State of Kuwait Second National Communication

Submitted To

The United Nations Framework Convention on Climate Change

Prepared with technical support of United Nations Environment Programme & funded by the Global Environment Facility (GEF)

By Environment Public Authority

July – 2019

Kuwait - EPA

البلاغ الوطني الثاني لدولة الكويت

الخاص بإتفاقية الأمم المتحدة الإطارية لتغير المناخ

نحو استراتيجية مستدامة

FOREWORD

On behalf of Kuwait's government, it is my pleasure to submit Kuwait's Second National Communication to the Secretariat of the United Nations Framework Convention on Climate Change (UNFCCC). This communication was prepared according to the guidelines approved by the parties and the methodologies of the Intergovernmental Panel on Climate Change (IPCC).

Kuwait already is experiencing high temperatures up to 48 degrees Celsius in the summer, with a reading of 54 degrees Celsius in July 2016 north of Kuwait City. Notably, this was the highest temperature in the Eastern Hemisphere and Asia in recorded history. With climate projections showing even higher future temperatures and a decrease in the already low annual rainfall of Kuwait, the negative impacts of climate change on the country, especially those related to food security, water resources, public health, marine ecosystems, and coastal zones, have come in to focus.

Kuwait's Second National Communication presents the results of a series of studies that reveal how changes in local temperature and rainfall patterns, as well as rising seas, are expected to adversely affect vital sectors of the country. This report also includes an inventory of greenhouse gases from key sectors, with an analysis of the emission reduction potential of a set of voluntary mitigation efforts through 2035.

In order to address climate change, the Kuwait Environment Public Authority established the Environmental Protection Law in 2014 and completed its bylaws in 2018. This represents an important pivot point for Kuwait, as there is now legislative and regulatory authority for monitoring and documenting greenhouse gas emissions. Both the public and private sectors are being engaged to ensure that future greenhouse gas emission inventories are complete, consistent, and accurate.

Sheikh Abdullah Ahmad Al Hamoud Al-Sabah

Chairman of the Board & Director General of Kuwait,

Environment Public Authority

The State of Kuwait

ENVIRONMENT PUBLIC AUTHORITY

Acknowledgments

This document was the result of a fruitful partnership and cooperation between the Kuwait Environment Public Authority (KEPA) and the Regional Office for West Asia of the United Nations Environment Programme (UNEP), which oversaw the preparation of the Second National Communication project and provided training and technical support to national experts. In addition, the Global Environment Facility (GEF) provided financial support during all stages of the preparation of the document. Finally, I would like to thank all those who participated in the preparation of this work, particularly all ministries, governmental agencies, nongovernmental organizations, and the private sector for their support and assistance with the various working groups during the preparation of this document. Hopefully, this document will become a useful reference for policymakers, researchers, and all those interested in climate change and its negative impacts on the State of Kuwait.

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LIST OF ACRONYMS

°C	degrees centigrade
AFOLU	Agriculture, Forestry, and Other Land Use
ANOVA	analysis of variance
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
AVHRR	Advanced Very High-Resolution Radiometric satellite
Bcf	billion cubic feet
BCM	billion cubic meters
BIPV	Building-integrated PV systems
CCS	Carbon capture and storage
CDM	Clean Development Mechanism
CFP	Clean Fuels Project
CH_4	methane
CIS	Coastal Information System
CIVATF	Climate Impacts, Vulnerability and Adaptation Task Force
CNG	Compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CORDEX	Coordinated Regional Climate Downscaling Experiment
CVI	coastal vulnerability index
e-MISK	environmental monitoring information system of Kuwait
FGRU	Flare Gas Recovery Unit
GCC	Gulf Cooperation Council
GCM	General Circulation Model
GDEM	Global Digital Elevation Model
GDP	gross domestic product
GEF	Global Environment Facility
Gg	Gigagrams (i.e., one billion grams)
GHG	Greenhouse gas
GIS	Geographic information system
GLOBE	Global Learning and Observations to Benefit the Environment
GW	gigawatt (billion watts)
GWh	gigawatt-hour (billion watt-hours)
GWI	Global Water Intelligence
H_2S	hydrogen sulfide
HFC	hydrofluorocarbons
ICBA	International Center for Biosaline Agriculture
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
KEPA	Kuwait Environment Public Authority
KEPS	Kuwait Environment Protection Society

KFAS	Kuwait Foundation for the Advancement of Sciences
kg	kilogram
KISR	Kuwait Institute for Scientific Research
km	kilometers
KM	Kuwait Municipality
km2	square kilometers
KMA	Kuwait Medical Association
KPC	Kuwait Petroleum Corporation
KU	Kuwait University
kV	kilovolt (thousand volts)
kWh	thousand watt-hours
l/cap/day	liters per capita per day
LIDAR	Light Detection and Ranging
LNG	Liquified natural gas
LPG	liquid petroleum gas
m	meters
m/s	meters per second
m3	cubic meters
MENA	Middle East and North Africa
MEW	Ministry of Electricity and Water
MHTL	Mean high tide level
Mm3	million cubic meters
MMSCFD	million standard cubic feet per da
MOH	Ministry of Health
MOU	Memorandum of understanding
MPW	Ministry of Public Works
MRV	Measurement, Reporting and Verification
MSF	multi-stage flash
MSW	Municipal solid waste
N2O	nitrous oxide
NC	National Communications
NCD	Noncommunicable disease
NDC	Nationally Determined Contribution
NGCC	natural gas combined cycle (power station)
NGO	Nongovernmental organization
NHA	National Housing Authority
NMHC	nonmethane hydrocarbon
NOAA	National Oceanic and Atmospheric Administration
NOX	nitrogen oxides
NRP	New Refinery Project
NTF	National circumstances & other information Task Force
O_3	ground-level ozone
PAAET	Public Authority for Applied Education and Training
PAAF	Public Authority for Agriculture and Fisheries

PACI	Public Authority for Civil Information
PFC	perfluorocarbons
pH	Potential of Hydrogen
PM_{10}	particulate matter less than 10 microns in diameter
PSC	Project Steering Committee
PV	photovoltaic (solar)
QSAS	Qatar Sustainability Assessment System
R&D	research and development
RCM	Regional Climate Model
RCP	Representative Concentration Pathways
RO	reverse osmosis
ROWA/UNEP	Regional Office for West Asia of the United Nations Environment Programme
SCPD	Supreme Council for Planning and Development
SEI-US	Stockholm Environment Institute – US Center
SLR	Sea level rise
SNC	Second National Communication
SO_2	sulfur dioxide
SSS	sea surface salinity
SST	sea surface temperatures
TDS	total dissolved solids
TNA	Technology Needs Assessment
TWW	Treated wastewater
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

EXECUTIVE SUMMARY

The State of Kuwait is located at the northeastern corner of the Arabian Peninsula and has borders. State of Kuwait covers a total land area of nearly 18 thousand square km and is approximately 170 km wide from East to West and 200 km long 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.

National Circumstances

Kuwait has a hyper arid desert climate that is highly variable with recurrent extremes. Maximum daily temperatures can reach 45°C in the summer during which there is no rainfall. Much of Kuwait is characterized by loose, mobile surface sediments that have very low levels of nutrients and organic matter. While rich in terrestrial and marine biodiversity, these systems are fragile and highly vulnerable to climate change. Kuwait is also one of the world's most water-stressed countries, with the lowest per capita renewable internal freshwater availability of any country, requiring extensive seawater desalination to meet the water demand. The population is overwhelmingly urban and has grown rapidly since the discovery of oil in the late 1930s, with over 98% of the population currently living in urban areas which are mostly located along the coast. A modern country with an extensive, modern and well-maintained network of road infrastructure, Kuwait also has a modern healthcare system and a healthy populace; recent trends show a decrease in the incidence of communicable diseases and an increase in life expectancy in the country. Kuwait is one of the world's leading oil producers, possessing the world's fifth largest crude oil reserves in the world and has one of the wealthiest economies in the Arabian Gulf region. Throughout its modern history, Kuwait has heavily relied on food imports because only a negligible fraction of food demand can be met by local agriculture.

Greenhouse Gas Inventory

Kuwait compiled an update to its inventory of greenhouse gas emissions for the year 2000 (see Table ES-1). The total and net greenhouse gases (GHG) emissions in 2000 were 48,712 Gg CO2-equivalent, including 46,533 Gg of emissions from energy; 873 Gg of emissions from industrial processes and product use; 102 Gg of emissions from agriculture, forestry, and other land use, and 1,205 Gg of emissions from waste. Emissions from perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulfur hexafluoride (SF6) in Kuwait are negligible because the products containing these gases are not produced in the country.

	GHG Sources & Sinks	CO_2-eq	CO_2	CH_4	N_2O
1	Energy	46,535	46,192	7.5	0.61
2	Industrial processes and product use	873	873	0.0	0.0
2	Agriculture, forestry and other land use	102	-9.2	5.0	0.019
4	Waste	1170	0	54.1	0.11
	Total National Emissions	48,683	47,065	66.6	0.74
	Net National Emissions	48,683	47,056	66.6	0.74

Vulnerability and Adaptation

All land areas of Kuwait will become warmer in the future, with the greatest change projected to occur during the winter months. Across the entire country, annual average temperatures show the greatest rise under RCP8.5, this scenario predicts an increase between 4.3° and 4.5°C in temperature compared to the historical average by the 2071-2100 period. Kuwait will also become drier in the future, with average annual rainfall in the western part of the country showing the greatest decrease under, i.e., values approximately 15% and 18% lower than the historical average, under RCP8.5. The Arabian Gulf water will also experience change. Historical monthly sea surface temperatures in the Arabian Gulf have steadily increased at a rate of 0.6 (±0.3) °C per decade, which is three times greater than the concurrent global average.

Many sectors are vulnerable to these climatic changes, with potentially grave environmental and social effects, compounded by the country's adaptation challenges. Key findings of the vulnerability assessments are summarized in the bulleted list below.

- *Coastal* zones: Rising sea levels pose threats such as wetland flooding, aquifer and agricultural soil contamination, destructive erosion and habitat loses for fish, birds, and plants. Sea level rise (SLR) also poses a threat to the built environment via the extension of Arabian Gulf waters farther inland, particularly under high tide conditions and especially in combination with storm surges associated with extreme storm events. Boubyan Island will be greatly impacted by SLR, with roughly half the island inundated in the highest SLR scenario. Only the relatively high land in the interior of the island will be visible by the end of this century. Coastal areas along Kuwait Bay are also projected to be adversely impacted by rising seas, especially the western coast near Doha Port and the densely populated neighborhoods around Kuwait City.

- *Water resources:* population growth, urbanization, industrial growth, and agricultural development are key drivers underlying Kuwait's high per capita water consumption. Coupled with a hyper arid environment, low annual rainfall, no permanent lakes or rivers, and limited fresh groundwater resources, sustainable water resource management is a key national priority. A number of potential adaptation policies have been analyzed (i.e., water tariffs, improved water efficiency, leak reduction, and improved irrigation efficiency) with each policy showing significant water savings and reduction in carbon dioxide emissions.

- *Marine ecosystems*: Kuwait's marine waters and coastal areas include highly productive habitats, e.g., intertidal mudflats, seagrass, algal beds, mangroves, and coral reefs. These habitats support important commercial fisheries, marine biodiversity and endangered species such as green turtles. Recent trends show a loss of coral reef coverage with increasing Gulf water temperatures, as well as massive fish kills.

- *Public health:* with climate change, increased heat stress from higher temperatures and increased cardiovascular and respiratory diseases associated with more frequent dust storms, represent looming health threats to the population. These additional risks could exacerbate current major health problems such as ischemic heart disease, stroke, road injury and lower respiratory infections, while potentially undermining Kuwait's social protection systems.

Greenhouse Gas Mitigation

Kuwait is committed to efforts that harmonize economic growth with a low-carbon, climate-resilient development. Domestically, the country has already undertaken several strategic projects to reduce its carbon footprint by promoting clean energy initiatives, introducing new low-carbon technologies, and developing long-term partnerships to exploit sustainable energy opportunities. Progress towards such actions is already underway, when these actions are fully implemented by 2035, they will result in total annual emission reductions of approximately 5,600 Gg, with cumulative emission reductions of nearly 60,000 Gg of CO_2e.

Constraints, Gaps and Needs

Inadequate capacity (technical, financial and institutional) remains one of Kuwait's significant challenges as the country confronts climate change. Enhancing capacity will depend on overcoming serious institutional, financial and technical constraints and gaps that currently interfere with effective action. With adequate support, Kuwait can build climate change resilience and explore the viability of low-emission development trajectories.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF BOXES

1. National Circumstances

This chapter provides a description of Kuwait's national circumstances, as well as an overview of the national socioeconomic, climatic, and environmental context in which climate change challenges are being addressed.

1.1. Geography

The State of Kuwait is located at the northeastern corner of the Arabian Peninsula (see Figure 1-1) and has borders with Saudi Arabia to the south and Iraq to the north and west. Kuwait lies between the latitudes 28°30'and 30°5' North and longitudes 46°33' and 48°30' East, covering a total land area of 17,818 km^2 that includes nine uninhabited islands. Kuwait is approximately 170 km across from East to West and 200 km across from North to South. Kuwait shares a 495 km border with Saudi Arabia to the south and a 195 km border with Iraq to the north and west. The capital of Kuwait is Kuwait City. The country is divided to 6 administrative governorates; and the governorates are further subdivided into administrative areas. The country's topography is predominantly flat sandy desert, and is characterized by two distinct areas, as follows:

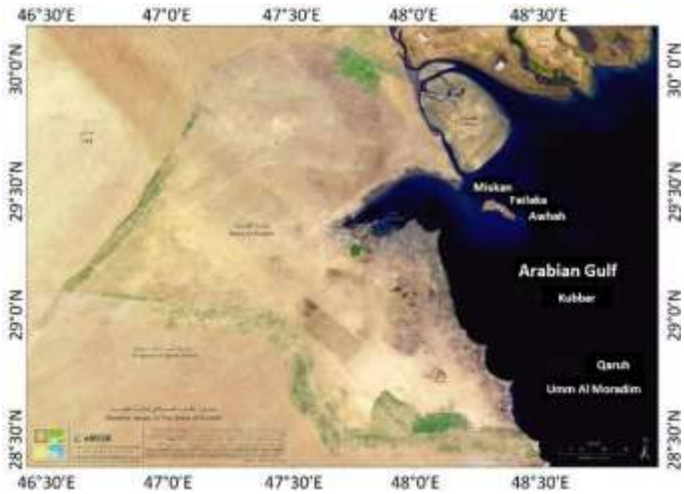

Figure 1-1: Satellite image of the State of Kuwait.
(Source: e- Misk, KEPA)

- *Northern zone.* This area includes Kuwait Bay and five islands: Boubyan, Warba, Maskan, Failaka, and Ouha. Kuwait Bay is a shallow but very important coastal and marine habitat with high productivity and diversity. Its coastal zone accounts for nearly half of the country's shoreline. The two largest islands (Boubyan, 863 km2 and Warba, 212 km2) remain in an undisturbed condition and are home to migratory birds and rich marine biodiversity. Boubyan is the second largest island in the Arabian Gulf and is home to pristine marine and terrestrial ecosystems of regional and international importance. The northern half of island is a designated marine protected area named the Mubarak Al Kabeer Marine Reserve (MKMMR) and was recently designated as a Ramsar Convention Site.1
- *Southern zone.* The area extends from Ras Al-Ardh to the border with Saudi Arabia. Its coastal stretches include sandy and mixed shores, as well as the coral reef islands of Kubbar, Qaruh and Um Al-Maradim. Many intertidal marshes, known as *sabkhas*, are also found in this zone; the largest is Al-Khiran Sabkha, which was transformed into a large waterfront city. The southern region of this zone is a monotonous plain covered by sand. Al-Ahmadi hill, 125-m high, is the sole exception to the flat terrain, Portions of Wadi Al- Batin and Ash-Shaqq the only major valleys in the zone of, lie within the western

[1] In 2015 Kuwait became the 169th Contracting Party of the Ramsar Convention on Wetlands; and on 17 May 2017 announced the designation of the MKMMR.

and southern reaches of the country, respectively. Rocks ranging in age from the early Miocene (less than 24 million years old) to recent times are exposed within the boundaries of Kuwait.

1.2. Climate

Kuwait has a hyper arid desert climate that is highly variable with recurrent extremes. Maximum daily temperatures can reach 45°C during the summer during which there is no rainfall (see Figure 1-2).

The climate is marked by four distinct seasons, with long, hot and dry summers and short winters, as briefly described in the bulleted list.

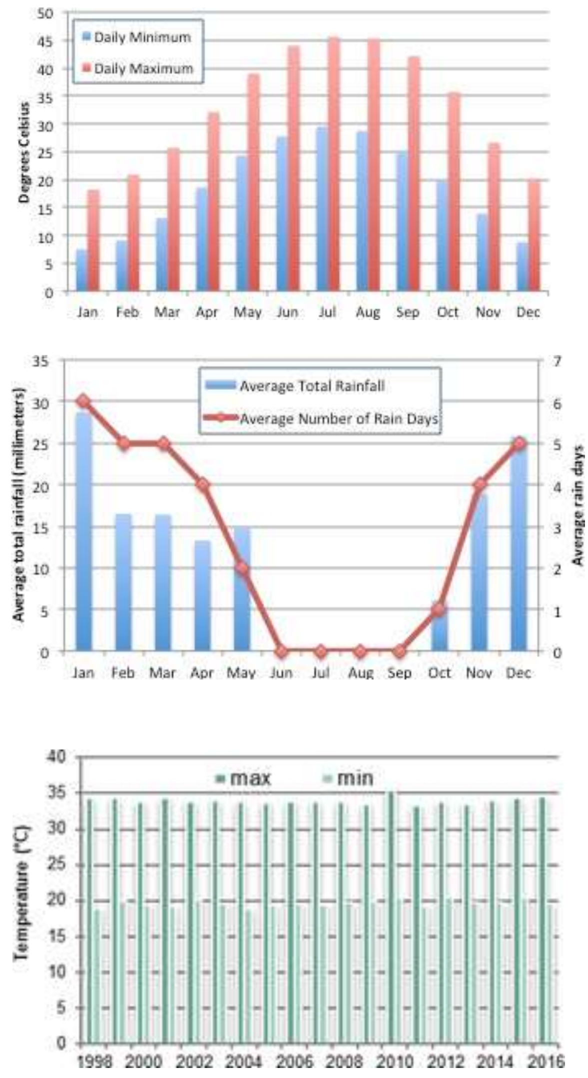

Figure 1-2: Top: Daily minimum and maximum temperatures in each month, averaged over 1962-2016; middle: total rainfall in each month, averaged over 1962-2016; bottom: highest and lowest average annual temperature recorded over the period 1998-2016.(Source: Kuwait Civil Aviation - Metrological Department)

- *Winter*. The winter season occurs over a 2-month period between 6 December and 15 February. These months are cold, and often experience a northwesterly wind. The lowest recorded temperature was −4°C recorded and was recorded at the Kuwait International Airport in January 1964. Low temperatures, clouds, rain and a cold northwesterly wind called (*Shamal*) characterize this season. Two distinct climatic periods within the winter season are evident, as described in Box 1-1.
- *Spring*. The spring season is a 3-month period from16Februaryto20Mayand 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 bulleted list. Two distinct climatic periods within the spring season are evident, as described in Box 1-1.
- *Summer*. The summer season occurs over an approximately 5-month period from 21 May to 4 November and is characterized by a significant increase in both humidity and temperature. Summer is typically hot, dry and humid, with daily maximum temperatures ranging from 43°C to 48°C. The highest-ever recorded temperature in summer was 54.0 °C at Mitribah in northwest Kuwait on July 21, 2016 (Kuwait Civil Aviation Metrological Department). I fact, this was the highest reliably recorded temperature on the planet in the last 76 years, as documented by the World Meteorological Organization (WMO). The prior highest temperature was 52.9°C, which was also recorded in Mitribah. The climate during the summer is divided into three distinct periods, as described in Box 1-1

- *Autumn.* The autumn season occurs 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 coldnights.

The climate of Kuwait is further characterized as follows:

- *Rainfall.* Figure 1-3 summarizes the annual rainfall from 1998 to 2016. Rainfall is concentrated in the winter and spring months. Rainfall totals are highly variable from year to year, and drought is a recurrent phenomenon. The average annual rainfall is typically approximately 112 millimeters (mm) per year and varies from 75 to 150 mm/yr. The annual recorded rainfall levels at Kuwait International Airport have been as low as 34.4 mm and as high as 218 mm, while a level of 319.5 mm was recorded in Umm Al-Maradim Island in October 2013.

- *Humidity:* from mid-August through September, humidity can exceed 95% in coastal areas. This is due to high seawater temperatures coinciding with tropospheric temperature inversions.

  Over the period 1987 through 2017, the average relative humidity was 57%.

Box 1–1: Climatic sub-periods in Kuwait

Winter sub-periods:

- *Cold winter period (Murba'ania; 6 December to 15 January).* Temperatures can drop below 0°C, especially during the night or when northwesterly winds are strong. Warm intervals (>30°C) are common due to a humid southeasterly wind.
- *Mild winter period (16 January to 15 February)*. Southeasterly winds lead to overcast/rainy conditions often followed by northwesterly winds that bring cold air, leading to dense fog and frost conditions.

Spring sub-periods:

- *Cold moderate spring period (*16 February to 8 April). Temperatures begin to increase due to a hot southerly wind (known as Al-Suhily) that lasts for several days at a time. Maximum temperatures may reach 41°C.
- *Warm spring period (*9 April to 20 May). Thunderstorms (known as Al-Sarayat) are common and typically develop in late afternoon or evening, accompanied by severe dust storms. Temperatures gradually increase from approximately 30°C to 47 °C by the end of the period.

Summer sub-periods:

- Transition period (21 May through 5 June). A transition period between late spring and actual summer conditions. Skies are generally clear, and winds are variable in direction and strength. Average maximum temperatures range from 40° to 44°C.
- Dry summer period (6 June through 19 July). Characterized by a consistent hot and dry northwesterly wind (*Semoom*) that contributes to strong dust storms with visibility of few meters, especially at noon. Average maximum temperatures range between 42° and 46°C.
- Wet summer period (20 July through 4 November). Characterized by light easterly and southeasterly winds that lead to high humidity. Cloud cover is minimal, and rainfall is less.

- *Dust storms:* given the geographical location of Kuwait, dust storms are regular phenomena in the country. While they can occur in any season, dust storms are particularly frequent in summer and can reach speeds up to 150 km per hour (see Figure 1-4). Dust sources are in the Mesopotamian region which includes Syria, Iraq, western Iran, and the northeastern portion of the Arabian Peninsula.

  Dust activity in the Tigris-Euphrates basin begins around May, reaches a maximum in July and is much reduced by September–November. In spring, the region is affected by north-westerly Shamal winds that transport dust down to the Gulf.

  Dust storms are aggravated by overgrazing and camping practices. These storms are known to contribute to serious health impacts in Kuwait such as asthma attack incidence rates of 175 per day and have increased road traffic accident rates by up to three times the normal rates.

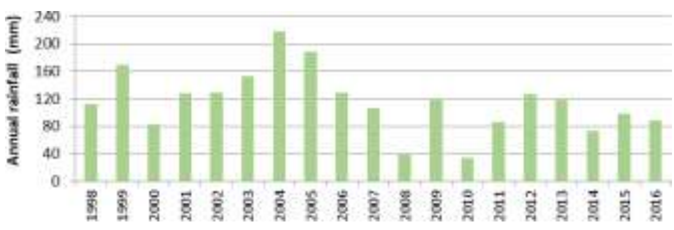

Figure 1-3: Average annual rainfall over the period 1998-2016.

(Source: Kuwait Civil Aviation - Metrological Department)

Figure 1-4: Recent severe dust storms over Kuwait City.
left storm on 17 June 2018. (Photo: Sarah Al-Sayegh); right: storm on 18 February 2018 (Photo: Kuwait Times, 19 February 2018)

1.3. Land and vegetation

Much of Kuwait is characterized by loose, mobile surface sediments. Soils are divided into ten groups, all of which have very low levels of nutrients and organic matter (see Figure 1-5). The soil moisture content is also very low because of high evaporation rates and hard pans (locally known as *gutch*) that reduce water permeability. Less than 1% of Kuwait's land area is considered arable.

