced, resulting in significant electricity savings. High performance buildings are often characterized by advanced control systems such as these.
- *Building rating systems:* This technology involves the development of a system that can provide a meaningful metric for measuring the energy performance of residential buildings. Such a system can provide an objective signal to commercial architects, designers, and builders regarding what constitutes a "high performing" building from an energy perspective. Two examples from the Gulf region, the Pearl Rating System in the Abu Dhabi emirate's *Estidama* (sustainability in Arabic) program and the residential component of Qatar's Sustainability Assessment System (QSAS) may be helpful in informing the development of a rating system for Kuwait.
- *Building codes:* From a policy perspective, standards and codes are often used as a means of regulating and promoting energy-efficient building design and construction. These codes generally regulate wall and roof insulation, window glazing, ventilation, cooling efficiencies, cooling refrigerants and lighting. In Kuwait, the Energy Conservation Code of Practice (R-6), developed in 1983, sets minimum requirements for efficient energy use in new and retrofitted residential buildings. Efforts are underway since 2009 to update the code to energy conservation codes developed by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE 90.2).
- *Incentives for renewable:* Incentives may be used to shift behavioral trends among consumers, driven by the prospects of cost savings. Incentives for renewable energy would encourage investment in the use of solar energy for distributed household-scale energy production and domestic hot water heating. Such incentives are currently not in place in Kuwait.
- *Reduced subsidies:* Tariffs may also be used to affect consumer behavior. For example, retail electricity prices that reflect the total costs of electricity (i.e., production, transmission, distribution, and non-price factors) would encourage more electricity conservation. In Kuwait, residents are charged the lowest electricity rate in the world, at US$ 0.007per kWh, which is only 5% of the actual cost of electivity in Kuwait. Notably, this price has not changed since 1962 (Krane 2012).
- *Awareness campaigns:* Since people tend to take energy for granted, many are unaware of opportunities to reduce energy use. Some may claim to favor energy efficiency, but are unclear regarding the changes involved in behavior. In Kuwait, the *Tarsheed* awareness campaign was implemented following the electricity crisis of 2006. The campaign, with a budget of nearly US$ 36 million Kuwaiti Dinars, uses billboards, newspapers, television, airport public announcements to urge consumers to shift power demand away from afternoon peak periods. As a specific example, the campaign encourages residents to do laundry during the evening hours when lower air conditioning requirements prevail.

Table 5-3: Mitigation technology evaluation results for residential building performance

Technology	Mitigation Potential	Resources Available in Kuwait	Cost Benefit	Contribution to development priorities	Currently Implemented (or in process)
Advanced Controls	High	Medium	High	High	Yes
Building Rating System	Medium	Medium	High	High	No
Building Codes	High	Medium	Medium	High	Yes
Incentives for Renewable	Medium	High	Medium	Medium	No
Reduced Subsidies	Medium	High	High	High	No
Awareness Campaigns	Medium	Medium	High	Medium	Yes

5.3 Adaptation technology assessment

Three sectors that are considered highly vulnerable to climate change impacts were the focus of the adaptation technology assessment, coastal zones, water resources, and public health. An overview of the results of the assessment is provided in the subsections below.

5.3.1 Coastal zones

As discussed in Chapter 3, the majority of Kuwait's population resides and works in close proximity to the coastline, rendering the population and infrastructure susceptible to the impacts associated with climate change-induced sea level rise. With the buildup of chalet vacation homes along the coast and other infrastructure investments, the protection of coastal zones is increasing as a national priority.

Technologies for Kuwait's coastal zones refer to a range of options that can to reduce the vulnerability of people and infrastructure from the adverse impacts of rising seas. Some measures are already being implemented in Kuwait to address coastal erosion. Other measures represent new and potentially effective responses to future inundation and erosion threats. A brief overview of these priority technologies is provided in the bullets below. Table 5-4 summarizes the results of the evaluation of these technologies.