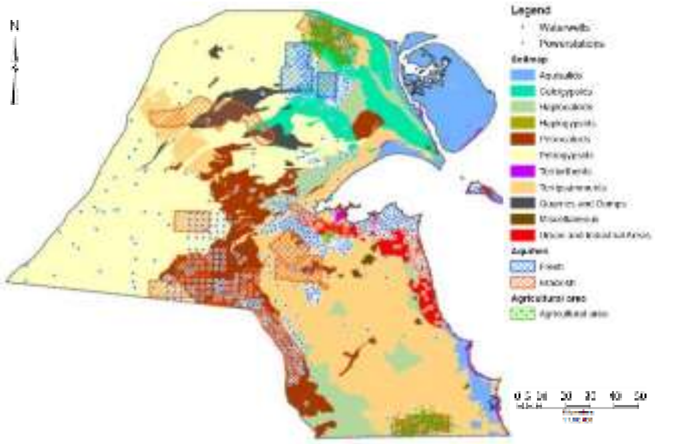

Figure 1-5: Soils, aquifers and groundwater-irrigated agricultural areas of Kuwait.
(Source: PAAF, KISR)

The vegetation of Kuwait is broadly classified as open scrub of the Saharo - Arabian floristic region, which is contiguous with the Northern Plains of eastern Saudi Arabia (Royal Botanical Gardens-Kew, 2010). Kuwait occupies part of the large, low-lying desert plain covering most of Eastern Arabia and is mostly characterized by desert and coastal plains (see Figure 1-6). Coastal areas comprise important marine habitats, many with high productivity and diversity, including salt marshes and tidal mudflats.

1.4. Desertification

Several studies have assessed desertification in parts of Kuwait (Shahid *et al.*, 1999; Al-Dousari *et al.*, 2000; Omar *et al.*, 2001; Misak *et al.*, 2002; Al-Awadhi *et al.*, 2005). Seven processes or indicators of land degradation have been recognized, with a general agreement that these processes affect approximately 70% of Kuwait's land area. These indicators are deterioration of vegetation cover; soil crusting and sealing; soil erosion by wind; soil erosion by water; soil compaction; soil contamination by oil; and soil salinization. And are mapped in Figure 1-7.

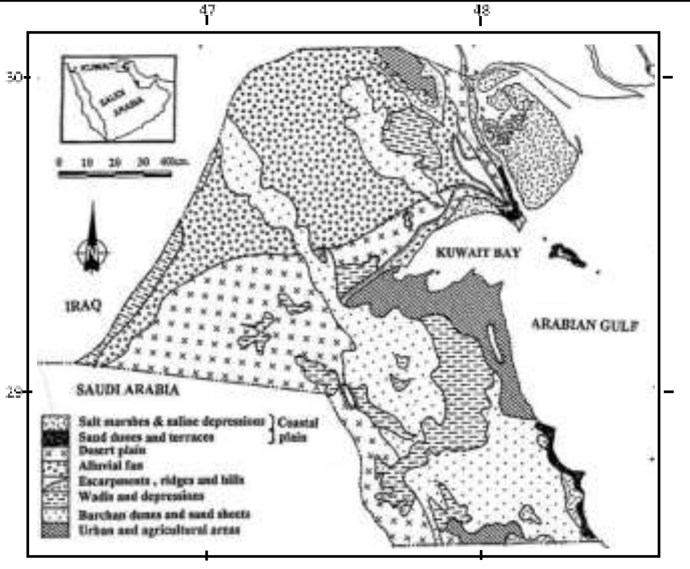

Figure 1-6: Ecosystems of Kuwait.
(Source: Samira AS Omar, Raafat Misak ;2007, KISR)

The deterioration of vegetation cover, with a decline in the alpha diversity of plant species, is one the most obvious indicators of desertification in Kuwait's desert ecosystem. Overgrazing is considered the prime driver of vegetation degradation on rangelands, a conclusion supported by several studies that document much greater vegetation cover in areas fenced off and unavailable to livestock than in areas accessible to grazers (Omar, 1991; Zaman, 1997; Shahid *et al.*, 1999). This form of desertification is particularly severe around watering points where it is exacerbated by soil trampling and compaction due to the congregation of animals (Al-Awadhi et al., 2005).

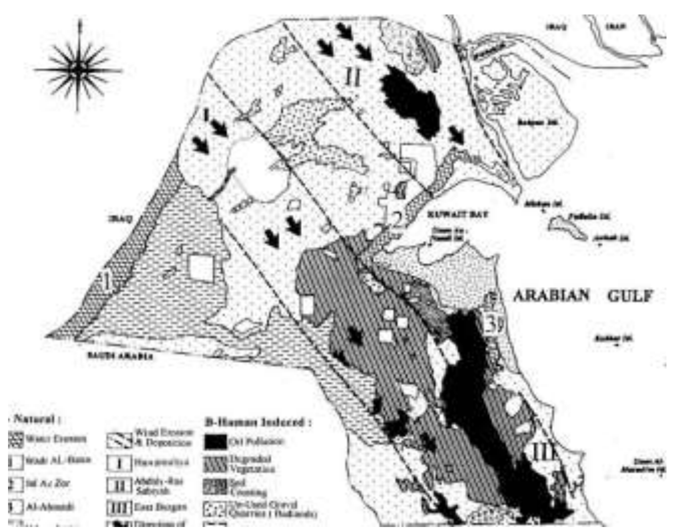

Figure 1-7: Preliminary land degradation map of Kuwait.
(Source: Al-Dousari et al., 2000)

Other important localized causes of vegetation deterioration are spring camping, the uprooting of woody shrubs used as fuel and military maneuvers. One survey indicates that at least 65% of Kuwaiti soils are affected by some degree of compaction, which inhibits the infiltration capacity of these soils by 40–100% and increases their bulk density by up to 50% (Misak, 2001).

Wind erosion occurs naturally on many of Kuwait's desert surfaces, particularly those consisting of active sand sheets and sand dune fields. Elsewhere, vegetated sand sheets have also been mobilized where the stabilizing cover of vegetation has suffered from degradation and trampling. These mobile sediments represent a serious hazard to human activities. The annual cost of clearing sand encroachment from oil installations in Kuwait is more than US$1 million. The annual expenditure needed to remove sand from the Ali As-Salem airbase is similar (Ramadan & Al-Dousari, 2013). Local sources of fine particulates contribute to the numerous dust storms that affect Kuwait, although the country is also affected by desert dust transported from neighboring countries and further afield. Associated wind-erosion impacts include hazards to aircraft and maritime traffic, effects on oil operations and green energy production, and serious human health problems due to the low air quality.

1.5. Biodiversity

Kuwait is committed to its international obligations regarding the conservation of its native biodiversity. On 5 June 2017, Kuwait ratified the Nagoya Protocol, which is a supplementary agreement to the Convention on Biological Diversity, that sets forth obligations on access to genetic resources and the fair and equitable sharing of benefits arising from their utilization. With this ratification Kuwait became the 100th party to such protocol. On the same date, Kuwait also ratified the Cartagena Protocol on Biosafety to the Convention on Biological Diversity and became the 171st party to the protocol.

The Worldwide Fund for Nature (WWF) classifies Kuwait's terrestrial ecosystem as a desert with xerophytic (Greek xero for dry, phuton for plant) scrub. This classification is based on the high variability in intra-annual annual rainfall (see earlier Figure 1-2), and the high evaporation rate which exceeding the rainfall.

Approximately 375 plant species have been recorded in Kuwait Approximately two thirds (256 species) of these species are annuals. Low shrub species and herbaceous perennials form the main constituents of the perennial vegetation with only a few large shrubs, and a single tree species present (Halwagy & Halwagy 1974, Halwagy et al. 1982, Mandaville 1990, Omar et al. 2001, Ghazanfar 2006).

Kuwait has colorful terrestrial and marine biodiversity (see Figure 1-8). This diversity is fragile and vulnerable to the impacts of climate change; desertification and other threats resulting from anthropogenic activities, including habitat destruction, overgrazing, pollution, and illegal hunting and overfishing. The last inventory of wild animal species in Kuwait documented the presence of more than 300 bird species, 20 mammal species and 40 reptile species.In Kuwait, 648 species of insects have, belonging to 414 genera and 22 orders.

Figure 1-8: Examples of biodiversity in Kuwait.
Top left: Lizard; top right: Al-Sheriab (shore Crab); bottom right: Arabian red fox (Vulpes arabica); bottom left: Black-winged Stilt (Credits: Faisal Al-Nomas; KEPA)

The largest order is that of beetles (Coleoptera) with 230 known species, followed by butterflies and moths (Lepidoptera) with 76 recorded species, bees, wasps and ants (Hymenoptera) with 71 species, flies (Diptera) with 69 species, and finally locusts (Orthoptera) with 34 known species (Al-Houty,1989).

The native flora of Kuwait consists of 374 plants: dwarf perennial bushes, annual grasses, and herbs. These plants comprise 256 annuals, 83 herbaceous perennials, 34 under shrubs and 1 tree. Native plants have developed mechanisms to survive in the country's extreme environmental conditions. In practical the perennials must endure the harsh climate more than the annuals, which propagate only after the seasonal rainfall (Shamal Azzour: https://www.aznoula.com). Important plant communities in this floristic region in Kuwait are briefly described in the bulleted list (Halwagy & Halwagy, 1974; Halwagy *et al*., 1982; Mandaville, 1990; Omar *et al*., 2001; Ghazanfar, 2006).

- *Haloxylon salicornicum community*. Extends from Iraq in the northeast down to the northern edge of the Rub'al Khali in Saudi Arabia. Found predominantly on sandy and sandy-gravelly soils and composed of the dominant shrub *Haloxylon salicornicum*, this is the largest community in northeast Arabia. In Kuwait, the *Haloxylon salicornicum* community is present in the north and northeast. Associates are *Astragalus spinosus* and *Chrozophora spp*.

- *Rhanterium epapposum community*. Extends from eastern Saudi Arabia and the south to the United Arab Emirates. This community is present on deep and shallow sand. The dominant species is *Rhanterium epapposum* with associates *Convolvulus oxyphyllus* and *Moltkiopsis cilata*. Other species, such as *Gynandriris, Anthemis*, and *Cornulaca*, are associated with the community in specific soils and topographies. *Rhanterium epapposum* is very palatable to livestock, and overgrazing has greatly affected its occurrence. This species is not common in Kuwait and is presently found only in protected areas.

- *Stipagrostis plumosa community*. Found mostly in the west and southwest of Kuwait with dominant grass, the occurrence of *Stipagrostis plumosa* is a result of degradation and disturbances. Under proper management, this community develops into the *Rhanterium epapposum* community or, on saline soils, into the *Haloxylon salicornicum* community. In the southwest, *Centropodia forskalii*, a perennial grass, is dominant with *Stipagrostis plumosa* as the chief associate (recognized as a separate community by Omar *et al.* 2001).

- *Cyperus conglomeratus community*. Found throughout the Arabian Peninsula, this community is present on sand, occurring on both mobile and stable dunes and sand sheets, and forming hummocks. In Kuwait, the *Cyperus conglomeratus* community is found in the south. An excellent sand binder and not readily eaten by livestock, this species can thrive with moisture from dew. Associates are usually annual species (*Astragalus annularis, Brassica tournefortii, Plantago albicans*).

- *Halophytic communities*. Three halophytic communities, *Zygophyllum*, *Pennisetum* and *Halophyletum*, from the coastal inland region are composed primarily of halophytic shrubs. *Salicornia europaea* grows on low, frequently inundated mud banks or along creeks and is sometimes associated with *Aeluropus lagopoides* and *Bienertia cycloptera* or with *Juncus rigidus* on the fringes of creeks. The *Halocnemum strobilaceum* community occupies the lower marshes along the shoreline, where the seaward edge is very frequently inundated by tides. The *Seidlitzia rosmarinus* community occurs further inland than the *Halocnemum strobilaceum* community, while *Nitraria retusa* occurs above the high tide mark and dominates the middle marshes. Finally, the *Tetraena qatarensis* (syn. *Zygophyllum qatarense*) community occurs on elevated, coarse sandy sites on the landward edge of marshes. The salt marshes are fringed by nonhalophytic communities such as the *Cyperus conglomeratus* community, the *Rhanterium epapposum-Convolvulus oxyphyllus-Stipagrostis* plumose community and the *Haloxylon salicornicum* community; the latter covers most of the territory of Kuwait.

Kuwait has a rich profile of invertebrate and vertebrate fauna. The intertidal zone is colonized by many species of Ocypode crabs, including the endemic crab *Leptochryseus kuwaitnese*. The blue-spotted Mudskipper *Boleophthalmus boddarti* is another inhabitant of the intertidal zone. The most common scorpion is the black scorpion *Androctonus crassicayda*, while the most common spiders are the wolf spiders *Pardosa sp*., the crab spiders *Thomisus sp.*, the sun spiders *Galeodes sp*., the velvet mites *Dinothrombium sp.*, and *Tarantula sp.* (KEPA, Fifth National Report, 2014).

One of the most common insects in Kuwait is the ground beetle (*Tenebrionidae*). The most famous beetle species is probably *Trachyderma hispida*, which is omnipresent in houses and in the desert. Active during the day, this black beetle makes burrows for larvae and pupae beneath the soil cover.

The reptile fauna of Kuwait is depauperate, with no endemic species, although 40 species have been recorded. The common reptiles of Kuwait include the dhub *Urmastyx microlepis*, the Agma lizard and the wirral *Varanus griseus*. There are several species of snakes in Kuwait, such as the sand boa *Eryx jayakari*, the Arabian boa *Malpolon moilensis* and the sand viper *Cerastes cerastes*.

Twenty-eight mammalian species live in Kuwait. Sadly, four large mammals have been exterminated: the dorcas gazelle, the mountain gazelle (*Idmi*), the Arabian sand gazelle and the Asiatic cheetah (*fahd*). Other large carnivores, such as wolves, caracals, and jackals, are now extremely rare. Habitat destruction and extensive and unregulated hunting are driving endangered mammalian species, such the fennec fox, the red fox, the honey badger, the Indian gray mongoose and the wild cat, to extinction.

Due to ecological and anthropogenic activities, most large mammals that were native to Kuwait have been wiped out or have disappeared. (Kuwait Times, 11 March 2017). Over the past few decades, the desert of Kuwait has witnessed a dramatic decline in biodiversity, as many species, such as the Arabian oryx *Oryx leucoryx*, the Arabian wolf *Canis lupus arabs*, the striped hyena *Hyaena hyaena*, the golden jackal C*anis aureus*, *Mellivora capensis*, the dorcas gazelle *Gazella dorcas*, the sand gazelle *Gazella subgutturosa*, Ruppell's fox *Vulpes rueppellii*, have disappeared (https://www.aznoula.com). In addition, several species of birds, such as the houbara bustard *Chlamydotis undulate* and lanner falcon *Falco biarmicus feldeggi*, have been wiped out. Concerning reptiles, over 40 species of reptiles and amphibians have been recorded in the dry areas of Kuwait

Although no specific studies have investigated the current status of these reptiles, like other native fauna of Kuwait, their distribution has been minimized and is restricted to remote areas with minimal human interference. In general, the fate of desert reptiles is not expected to be better than the fate of extinct birds and other species. Habitat loss and fragmentation, human impacts and overcrowding are the main causes of extinction. Habitat fragmentation continues to threaten the wildlife in Kuwait.

Genetic clustering, species isolation, and the intensification of genetic mutations that may lead to population breakdown in isolated groups are some of the threats that habitat fragmentation poses. (https://www.aznoula.com).

The Kuwaiti government strives to preserve national biodiversity through several policies and procedures. Environmental police are enforcing the implementation of the Environmental Protection Law on violators hunting or polluting the environment or fishing in restricted areas. Article 100 of Kuwait's Environmental Act, which became effective in 2014, bans the hunting and collection of fauna or destruction of nests in areas where wild species live. The article states that native fauna, including all mammals, birds and reptiles, cannot be killed, collected, or hunted, cannot have their nests destroyed, and cannot be harmed by any activity.

Kuwait has also allocated 11.65% of its terrestrial and coastline as nature reserves and protected parks. At present, there are twelve reserve areas across the country (see Figure 1-9). The largest and most significant reserves are as follows:

- *Sabah Al-Ahmad Nature Reserve.* Located at the north- east part of Kuwait, this reserve covers 325 km^2 and is area where threatened animals and plants are reintroduced, and natural characteristics of the native ecosystem is preserved.
- *Mubarak Al-Kabeer Reserve.* Located in the north of Boubyan Island and the entire territory of Warba Island, this reserve covers 510.2 km^2 and consists of low sandy and muddy surfaces, and numerous channels and bays with rapid currents tides that are rich in food abundance, which contributes to a richness in marine organisms. The reserve accommodates dolphins during the summer and migratory birds, such as flamingos, watercress and small derricks in winter.

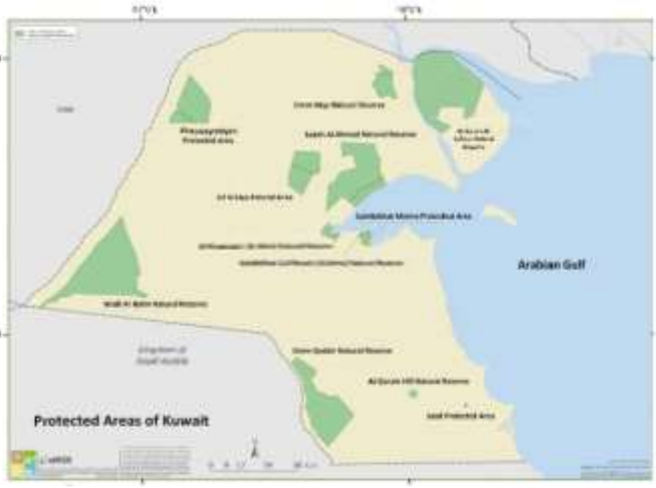

Figure 1-9: Protected Areas of Kuwait.
(Source: EPA e-Misk – Kuwait)

Migratory birds use Kuwait as transit base in different times of the year. 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 migratory and wintering species. To date, 220 bird species have been recorded in the reserve (Bird Life International, 2012). Another site for migratory birds is Kubbar Island, located roughly 30 kilometers off the southern coast of Kuwait, and a breeding ground for three migratory species of terns, nesting in Kubbar from early May to August.

However, the vegetation of Kuwait is under threat of extinction due to many factors including; setting up extensive recreational camps, gravel quarrying, oil exploration and the destructive activities during the 1990/1991 war; all of these factors have increased pressure on Kuwait's vegetation. Decades of low enforcement and compliance of ecosystem protection laws is another major cause of the destruction of the native biodiversity. A study conducted in protected and unprotected areas has shown that the plant cover in the unprotected areas is 80% less than that of the protected areas. (Shamal Azzour: https://www.aznoula.com).

1.6. Water Resources

Kuwait is one of the world's most water-stressed countries, with the lowest per capita renewable internal freshwater availability of any country.[2] Water supply consists of desalinated seawater, groundwater and treated wastewater. On a per capita basis, roughly 900 liters per day are consumed in Kuwait, one of the highest rates in the world (ESCWA, 2011).

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[2] FAO AQUASTAT data accessed June 2016.

Desalinated water is produced in six multi-stage flash distillation plants and one reverse osmosis plant. These are large facilities located near the coast and co-produce electricity (see Figure 1-10). Desalination plants provide more than 90% of Kuwait's potable water needs.

Figure 1-10: **Al-Zour North independent power station and desalination plant, installed in 2015.**
(Source: engie.com)

Much of the available groundwater is brackish (total dissolved solids (TDS) ranging from 1,000 to 7,000 mg/l) and saline (TDS ranging between 7,000 to 20,000 mg/l) PAAF, 2006) Freshgroundwater (TDS less than 1,000 mg/l) is very limited and available in two freshwater lenses, Raudhatain and Umm Al Eish, of the transboundary Dammam aquifer. These freshwater lenses are formed due to a combination of unique conditions that include high intensity rainfall of short duration, and a geomorphology and lithology that enable rapid infiltration to the underlying groundwater. From historical pumping and water quality variation data acquired between 1963 and 1977, the sustainable extraction rate for Raudhatain and Umm Al Eish, which would avoid the uplift of deeper saline water, is estimated to be 3,500 and 5,500 m3/day, respectively (Kwarteng *et al*,, 2000). Fresh groundwater is considered a strategic reserve for drinking purposes only.

Brackish groundwater is used for agricultural and domestic purposes and as drinking water for cattle. This water is produced from the Al-Shigaya, Al-Qadeer, Sulaibiyah, Wafra and Abdally fields. The production capacity of these fields is about 545,000 m3/day. In general, groundwater quality and quantity are deteriorating due to the continuous pumping of water. In Wafra in the south, 50% of the wells pumped water had a salinity level higher than 7,500 ppm in 1989, reaching 75% and 85% in the years 1997 and 2002, respectively. In Abdally in the north, these figures were estimated at 55, 75 and 90%, respectively. For Wafra, reported monitored wells over a similar time period and results showed that salinity is increasing from 5-14,000 ppm to 8-14,000 ppm in wells (Akber, 2009).

A significant percentage of wastewater is being discarded and flows back into the Gulf sea water. Over 90% of the population is connected to a central sewerage system. This offers an important potential for treated wastewater (TWW) reuse that can contribute to alleviating high irrigation water demand for landscaping and agriculture. Planning is underway to distribute water from the Sulaibiyah treatment plant as follows: 40% to the south for the Wafra agricultural area, 40% to the north to the Abdally agricultural area, with 20% to remain in the Sulaibiyah area agricultural area. There are GCC guidelines allowing use of quaternary TWW for growing vegetables, fruits and other crops in times of crises.

Kuwait has recently implemented a vigorous campaign that aims to reclaim and reuse all treated wastewater. A recent paper by Al-Anzi, Abusam and Shahalam (2010) presents the current status of wastewater treatment, reclamation and reuse in Kuwait, and discusses the impact of wastewater reuse on the amounts of pollutants discharged into the sea. "Analysis of the historical records of the waste water treatment plants has indicated that the reuse of reclaimed wastewater in Kuwait has greatly reduced the amounts of pollutants discharged into the sea, from about 65% of treated wastewater in year 2000 to less than 30% in year 2010. However, the amounts of treated wastewater discharged into the sea were predicted to start increasing again by the year 2020, especially if the future plans of the Ministry of Public Works (MPW) are not implemented by that time."

A study undertaken by Alhumoud and Madzikanda, in 2010 also shows that "the overwhelming majority of the respondents (77.91%) objected to using reclaimed water for drinking and only 16.83% said they might consider drinking it. The majority of respondents (75.28%, 66.80% and 55.60%) did not object to using the reclaimed water for agricultural irrigation, car washing and house washing. In addition, data showed that most of the respondents, even the ones that possessed enough knowledge about the subject, strongly opposed using reclaimed wastewater for human use (showering/bathing: 60.03%, clothes washing: 52.40% and cooking: 78%), regardless of its quality and cost". Reasons and objections for not using treated wastewater were: health (69%), psychological (54%), religion beliefs (29%), mistrust of the workmanship at the plant (25%), fear of mechanical breakdown (19%), while seven% reject it for other reasons. People with high educational attainment showed a greater willingness, compared with other groups, to use treated wastewater for different purposes. This may be because they are more familiar with the different potential uses. Nearly 58% of the sample thought that fresh water supply would be a problem in the future. About 32% believed to some extent that it would be a problem and ten% said it would not be a problem. In the future there may be more acceptance of the use of tertiary or quaternary treated water in Kuwait.

1.7. Demography

Kuwait has an overwhelmingly urban population that has grown rapidly since the discovery of oil in the late 1930s, with over 98% of the population lives in urban areas. Between 1994 and 2016 the total population increased from 1.6 million to 4.8 million, at an average annual rate of 4.0% (see Figure 1-11). Over this time, the Kuwaiti population as a share of the overall population has declined from nearly 37.2% to nearly 30.4%. In contrast, the expatriate population has grown more rapidly over the same period - about 5% per year on average - while their ratio of total population rose from nearly 62.8% to 69.6% (PACI, 2018).

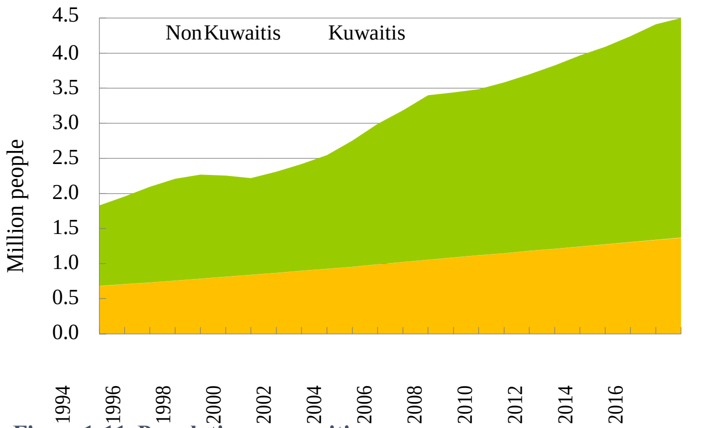


Figure 1-11: Population composition.

(Source: Public Authority for Civil Information, paci.gov.kw)

Kuwait's population is, like those of its Gulf neighbors, heavily skewed due to relative to age and gender (see Figure 1-12). By the end of 2017, most of total population (about 78%) was between 16 and 64 years of age and males roughly comprised 63%. This is in large part due to the presence of a large number of expatriate workers in the country in that age bracket (about 86%) that are mostly male (nearly 69%).

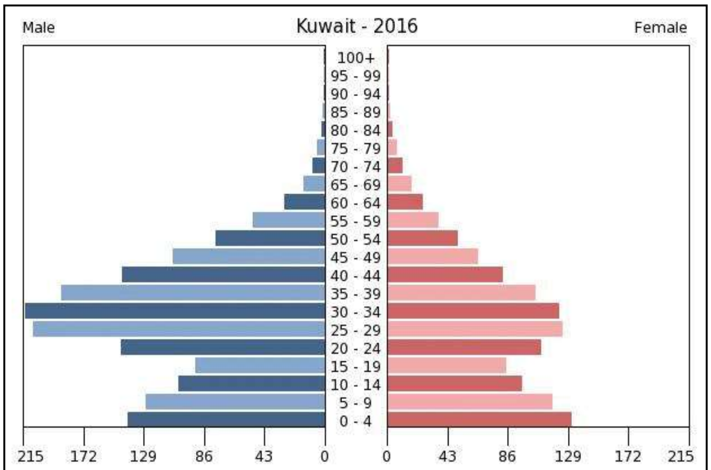


Figure 1-12: Population pyramid, 2016.

(Source: Public Authority for Civil Information, paci.gov.kw)

In contrast, Kuwaitis under the age of 20 accounted for the majority, about 45.2 percent, of the national population in 2016. On the other hand, the gender distribution in the case of Kuwaiti national population is modestly biased towards females (51%).

Regarding educational levels, illiteracy rate among population during the 10 years was confined to about 3 percent, while those who just read and write were 27 percent, holders of school certificates ranging from primary to secondary represented 45.4% of the population (see Figure 1-13).

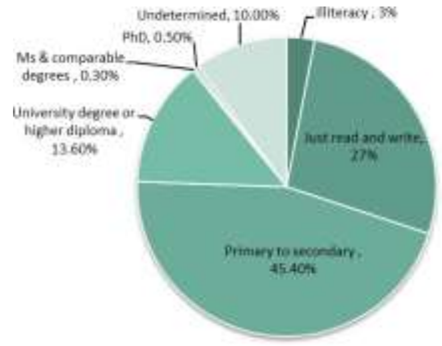


Figure 1-13: Educational profile.
(Source: Alghais and Pullar, 2016)

1.8. Urban Development

Since the first half of the twentieth century, Kuwait City has transformed itself from a small walled city to a metropolitan area experiencing rapid and unprecedented population growth with only a relatively small increase in the extent of its urban area. Most of the highly urbanized areas are located along the coast (see Figure 1-14). This has led to a number of lifestyle, economic and environmental challenges (Alghais and Pullar, 2016).

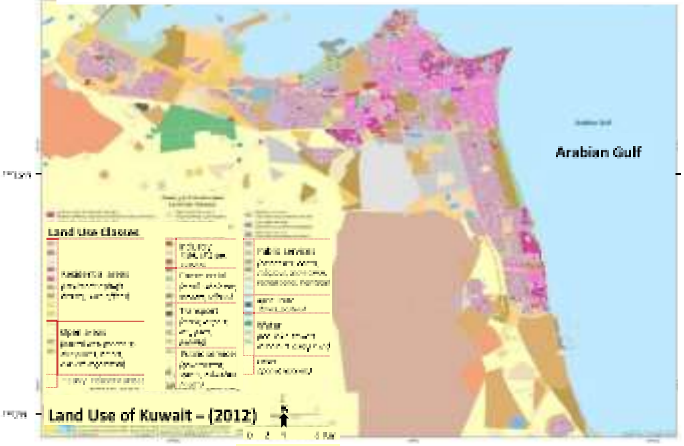


Figure 1-14 GIS map of land use in State of Kuwait.
(Source: e- Misk, KPA)

Future urban developments are planned for beyond the the periphery of existing urban centers. Two of the most prominent are briefly described in the bullets below.

- *Kuwait's Islands Project.* The initial phase of an ambitious project to transfer five of the Kuwaiti uninhabited islands (Boubyan, Failaka, Warba, Miskan and Ouha) into economically feasible areas was presented to His Highness the Amir who backed the initiative as part of the Kuwait future strategy and a corner stone of the vision to transform Kuwait into a regional and global trade and financial hub, while also boosting development of all other sectors of the economy. The project aims to support the country's development through various projects on these islands, which will turn them into free trade zones that link the East to the West. The Supreme Council of Planning is studying the benefits of adopting other international models to create a comprehensive and multi-purpose free trade zone in these islands to enhance Kuwait's regional and international competitiveness and attract foreign investment. Realization of the project will require new legislation, exceptional resolutions, and other governmental measures.
- *Madinat Al-Hareer (Silk City).* Madinat Al Hareer project (see Figure 1-15) was initially proposed by the Tamdeen Group, a private corporation before its approval by the government where it becomes part of the Kuwait future strategy. The project site is Al- Subiya in northern Kuwait and would cover about 250 km^2. The project is planned to be built in phases and be completed within 25 years at an estimated cost of US$ 132 billion.

The city will be connected to Kuwait City via the Jaber Causeway. It will accommodate at its center a one-kilometer high skyscraper tower (Burj Mubarak) that will be surrounded by mixed- use tall building. The proposed capability of the city housing is expected to reach 700,000 people. One of its four villages are the Ecological Village which will includes national parks and reservations for wild animals and rare planets as well as nature reserves for migrating birds from central Asia and Africa. The village will include a center for environmental studies and vast green spaces, as well as be surrounded by a green belt of gardens and vast green spaces. The Chinese government has shown interest in collaborating on the project along with others in the five Kuwaiti islands as part of the Chinese 'One Belt, One Road' initiative promoting economic prosperity of Eurasia countries.

Figure 1-15: Conceptual rendition of Silk City to be built at Subyia. (Source: Tamdeen Group)

1.9. Public Health

Due to a modern healthcare system, there has been a decrease in the incidence of communicable diseases and an increase in life expectancy over the recent past. Today, the burden of disease has shifted towards non-communicable diseases and injuries (see Figure 1-16). Trends are showing steady increases in the incidence of coronary heart disease, cancer and accidents and injuries (mainly road traffic accidents). In addition, the incidence of diabetes and obesity is on the rise. Various NGOs have begun to focus attention on these conditions.

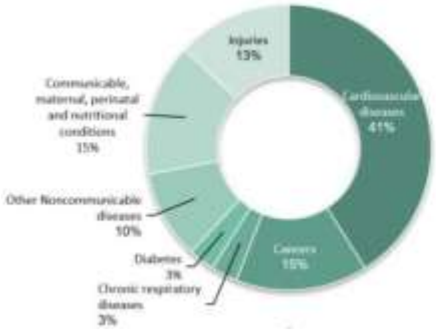


Figure 1-16: Premature mortality from Noncommunicable diseases, 2016.
(Source: WHO Noncommunicable Diseases Kuwait Profile)

In recent decades, the number of motorized vehicles has grown significantly lead to increased air pollutant emissions (PM_{10}, CO, NO_x, O_3, SO_2 and VOCs) and poor urban air quality. Many studies have shown strong associations between particulate matter (PM) levels and a variety of adverse health outcomes, with PM levels are high enough in Kuwait to impose substantial health risks (Ward Brown et al., 2008).

1.10. 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 Mubarak Al-Kabeer.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 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.

Legislative power is vested in the Emir and the parliament which convenes in the National Assembly building (see Figure 1-17). Parliament consists of fifty members, who are chosen in direct elections that are held every four years. In accordance with the country's constitution, the fifteen 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.

Figure 1-17: Kuwait National Assembly building.
(Source: KNA official website)

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 a 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.

1.11. 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. Crude oil & natural gas sector dominates the economy. On average, it represents nearly 50% of the country's real GDP.

Other sectors are not actually fully independent of the oil and gas sector as they are heavily dependent on oil and gas revenues. Social services, for example, are entirely funded by public oil revenues. The largest manufacturing industries are oil-based, and most other activities are heavily subsidized with oil income. Figure 1-18 (left) shows the percentage contribution of oil and non-oil sectors to real GDP (at constant prices of 2010) between 2006 and 2015. Figure 1-18 (right) shows the growth trend of these two sources of real GDP during the same period. Because of such a reliance on oil income, Kuwait's economy continues to be highly vulnerable to changes in global oil demand, as well as international oil market price volatility.

Over the period 2006–2015, nominal GDP per capita has shown a decline of 12.6% from nearly 30.7 thousand U.S. dollars in 2006 to nearly 26.7 thousand U.S. dollars in 2015. However, during the same period of time, real GDP per capita has shown a strong growth of 63.6% from 18.6 thousand U.S. dollars in 2006 to 30.2 thousand U.S. dollars in 2015 (see Figure 1-19, left). Over the same period of time, the GDP per capita using the purchasing power parity (PPP) basis has averaged 80.4 thousand U.S. dollars, which is one of the world highest levels. However, PPP-GDP per capita has declined by 6.4 percent. Figure 1-19 (right) shows the decline in GDP per capita at PPP basis over the period 2006 – 2015.

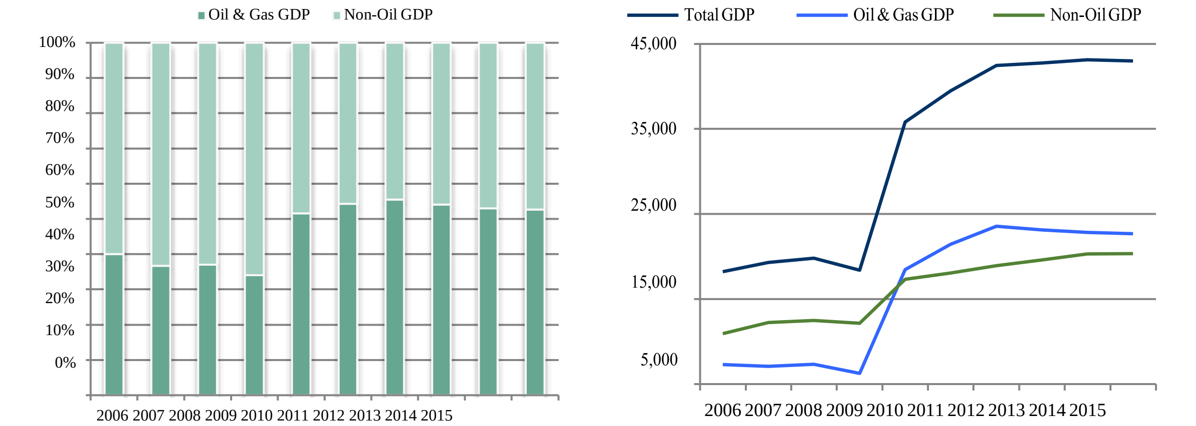


Figure 1-18: Shares of oil and gas sector and non-oil sectors of total real GDP, 2006–2015 (Left); Right: Trends in the contribution to total real GDP from oil and non-oil sectors, 2006 – 2015.
(Source A. Al-Mejren-2018)

In addition to the oil and gas sector, there are four other activities with large GDP shares. They include social services, financial services, transport and manufacturing. Together, these sectors account for about 90% of the non-oil sector's contribution to real GDP and 42% of the entire real GDP, with the remaining 5% of non-oil GDP accounted for by agriculture, utility, construction, and trade sectors. An overview of the major sectors is provided in the bullets below. Figure 1-20 presents their relative contribution to GDP in 2015.

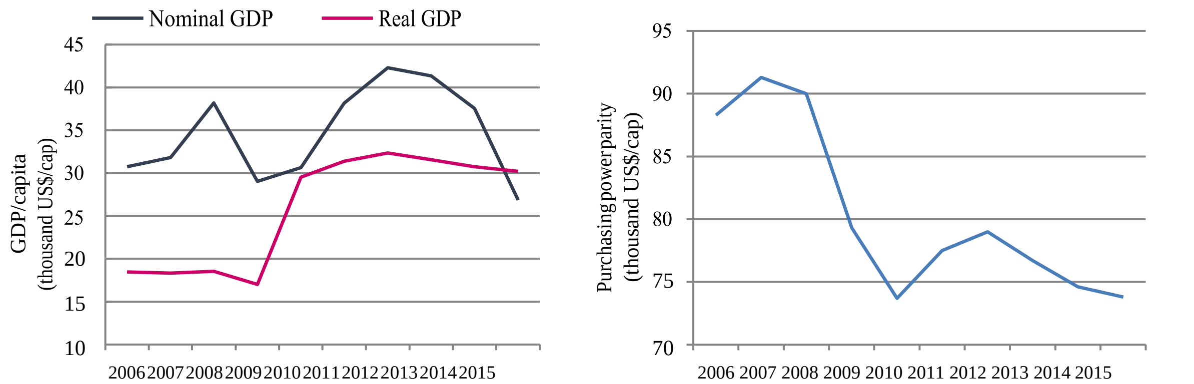


Figure 1-19: Nominal GDP per capita versus real GDP per capita, 2006 –2015 (Left); Right: GDP per capita at purchasing power parity, 2006 – 2015. (Source: A. Al-Mejren-2018)

- *Social services:* The contribution of this sector to real GDP is in the form of government expenditures on basic services (e.g., health care). The overall contribution to overall real GDP in 2015 was about 17%.
- *Financial services:* This sector, which includes banking, insurance, real estate and other financial and business services, plays a substantial role in the nation's economy where its contribution to real GDP was about 14%.
- *Transport:* This sector includes road and ports development, storage and communication services. Its contribution to real GDP in 2015 was about 6%.
- *Manufacturing:* This sector consists primarily of petrochemical industries, building materials, metal and steel production. Its overall contribution to real GDP was about 5%.

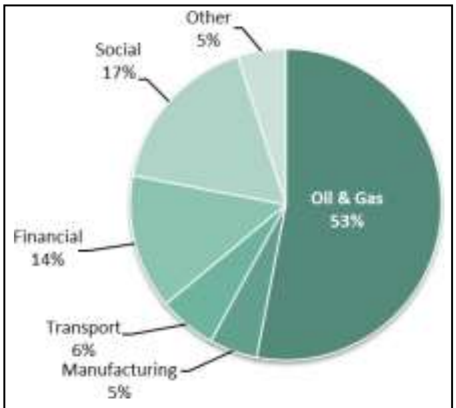


Figure 1-20: Sectoral contribution to Kuwait's real GDP, 2015.
(Source: Central Statistical Bureau, Kuwait)

1.12. Oil & gas

Kuwait is one of the world's leading oil producers. 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. As result of Kuwait having a strong economy it had a per capita Gross Domestic Product (GDP) in 2015 of US$65,400.3 The country enjoys macroeconomic and financial stability and has a very solid financial position with accumulation of considerable public and external accounts surpluses.

Kuwait, a member of the Organization of Petroleum 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. Kuwait Petroleum Corporation (KPC), the Ministry of Oil, and the Supreme Petroleum Council are the government institutions that are responsible for the petroleum sector in Kuwait. KPC is an umbrella establishment with multi subsidiaries including Kuwait Oil Company (KOC), which manages crude oil and natural gas production; Kuwait Gulf Oil Company, which manages offshore crude oil and natural

[3] Economist Intelligence Unit estimate (purchasing power parity).

gas operations in the Partitioned Neutral Zone between Kuwait and Saudi Arabia, the Petrochemical Industries, and Kuwait National Petroleum Company (KNPC), which operates the country's three oil refineries.

The Ministry of Oil estimates the country's proven oil reserves at 101.5 billion barrels, just over 7% of the world total. Additional reserves of about five billion barrels is held in the Partitioned Zone with Saudi Arabia. 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. Figure 1-21 shows the distribution of Kuwait's oil fields.

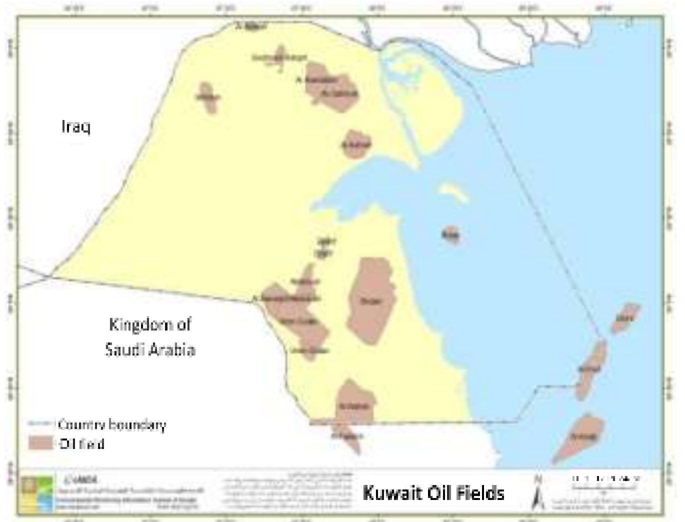


Figure 1-21: Kuwait's oil fields. (Source: e-Misk, KPA)

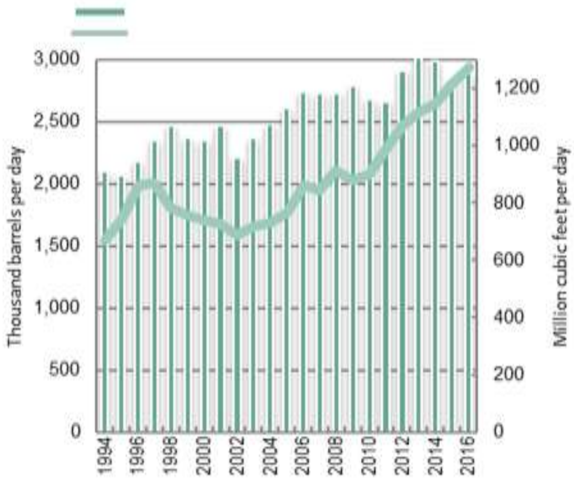
Gross crude oil production in Kuwait reached about 2.883 million barrels per day in 2016 while natural gas production exceeded 1,200 million cubic feet per day in that year (see Figure 1-22, left). In January 2018, KPC officials disclosed plans for the company to spend over $500 billion to boost its crude production capacity to 4.75 million barrels per day by 2040. Nearly $114 billion of this amount was allocated over the next five years. Kuwait's current crude oil production capacity is about 3.15 million barrels per day (bpd).

About one-sixth of Kuwait oil and gas production is consumed in the domestic market. According to estimates by KNPC, which produces and markets the refined products, half of the domestic consumption goes to power plants and seawater desalination units, while the rest is consumed mainly by the oil industry itself, followed by the transport sector. Only a small proportion is consumed by households. Figure 1-22 (right) shows the Kuwait's daily consumption of crude oil and oil Products in thousands of equivalent barrels of crude 1994 – 2016. The decline in oil consumption since 2009 was due, among other factors, to the shift toward the use of more natural gas in power stations and petrochemical industries. Finally, due to low natural gas production relative to consumption requirements, Kuwait has been a net importer of natural gas since 2009. In 2016, Kuwait's total imports of natural gas reached about 152.3 billion cubic feet, nearly 417 million cubic feet per day. (KNPC data).

1.13. Industry

In 2016, the industrial sector's contribution to GDP was 7.2% (current prices) and 5.7% (constant prices). Since 1994, nearly all manufacturing industries demonstrated some improvement in term of their contribution to the GDP (see Figure 1-23). Chemicals and chemical products exhibit an almost two-fold increase in the GDP through the years 2000-2016.

This alone gives chemical industries a special significance. Although growing, recycling has the lowest GDP contribution compared to other manufacturing activities.



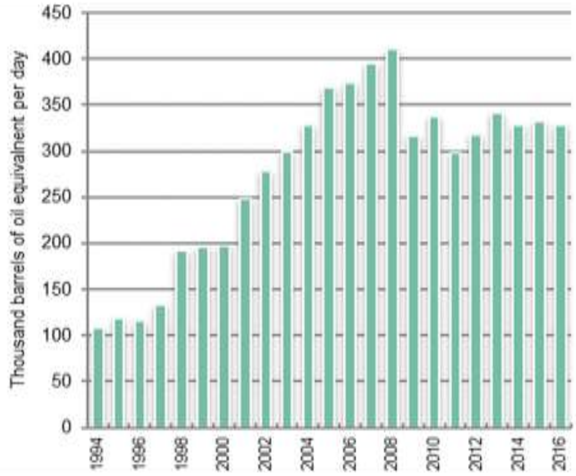


Figure 1-22: Kuwait's daily crude oil and dry natural gas production, 1994-2018 (Left).
(Source: Kuwait Petroleum Corporation);
Right: Kuwait's daily crude oil and oil by product consumption, 1994-2018.(Source: Organization of Arab Petroleum Exporting Countries (OAPEC) Data Base)

1.14. Agriculture, Livestock, Fisheries, and green areas

An arid climate and poor soils mean that Kuwait's arable area is limited. The Public Authority for Agriculture Affairs and Fish Resources (PAAF) records only 18,900 ha as being cropped, although crops provide 56% of the gross value of agricultural production in Kuwait (CBS data). In real terms, the agriculture sector's contribution to GDP is very small, 0.53% in 2016 (World Bank development indicators).

Farming systems are composed of small- and intermediate holders as well as specialized agribusinesses focused on growing date palms, greenhouses, open field vegetables, livestock production, and dairy/poultry production. Farms differ in size, productivity, profitability and marketing potential. Cropping systems are based on pure stand cultivation; monoculture and irrigation techniques vary from basin, furrow to micro-irrigation. Concerns related to yield limitation exist and are mainly caused by pests and poor crop management and systems optimization practices.

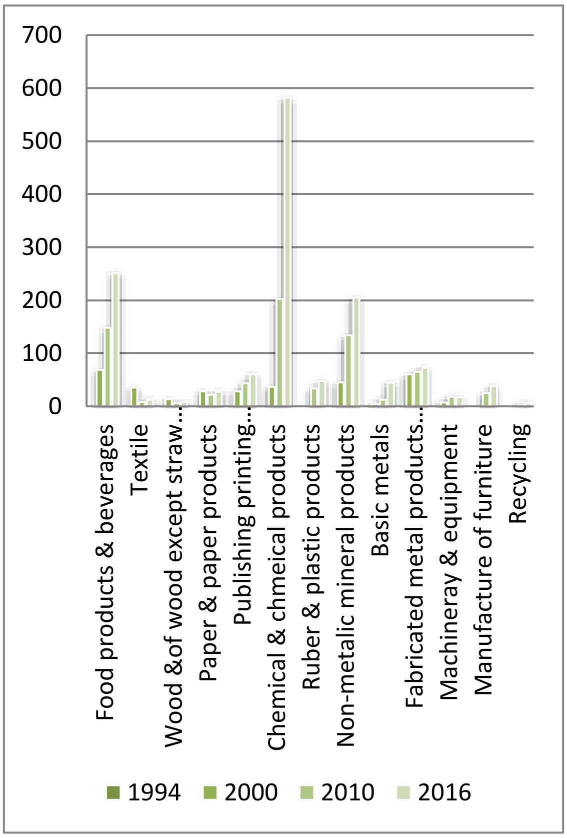


Figure 1-23: Contribution of manufacturing activities to GDP in million KD, 2016.
(Source: Central Statistical Bureau)

Livestock and animal production provide about 38% gross value of agricultural production in Kuwait (CBS data). Livestock production under Kuwait's harsh climatic conditions and shortage of good quality fresh water at reasonable cost makes fodder production and livestock production in Kuwait difficult. All local livestock production is subsidized, particularly the dairy industry, and depends heavily on most animal feed being imported, which means higher costs of production, requiring subsidies for most local livestock products to compete pricewise with imported products. Grazing is widespread, with sheep, goats and camels the main livestock involved (see Table 1-1).

Table 1–1: Livestock population characteristics, 2013-2014 (Source: Kuwait Central Statistical Bureau, Annual Agricultural Statistics)

Livestock type	Total head (2013-2014)	Percent change over 2009-2010 levels
Sheep	628,041	+ 41%
Goats	153,391	+ 1%
Camels	9,192	+ 11%

The Public Authority for Agricultural Affairs and Fish Resources (PAAF), was established in 1983 to manage all type of activities in the agriculture sector and to formulate policies for developing plant, animal, and fishery resources, including land allocation. In order to support local agricultural production PAAF heavily subsidizes selected agricultural activities. Table 1-2 summarizes the various agricultural subsidies provided by the government during the fiscal year of 2015/2016. A portion of the subsidies is directed towards the expansion of protected agriculture production in greenhouses, encouraging water saving irrigation technology, and the utilizing treated wastewater in irrigation.