- *Coastal information systems:* This refers to information management regarding key features of the coastal zone, such as high-resolution land elevations and sea levels based on tide gauge data. In Kuwait, a Coastal Information System (CIS) has been developed based on hydrodynamic models to predict wave height and period from wind data for Kuwait's territorial waters. This information translates into water level and current statistics as well. These forecasts are accessible on the internet through a graphical user interface at http://www.hceatkuwait.net/ (Al-Salem 2008).
- *Tidal barriers:* This technology involves the construction of "hard" coastal protection structures. These include seawalls, levees, floodbanks, stopbanks, and embankments. Each functions essentially as a barrier against the sea level at the maximum high tide level.
- *Setbacks:* This refers to establishing a rigorous definition of what constitutes "buildable land", i.e., land that is located a safe distance inland from coastal inundation zones. Construction within the zones at risk from future sea level rise would not be permitted. These setbacks can be established relative to either elevation or lateral distance from the coast.
- *Prediction/prevention Center:* This refers to the establishment of a Center in Kuwait to develop the systems, protocols, and models to address the impacts of climate change on coastal zones. The focus of such as Center would be to systematically develop the

technical capacity to predict the assorted impacts of sea level rise on the coastal and marine environments, as well as to develop management plans to cope with coastal threats and disasters.

- *Awareness campaigns:* This refers to the development of programs to increase the understanding of coastal developers, builders, and the public at large regarding the emerging threats from sea level rise.

Table 5-4: Adaptation technology evaluation results for coastal zones

Technology	Adaptation Potential	Resources Available in Kuwait	Cost Benefit	Contribution to development priorities	Currently Implemented (or in process)
Coastal Information System	Medium	Medium	Medium	Medium	Yes
Tidal Barriers	Medium	Medium	Medium	Medium	Yes
Setbacks	High	High	High	Medium	No
Prediction/ Prevention Center	High	Medium	High	Medium	Yes
Awareness Campaigns	Medium	Medium	High	Medium	Yes

5.3.2 Water resources

As discussed in Chapter 3, the challenge to effectively manage Kuwait's already scarce water resources will likely intensify under climate change. Kuwait's dry, hyper-arid climate places great stress on the scarce freshwater resources available, while desalinated water is both costly and a source of greenhouse gas emissions.

Technologies to manage Kuwait's water resources refer to a range of options that can either increase water supply or increase the efficiency with which water is consumed. Some measures are already being implemented in Kuwait to address water supply and demand. Other measures represent new and innovative responses to water balance constraints. A brief overview of these priority technologies is provided in the bullets below. Table 5-5 summarizes the results of the evaluation of these technologies.

- *Water resources program:* This refers to information management regarding key features of the coastal zone, such as high-resolution land elevations and sea levels based on tide gauge data. In Kuwait, a Coastal Information System (CIS) has been developed based on hydrodynamic models to predict wave height and period from wind data for Kuwait's territorial waters. This information translates into water level and current statistics as well. These forecasts are accessible on the internet through a graphical user interface at http://www.hceatkuwait.net/ (Al-Salem, *et al.,* 2008).

- *Water pricing:* This refers to water pricing strategies that can affect consumer behavior. For example, water prices that reflect total costs of extraction/production would encourage more water conservation. In Kuwait, one study predicted a 33% reduction in water from a water pricing strategy that included a free daily allowance of 150 liters per capita, followed by a constant rate of $1 per additional thousand liters of water (Milutinovic, 2006).

- *Reverse osmosis desalination:* This technology involves using semi-permeable membranes and pressure to separate water from salt. Compared to other types of desalination technology, reverse osmosis has sharply reduced energy requirements. While the use of solar photovoltaic panels could further reduce fossil fuel needs, some supplementary fuels or thermal storage systems would be necessary to account for the intermittent nature of solar power (Darwish, 2011).

- *Multi-stage flash desalination:* This technology is the most commonly used in the Arabian Gulf region for desalination. It involves the use of countercurrent heat exchangers to flash evaporate water into steam and collects the resulting condensation.
- *Building retrofits:* This refers to the installation of water-efficient devices in residential buildings. This is particularly important for Kuwait as the residential sector generates the greatest demand for freshwater. Examples of retrofits include new plumbing fixtures, new or tightened seals, water-efficient appliances such as dishwashers and washing machines, and upgrades to HVAC systems. Devices can be installed to measure water consumption and make the consumer more aware of their consumption.
- *Irrigation water use efficiency:* This refers to several types of technology to reduce water demand such as bio-diverse plantings, hydrozoning, and smart-irrigation controls. Bio-diverse plantings refer to the selection of particular plants for irrigation that account for Kuwait's harsh climate and biodiversity conditions. Hydrozoning refers to the process of segregating plants based on their water needs to prevent unnecessary or excessive irrigation. Smart irrigation control refers to systems that can sense weather conditions and irrigate plants to maximize efficient water use.
- *Awareness campaigns:* This refers to the development of programs to increase the understanding of the public at large regarding the emerging threats from climate change on Kuwait's precious water resources.