Table 1–2: Breakdown of agricultural subsidies, 2015-2016 (Source: Public Authority for Agricultural Affairs and Fish Resources)

Subsidy	Value of Subsidy (million US$)	Subsidy share(%)
Subsidy for plant productions	8.2	27%
Subsidy for fodders	15.7	51%
Subsidy for fisheries	0.5	2%
Subsidy for milk and cows	3.9	12%
Subsidy for palm trees	1.8	6%
Other Subsidies	0.5	2%
Total	30.6	100%

Over the years, Kuwait's food production has been growing substantially. Figure 1-24 reflects the growth of the value of such production for three years (1990, 2000 & 2014) using the index number of each type of food production (excluding cereals because of the sharp increase in its 2014's value). Kuwait's crops, which are mostly grown in greenhouses in Wafra, Abdally, Jahraa and Sulaibiya, include tomatoes, cucumber, pepper, okra, green beans, marrow, eggplant, strawberry, onion, mallow, coriander, peppermint, melon, parsley, cabbage, lettuce, snake cucumber, dill, cauliflower, purslane, watermelon and red radish. Roots and tubers include Potatoes, Radishes and Root Beets; while vegetables are varied including onions, and green leafy vegetables. Total value of crops products has increased threefold from 2006/2007 to 2016/2017.

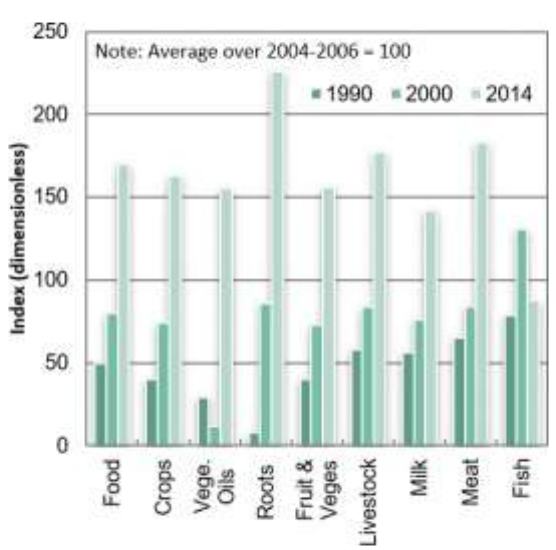


Figure 1-24: Values of Kuwait food production indices. (Source: PAAF)

The country's key policy objective in agriculture is to provide for some of the local needs. To enhance the locally available food, 500 plots of land (see Figure 1- 25), each with 50,000 square meters, were allocated by PAAF in Al-Abdali, the northeastern town, to support meat and poultry production in particular.

A sub-project of 200 integrated farms was also launched aiming to increase plants, crop production and to support other agricultural activities such as sheep farming, fish farming, poultry and other activities. However, 50 larger plots, each with 170,000 square meters for raising cattle and milk production are being removed as the current location obstructs a proposed railway route.

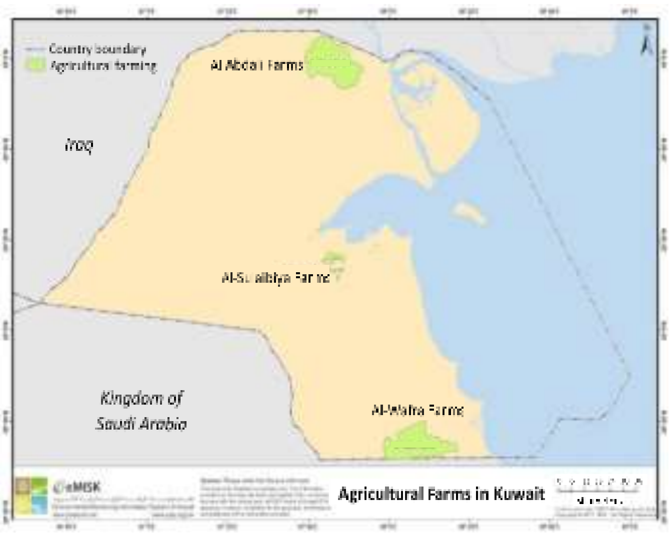


Figure 1-25: Agriculture areas in Kuwait.
(Source: e-Misk)

Since the 1990s overfishing and environment degradation caused 50% decline in the total local fisheries product (Al-Husaini *et al*., 2015). Fish products are actually the most important renewable food resource (fin-fishes and shrimps) with an annual production about 4,500 tonnes, representing only 16% of total demand. Most of the commercial important species are zobaidy (*Pampus argenteus*), harmoor (*Epinephelus coioides*), suboor (*Tenualosa ilisha*) and newaiby (*Otolithes ruber*). Total imported fish products including both fresh and frozen reached 23,285 tonnes in 2012.

Aquaculture practices have been growing in response to the emergence of protected coastal and marine areas. The reduced access to fishing has been partly offset by fish farming projects. These projects provide fish and shrimp to local market throughout the year at reasonable prices. Among these projects is a 10 km^2 pilot project of floating fish culture in the Al-Khiran area, with an expected productivity of nearly 2,000 to 3,000 tonnes of fish annually. The proposed Boubyan Island project has an expected yield of 3,000 tonnes of fish, 3000 tonnes of shrimp, and 60 tons of marine algae. Other proposed projects include the cultivation of wild fish in Al-Sulaibia, Al-Wafra and Al-Sabia, utilizing treated wastewater for fish farming. The proposed 8 km^2 Al-Sabia shrimp farm project will include 300 breeding ponds and two water pumping stations with an expected production capacity of 2,000 tonnes of shrimp annually. In addition, there is a shrimp reproduction plant with an annual capacity of six million shrimp larvae.

Aquaculture is relatively new and potential source of fish production in Kuwait. It is currently being expanded to supplement local depleted landings from capture fisheries. Two types of aquaculture systems are practiced in Kuwait: (i) culture of Nile tilapia (*Oreochromis niloticus*) in concrete tanks using brackish water in agricultural farms, and (ii) culture of marine species such as gilthead bream (*Sparus auratus*), European sea bass (*Dicentrarchus labrux*) and sobaity sea bream (*Sparidentex hasta*) in cages located in the Kuwait Bay. Two key events – the mass fish kills in 2001 in the Kuwait Bay and the Iraq war in 2003 – crippled production. Most of the cages were destroyed as nobody was allowed to go near the cages due to security reasons during the war.

As for green areas, PAAF is active in establishing parks and gardens as well as projects of planting trees and greenery on the sides of roads and in public squares. In this regard, there are 134 public parks, and 635 projects of side road planting extended to nearly 1,700 km long. The landscaping areas cover about 1.2 million square meters. The projects are divided into 12 sites with an area of 34 thousand acres, in addition to a number of parks such as Al-Salmiya Bolivar, Al-Wafra and Al-Abdali.

1.15. Food Security

Throughout its modern history, Kuwait has heavily relied on food imports since only a negligible fraction of food demand can be met by local agriculture. Kuwait produces roughly 1% of its crops from its arable land, using traditional agriculture practices (Analysis of Hydroponic Agriculture in Kuwait - Market trend, Growth and Opportunities (2015-2020), December 2017, Mordor intelligence). Almost all of its fruits and vegetable produce come from hydroponic or horticulture practices (see Figure 1-26).

Kuwait has always faced a unique set of food security challenges due to its climate, limited arable land and water scarcity. Full food self-sufficiency, meaning the country producing all its food requirements, is understood to be an impractical and unachievable goal with an expectation of continued reliance international food trade markets. The Council of Ministers established a Ministerial Committee to supervise the development of a Food Security Investment Strategy for Kuwait. The overwhelming conclusion of the evaluation was that Kuwait currently enjoys a high level of food security.

Figure 1-26: Hydroponics farming in Kuwait.
(Source: Kuwait News Agency website)

Food is readily available and accessible to all residents and Kuwait ranks internationally as one of the most food secure countries thanks to its economic circumstances and government policy.

Kuwait is resource rich, has a large international wealth reserve, easy access to the global food markets, a generous government food subsidy program and significant strategic reserves of basic food commodities. Nevertheless, opportunities have been identified for improving efficiency through the use of incentives and reforms, including the reforms to the system of subsidies, reduction in food waste and encouraging greater efficiency through competition within the supply chain.

1.16. Energy

Regarding natural gas, Kuwait had an estimated 1.8 trillion cubic meters of proven natural gas reserves as of 2015. Kuwait's reserves are not considered significant relative to global reserves and this has spurred an extensive drive in natural gas exploration. The utilization of the discovery of large non-associated gas reserves, which was discovered in the northern area of the country had been delayed by parliamentary opposition since 2006. However, in September 2016, Kuwait awarded contracts to international companies to enable the start-up of production of gas from these reserves by 2018. Yet, the $3.6 billion second phase plan of the project is on hold after tenders were unexpectedly cancelled in late 2017.

Total daily average production of associated and non-associated natural gas increased during 2016 to 1,737 million standard cubic feet per day (MMSCFD) against a target of 1,530 MMSCFD, i.e. higher by about 14%. In addition, average production of dry (non-associated) gas reached 1272 million cubic feet per day, i.e. nearly 464.4 billion cubic feet in 2016. In addition, average gas exported to the LPG unit in KNPC amounted to 1625 million standard cubic feet per day

(MMSCFD), exceeding the target of 1465 MMSCFD. On the other hand, KOC has succeeded in reducing gas flaring to 1%, and strive to achieve less than 1% in line with its strategy. However, despite its efforts, repeated closure of KNPC Acid Gas Removal Plant had pushed KOC's gas flaring rate to 1.31%, higher than the tolerance level of 1.15%.

Regarding electricity, given Kuwait's harsh climate, high population growth rate, and rapid socio- economic growth, demand for electricity is steadily increasing to keep pace, particularly during the hot summer periods. For Kuwait, coping with such multidimensional growth in electricity demand has proved to be a major challenge with repeated power outages experienced in 7 residential areas during the hottest month of July 2016 when temperatures exceeded 50°C.

Total installed electric capacity in 2016 was about 18,850 megawatts (MW). Small (18-42 MW) and medium (100-200 MW) gas turbines account for about 40% of total installed capacity and are usually used in emergencies or during the time of peak load. Due to the high operational costs and low thermal efficiency of gas turbines, they are usually kept as standby with a high level of availability.
The remaining electric capacity consists of steam turbines ranging in size from 120 to 300 MW and combined cycle units (185-280 MW). Natural gas, heavy fuel oil, crude oil and gas oil, are all used as primary fuels for electric generation depending on boiler design, with priority given to natural gas relative to its availability. Figure 1-27 presents the development of total power installed capacity in MW between 1994 and 2016.

Over the period from 2000 to 2015, electricity generation has been increasing by 5.1% on average per year. (Ali and Alsabbagh, 2018). The Ministry of Electricity and Water (MEW) is solely responsible for generation, transmission and distribution of power and water in Kuwait. Although the country has been slow to reform such a vital sector, progress is taking place as the government looks to attract foreign investors. Three major Public-Private Partnership projects are expected to be launched soon: the 2.7 GW Al-Zour North Second and third Project, the three phases of 5.4 GW Al- Khiran Project and the 3.6 GW Al- Nwaiseeb Project. Within the vision of New Kuwait, Kuwait started a three- phase process, with the goal of generating a total of 3,070 MW of renewable energy (15% of the country total annual consumption) by 2030. The first phase is comprised of 70 MW energy park built on a 100- square- kilometre area in Al-Shigaya, a desert zone about 100 km west of Kuwait City.
The second and third phases are projected each to produce 1,500 MW individually. The country determination to increase investments in the renewable sources of energy, mainly solar and wind has intensified after its decision to abandon its plan to construct a nuclear plant.

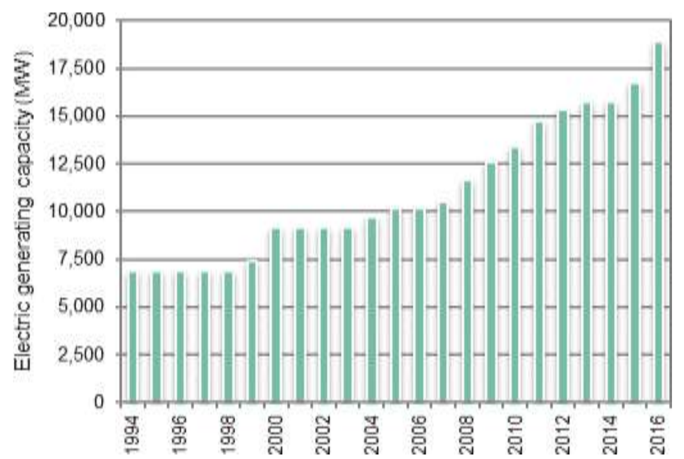


Figure 1-27: Total installed electric capacity, 1994-2016. (Source: Ministry of Electricity and Water, Statistical Yearbook 2017: Electrical Energy)

Kuwait ranks fifth in the world in terms of per capita electricity consumption. Between 1971 and 2014, Kuwait's per capita electricity consumption has been growing by an average annual rate of

3.8% (from 3,011.95 kWh in 1971 to 15,213 kWh/cap/year in 2014). The residential sector accounts for 64% of the country's total electricity consumption, a much higher share the OECD countries (31%) . While the country's harsh weather is a key factor behind this level of demand, the highly subsidized energy tariffs is believed to be the biggest driver behind such extraordinary electricity consumption in Kuwait. The cost of electricity is subsidized by more than 90%. Electricity cost of production is about $0.130 per KWh but is priced to consumers about $0.007 per KWh. (https://oxfordbusinessgroup: Rising Cost Growing Demand has Prompted Drive Boost Generating Capacity and Explore Alternatives).

Table 1–3: Municipal solid waste generation, 2016 (Source: KM)

Landfill	Area size (km^2)	Solid waste (thousand tonnes)
Mina Abdullah	2.42	478.3
South of 7th ring road	5.35	1,381.8
Al-Jahra	1,67	465.
Total	9.44	2,325.2

Over the past decade, Kuwait has adopted policies aimed at reducing per capita electricity consumption and has organized several public awareness campaigns to specify the urgency of energy conservation. Policies attempt to reduce electricity consumption in the building sector in general in Kuwait. These policies include the update of the Energy Conservation Program in 2014, the use of renewable energy to generate electricity and the setting of renewable energy penetration targets. Within the government energy reform initiative of 2016, electricity and water rates have been revised and adjusted to encourage consumers to rationalize consumption. The new tariffs became effective on 22 November 2017.

1.17. Waste

Despite the small geographical area of the country and the relatively small population, Kuwait has one of the highest per capita rates of municipal solid waste (MSW) generation in the world, 1.32kg/capita/day. Kuwait produces more than 1.9 million tons of municipal solid waste annually. Figure 1- 28 summarizes the typical composition of MSW, with the largest share being organic food wastes at 45%. Paper and plastics, prime candidates for recycling and reuse, together make up 40% of total solid waste generation.

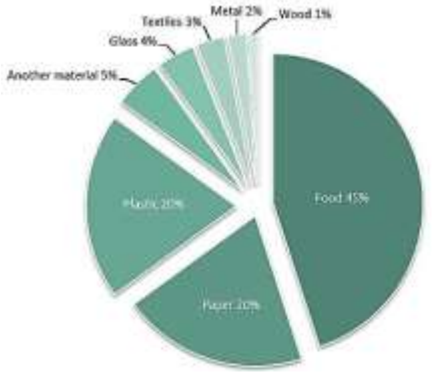


Figure 1-28: Weighted averages of all waste composition.
(Source: KM, Fichtner ; 2013)

Until recently, the dominant MSW disposal method has been landfills. In contrast to its limited area, Kuwait used to have a relatively large number of landfills sites (14 in total), of which 11 have been closed prior to achieving their capacity, because of improper disposal methods and concerns related to public health and environment. Such dumpsites generate huge amount of toxic gases (methane, carbon dioxide etc.) and are plagued by spontaneous fires. Characteristics of the three remaining landfills - Mina Abdullah, Al-Jahra and South of 7th Ring Road - are summarized in Table 1-3. The total area of these landfills is estimated at 9.44 km^2.

The management of domestic wastewater is the responsibility of the Ministry of Public Works. In 1965, the first sewer system was established in Kuwait, and the first domestic wastewater treatment plant was commissioned in the 1970, with a capacity of 100,000 m^3/day. By 1994, there were 3 established domestic wastewater treatment plants; and to meet the further increase in the rate of water consumption per person (275 liter/day) more domestic wastewater treatment plants were built, which make the number reach on total of 7 treatment plants. Table 1-4 lists the domestic wastewater treatment plants, along with the treatment type, design values and daily inflow.

There are 7 industrial areas, as presented in Figure 1-29, where the majority of industrial units are located. In the past, most of these industrial areas were not connected to the sewer system, resulting in the industrial wastewater effluents discharged directly to the environment without treatment.

Table 1–4: Domestic wastewater treatment plant characteristics (Source:MPW)

Treatment plant	Treatment type	Design inflow (thousand m^3/day)
Sulibiyah (Al-Ardeiah)	Reverse Osmosis	425
Kabd (Al-Jahra)	Tertiary treatment	180
Al-Reqah	Tertiary treatment	180
Um-Alhaiman	Tertiary treatment	27
Wafrah (not working)	Tertiary treatment	4,500
Subah Al-Ahmad Marine city	Tertiary treatment	5,000
Khiran City (not functional yet)	Tertiary treatment	1,500

In 2010, an industrial wastewater treatment plant was established in Al-Wafra area with a capacity of 8,500 cubic meters per day, with the possibility of increasing the capacity to about 15 thousand cubic meters per day. With the passing of Environment Law No. 42 in 2014, as amended by Law No. 99 in 2015; Article 35 committed all government agencies and the private sector to treat industrial wastewaters produced by their facilities. Accordingly, the Central Station was designated to receive the industrial treated wastewater from the different sectors.

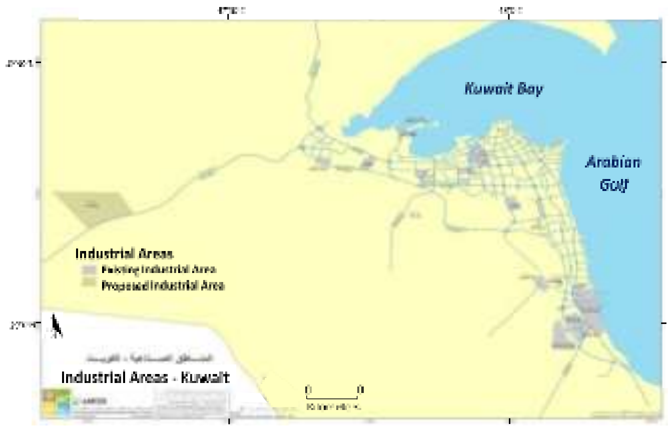


Figure 1-29: Kuwait industrial areas. (Source: e-Misk)

The Ministry of Health is responsible for the disposal of medical wastes, the treatment of such wastes through sterilization by autoclave and final backfilling in the Kuwait Municipality landfill sites. Most medical wastes are sent to incinerators. Currently, the Ministry of Health manages three incinerators as listed in the Table 1-5.

1.18. Transport

Kuwait has an extensive, modern and well-maintained network of road infrastructure. In addition, Kuwait's most recent Midrange Development Plan includes several ambitious projects that expand and upgrade the country's major highways and other means of transport. In fact, the development of transport infrastructure in general is an essential part of the "New Kuwait" vision. Various transport key projects are in progress including the expansion of

Table 1–5: Incinerators of Kuwaiti Ministry of Health (Source:MOH)

Incinerator name	Online year	Capacity (kg/hour)
Shuaiba-1	2002	500
Kabd-1	2009	500
Shuaiba-2	2014	500

airport facilities, a railway, a metro, bridges and seaports. In light of the ongoing technological advancement in the telecommunications industry which has become a basic part of all contemporary infrastructure, Kuwait also recognizes that the term "infrastructure" goes beyond the traditional concept of land, sea and air transportation.

To achieve a "sophisticated modern transport and communication infrastructure", the government is striving to realize five targets: (1) increasing the capacity of Kuwait's International Airport; (2) addressing the domestic traffic problem; (3) developing new economic and urban center at the Northern part of the country, (4) maximizing the capacity of ports to support the transition of Kuwait to a financial and commercial hub; and (5) modernizing the technologies of the telecommunications sector and keeping abreast of the continuous advancement in this field.

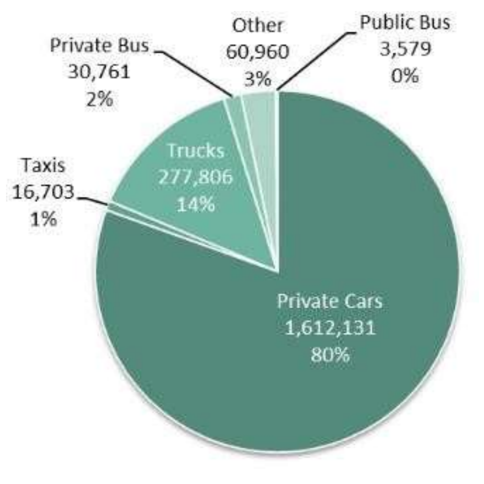


Figure 1-30: Vehicle stock profile, 2016.
(Source: CSB, the annual statistical abstract 2015/2016)

Kuwait has an extensive, modern and well-maintained network of road infrastructure. By 2016, the total length of paved roads exceeded 7,100 km. Yet, despite such great expansion in road capacity, the pace of increase in the number of vehicles in Kuwait outperforms such expansion. In the same year, the number of vehicles number had exceeded 2 million, of which 80% were private. The rest consists of public and private trucks, buses and taxis. (Figure 1-30) presents the distribution of vehicles by type in Kuwait in 2016.

The second pillar of the Mid-Range Plan which deals with the domestic traffic problem includes the development of new roads and ports that link the Northern part of Kuwait with neighboring countries, limiting traffic congestion and involving the private sector in the construction of the needed infrastructure. This program includes the 37-km long Sheikh Jaber Al-Ahmad Sea-Bridge terminals (Figure 1-31), which seeks the efficiency of the transport network reduce the traffic congestion and shorten the distance between Kuwait City and Sabiya at the Northern part of Kuwait Bay. The Bridge which entered its pre-final completion phase includes the construction of two artificial islands containing buildings for traffic and emergency services, the authority which monitors the maintains the bridge, a fuel station and a marina, as well as a main navigation bridge with a height of 23 meters and an opening of 120 meters for the passage of ships.

Figure 1-31: Sheikh Jaber Al-Ahmad cross-sea bridge.
(Source: e-Misk)

In addition, the 570 km long railway network project, which aims to increase trade volume and to facilitate the movement of passengers among GCC countries, will have a positive impact on the domestic traffic by reducing the need for road transport and reducing pollution resulting from the use of vehicles and trucks.

The project also aims to encourage the private sector to participate in the construction and development of the national projects and to benefit from its practical experience, which has a positive impact on the local economy, especially through the transfer of technology and knowledge, thus enhancing the efficiency of employees and raising the level of services provided as well as creating more career opportunities.

The Metro Transport Systems Project (Metro Kuwait) aims to link local suburbs and commercial centers, with a view of reducing the use of private means of transport and thus reducing traffic congestion, number of car accidents, passenger casualties, and air pollution resulting from car exhausts; and creating more than 1,500 job opportunities.

Figure 1-32: Kuwait international airport new terminal
(Source: Ministry of Public Works website)

Air Transport. The development of air transport system includes the increase of the capacity of the country's international airport to 25 million passengers through the construction of new passengers' facilities using the highest world specifications, adding new terminals (Figure 1-32), increasing the efficiency and the capacity of the runway to enable it to receive modern aircraft and the Airbus A380, adapting the world latest technologies of air navigation and the latest international standards, and adding a new air control tower serving the third runway and the middle corridor.

Maritime Transport. There are further plans to develop the maritime transport system to maximize the capacity of the ports to enable it to support the transformation of Kuwait into a regional financial and commercial hub. At the top of the maritime transport program is the project of Mubarak Al-Kabeer Port, which seeks to increase trade exchange activities, boost the volume of regional trade, increase the volume of investments, increase economic resources, raise economic growth rates, develop the services provided by sea ports, increase their absorptive capacity and contribute to the reconstruction and development of the new northern urban area. Mubarak Al-Kabeer port will have a capacity of 24 berths, an ability of receiving outsized ships and a capability to handle nearly eight million containers. The project will help in the creation of an industrial zone and providing thousands of new job opportunities.

The development of Shuwaikh seaport (see Figure 1-33) is an essential part of the program. It aims to increase the efficiency of the navigation channel in the port to accommodate larger number of up-to- date container vessels with deeper depths, in addition to the enhancement of safety factor.

Figure 1-33: Shuwaikh seaport.
(Source: Kuwait Ports Authority website)

1.19. Impact of Response Measures

In the implementation of the commitments of the United Nations Framework Convention on Climate Change (UNFCCC), the signed international parties have agreed to consider the specific needs and concerns of developing countries arising from the impact of the execution of response measures taken by these international parties in combating the climate change.

Therefore, parties of the convention, when addressing climate change concerns, shall strive to minimize adverse economic, social and environmental impacts on other parties, especially developing countries and parties with special circumstances, and to ensure that their development programs are not affected by the response measures. This special treatment has been endorsed to the concerned developing countries in the Paris Agreement (UNFCC, 2015). In fact, Kuwait is among the designated group of developing countries to be affected by the adverse impacts of these measures. Kuwait also suffering from a wide range of climate change consequences including a rapid increase in temperature, desertification, rising sea level, and loss of biodiversity. Some of the response measures relevant to Kuwait's oil and energy sector that are in the process of exploration or actual implementation are outlined below.

Carbon Taxes

Kuwait economy relies heavily on its oil exports, which virtually represent the only source of government income, and contribute to more than half of the country's GDP. Since the linkages between climate change and greenhouse gas emissions was established in the 1980s, crude oil and its derivatives, as key sources of emissions became under tough pressures from environmental concerned policies and procedures in many developed countries. The idea of carbon taxes has been embraced by these countries. Such taxes would eventually reduce oil consumption and encourage the use of clean renewable resources, a trend that would ultimately reduce the income of oil-exporting countries, including Kuwait.

New Sources of Energy

Additionally, the world has witnessed a shift in the nature and pattern of its dependence on oil products since the unprecedented rise in oil prices in the first half of the 1970s, where it becomes less dependent on oil in power generation which has shifted toward the use of alternative fuel such as nuclear, natural gas and renewable sources. With this shift, most of the world oil consumption goes now to the transport sector. However, this sector is also threatened by the shift from the use of oil-based fuels to other substitutes, especially with the recent development of hybrid and electric cars. Many advanced countries support the spread of such alternative means of transport which would eventually leads to lower demand on oil.

Investment in Clean Fuels

In response to tightening environmental standards on oil products by developed countries, Kuwait has been quick to invest in the production of environmentally friendly oil products through the largest project in Kuwait's history - the Clean Fuel Project (15.5 billion U.S. dollar) which includes the modernization of Mina Al-Ahmadi and Mina Abdullah refineries. Kuwait also retired its Shuaiba refinery and decided to replace it with Al-Zour refinery, which is specialized in producing fuel that is compatible with emerging environmental standards in developed countries.

Investment in Other Clean Products

Kuwait has also committed itself to upgrade its petrochemical products by updating the specifications of these products in order to ensure that they meet the newly required specifications in advanced markets. Likewise, the Ministry of Commerce and Industry has committed the local manufacturing sectors to comply with the new international standards in the production of their products.

Fuel switching and demand side efficiency

In order to reduce harmful emissions caused by the fuel mix in electricity production in Kuwait, the Ministry of Electricity and Water has shifted most of its power generation plants from the use of oil to natural gas. Kuwait has also launched several programs to use renewable energy sources, especially solar energy. Through intensive media campaigns, Kuwait is encouraging consumers to rationalize consumption of electricity, water and fuel. Besides, since 2016, the country has moved towards changing the energy pricing structure.

Investment in Indoor Activities

Climate change forces countries with harsh weather, such as Kuwait, to invest heavily in sheltered buildings for indoor activities. Examples of such buildings include covered sport areas, gymnasium halls, schools, public facilities and markets. In addition to the high construction costs, these buildings also require high operating costs, efficient air-conditioning systems and greater consumption of electricity and fuel.

Promotion of occupational safety

Rising temperatures, in the relatively long summer period of Kuwait, that approach or exceed 50 degrees Celsius in many days of July and August. Kuwait has taken steps to stop outdoor labor activities under such conditions in an effort to ensure the health and safety of its labor worker. Such disruption of work increases the cost of production and delays the completion of projects.

New Development Projects

In compliance with world effort towards lower greenhouse gas emissions, Kuwait has been adhering to environmentally friendly standards in its various new development projects, such as Sheikh Jaber Causeway project, the new urbanization projects, the new power plants project, etc. In addition to such impact of response measures on Kuwait's oil and energy sector, the economy of Kuwait might be affected by response measures on area like: Consumer goods subject to eco-labelling and standards; Energy-intensive trade-exposed goods (such as aluminum, iron and steel, cement, chemicals, and pulp and paper); Air-freighted goods; Tourism; Marine-transported goods; and Agriculture.

Kuwait also might be influenced by decision and measures taken several relevant international organizations as: The World Trade Organization (WTO); International originations for standardizations (ISO); International Civil Aviation Organization (ICAO); International Maritime Organization (IMO); and the General Agreement on Tariffs and Trade (GATT).

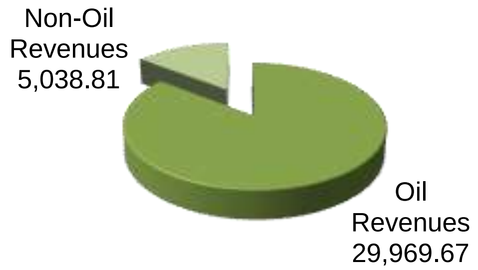


Figure 1-34 Gross domestic product by economic activity (b) for the years 2012-2013 (Million KD).

Source: Central Statistical Bureau, National Accounts Statistics of 2016.

Diversification of Economy

Kuwait has a relatively open economy dominated by the oil industry and government sector. It is one of strongest economies in the GCC with per capita GDP of around US$85,659.55 (IMF, 2012). The country enjoys macroeconomic and financial stability and has very solid financial position with accumulation of considerable public and external accounts surpluses. The latest published National Accounts Statistics of 2011 indicated that oil and gas sectors were still the dominant natural resource form shaping the economic activities in Kuwait, composing 57% of the general output, whereas fisheries, agriculture and livestock collectively compromised only 1%.

1.20. Implementation arrangements

The preparation of the Second National Communication (SNC) was participatory in nature and has in its core objective the establishment of foundational national capacities to prepare subsequent NCs and other reporting obligations such as the BUR. The national team was selected primarily from relevant ministries and institutions and with the senior management of the Climate Change section from KEPA for coordinating the team, some of those experts were members of the negotiating team who's familiar of climate change and the convention obligations.

The Kuwait Environment Public Authority (KEPA) is the focal point of the United Nation Framework Convention of Climate Change UNFCCC. The Climate Change Section is a unit of Air Quality Monitoring Department and is the implementing entity of the UNFCCC in the State of Kuwait. The two major responsibilities of the Climate Change Section are as follows:

- Leading the negotiating team, which includes the all the state agencies and other stakeholders concerned with climate change; and
- Managing the reporting system such as Nationally Determined Contributions (NDC's), National Communications (NC's) & Biennial Update Reports (BUR's).

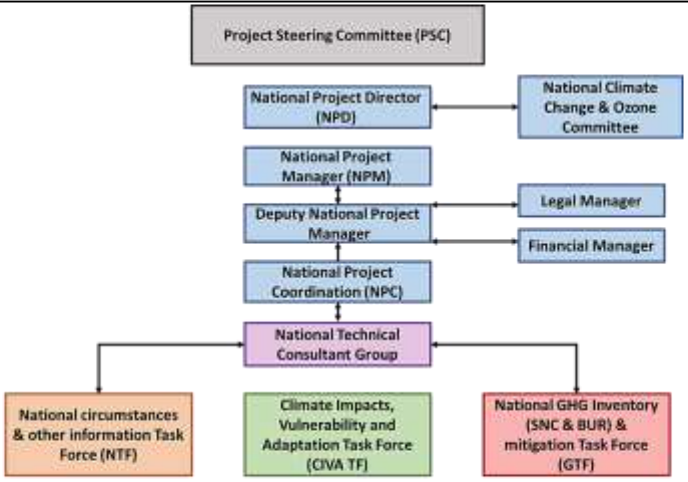


Figure 1-35: Organizations structure for the development of the SNC.

The knowledge developed during the preparing Kuwait's Initial National Communication (INC) was utilized to build up the organizational and technical structure of the SNC & biennial updated reports (BUR). The capacity was built up by engaging and training key stakeholders, namely KEPA technical staff, public sector staff, and civil society stakeholders. Key organizations participating in the development of the SNC are indicated throughout the Acknowledgements section.

A Project Steering Committee (PSC) oversaw the overall coordination and implementation of the SNC, while the National Climate Change & Ozone Committee provided overall policy and cross-sectoral guidance. The KEPA executed project activities at the national level and appointed a National Project Coordination (NPC) who worked under the supervision of a National Project Director (NPD). A small project management support team was established at KEPA to facilitate implementation and reporting. Three Task Forces (TF) were established as follows:

- *National circumstances & other information Task Force (NTF).* This task force developed SNC contents regarding national circumstances, technology needs assessments, research and systematic observation, and capacity building and institutional framework sector.

- *National GHG Inventory (SNC & BUR) & mitigation Task Force (GTF).* This task force developed SNC contents regarding emissions associated with all sectors of the Kuwaiti economy (i.e., oil and gas, energy, transport, waste sector, industry, and agriculture sector. This task force also addressed domestic measurement, reporting and verification (MRV).
- *Climate Impacts, Vulnerability and Adaptation Task Force (CIVA TF*). This task force developed SNC contents regarding vulnerability of sectors and systems in Kuwait, namely, water resources, public health, coastal zones, and marine ecosystems. This task force also focused on climate, dust storms, and Arabian Gulf waters.

Memberships of the various TFs from government institutions and stakeholders were established based on the technical dictates and expertise requirements of the scopes of work. Each Task Force Head submitted a report to the NPC, which was followed up by a technical review process, with subsequent revisions as needed. Figure 1-34 illustrates the organizational structure of the project.

1.21. List of references

Akber, A. 2009. Water Security in Kuwait: Aspirations and Realities. KISR Water Resources Centre presentation.

Al-Anzi, B., Abusam, A and Shahalam, A. 2010. Wastewater Reuse in Kuwait and Its Impact on Amounts of Pollutants Discharged into the Sea. Al-Anzi et al., *J Environ Anal Toxicol*. http://dx.doi.org/10.4172/2161-0525.S3-003

Al-Awadhi, J., Omar, S., & Misak, R. 2005. Land degredation indecators in Kuwait. *Land Degredation and Development*. 16: 163-176.

Al-Dousari, A, Misak, R, and Shahid, S. 2000. Soil Compaction and Sealing in AL-Salmi Area, Western Kuwait. *Land Degradation & Development*. 11: 401-418. 10.1002/1099-145X(200009/10)11:53.0.CO;2-4.

Al-Houty, W. 1989. *Insect fauna of Kuwait*. Kuwait University Press, Kuwait.

Al-Husaini, M &, Bishop, J, Al-Foudari, M, and Al-Baz, Al. 2015. A review of the status and development of Kuwait's fisheries. *Marine pollution bulletin*. 100. 10.1016/j.marpolbul.2015.07.053.

Alghais, N and Pullar, D., 2018. Modelling future impacts of urban development in Kuwait with the use of ABM and GIS. *Translation in GIS*. Vol 22 (1): 20-42 . DOI: 10.1111/tgis.12293

Alhumoud J.M., and Madzikanda, D. 2010. Public Perceptions On Water Reuse Options: The Case Of Sulaibiya Wastewater Treatment Plant In Kuwait. *International Business & Economics Research Journal*. Vol: 9, Number 1.

Ali, H. and Alsabbagh, M., 2018. "Residential Electricity Consumption in the State of Kuwait", *Environment Pollution and Climate Change*. 2:1.

A. Al-Mejren,official national accounts data of the State of Kuwait published in the Annual Statistical Abstract Series, Central Bureau of Statistics for the designated years,2018.

BirdLife International, 2012. "Important Bird Areas factsheet: Al-Jahra Pool Nature Reserve", available at http://www.birdlife.org/datazone/sitefactsheet.php?id=8208

ESCWA (2011) Water Development Report 4. National Capacities for the Management of Shared Water Resources in ESCWA Member Countries.

Ghazanfar, S.A. (2006). Saline and alkaline vegetation of NE Africa and the Arabian Peninsula: an overview. In: M. Orzturk, Y. Waisel, M.A. Khan & G. Gork (eds), *Biosaline agriculture and salinity tolerance in plants*. Birkhaeuser Publishing Ltd. Pp. 101–108.

Halwagy, R. & Halwagy, M. 1974. Ecological studies on the desert of Kuwait II. The Vegetation. *J. University of Kuwait.* 1: 87–95.

Halwagy, R., Moustafa, A.F. & Kamal, S.M. 1982. On the ecology of the desert vegetation in Kuwait. *J. Arid. Environ*. 5: 95–107.

KEPA. 2014. Fifth National Report, Convention on Biodiversity (CBD). Kuwait Environmental Protection Authority, Kuwait.

Kwarteng, A, Viswanathan, N, Al-Senafy, M, and Rashid, T. 2000. Formation of fresh ground-water lenses in northern Kuwait. *J. of Arid Environments*. 46: 137-155. 10.1006/jare.2000.0666.

Mandaville, J.P. 1990. Flora of Eastern Saudi Arabia. Kegan Paul International London and New York jointly with the National Commission for Wildlife Conservation and Development, Riyadh, 1990. ISBN 07103-0371-8

Misak, R, Al-Awadhi, J, Omar, S,and Shahid, S. 2002. Soil Degradation in Kabd Area, Southwestern Kuwait City. *Land Degradation & Development*. 13: 403 - 415. 10.1002/ldr.522.

Omar, S., Misak, R., King, P., Shahid, S.A., Abo-Rizq, H., Grealish, G & Roy, W. 2001. Mapping the vegetation of Kuwait through reconnaissance soil survey. (2005). *J. Arid. Environments*. 48: 341–355.

OMAR, S.A. 1991. Dynamics of range plants following 10 years of protection in arid rangelands of Kuwait. *J of Arid Environments*. 21:99–111.

Public Authority For Civil Information (PACI), 2018. Population data available at www.paci.gov.kw/en

Ramadan, A, and Al-Dousari, A. 2013. Optimization of A KISR-Developed Sand Control System Using Wind Tunnel Simulations. Progress Report 1. KISR, Kuwait.

Royal Botanical Gardens-Kew, 2010. KNFP/PAAF Restoration Planning for Damaged Lands in Kuwait – Initial Report. Kuwait National Focal Point. Kuwait.

Shahid SA, Omar SA, Al Ghawas S. 1999. Indicators of desertification in Kuwait and their possible management. *Desertification Control Bulletin*. 34: 261–266.

UNFCCC,2015. Paris Agreements.

Ward Brown, K, Bouhamra, W, Lamoureux, D, Evans, J.S., and Koutrakis, P. 2008. Characterization of Particulate Matter for Three Sites in Kuwait, *J of the Air & Waste Management Association*,. 58:8, 994-1003, DOI: 10.3155/1047-3289.58.8.994

Zaman S (1997) Effects of rainfall and grazing on vegetation yield and cover of two arid rangelands in Kuwait. *Environmental Conservation*, 1997 - cambridge.org

2. Greenhouse Gas Inventory

This chapter presents estimates of national anthropogenic greenhouse gas emissions and sinks for the year 2000. The inventory includes four categories: energy; industrial processes and product use (IPPU); agriculture, forestry and other land use (AFOLU); and waste. The results presented below are based on an inventory assessment prepared by KEPA, (2018).

2.1. Methodology

The methodology used to develop the inventory is based on the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* and the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (Good Practice Guidance) prepared by the Intergovernmental Panel on Climate Change (IPCC).

References and sectoral approaches were implemented to estimate GHG emissions in each emission category. Emissions up to the year 2016 were estimated using the inventory results for the year 2000 using IPCC's Inventory Software (Version 2.54). The Tier-1 approach of the IPCC guidelines was utilized in the calculations for all reporting categories.

In the subsections that follow, GHG emissions are reported both in absolute units of carbon dioxide, methane and nitrogen oxide emissions, as well as in units of CO_2-equivalent by applying 100-year GWPs of 1 for CO_2, 21 for CH_4, and 310 for nitrogen oxide, as recommended by the IPCC in its Second Assessment Report. Unless, as noted, default emission factors from the IPCC guidelines have been used.

2.2. Total GHG Emissions

Table 2-1 presents total GHG emissions and sinks for the year 2000. Total and net GHG emissions in 2000 were 48,683 Gg CO_2-equivalent, which includes 46,535 Gg from energy; 873 Gg from industrial processes and product use; 102 Gg of emissions from agriculture, forestry and other land use and 1,170 Gg from waste. CO_2 sequestration in 2000 amounted to 9.2 Gg. Emissions from perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulfur hexafluoride (SF_6) in Kuwait are negligible as the products containing these gases are not produced in the country.

Table 2- 1: presents total GHG emissions and sinks for the year 2000.

	GHG Sources & Sinks	CO_2-eq	CO_2	CH_4	N_2O
1	Energy	46,535	46,192	7.5	0.61
2	Industrial processes and product use	873	873	0.0	0.0
2	Agriculture, forestry and other land use	102	-9.2	5.0	0.019
4	Waste	1170	0	54.12	0.11
	Total National Emissions	48,683	47,065	66.6	0.74
	Net National Emissions	48,683	47,056	66.6	0.74

Energy-related activities accounted for the dominant portion of GHG emissions in Kuwait in 2000. Approximately 95.6% of all GHG emissions are associated with the combustion of fossil fuels for electricity production and transport, as well as the release of fugitive emissions from oil and gas operations. Emissions from waste management accounted for 2.4% of all GHG emissions, followed by IPPU and AFOLU categories which accounted for about 1.8% and 0.2% of total emissions, respectively.

2.3. GHG Emission Trends

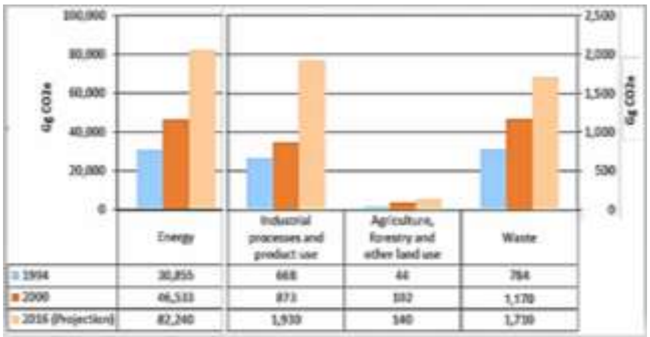


Figure 2- 1: Breakdown in total GHG emission trend, 1994 - 2000, and projection through 2016.

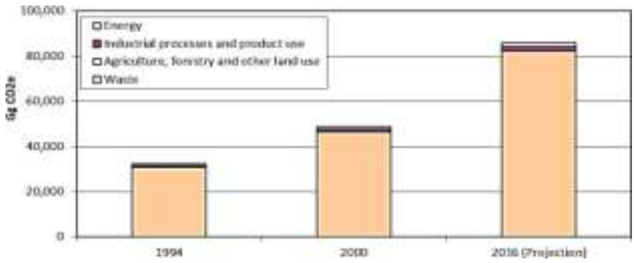


Figure 2- 2: Total GHG emission trend, 1994 - 2000, and projection through 2016.

Figure 2-1 presents the trend in total GHG emissions for the previous 1994 inventory and the GHG inventory for the year 2000. In addition, projected GHG emissions for 2016 are also plotted. Over the 1994-2000 period, total emissions have increased by about 50%; from 32,351 Gg CO_2-equivalent in 1994 to about 48,683 Gg CO_2-equivalent in 2000, or roughly 7%/year. By 2016, national emissions are projected to reach about 86,020 Gg CO_2-equivalent. Figure 2-2 compares GHG emissions for each sector for the years 1994, 2000, and a projection to 2016 and highlights the fact that energy is the main component responsible for the overall increasing trend in GHG emission levels in Kuwait. Over the 1994-2000 period, CO_2-equivalent emissions from energy use have increased by 51%, or about 7.1% per year, due primarily to increased energy use for electricity generation, desalinated water production, and process heat in manufacturing. Notably over the 1994-2000 period, CO_2-equivalent emissions from AFOLU, though small in absolute terms, increased by 131%, or about 15% per year. For the forecast period from 2000 to 2016, total GHG emissions are projected to increase by 77%, or about 3.6% per year. While energy related GHG emissions growth continues to represent the overwhelming majority of Kuwait's emissions, the growth rate is projected to slow to 3.6% per year, or roughly half the 1994-2000 rate. This trend holds true for AFOLU- and waste-related GHG emissions, which are projected to slow to 2.0% and 2.4% per year, respectively, and are well below their 1994-2000 growth rates. On the other hand, IPPU-related emissions are projected to grow by 5.1% per year, or roughly 0.5% per year more than the 1994-2000 growth rate.

2.4. Energy

The energy sector includes electricity generation, water desalination, Oil and gas combustion activities, manufacturing industries and construction, other fossil fuel combustion activities, and fugitive emissions from oil & gas operations. Table 2-2 provides a breakdown in energy sector GHG emissions for the year 2000 for these source categories. Relative to overall anthropogenic GHG emissions in Kuwait, the 46,533 Gg CO_2-equivalent represents about 96% of total national emissions.

Table 2- 2: Breakdown in energy sector GHG emissions for the year 2000.

GHG Sources & Sinks	CO_2-eq	CO_2	CH_4	N_2O
Electricity & water	25,652	25581	0.89	0.17
Oil & Gas	7,225	7219	0.13	0.01
Manufacturing & construction	824	823	0.01	0.00
Transport	6,890	6,749	2.00	0.32
Other combustion activities	236	235	0.02	0.00
Fugitive emissions (oil & gas)	5,707	5,586	4.50	0.08
Total National Emissions	**46,533**	**46,192**	**7.53**	**0.59**

Figure 2-3 illustrates the breakdown in energy related GHG emissions in 2000 by activity. Emissions from electricity and desalinated water production are primarily associated with the combustion of natural gas and oil products showed the highest share of GHG emissions, about 55%. Transport activities are based overwhelmingly on the use of gasoline and diesel oil and accounted for about 15% of total emissions from energy-consuming activities. Fugitive emissions of methane, a gas that has a high global warming potential, accounted for about 12% of

all GHG emissions in the energy industries sector Other combustion activities and manufacturing/ construction accounted for the remaining 3%.

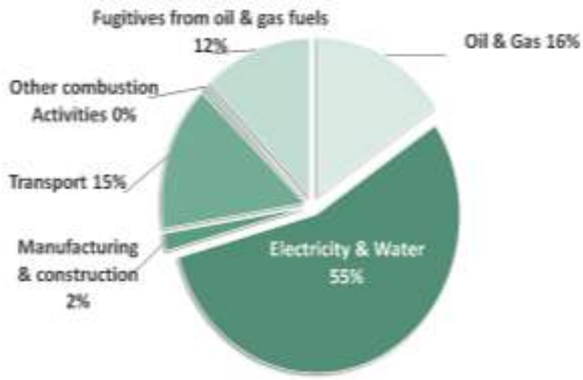


Figure 2- 3: Breakdown of GHG emissions associated with energy activities, 2000.

2.5. Industrial Processes and Product Use

Table 2-3 summarizes GHG emissions associated with industrial processes and product use in 2000. Industrial processes are the third largest emitter of anthropogenic GHG emissions in Kuwait, accounting for 873 Gg of CO_2– equivalent, or about 2.2% of national CO_2–equivalent emissions in 2000.

The mineral and chemical industries represent the sole source of emissions from industrial processes and product use. For the mineral industry, GHG emissions are associated with cement, lime and glass production and account for about 75% of total sectoral GHG emissions. For the chemical industry, emissions are solely associated with ammonia production.

Table 2- 3: GHG emissions associated with industrial processes and product use in 2000.

GHG Sources & Sinks	CO_2-eq	CO_2	CH_4	N_2O
Mineral industry	653	653	0.00	0.00
Chemical industry	220	220	0.00	0.00
Total National Emissions	**873**	**873**	**0.00**	**0.00**

2.6. Agriculture, forestry, and other land use

Table 2-4 summarizes GHG emissions associated with agriculture, forestry, and other land use in 2000. Agricultural practices are the smallest source of anthropogenic GHG emissions in Kuwait, accounting for net national emissions on only 102 Gg of CO_2–equivalent, or about 0.2% of net national CO_2–equivalent emissions in 2000. Most of the emissions from AFOLU activities are associated with methane production from livestock. Kuwait's extensive managed green areas acted as a CO_2 that resulted in a sequestration of 11 Gg CO_2-equivalent.

Table 2- 4: GHG emissions associated with agriculture, forestry, and other land use in 2000.

GHG Sources & Sinks	CO_2-eq	CO_2	CH_4	N_2O
Livestock	107	0	5.0	0.01
Land	-11	-11	0.0	0.00
Aggregate & non-CO2 sources on land	5	2	0.0	0.01
Total National Emissions	**112**	**2**	**5.0**	**0.02**
Total Net Emissions	**102**	**-9**	**5.0**	**0.02**

2.7. Waste

Table 2-5 summarizes GHG emissions associated with waste management activity in 2000. Relative to overall anthropogenic GHG emissions, the 1,170 Gg CO_2-equivalent represented about 2.4% of total national emissions. Waste-related GHG emissions are associated with solid waste disposal, and wastewater treatment and discharge.

Table 2- 5: GHG emissions associated with waste management activity in 2000.