Table 5-5: Adaptation technology evaluation results for water resources

Technology	Adaptation Potential	Resources Available in Kuwait	Cost Benefit	Contribution to development priorities	Currently Implemented (or in process)
Water Resources Program	High	High	Medium	High	Yes
Water Pricing	High	High	High	High	No
Reverse Osmosis Desalination	High	Low	High	Medium	No
Multi-Stage Flash Desalination	High	High	Medium	Medium	Yes
Building Retrofits	Medium	Medium	Medium	High	Yes
Irrigation Water Use Efficiency	High	High	Medium	High	Yes

5.3.3 Public health

Climate change is expected to exacerbate public health primarily through the impacts on air quality. Under the increased temperatures associated with climate change, it is possible that dust storm frequency and intensity could increase, as well as concentrations of ozone emissions of volatile organic compounds and nitrogen oxides in the presence of sunlight and increasing temperatures.

Technologies to build resilience against climate change impacts on public health in Kuwait refer to a range of options that can monitor or reduce environmental loadings that lead to indoor/outdoor air pollution that can contribute to respiratory diseases. Some measures are already being implemented in Kuwait to monitor air pollution. Other measures represent new and innovative responses to public health threats. A brief overview of these priority technologies is provided in the bullets below. Table 5-6 summarizes the results of the evaluation of these technologies.

- *Air quality monitoring:* This technology refers to the development of an enhanced air quality information and monitoring infrastructure to cope with the additional threats to public health from climate change. Currently in Kuwait, the Kuwait Institute for Scientific Research an air monitoring station which can measure NOx, CO, CO_2, H_2S,

SO_2, O_3, CH_4 and non-methane hydrocarbon concentrations at various sites (Khan 2008). The government operates and maintains an additional 13 air quality stations to monitor concentrations of SO_2, NO_2, CO, ground-level ozone (O_3), and particulate matter less than 10 microns in diameter (PM_{10}).

- *Vegetation:* This refers to the role that drought-resistant vegetation can play in controlling and reducing dust fallout from dust storms and land degradation. In Kuwait, one study showed that vegetation decreases dust fallout by at least two-thirds in densely vegetated areas. Terrestrial vegetation options include *Nitrariaretusa*, a large plant particularly appropriate for areas like Kadhma and Al-Mutla northwest of Kuwait City. Other options include the expansion of conservation land to include major sources of dust, muddy playas, and muddy tidal flats; green belts in the open desert to reduce high wind speeds; and cultivating marshes with salt-tolerant vegetation, like mangroves, to reduce amounts of airborne salt in the winter. (Al-Dousari 2006).
- *Awareness campaigns:* This refers to the development of programs to increase the understanding of the public regarding measures that can reduce dust levels, such as environmentally friendly camping practices.

Table 5-6: Adaptation technology evaluation results for water resources

Technology	Adaptation Potential	Resources Available in Kuwait	Cost Benefit	Contribution to development priorities	Currently Implemented (or in process)
Air Quality Monitoring	Medium	Medium	Medium	Medium	Yes
Vegetation	High	High	Medium	High	No
Awareness Campaigns	Medium	Medium	High	Medium	Yes

5.4 Barriers to technology transfer

The priority technologies discussed above for mitigation and adaptation face a number of barriers for widespread adoption in Kuwait. Two particular barriers to technology transfer/adoption – existing technology policymaking/regulatory environments and location-specific constraints - have been identified during the TNA process as requiring urgent attention. An overview of these key barriers is provided in the bullets below.