GHG Sources & Sinks	CO_2-eq	CO_2	CH_4	N_2O
Solid waste disposal	**1,136.5**	**0**	**54.121**	**0.0**
Wastewater treatment & discharge	**34.121**	**0**	**0.001**	**0.11**
Total National Emissions	**1170.6**	**0**	**54.122**	**0.11**

2.8. Emissions by Greenhouse Gas Type

The following bullets provide an overview of GHG emission totals by all GHG types for the year 2000.

- *CO_2:* Net CO_2 emissions were estimated to be 47,056 Gg, or 96.6% of Kuwait's total greenhouse emissions in the year 2000. Figure 2-4a summarizes the contribution associated with CO_2 emissions at both the sector and activity levels.
- *CH_4:* Methane had the second largest share of greenhouse gas emissions. Total CH_4 emissions were estimated to be about 66.6 Gg, or about 2.9% of Kuwait's total greenhouse emissions on a CO_2-equivalent basis. Figure 2-4b summarizes the contribution associated with CH_4 emissions at both the sector and activity levels.
- *N_2O:* Nitrous oxide emissions were very small compared to other GHGs. Total N_2O emissions were estimated to be only about 0.74 Gg, or about 0.5% of Kuwait's total greenhouse emissions on a CO_2-equivalent basis. Figure 2-4c summarizes the contribution associated with N_2O emissions at both the sector and activity levels.

2.9. Uncertainty assessment

Emissions/removals estimates are based on three key factors: methodology, modeling, and input data and assumptions, While each of these three contribute to uncertainty levels, they were kept to low levels as possible. There is minimal uncertainty associated with methodology as appropriate QA/QC procedures and the IPCC Software was used as the main tool in the inventory. On the other hand, there is uncertainty associated with input data and assumptions (i.e., emission factors and activity data). Default emission factors provided in the 2006 IPCC Guideline were adopted, thus reflecting the uncertainty embedded in these estimates.

For Kuwait, CO_2 represents about 97% of GHG emissions and are associated with the categories listed previously in table 2-2. Hence, the overwhelming majority of any uncertainty in the inventory will be associated with these categories. Using the results from Table 7a – Uncertainties generated as part of the IPCC Software Report, all of the combined uncertainty levels are below 10%. This suggests a high level of confidence in the inventory results.

2.10. Quality Control

QC/QA Program was implemented in this inventory according to IPCC good practice guidance. Specifically, the 12 QC activities called for in Table 8.1 of the guidance document were followed without exception where applicable.

2.11. Key Category Analysis

The analysis was performed using Approach 1 recommended in 2006 IPCC Guidelines for National Greenhouse Gas Inventories Vol.4 Ch.4. Key categories were identified using a pre-determined cumulative emissions threshold and were those that, when summed together in descending order of magnitude, add up to 95% of the total level. Given Kuwait's circumstances as major oil producing and exporting country which leads to uniformity of emissions in Kuwait over the years (energy sector was always the leading sector in economy and therefore in GHG emissions), the analysis was limited to level assessment excluding trend assessment. Analysis was also limited to CO_2 since the latter represents 97% of total GHG emissions. Table 2-6 summarizes the results of key category analysis.

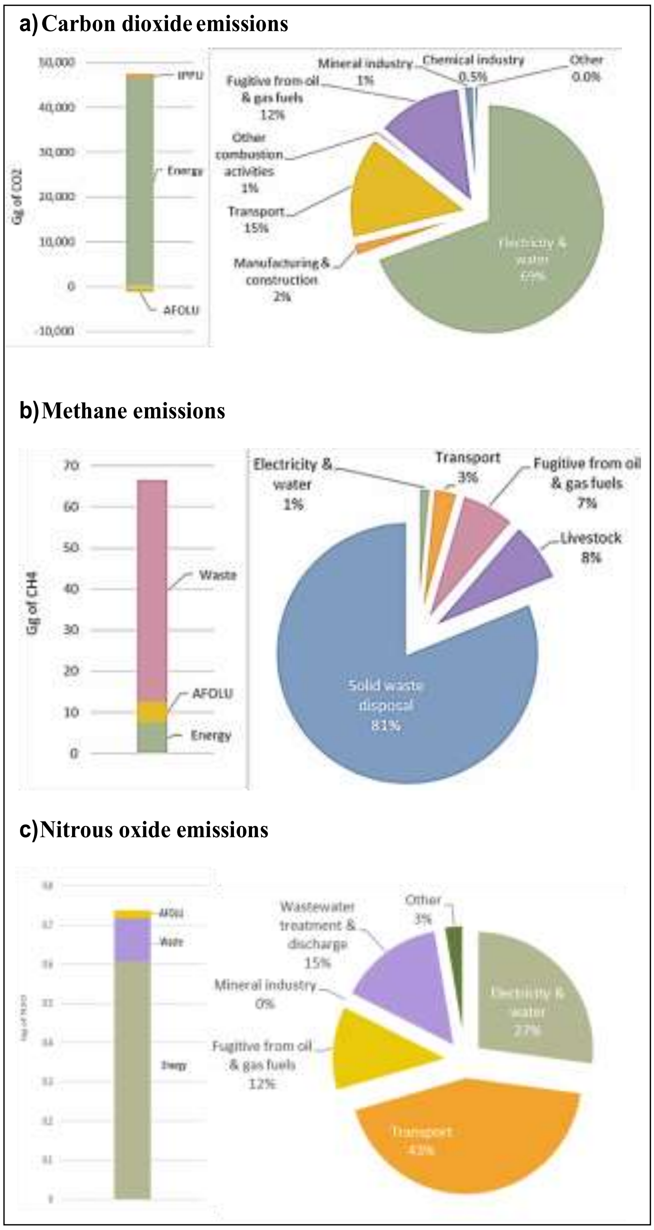


Figure 2-4: Breakdown in GHG emissions, 2000 (Gg).

Table 2- 6: Key category analysis results.

IPCC Category	GHG	Emissions in 2000 (Gg)	Level assessment (%)	Cumulative Total of level assessment (%)
Electricity & Water	CO_2 - eq	25,652	53	-
Oil & Gas		7,225	15	68
Transport		6,890	14	82
Fugitives from Oil & Gas		5707	12	94
Waste		1170	2.4	96.4
Total National Emissions		46644	1	96.4

2.12. Challenges and Recommendations

The primary challenge to the development of the current GHG inventory is data-related, namely availability, accuracy, and consistency. These challenges are rooted in administrative and institutional barriers that impede the application of locally available technical capacity to collect, manage, and analyze pertinent data. Addressing these challenges should address the following:

- Establish and enforce a national statistical data system, which logs operational and production data and information, in governmental and private organizations.
- Establish strategic collaboration agreements between KEPA and public organizations to ensure a sustainable supply of related data.
- Given the above two points, a national emissions inventory system is to be developed with key sectors in the country.
- Hold periodic workshops for public organizations for training and educating critical authorities with the IPCC emissions inventory system.
- Call for and support the conduction of a national project to determine local emission factors related to the indigenous resources.
- 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.

2.13. List of references

Kuwait Environment Public Authority, Kuwait, 2018." greenhouse gas inventory report for Kuwait second national communications under the UNFCCC, assorted sectoral reports and spreadsheets.

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

IPCC, 2006. "Guidelines for National Greenhouse Gas Inventories"

3. Vulnerability and Adaptation

This chapter presents an overview of key sectors that are highly vulnerable to climate change in Kuwait, namely water resources, coastal zones, and agriculture. Coupled with the assessment of vulnerability in each of these sectors are a set of recommended adaptation strategies for which international support will be critical.

3.1 Climate

Outputs of regional climate experiments undertaken as part of the COordinated Regional Climate Downscaling EXperiment (CORDEX) were used as the basis for projecting Kuwait's future climate. The aim of the CORDEX initiative is to better understand relevant regional and local climate phenomena, their variability and future changes, through downscaling of coarse resolution General Circulation Models (GCMs) that were part of the Coupled Model Intercomparison Project - Phase 5 (CMIP5), as well as to evaluate and improve regional climate models and dynamical downscaling techniques. CORDEX is a global initiative where scientists from 14 distinct regions of the world work together to downscale climate data to high resolution spatial scales that better capture local topographical features and meteorological characteristics.

3.1.1. Approach

One of the regions in this framework is the CORDEX-MENA domain which includes the whole Arabian Peninsula as well as North Africa and southern Europe (see Figure 3-1). Outputs from the CORDEX-MENA domain were obtained to develop an understanding of Kuwait's future climate, with a focus on the change in annual average temperature and rainfall the period 2071-2100 relative to the historical climate. Information was available for an ensemble of GCMs that were downscaled using a set of Regional Climate Models (RCMs) from which average values were computed. Two Representative Concentration Pathways (RCPs), RCP4.5 and RCP8.5 were considered for projections up through the year 2100. The spatial resolution of the RCMs was about 50 km. A total of 11 GCM-RCM combinations were considered. Table 3-1 provides a list of the GCMs and RCMs whose outputs were used in establishing Kuwait's future climate.

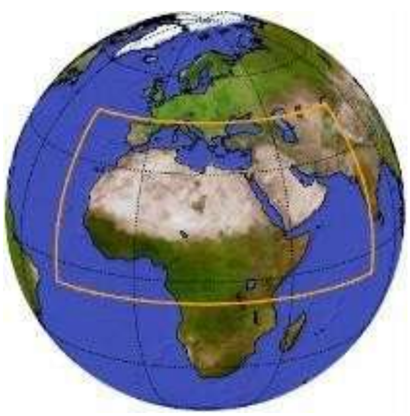


Figure 3-1: Spatial domain for the CORDEX-MENA region

3.1.2. Results

The change is average annual temperature for Kuwait over the period 2071-2100 is shown in Figure 3-2 for RCP4.5 (left) and RCP8.5 (right). Temperature increases are projected to be evenly distributed across the inner portions of Kuwait, on the order of about 2.5° to 2.7°C higher than the historical average under RCP4.5 and on the order of about 4.3° to 4.5°C higher than the historical average under RCP8.5. Future increases are slightly smaller over coastal areas, ranging from roughly 1.7° to 1.9°C higher than the historical average under RCP4.5 and on the order of about 3.5° to 3.7°C higher under RCP8.5.

Table 3-1: List of GCMs/RCMs in the CORDEX-MENA initiative

GCM name (acronym)	RCM name (acronym)						
	Aire Limitée Adaptation dynamique Développement InterNational (ALADIN)	Consortium for Small Scale Modeling - Climate Limited-area Modelling-Community (CCLM4-21)	Rossby Centre regional Atmospheric model (RCA4)	Regional Climate Model (RegCM4-4)	REgional MOdel (REMO2009)	Weather Research Forecasting model (WRF351)	Weather Research Forecasting model (WRF36)
Community Earth System Model, Version 1.0 (CESM1)						✓	✓
Centro Euro-Mediterraneo sui Cambiamenti Climatici Climate Model (CMCC-CM)		✓					
Centre National de Recherches Météorologiques (CNRM-CM5)	✓		✓				
National Oceanic and Atmospheric Administration Geophysical Fluid Dynamics Laboratory model (GFDL-ESM2M)			✓	✓			
Coupled earth system model being used by the Met Office Hadley Centre for the CMIP5 Centennial simulation (HadGEM2-ES)				✓			
Max Planck Institute for Meteorology Earth System Model, LR-r1 configuration (MPI-ESM-LR-r1)					✓		
Max Planck Institute for Meteorology Earth System Model, LR configuration (MPI-ESM-LR)				✓	✓		

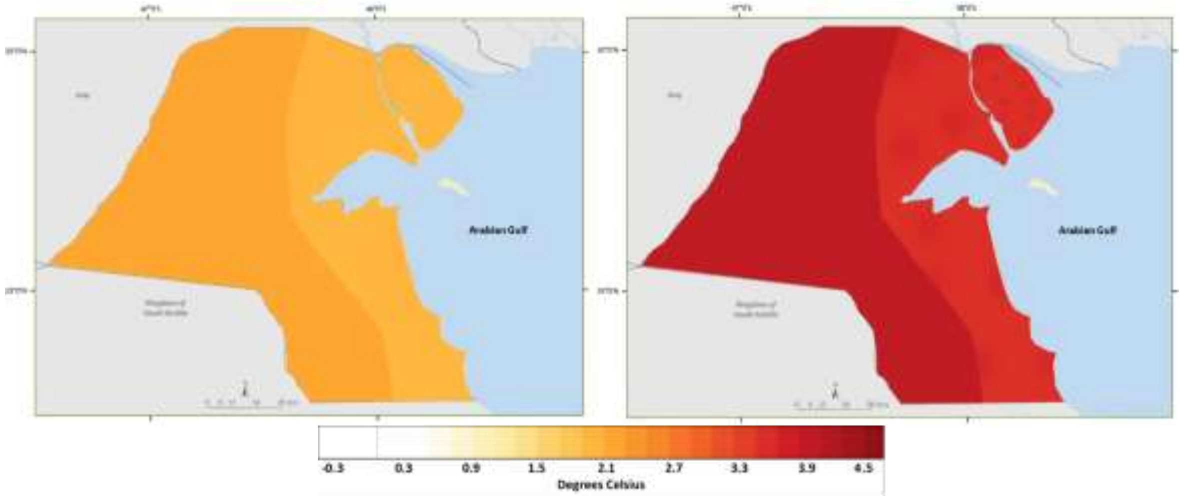


Figure 3-2: Annual average projected change in temperature under RCP4.5 (left) and RCP8.5 (right) for the 2071-2100 period (Sources: CORDEX-MENA; ICBA)

Average future rainfall change for Kuwait over the period 2071-2100 is shown in Figure 3-3 for RCP4.5 (left) and RCP8.5 (right). Under RCP4.5, rainfall decreases are projected to be evenly distributed over the northern portions of Kuwait, on the order of about 3% to 6% lower than the historical average, while the southern portions of the country are projected to experience even steeper reductions, roughly between 15% and 18% lower than the historical average. Under RCP8.5, rainfall decreases are projected to be evenly distributed over the eastern portions of Kuwait, on the order of about 6% to 9% lower than the historical average, while the western portions of the country

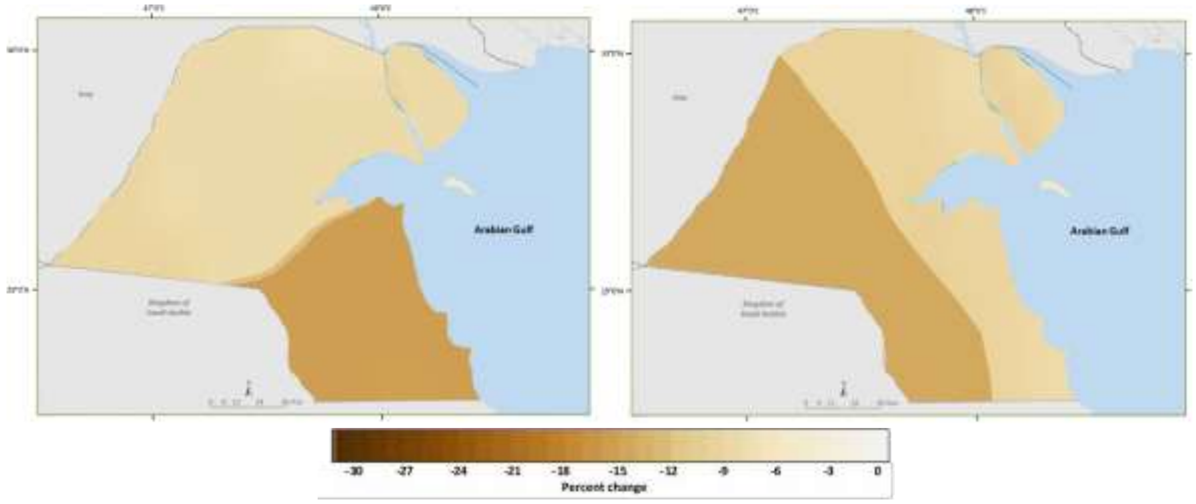


Figure 3-3: Annual average projected change in rainfall under RCP4.5 (left) and RCP8.5 (right) for the 2071- 2100 period (Sources: CORDEX-MENA; ICBA)

are projected to experience even steeper reductions, roughly between 15% and 18% lower than the historical average.

3.1.3. Climate policy implications

The above findings point to several promising areas of future activity. Specifically, the following research areas are considered high priorities that could be pursued within the CORDEX-MENA initiative or independently within Kuwait.

- *Narrowing the spatial domain.* The current CORDEX-MENA spatial domain is quite extensive. A new domain focused solely on the Arabian Peninsula, pursued in coordination with relevant organizations in the region, would be preferable;
- *Projecting tropical storm frequency.* Given the potential for changes in the frequency, intensity, and pathway of tropical storms originating in the Indian Ocean, additional model runs should seek to capture impacts of sea surface temperatures on cyclones.
- *Sandstorm/dust modeling.* Given the importance of dust, it would be valuable to explore how a changing climate might impact dust formation, transport and deposition in the region.

3.2. Changes in the Arabian Gulf

Observed changes in the physical and chemical properties of Arabian Gulf waters adjacent to Kuwait were reviewed and synthesized in order to develop a baseline understanding of recent changes in the Gulf due to increasing GHG concentrations (Alhazeem, *et al.*, 2018).

3.2.1. Background

The Arabian Gulf is surrounded by a hyper-arid environment characterized by high air and sea temperatures, high evaporation rates, and low annual rainfall (Alhazeem, 2007; Riegl and Purkis, 2012). Aside from the Shatt Al-Arab waterway in Iraq and some small Iranian rivers, there is no freshwater inflow to the Gulf. This contributes to naturally high salinity levels which are further exacerbated by highly saline brine discharges associated with many seawater desalination plants in the region.

3.2.2. Approach

Trends in seawater temperature, salinity, and pH were examined based on local marine station data as well as publicly available satellite data. Available local marine data covering the period since 2011 were obtained from the Meteorological Department within the Directorate General of Civil Aviation, which oversees marine data gathering at eight marine stations in Arabian Gulf waters. Satellite data from 1985 are from NOAA's Advanced Very High Resolution Radiometric (AVHRR) satellite. Locations of Kuwait Bay, Kubbar Island, Qaru Island, and Umm Mudayrah Island for which seawater trends are reported are shown in Figure 3-4. Brief descriptions of these areas are provided in the bullets below.

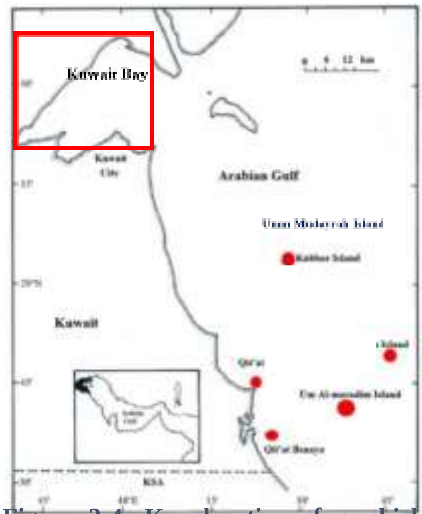


Figure 3-4: Key locations for which physical properties of Arabian Gulf water are reported (Source: adapted from Mahmoud and Jose, 2017)

- *Kuwait Bay*. This is a sheltered and a highly productive marine ecosystem where water temperature and salinity are higher than in open waters (Al-Yamani et al., 2004). Water depth is shallow, around 5 meters. The Bay is high in turbidity and has a very slow counter-clockwise current due to the nature of semi-closed system (Al-Rashidi et al., 2009; Al-Mutairi et al., 2014).
- *Open waters of northern Arabian Gulf*. The marine environment surrounding Kubbar Island, Qaro Island, Umm Mudrayah Island and other northern Gulf areas displays very strong seasonal oscillations, characterized by a strong stratification of temperature and salinity during summer and a fairly mixed vertical profile during winter months (Thoppil & Hogan, 2010). This area is characterized by intense evaporation rates and complex circulation processes.

3.2.3. Results

Historical monthly sea surface temperatures (SST) in the Arabian Gulf show a wide range. Average SSTs are highest in August and lowest in January, as illustrated in Figure 3-5 (left) for Kubar and Qaru islands for the period 2010 through 2017. Annually, the average SST for these locations is about 26.3°C. While similar seasonal trends prevail for Kuwait Bay, there has been a statistically significant increase in SST over the period 1985-2002 (see Figure 3-5, right), as derived from satellite data. SST has steadily increased at a rate of 0.6 (±0.3)°C/decade, a trend three times greater than the concurrent global average (Al-Rashidi, *et al.*, 2009).

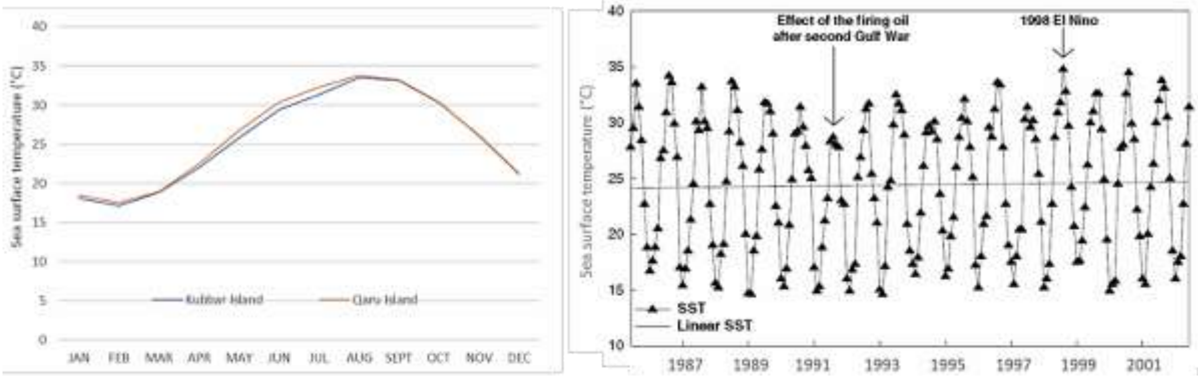


Figure 3-5: Left: Average monthly sea surface temperature at Kubbar and Qaru Islands, 2010-2017 (Source: Kuwait Meteorological Department); Right: Average annual sea surface temperature in Kuwait Bay, 1985- 2002 (Source: Al-Rashidi, et al., 2009)

It is estimated that about half of this increase can be attributed to factors that are global in nature, rather than regional or local.

Historical monthly sea surface salinity (SSS) in Arabian Gulf waters around Kuwait show little variation throughout the year. Average SSS levels are illustrated in Figure 3-6 for Umm Mudrayah Island for the period 2014 through 2016, based on marine station data. Average recorded salinity levels are about 40 parts per thousand (ppt) for each month. This is roughly the midpoint of average salinity levels for Kuwait's Arabian Gulf waters which range from about 38.6 to 42.4 ppt (Alhazeem, *et al.*, 2018).

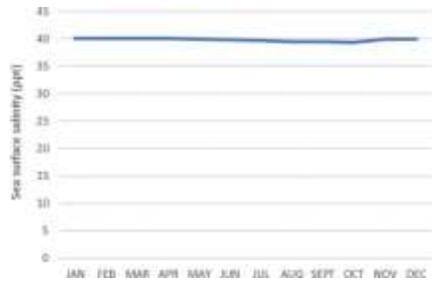


Figure 3-6: Average monthly sea surface salinity at Mudrayah Island, 2014-2016 (Source: Al-Rashidi, *et al.*, 2009)

The Arabian Gulf is a major aquatic sink in the region for sequestering atmospheric CO_2. This has led to acidification of the marine environment, with average pH levels over the 2006-2016 period ranging from 8.3 to 8.5. There are notable interannual pH trends for various marine locations around the southern end of Kuwait Bay, as illustrated in Figure 3-7.

3.2.4. Climate policy implications

The above findings point to several challenges inherent to of climate change policymaking in Kuwait. While historical trends in sea surface temperature, sea surface salinity, and pH have been established, the actual response of these physical and chemical parameters to future increases in atmospheric CO_2 concentrations remains poorly understood at this time. The next step is to undertake regional ocean modeling of the northern Arabian Gulf system to better understand how these waters will be affected under future climate change.

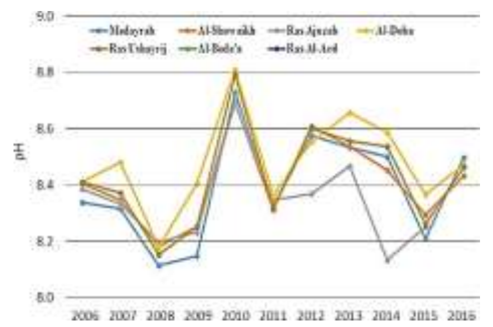


Figure 3-7: Average monthly sea surface salinity at Mudrayah Island, 2004-2016 (Source: Al-Rashidi, *et al.*, 2009)

3.3. Coastal zones

Rising sea levels pose threats of wetland flooding, aquifer and agricultural soil contamination, destructive erosion and lost habitat for fish, birds, and plants. Sea level rise also poses a threat to the built environment in the form of Arabian Gulf waters reaching further inland, particularly under high tide conditions and especially when combined with storm surge associated with extreme storm events. This section summaries the results of a study to assess the risks to urban livelihoods and infrastructure from sea level rise along the entire coastline (Al-Sahli, *et al.*, 2018).

3.3.1. Background

Kuwait's coastal zone consists of two distinct regions (see Figure 3-8). The northern region extends from the Kuwait-Iraq border to the northern coast of Kuwait Bay. This area is largely devoid of infrastructure, although some large projects have recently started, such as Mubarak Al-Kabeer Port on Boubyan Island (Al-Gabandi, 2011; Baby, 2014). The southern region extends from the western and southern coast of Kuwait Bay to the Kuwait-Saudi Arabia border. This area is highly urbanized and is where most of Kuwait's economic activity and infrastructure are concentrated, mostly within 20 km of the coastline.

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The total length of the Kuwait coastline is about 500 km including the islands (Baby, 2014). The southern coastal area of Kuwait Bay hosts Kuwait City, the capital, and the main commercial port, Shuwaikh Port. The southern coast includes residential, commercial and recreational areas, power plants, and desalination stations (Al Bakri and Kittaneh, 1998). Artificial sandy beaches, accounting for about 5% of the shoreline, have been developed in recreational areas. Other key features of Kuwait's coastal zones are summarized in the bullets below.

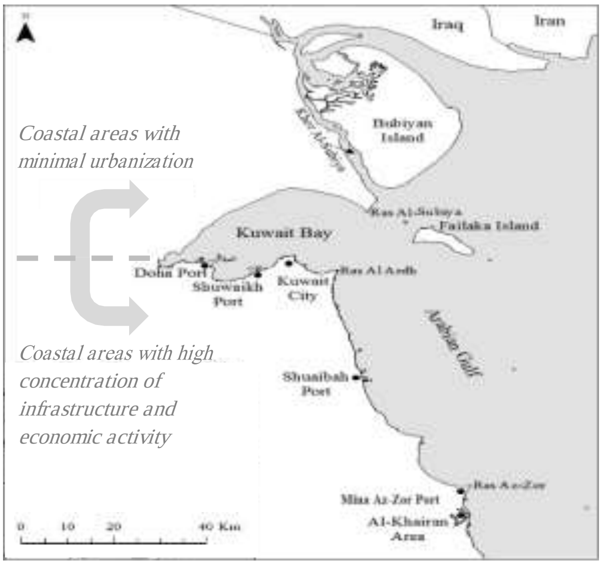

Figure 3-8: Kuwait's main zones along shoreline

- *Geomorphology:* Kuwait's coastal zones overlie an isostatically stable region (Förster et al. 2009; Lokier et al.2015; Stevens et al. 2014). Shorelines can be grouped into six classes based on morphosedimentary patterns: Soft mud tidal flats, sandy-rocky tidal flats, coral reefs, artificial sandy beaches, and oolitic limestone beaches. The soft mud tidal flats are found around Boubyan Island, Ras Al-Subiya tidal channel, Kuwait Bay, and the Al-Khairan area. Sand beaches extend on the south coast from Ras Al Ardh to Ras Az-Zor, while oolitic limestone beaches are found south of Ras Az-Zor (Abou-Seida and Al-Sarawi, 1990). Sandy-rocky tidal flats are found on the southwestern coast of Kuwait Bay, the southern coast of Boubyan Island, and the Ras Al-Subiya headland.
- *Biodiversity:* Kuwait's coastal zones are rich in biodiversity. Subkhas (i.e., coastal salt marshes) along the northern coast are productive ecosystems supporting numerous plant species and other organisms (El-Ghareeb et al., 2006). Coral reefs in southern offshore islands of Kuwait are unique environments that support various trophic levels. Various migrating bird species are found on the islands during winter and summer seasons, supported by rich foraging areas within the intertidal zones, while other bird species inhabit the islands for breeding (Al-Yamani et al. 2004). Many marine organisms ranging from autotrophic species, such as flagellates and diatoms, to higher trophic level species, such as mollusks and demersal fishes in habit the intertidal ecosystem.
- *Tides and waves:* Kuwait's Tides are generally mixed semi-diurnal with a mean range of approximately 3 meters. The tidal range along the north coast varies from 3.5 to 4.0 meters, whereas the average tidal range along the south coast is about 1.8 m. The tidal range height significantly depends on wind direction and coast orientation

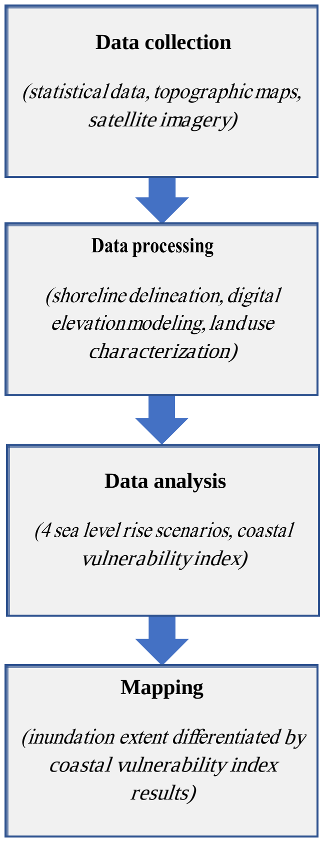

Figure 3-9: Main elements of the coastal zone vulnerability assessment

(Batista, et al. 2004; Paul & Ismail, 2012; Quinn et al. 2012). The dominant northwesterly winds contribute in decreasing tidal heights while secondary southeasterly winds rise the tidal height (Al-Hasem, 2002). Waves and longshore currents have generally limited influence on north coast and relatively strong influence on south coast (Abou-Seida & Al- Sarawi, 1990).

- *Intertidal zones:* The intertidal zone along Kuwait coast exhibits two distinct geographic patterns. The intertidal zone in the north extends gently seaward from 200 to 1,500 m and is characterized by low-energy waves, whereas the intertidal zone in the south is steep and narrow, less than 500 m wide, characterizing by moderate to high-energy waves (El-Ghareeb et al. 2006; Khalaf 1988).

3.3.2. Approach

The main objective of the coastal zone study was to characterize the vulnerability of Kuwait's entire shoreline to sea level rise (SLR). Extensive data collection and processing activities were undertaken from local and publicly available international sources. GIS techniques were employed to calculate a coastal vulnerability index (CVI) and establish the horizontal extent of seawater inundation into vulnerable areas. The major elements of the study are illustrated in Figure 3-9. A brief overview of the methodology applied is provided in the bullets below.

- *Coastal vulnerability index (CVI):* A CVI was calculated for all segments of the Kuwait shoreline, including the islands, using widely used methods (Gornitz, *et al.*, 1991; McLaughlin and Cooper, 2010; Palmer *et al.*, 2011; and Mohamad, *et al*., 2014). Four physical parameters (i.e., elevation, coastal slope, geomorphology, distance to 20-meter isobath) and two socio-economic parameters (i.e., population, and land-use/land-cover) were incorporated into the CVI calculations. The six parameters were ranked on a scale of one to four: the value of one represents the lowest vulnerability; and the value of four is very high vulnerability and manipulated in GIS using map algebra analysis. All layers were given the same weight. (see Table 3-2).

- *Inundation extent:* Four sea level rise scenarios were considered above mean high tide: 0.5 meters, 1.0 meters, 1.5 meters, and 2.0 meters by the end of this century. Northern shorelines were delineated using georeferenced topographic maps; shorelines not covered by the topographic maps, such as the south eastern part of Boubyan Island and southern areas of Kuwait, were delineated using satellite imagery. As LiDAR elevation data was unavailable, the USGS' Global Digital Elevation Model was calibrated to Kuwaiti conditions and used to create an elevation layer of coastal areas. The extent of inundated area under each scenario was estimated using GIS spatial analysis tools following the method used by Bhadra *et al*. (2011). Areas with elevations below the projected SLR and connected with seawater were considered to be inundated.

3.3.3. Results

Total inundated coastal area under the four scenarios are summarized in Table 3-3 relative to the CVI scores. Under the lowest SLR scenario, a total of 185 km^2 of land is projected to become inundated, absent any coastal protection measures. This inundated land area increases to 454 km^2 in the highest SLR scenario. Notably, very little of the very highly vulnerable land, as reckoned by the CVI score, is inundated under any scenario; ranging from less than 1 km^2 in the lowest SLR scenario to only 1.8 km^2 in the highest SLR scenario. In fact, coastal areas that are classified as having only moderate vulnerability shows the highest share of inundated land, ranging from 78% in the Mean high tide + 1.0 meters scenario to 81% in the lowest SLR scenario.

Figure 3-10 shows that spatial distribution of inundated areas for Boubyan Island (left) and the southern area of Kuwait Bay (right) under each of the seal level rise scenarios. Boubyan Island would be highly impacted under all sea level rise scenarios. Roughly half of the island would be inundated in the highest SLR scenario. Only the relatively higher land in the interior of the island would be visible by the end of this century. Coastal areas along Kuwait Bay are also projected to be adversely impacts by rising seas, especially the western coast near Doha Port and densely populated neighborhoods around Kuwait City where there are many areas for which CVI scores showed high or very high vulnerability. Notably, while much of this coastal area currently has hard coastal protection structures such as seawalls and bulkheads to protect roads, buildings and other infrastructure, such installations were based on pre-SLR design criteria and would likely need to be replaced or retrofitted to offer the same level of protection service.

Table 3–2: Parameter characterizations for coastal areas together with vulnerability rankings

Type	Parameters	Vulnerability Rank			
		1 (low)	2 (moderate)	3 (high)	4 (very high)
Physical	Elevation (m)	≤ 0.5	≤ 0.5	≤ 0.5	≤ 0.5
	Coastal Slope (%)	> 3	1.5 – 3	0.5 – 1.5	≤ 0.5
	Geomorphology	Rocky Coast	Sand and rocks	Sand	Mudflats, clay/rocks, or sand
	Distance to 20m	> 4km	2 – 4km	1 – 2km	< 1km
Socio-economic	Population	≤ 1,116	1,117 – 3,789	3,790 – 8,836	8,837 – 23,200
	Land-use	Mudflats, vacant areas, bare soil, environmental reserves, green areas	Other types of land use	Recreational Areas, and sport complexes/ fields	Urban and industrial Areas

Table 3–3: Inundation results, by coastal vulnerability index bin

Extent of inundation (km^2) and share of land inundated (%), mapped onto coastal vulnerability bins:

Parameters	1 (low) 1.00 ≤ CVI ≤	2 (moderate) 1.50 < CVI ≤	3 (high) 2.50 ≤ CVI ≤	4 (very high) 3.50≤CVI≤	Total
Mean high tide + 0.5 meters	0.2 (0.1%)	150 (81%)	34 (18%)	0.9 (0.5%)	185.203 (100%)
Mean high tide + 1.0 meters	0.04 (0.02%)	180 (78%)	47 (21%)	1.3 (0.6%)	228.670 (100%)
Mean high tide + 1.5 meters	0.04 (0.01%)	298 (78%)	83 (22%)	1.5 (0.4%)	382.160 (100%)
Mean high tide + 2.0 meters	0.04 (0.01%)	359 (79%)	93 (21%)	1.8 (0.4%)	453.622 (100%)

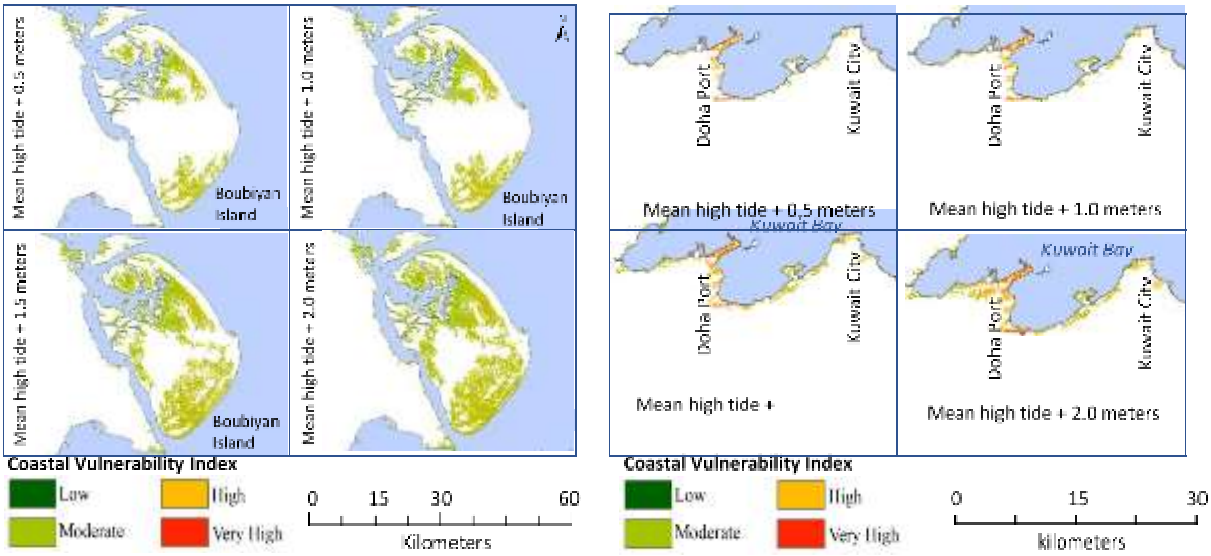

Figure 3-10: Inundated areas for Boubyan Island (left) and the southern area of Kuwait Bay (right)

Figure 3-11 shows the spatial distribution of inundated areas for Shuaibah Port and the Al-Khairan recreational area. These are the only other major areas in Kuwait where there exists significant infrastructure and population density. Unlike Kuwait City, the CVI scores showed mostly moderate vulnerability, with very few locations in the Al-Khairan Recreational Area showing high vulnerability, and no areas with very high vulnerability in either Shuaibah Port or the Al-Khairan Recreational Area.

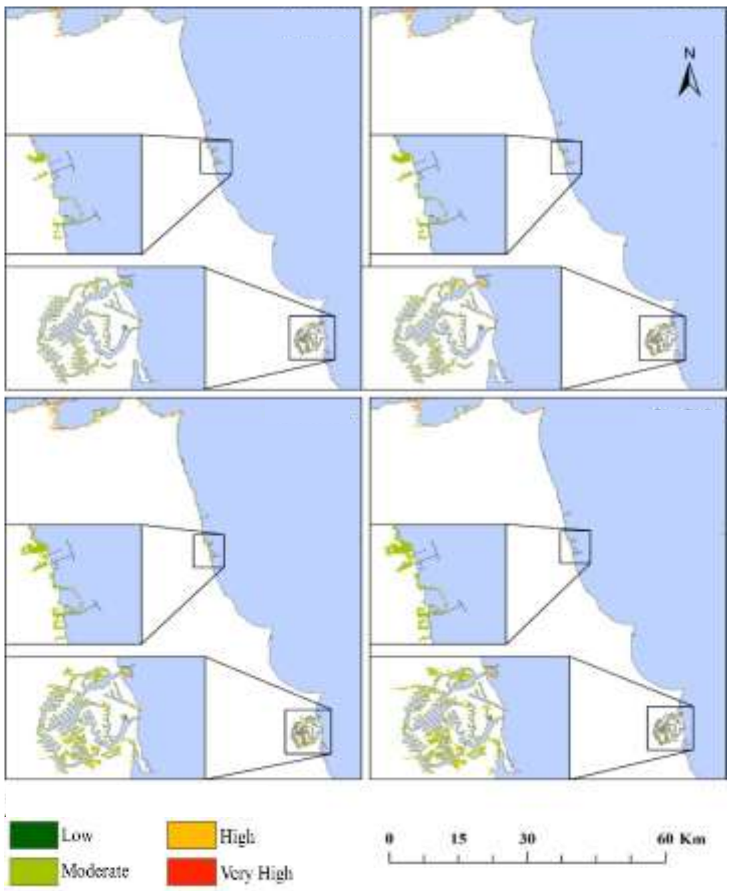

Figure 3-11: Inundated areas for Shuaibah Port and Al-Khairan recreational area

3.3.4. Climate policy implications

The above findings confirm that risings seas pose a critical challenge to risk management for Kuwait's coastal zones. These areas have experienced rapid population growth accompanied by the installation of long-lived infrastructure assets, trends that are expected to continue in the near- to mid-term. Assessing coastal vulnerability to SLR is a fundamental step in understanding the scope of the challenge that confronts decisionmakers regarding the design of viable adaptation strategies. This is further exacerbated by the fact that the current version of GCMs do not represent the air-land-water-ice system well, making actual projections of sea level rise can integrate factors such as accelerating deglaciation impossible. Nevertheless, two recommendations have emerged from the study that are premised on the precautionary principle. These are briefly discussed in the bullets below are considered strategic next steps in the face of uncertainty.

- *Avoid new infrastructure installation in areas classified as highly to very highly vulnerable.* New major development projects, such as power plants, desalination stations, and main ports, should not be established on such vulnerable coasts. Such installations are costly and long-lived and would likely face enormous upgrade costs if sea level rise was not fully considered in design specifications. Raising the awareness among decision makers to incorporate SLR scenarios into development plans is very important, especially now that construction has begun on Murabak Al-Kabeer Port on Boubyan island.
- *Strengthen the protection of coastal biodiversity.* SLR is expected to adversely impact coastal ecosystems, likely leading to a loss of some of Kuwait's rich coastal biodiversity. Protecting these environments through legislative action that restricts development activities is critical important for mitigating SLR consequences and promoting ecosystem resiliency to SLR. Extensive anthropogenic activities along the coast could significantly threat the coastal wildlife and consequently increase the vulnerability of the coasts of Kuwait to SLR. Recently established recreational sites along Kuwait coast, for instance, did not only destroy coastal habitats but also significantly changed the coastline of Kuwait. The continued expansion of recreational sites along Kuwait's coasts without due consideration of it environmental consequences would likely sharply diminish the tolerance of the coastal wildlife of Kuwait to rising seas.

Going forward, enhancing coastal information systems is an important priority for Kuwait. Data collection and information development are prerequisites for effective 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 improving stakeholder understanding of climate change impacts. 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.

3.4. Water resources

Population growth, urbanization, industrial growth, agricultural development are key drivers underlying Kuwait's high per capita water consumption. Coupled with a hyper-arid environment, low annual rainfall, no permanent lakes or rivers, and limited fresh groundwater resources, sustainable water resource management is a key national priority. This section provides an overview of a study to quantify the costs and benefits of specific strategies to promote sustainable water management strategies in Kuwait (AlHarbi, *et al*., 2018)

3.4.1. Background

Kuwait depends on three water resources; desalinated water, brackish groundwater, renewable groundwater, and treated wastewater. Figure 3-12 shows the relative shares of current water consumption associated with these sources. The bullets below details regarding water supply and demand trends.

- *Brackish and fresh groundwater*. Groundwater is extracted from the Ummer Radhuma-Dammam aquifer, a transboundary groundwater system underlying all of Kuwait. The lithology of the aquifer consists of 200 – 300 meters of soft, porous, chalky limestone and hardy crystalline dolomitic limestone with unmelodic and green shale at the base. Most of the groundwater is brackish with total dissolved solids (TDS) ranging from 3,000–10,000 mg/liter (MEW; Al-Rashed,2010).
Renewable fresh groundwater, with TDS ranging from 600 to 1,000 mg/liter, is only available in low quantities through deep subsurface lenses at Al-Rawdatain and Umm Al-Aish in the Northern part of Kuwait and represents typically less than 5% of annual consumption. Brackish groundwater is used for oil depressurization by the Kuwait Oil Company as well as irrigation for green areas and private farms in Al-Wafra and Al-Abdalli. Over the period 2006-2016, brackish groundwater use has been increasing by about 8.7% per year, with current consumption levels of about 1,238 liters per person per day (see Figure 3-13).

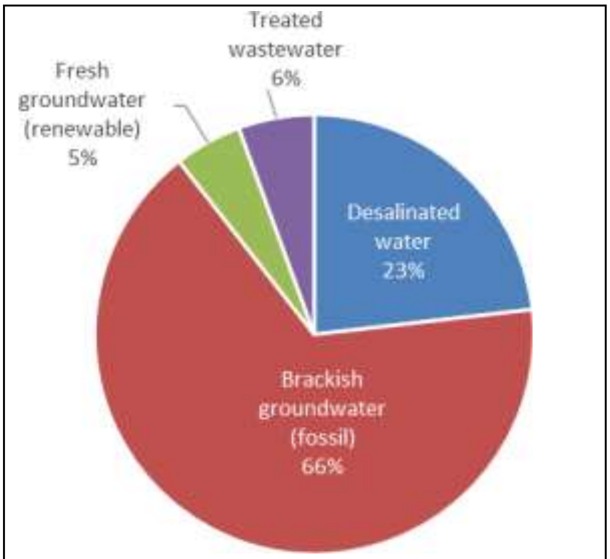

Figure 3-12: Water consumption profile in Kuwait (Source: MEW)

- *Desalinated water.* Desalinated waterproduced from Arabian Gulf seawater has been an important source since 1950. Kuwait relies on six desalination plants using multi-stage flash (MSF) technology (i.e., Shuaiba North, Shuaiba South, Doha East, Doha West, Al-Zour South, Sabiya) that account for 92% of total capacity and one plant using reverse osmosis (RO) technology (i.e., Shuwaikh). Additional RO capacity totaling 0.5 MM^3 per day are planned to come online in the near future (MEW, 2015). Over the period 2005-2015, desalinated water production increased by about 3.6% per year, with current consumption levels of about 417 liters per capita per day (l/cap/day) (see Figure 3-14). As a water security measure, there are currently 84 water.

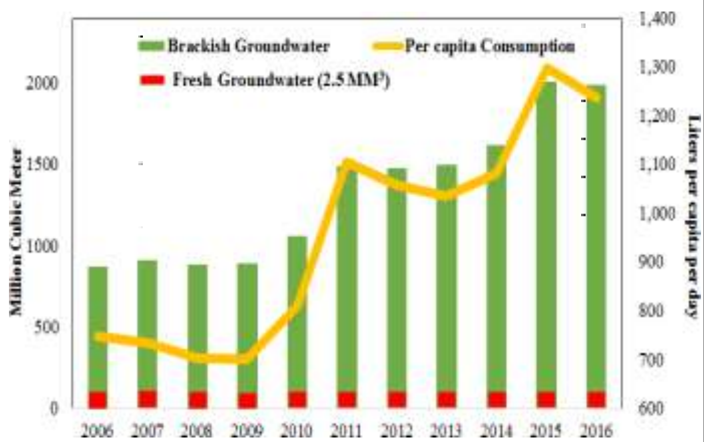

Figure 3-13: Kuwait groundwater consumption, 2006-2016 (Source: Central Statistical Bureau (CSB,2018).

- *Treated wastewater.* Treated Wastewater (TWW) has become a substantial and strategic water resource in Kuwait due to the high cost of desalination. The Ministry of Public Works (MPW)manages wastewater collection from all parts of Kuwait City and its suburbs through 4,700 km of gravity sewers,17 major pumping stations, 57 secondary pumping stations, and 1,600 km of pressure mains (Al-Essa, 2000). Six wastewater treatment facilities are located in the Kuwait City vicinity. Five of these plants use rapid sand filtration and chlorination treatment (i.e., Riqqa, Um Alhaiman, Kabd, Al-wafra, Kheran) and one uses using RO and ultra-filtration technology (i.e., Sulaibiya). These facilities process about nearly 90% of all wastewater generated, with the balance discharged into the Arabian Gulf. Over the period 2001-2014, wastewater generation has increased by about 3.7% per year (see Figure 3- 15). Between 50% and 60% of TWW is typically reused for irrigation of highway landscapes, households' greening, public parks, and artificial wetlands, with the rest discharged into the Arabian Gulf (MPW, 2010).