- *Policymaking and regulatory environment:* In Kuwait, policymaking and regulatory practices can often slow down necessary action for GHG mitigation. For example, policymaking related to electricity rate subsidies does not adequately account the extent to which these subsidies can thwart other important national development priorities. High electricity subsidies results in a situation where demand-side energy-efficient technologies, typically among the most cost effective of all GHG mitigation options, are too costly when compared to very low retail electricity prices.
- *Location-specific conditions:* Kuwait's hyper-arid desert climate presents a major barrier to many hard technologies that could be used for climate change adaptation. Both temperature, which can exceed 50°C in summer, and frequent dust storms, common between March and August, can have serious adverse effects on some of the technologies discussed in previous sections. Effective technology transfer requires maintenance and hygiene requirements that result from dust and sand accumulation. Additionally, the sudden cloudbursts that are common from October to April bring excessive amounts of rain capable of damaging key infrastructure.

5.5 Conclusions and recommendations

It will be important to overcome the barriers identified above in order to develop an enabling framework in Kuwait for technology transfer and local technological innovation. The Several key recommendations emerged from the TNA process to promoter an enabling environment, as briefly summarized in the bullets below.

- *Engage key stakeholders in government and the private sector:* Stakeholder engagement and collaboration through existing and new networks should be promoted. Such links, especially partnerships between government and the private sector, can be extremely beneficial in promoting and informing policies that can facilitate the transfer of technology for mitigation adaptation in Kuwait.
- *Reform and strengthen policies and measures:* Policies and measures must be altered to accelerate the adoption of technology transfer. Furthermore, monitoring, reporting and verification procedures should be set in place in order to properly enforce policies that support GHG mitigation and adaptation to climate change.
- *Foster the emergence of technology "champions":* This will involve the establishment of a national research center to support climate change adaptation and mitigation activities. Such investments lead to the emergence of technology champions and key players at all levels. The center would be responsible for identifying processes and measures to be changed, identifying information and training requirements, and building partnerships across stakeholder communities within Kuwait and among potential international partners.
- *Develop market-based technology support systems:* This involves encouraging the development of new markets for technology, and the accompanying financial/technology support services. Priority actions include familiarizing decision-makers of new opportunities, creating new mandates and investment incentives that promote market push-pull dynamics, and raising awareness through information campaigns.
- *Strengthen technical capacity and education:* Skills training and education on all levels are important for the transfer of technologies for adaptation and mitigation. Universities and vocational institutions in Kuwait have already begun educating students about climate change mitigation and adaptation challenges. Successful technology transfer will require the alignment of mitigation/adaptation needs with training for new technologies that can meet future mitigation and adaptation goals.

5.6 List of References

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6 Other Info: Public Awareness & Education

This chapter provides other information that help meeting the objectives of the United Nations Framework Convention on Climate Change (UNFCCC). To give a clear picture of the status of climate change at the State of Kuwait both education (including training courses) and public awareness need to be discussed.

6.1 Education

The belief that a better-educated people make a better developed community led Kuwait to invest heavily in educational institutions and to provide education for free from kindergarten to higher education (as with the health services). The ministry of education ensured that school grades encompass environmental education gradually. Almost all science courses at all levels (primary, middle school, and secondary school) discuss environmental topics and challenges in general. However, climate change subject in particular was sparsely discussed at some grades.

Kuwait University (KU) and the Public Authority for Applied Education and Training (PAAET), which are the main governmental tertiary education venues, offer specialized environmental college programs and specific climate change courses. These programs include: environmental technology management, environmental engineering, earth science and environment, and environmental health. With this mentioned, the schools curricula should be reassessed to include climate change topics in all grades. Some coordination between KU, PAAET, and private universities should also ensure a better coverage of climate change issues.

Actions taken by the Ministry of Education to raise environmental awareness include a Kids ISO 1400 program, a National Environmental Center for Students (Janoob Alsurra), and Forming and funding environmental teams in schools. Table 6-1 provides an overview of climate change principal concepts and sub-concepts in the Ministry of Education curriculum grades 1 through 12.

6.2 Public Awareness

To gauge the opinions and capabilities of the public (citizens and residents of Kuwait), a “national needs assessment” was conveyed in the form of questionnaire survey. The audience included government officials, business leaders, NGO representatives, scientists, clergy and youth. Among the topics that survey questions explored were climate change indicators, climate change implications, awareness channels, lifestyle, government role, and so forth. The questionnaires were implemented by students and faculty of environmental technology management department at Kuwait University. A total number of 9 collectors received training in survey techniques and conducted questionnaires in all possible forms (written, oral, and electronic).

Interestingly, out of 925 respondents, 75 percent have heard about climate before. The survey also reveals that 65.4 percent of stakeholders think that climate change a disaster that is about to happen. About the Kuwaiti government role in climate change issues, 78.5 percent are either dissatisfied with government’s role or not aware of any involvement. Finally, most respondents think that TV and Radio is the best climate change communication tools. The above are only sample questionnaires responses.

There are countless environmental NGOs in Kuwait, each specializing in a certain field. Environmental ad campaigns that accompany many of the exhibitions running all around the year are very informative and bring knowledge into action. Among the exhibitions worth mentioning is "REUSE", which is an annual exposition that offers non-profit organizations, companies, professionals and aspiring creative talents a place to show their accomplishments in the fields of social responsibility and sustainability.

6.2.1 Tarsheed Campaign

In the summer of 2007, the ministry of electricity and water initiated a national multi-million environmental conservation campaign called "Tarsheed" (see Figure 6-1). The main goal of the campaign was to reduce the per-capita consumption of electricity and water. The ministry delivered the conservation campaign through many channels, including SMS, radio and television advertisements, fliers, mailboxes, and highway billboards. The campaign ensured that all citizens and residents receive and understand the message by spreading the information in many languages such as Arabic, English, Urdu, and Hindi. The ministry also supplied a hotline for electrical emergency reporting as well as resource abuses. The success of Trasheed campaign led other GCC countries such as Saudi Arabia, UAE, and Qatar to adopt the campaign with slightly modified goals.

Figure 6-1: Tarsheed signs were in six different languages. Photos courtesy of Bany Maziad

6.2.2 Beatona Project

Kuwait's environmental protection agency created an extensive awareness and monitoring projects (see Figure 6-2). "Beatona", which translates to our environment, is the Kuwait official environmental portal. The project is developed and managed by the environmental monitoring information system of Kuwait (eMISK). Beatona.net is intended provide awareness though sharing authentic scientific information and real-time environmental news in a user friendly manner. The "environmental explorer" section of the website allows user to create their own multi-layered GIS maps. Among the layers are air quality monitoring stations, industrial emission monitoring locations, noise monitoring locations, drainage lines, water bodies, electric transformers, etc.

Figure 6-2: Awareness-building among the public through "Beatona and eMisk" project

Table 6-1: Climate change principal concepts and sub-concepts in the Ministry of Education curriculum (grades 1-12)

Level	Topic	Principal Concept	Sub-concept 1	Sub-concept 2
Grade 2	Nature around us	Get to know the components of the environment	Desert environment	Marine environment
Grade 3	Climate elements	The difference between climate and weather	Climate	Weather
Grade 3	My country's climate	Students should know the climate of Kuwait	The four seasons	
Grade 3	The beauty of Kuwait's nature	How to protect the environment		
Grade 3	Environmental protection is the duty of everyone	Instill environmental protection concept	Environmental reserve	
Grade 4	Jaber Al-Ahmad Marine Reserve	The role of reserves in protecting the environment	Marine reserve	
Grade 4	Environmental problems	How can students protect the environment	Recycling	
Grade 5	Natural plants in my country	Get to know the names of the plants of Kuwait		
Grade 5	Factors affecting the climate of Kuwait	Get to know the Climatic factors	Geo-location	Land and water distribution
Grade 6	Environment Science	Environment Science	Ecosystem's components	
Grade 7	The Arabian peninsula	The geography of the Arabian peninsula	The climate of the Arabian peninsula	
Grade 8	Environment	Develop an awareness of environmental issues		
Grade 9	Human and the environment	The elements of the environment	The elements of the environment	The relationship between human and environment
Grade 9	Environmental solutions	Environmental solutions	How to reduce the human-activity impact on the environment	Protection concept
Grade 9	Human-activity impact on the environment	Examples of plants chemical reactions	How humans impact nature cycles	Importance of biodiversity
Grade 11	Natural geography and its fields of study	Lithosphere, hydrosphere, atmosphere and biosphere	Pollution levels	Pollution types
Grade 12	Planet earth in danger	Raise the awareness of the importance of plants to the ecosystem	Ecosystems	