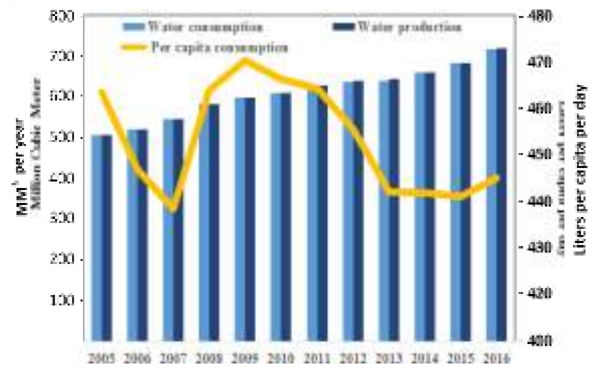

Figure 3-14: Kuwait desalinated water production and consumption, 2005-2016 (Source: MEW, 2015)

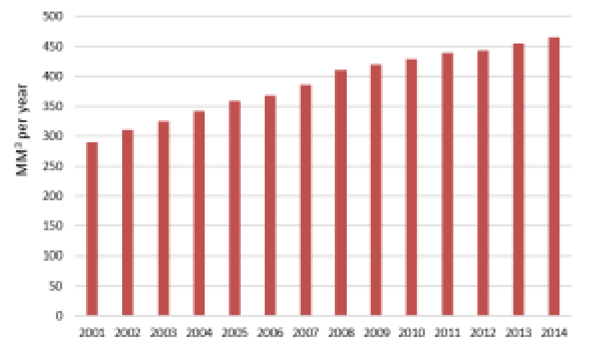

Figure 3-15: Kuwait wastewater generation,2001-2014 (Source: Analysis on Reclamation and Reuse of Wastewater in Kuwait, Aleisa and Shayji, KU, 2017)

3.4.2. Approach

Climate change is not projected to adversely impact Kuwait's brackish/fossil groundwater and desalinated water supplies which together account for about 90% of total supply. Nevertheless, there are likely to be indirect impacts of a changing climate water on water resource management. Therefore, the main objective of the water resource vulnerability assessment was to explore the direct costs and benefits of strategies that promote sustainable water resource management, as well as the co-benefits resulting in lower CO_2 emissions. Extensive data collection and analysis activities were undertaken from local sources. The Water Evaluation and Planning (WEAP) model was used to evaluate water supply and demand in Kuwait under two economic growth scenarios over the 2006-2035 period. The major elements of the study are illustrated in Figure 3-16. A brief overview of the methodology applied is provided in the bullets below.

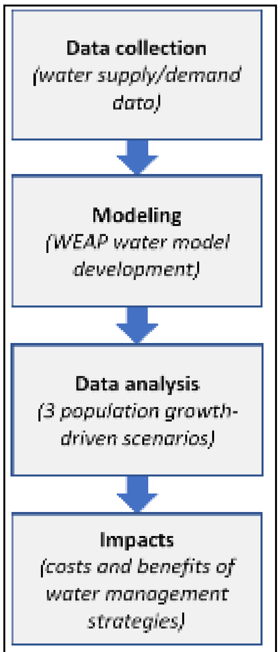

Figure 3-16: Main elements of the water resource vulnerability assessment

- *Scenario construction.* Three scenarios were developed. The Baseline Scenario assumes an average annual population growth rate of 3.2% for the entire planning period. Historical average per capita water consumption was assumed to apply throughout the planning period (i.e., 419 l/cap/day). For the industrial and agricultural sectors, an average annual water uses growth rate of 1.0% was assumed. The Normal Growth Scenario assumes a higher per capita water consumption of 427 l/cap/day, with the population growth rate and the industrial/agricultural water use growth rate remaining the same as in the baseline scenario. The High Growth Scenario assumes an even higher per capita water consumption of 430 l/cap/day, with the population growth rate and the industrial/agricultural water use growth rate remaining the same as in the baseline scenario.

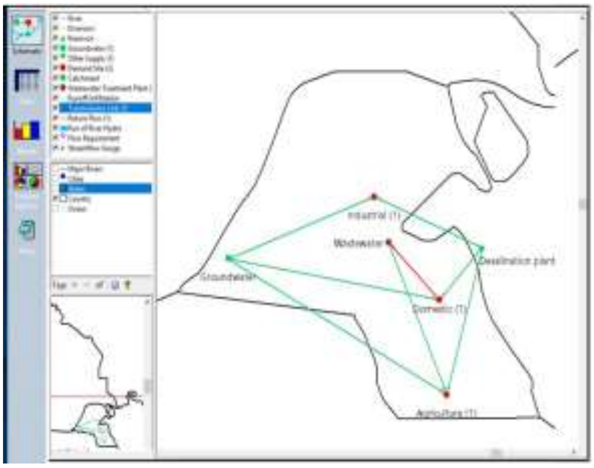

Figure 3-17: Kuwait's water supply/demand system, as modeled in WEAP (Source: AlHarbi, et al., 2018)

- *WEAP Model development.* Water supply/demand was modeled within WEAP by representing its key elements in a spatial schematic (see Figure 3-17). WEAP is a water supply/demand accounting model capable of quantifying the impacts of water policies on supply, demand, and implementation costs. The three main input elements represented within WEAP were water supply, water demand, and water transmission. Water supply elements include groundwater aquifers both fresh and brackish, rainfall, desalination plants and wastewater plants. Water demand sectors correspond to the domestic, agricultural and industrial sectors. Water transmission include links between supply sources and demand sectors, between rainfall and groundwater, and between demand sectors and either treatment or the sea. The water model was calibrated to match historical trends in Kuwait.

Table 3-4: Policies considered in the analysis

Policy name	Description
Water tariffs	Block-tariffs would replace the current flat rate of \$0.59 per m^3 by \$0.6/m^3 for the first 36 m^3; \$0.88/m^3 for the next 18 m^3; and \$1.1/m^3 above 55 m^3. Water demand elasticity in the residential sector from the application of these block rates was assumed to be approximately 7%, after Bushehri (2007).
Improved water efficiency	Installation of efficient water devices in households and businesses (e.g., low-flow showerheads, faucet aerators). This would lead to water use reductions of 20 - 40% after Aboaba and Alhaji (2001) and Al-Rumikhani (2001).
Leak reduction	Reduction of leaks from the pipe network system would result in 10% to 15% water saving.
Improved irrigation efficiency	Increasing irrigation efficiency of agriculture field from its current value of about 25% to 70% by 2035 through more efficient irrigation scheduling. Improving Irrigation efficiency would reduce agggregate water consumption by 30%.

Table 3–5: Summary of Costs and benefits associated with the implementation of the policies

Policy	Annual benefits (2035)		Cumulative benefits (2019-2035)		Costs		
	Water savings (BCM)	CO_2 reductions (million tonnes)	Water savings (BCM)	CO_2 reductions (million tonnes)	Net costs (billion 2016$)	Cost of water savings ($ per MM³)	Cost of avoided CO_2e emissions ($ per tonne)
Water tariffs	436	4.36	2.9	29	14.2	4.9	488
Improved water efficiency	623	6.23	4.1	41	13.2	3.2	318
Leak reduction	1,247	12.47	8.3	83	9.9	1.2	119
Improved irrigation efficiency	1,870	18.70	12.4	124	6.6	0.5	53

- *Policy analysis.* Four water resource management policies (i.e., water block tariff rates, Improved water efficiency, leak reduction, and improved irrigation efficiency) were evaluated individually (rather than in combination) within the WEAP modeling representation of the Kuwait water system. All policies were assumed to be phased in starting in 2019 and reaching full implementation by 2035. Table 3-4 provides a brief overview of the design of each policy. Key assumptions were 5% for the real discount rate; an average of 10 kg of CO_2 emissions for each cubic meter of water delivered; and the use of local capital and operations & maintenance costs for water efficiency devices.

3.4.3. Results

Table 3-5 summarizes the costs and benefits associated with the implementation of the policies individually in Kuwait under the High Growth Scenario. Net costs (i.e., costs of new technologies less savings from reduced water use) are incremental in nature. That is, they result from shifting the development pathway from the High Growth Scenario to a scenario that reflects the integration of each of the individual policies. Moreover, net costs represent the incremental costs to society from the implementation of the policies, rather than any segment of society. Benefits from the policies relative to the High Growth Scenario are presented in physical units for water savings and greenhouse gas emission reductions and are reported in annual terms for the year 2035 and in cumulative terms for the 2019-2035 period. Highlights are briefly described in the bullets below.

- Under the water tariff policy, there are cumulative water savings and CO_2 reductions (i.e., 2.9 billion cubic meters (BCM) and 29 million tonnes, respectively) that come at a net cost of $14.2 billion. This is equivalent to spending $4.9 for each cubic meter of water saved and $488 for each tonne of CO_2 avoided.
- Under the Improved water efficiency policy, there are significant cumulative water savings and CO_2 reductions (i.e., 4.1 BCM and 41 million tonnes, respectively) that come at a net cost of $13.2 billion. This is equivalent to spending $3.2 for each cubic meter of water saved and $318 for each tonne of CO_2 avoided.

- Under the leak reduction policy, there are high cumulative water savings and CO_2 reductions (i.e., 8.3 BCM and 83 million tonnes, respectively) that come at a net cost of $9.9 billion. This is equivalent to spending $1.2 for each cubic meter of water saved and $119 for each tonne of CO_2 avoided.
- Under the improved irrigation efficiency policy, there are the highest cumulative water savings and CO_2 reductions of all the policies (i.e., 12.4 BCM and 124 million tonnes, respectively) that come at a comparatively low net cost of $6.6 billion. This is equivalent to spending $0.5 for each cubic meter of water saved and $53 for each tonne of CO_2 avoided.

3.4.4. Climate policy implications

The above findings confirm that there are viable policies that could be implemented in Kuwait to reduce long-term water demand associated with high population and economic growth. These policies are particularly relevant given Kuwait's acutely limited natural limited water resources and high costs of desalinated water. Several efforts are recommended in support of these measures as briefly described in the bullets below.

- *Education and training:* These activities involve the introduction of climate change issues at different levels of the educational system, which can assist to build capacity among stakeholders to support adaptation in the future and can help to develop appropriate research activities and a greater awareness among citizens.
- *Awareness campaigns*: increase decision makers' and public awareness about impacts of climate change on water resources and the environment. This more effective if pertinent stakeholder or environmental NGOs are involved in the development and the role out of the strategy. Awareness campaigns can be performed via different forms include television, internet, andnewspapers.
- *Strengthening/changes in the fiscal sector:* Public policies may inspire and backing adaptation of individuals and the private sector, mostly through the establishment of fiscal incentives orsubsidies.
- *Science, research and development (R&D) and technological innovations:* R&D and innovation are necessary to allow responses to climate change in general, and to permit definite reactions to climate change vulnerability, including economic valuation of adaptations, technological adaptations (salt-resistant crop varieties), and surveys of new foundations of groundwater and better resource management.

3.5. Marine ecosystems

Kuwait's marine waters and coastal areas includes highly productive habitats, including intertidal mudflats, seagrass, algal beds, mangroves, and coral reefs. These habitats support important commercial fisheries, marine biodiversity as well as endangered species such as the green turtle. This section summarizes the results of an assessment of potential climate change impacts on a subset of these vulnerable ecosystems, namely coral reef ecosystems and commercial fisheries (Alhazeem, *et al.*,2018).

3.5.1. Background

Coral reef ecosystems play an important role in maintaining marine biodiversity and a genetic library for future generations (Moberg and Folke, 1999). In Kuwait, they function as an essential spawning ground, nursery, and breeding and feeding ground for many kinds of marine species such as commercial fish, marine turtles, worms, molluscs, crustaceans and sponges. Healthy coral reefs depend on a delicate balance between sea surface temperature, salinity and water column clarity, which affects the amount of sunlight reaching coral.

Other factors affecting coral growth are hydrodynamic in nature (e.g. currents, waves and storm frequency) and biologic such as larval sources, species diversity and disease occurrence (Done, 2011).

Kuwait has three well-developed offshore coral reef islands: Kubbar, Qaro, and Umm Al-Maradem (see earlier Figure 3-4). Coral cover diversity in Kuwait has reported low coral diversity with 24 Scleractinian species in 17 genera (Downing 1985). Some local coral species such as *Acropora* and *Stylophora* species are particularly sensitive to environmental stressors (e.g., increased sea surface temperature) have experienced bleaching events in recent years (see Figure 3-18). Coral communities around these islands already exist in extreme environmental conditions that are near tolerance limits for survival and reef development (Downing, 1985). With climate change, maximum sea surface temperatures are projected to rise in northern Arabian Gulf waters and likely adversely affecting the delicate balance among these factors.

Kuwait's commercial fisheries are subject to Decree Law Number 46 of 1980 (Concerning the protection of fish wealth) and have been regulated by the Public Authority for Agriculture Affairs and Fish Resources (PAAFR) since 1983. They are the second most important natural resource in Kuwait after oil and gas. In addition to being a renewable source of income, they contribute to Kuwait's food security and cultural heritage, while also providing recreational opportunities.

With its shallow intertidal waters, Kuwait Bay is a highly productive fish nursery habitat and supports a thriving fishing industry, with a range of species typically harvested (Wright, 1988, 1989). Of the over 345 fish and shrimp species found in Kuwait's waters (Al-Baz *et al*., 2013), there are 2 commercially important shrimp species - green tiger prawn *(penaeus semisulcatus)* and jinga shrimp *(Metapenaeus affinis)* - and 21 commercially important fish species (see Table 3-8). These 23 species typically account for about 41% of total annual catch. Despite their historical importance, fisheries in Kuwait and the surrounding region remain understudied and fish catch data remain inaccurate

Table 3–6: Major commercial fish species in Kuwait. (Source: Al-Hussaini, et al., 2015)

Family	Species	Common name
Carangidae	Parastromateus niger	Black pomfret
Cynoglossidae	Cynoglossus arel	Largescale tongue sole
Haemulidae	Plectorhinchus pictus	Trout sweetlips
	Pomadasys kaakan	Javelin grunter
Hemipteridae	Nemipterus peronii	Notched threadfin
Lethrinidae	Lethrinus nebulosus	Spangled emperor
Lutjanidae	Lutjanus malabaricus	Malabar blood snapper
Mugilidae	Liza klunzingeri	Klunzinger's mullet
	Mugil cephalus	Flathead mullet
Paralichthyidae	Pseudorhombus arsius	Largetooth flounder
Platycephalidae	Platycephalus indicus	Bartail flathead
Polynemidae	Eleutheronemaa	Fourfinger threadfin
Sciaenidae	Otolithes ruber	Tigertooth croaker
	Protonibea diacantha	Spotted croaker
Scombridae	Scomberomorus	Kingfish
	Scomberomorus guttatus	Indo-Pacific king
Serranidae	Epinephelus coioides	Orange-spotted
Sparidae	Acanthopagrus latus	Yellowfin seabream
	Argyrops spinifer	King soldier bream
Stromateidae	Tenualosa ilisha	Hilsa shad
	Pampus argenteus	Silver pomfret

Acropora dawning | *Stylophora pistillata* | *Favia pallida, Acropora arabensis and Favites pentagona* | *Goniopora lobata*

Figure 3-18: Examples of bleached coral species from Kuwait's coral reefs (Source: Alhazeem, et al., 2018)

(Al-Abdulrazzak and Pauly, 2013a, 2013b). While human activities have led to habitat destruction and degradation (Al-Husaini, *et al.*, 2018), climatic factors such as elevated sea surface temperatures have led to fish kills of massive proportion (Al-Marzouk, *et. al.*, 2005).

3.5.2. Approach

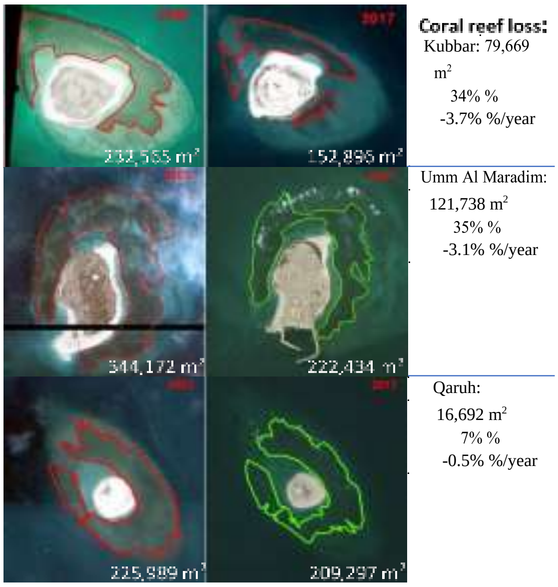

Figure 3-19: Change in coral reef area over time in Kubbar, Umm Al Maradim, and Qaruh (Source: Alhazeem, et al., 2018)

0Two distinct methodological approaches were applied to assess the impact of climate change on marine ecosystems. For coral reefs, the methodological approach consisted of estimating the change in coral reef coverage surrounding 3 islands - Kubbar, Um Al Maradim, and Qaru - for the period 2003 through 2017.

These islands are located 40 km, 25 km, and 60 km away from the Kuwaiti coastline, respectively (see earlier Figure 3-19). Both satellite and aerial images were acquired and analyzed using GIS techniques to define the change in spatial extent of the coral reefs surrounding the islands. The change in coral reef coverage over time was used as a proxy to establish the degree of impact of climatic and other factors on coral reef health.

For commercial fisheries, the methodological approach consisted of estimating the impact on fish landings (or fish catches) in Kuwait Bay associated by exploring the relationship between fish landings and changes in sea surface temperature and pH. The period for the assessment was 2006 through 2016. Daily data for marine parameters were obtained from monitoring stations in Kuwait Bay (see Figure 3-5). Data for fish landing statistics were collected from Kuwait's central statistical bureau and focused on the 23 main commercial shrimp and fish species. Data on fish kills were also collected to explore potential relationship with sea surface temperature. Relationships between fish landings and fish kills relative to elevated sea surface temperatures and pH levels were used as an indicator of the impact of these parameters on fish productivity.

3.5.3. Results

Coral reef coverage loss over time is illustrated in Figure 3-19. The total loss of area is greatest in Umm Al Maradim island, with nearly 122 thousand square meters of coral reef coverage lost. The annual average rate of loss is highest for Kubbar island at 3.7% per year. Coral reefs around Qaruh Island are the most robust with only 7% of the area lost in absolute terms and a much lower annual rate of loss.

It is noteworthy that these losses have occurred during a period when sea surface temperatures have been increasing at a rate of 0.6 (±0.3) °C per decade. This suggests a potential association between temperature increases and regional bleaching events that occurred in 2010, 2015, and 2016, an association that has been documented in other marine environments (Schoepf *et al.*, 2015; Done, 2011; Hennige *et al.*, 2010). On the other hand, Arabian Gulf coral reefs have shown a high tolerance to heat stress, rendering them uniquely resilient under extreme environmental conditions

(Riegl and Purkis, 2012b; Coles and Riegl, 2013; Hume *et al.*, 2013; Benzoni et al., 2006; and Alhazeem, 2007).

In addition, there has been several events of fish kills. The most severe cases were reported in 1999 when up to 30 tonnes of *Liza macrolepis* deaths occurred in Kuwait Bay from September to October. More than 80,000 fish of other species were killed in October (Heil, et. al.; 2001). Another massive fish kill occurred in Kuwait Bay during August and September of 2001, with over 2,500 tonnes of *Liza klunzingeri*, followed by several smaller scale fish kills. Notably, unusually high levels of algae were observed coupled with high temperatures (up to 35°C) and calm conditions (Gilbert, *et al.*, 2002).
Numerous other fish kill incidents have occurred in Kuwait Bay, although at smaller scales. Such experiences are consistent with documentation of warming water temperatures leading to increases in the frequency and severity of fish kills associated with plankton blooms (e.g., Sheppard *et al.*, 2010).

3.5.4. Climate policy implications

Kuwait's marine ecosystems may be vulnerable to climate change impacts. Multiple human stressors, such as habitat destruction and overfishing, are likely to exacerbate this vulnerability. Effective management of activities in the Arabian Gulf under climate change will help increase the resilience of marine ecosystems and the adaptive capacity of policy-making systems, for example by reducing other human perturbations, to ensure the sustainable flow of ecosystem services into the future. Effective implementation of ecosystem-based management that considers a much wider range of environmental and human stressors is fundamental to increasing the adaptive capacity of marine social-ecological systems to climate change. This includes strengthening the implementation and enforcement of current regulations and agreements to protect marine resources in the Arabian Gulf.

3.6. Public health

Climatic conditions can profoundly affect human health in Kuwait. Prevailing conditions of very high temperatures and frequent dust storms impose major health risks that can lead to premature mortality and health care facility visits, particularly among the elderly and very young. This section summarizes key health risks associated with climate change; reviews actions already taken to address climate/health linkages; and outlines a strategic approach to strengthen Kuwait's capacity to address climate change risks to public health (Alshatti, *et al.*, 2018).

3.6.1. Background

With climate change, increased heat stress from higher temperatures and increased cardiovascular and respiratory diseases associated with more frequent dust storms, represent looming health threats to the population. These additional risks could exacerbate current major health problems such as ischemic heart disease, stroke, road injury and lower respiratory infections, whilst potentially undermining Kuwait's social protection systems.

Average and maximum temperatures in Kuwait under a changed climate are projected to rise considerably. Numerous studies confirm that extreme heat leads to increased heat stress which adversely affects health, increasing the risk of morbidity and premature mortality through heat stroke, heat exhaustion and the exacerbation of chronic diseases (Basu, 2009; Xu, 2012; Turner et al., 2013; Basu, 2013; Xiang, 2014). The most severe heat-related illness is stroke and occurs when a person's temperature exceeds a critical threshold and is accompanied by a weak pulse, nausea, and fainting. Moreover, increased heat stress is associated with psychological distress, anxiety and mental health disorders (Wang et al. 2014; Tawatsupa et al. 2010). These potential health outcomes also apply to Kuwait's population, with outdoor workers (e.g., construction, green space maintenance), the elderly, and very young likely to be exposed to the greatest risks.

Dust storms already have large depositional rates, particularly across the northern Arabian Peninsula region. The highest annual depositional rates over Kuwait exceed 500 tonnes per square kilometer and are found in the western part of the country (see Figure 3-X), while annual dust deposition in the Arabian Gulf averages over 10 thousand tonnes for each cubic kilometer of seawater (Al-Dousari, et al., 2017). Severe dust storms result from strong winds that can exceed 45 km/hour, leading to high concentrations of coarse particulates (PM10, particles greater than 10 microns in diameter) that can lead to cardiovascular impacts (stroke, heart attack) and respiratory ailments (asthma attacks). Notably, the frequency of dust storms in the region has increased drastically in the last decade (Sissakiam, et al., 2013) and could potentially increase further under climate change. Some epidemiological studies in Kuwait show a strong association between dust storms and increased asthma and respiratory hospital admissions (Qasem *et al.*, 2008; Thalib and Al-Taiar, 2012; Alshatti, *et al.*, 2018), with other studies in Iran (Ebrahimi, et al., 2014) and Turkey (Al, et al., 2018) offering corroborating evidence, with yet other studies unable to affirm a direct relationship between dust storms and increased asthmatic attacks (Sabah, *et al.*, 2014). In any event, since there is already a high prevalence of asthma in Kuwait - 15% of adults and 18% of children are affected (Khadadah, 2012) – any aggravating factor such as increased dust storm frequency represents a critical health security issue.

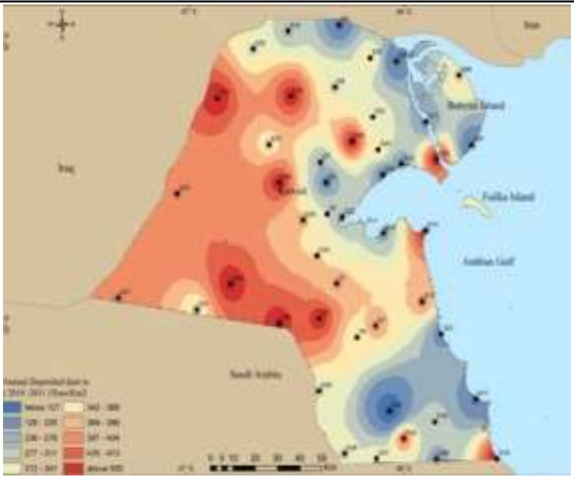

Figure 3-20: Annual dust fallout in Kuwait, 2010- 2011 (UNEP, et al., 2016)

3.6.2. Current coping strategies

In response to clear indications of a changing climate in Kuwait, several measures have already been put into place in recent years to cope with health impacts. These governmental actions have been taken as a proactive step to protect public health and maintain work productivity (see Table 3-7).

Table 3–7: Actions implemented to mitigate health impacts of climate change

Coping strategy	Actions
Adjust the official working hours	▪ The Ministry of Social Affairs and Labor of Kuwait issued a national law in 2005 for bidding any outdoor work from 11:00AM to 16:00PM from June to August as these are the times when the day temperature reaches its maximum level
Awareness campaigns on how to respond to dust and thunderstorms	▪ The Ministry of health of Kuwait launched several awareness campaigns through social media channels and health care centers advising individuals on how to react to dust events. It provided infographics and general advices that are applicable, easily comprehendible. ▪ Annual awareness campaigns on how to deal with the summer in Kuwait: The Ministry also launches annual media campaigns advising individuals on how to deal with Kuwait's hot summer days and how to avoid heat stress and its effects.
National health alerts for dust storms	▪ Whenever a dust event in expected, a national disaster alert is released through media channels to alert individuals about the event and what measures to be taken. All emergency rooms in Kuwait are notified to be well-prepared to expected increase in emergency visits due to such dust events. However, this system needs to enforce further to be activated during every event in collaboration with other public agencies. People in Kuwait themselves have adopted responsive measures to climate change impacts and effects. During the hot summer days, people tend to avoid walking in the streets at noon unless it's needed. Many cover their heads or even use an umbrella to decrease the effect of heat during the day.

3.6.3. *Climate policy implications*

While the country may not be able to influence climate change directly, an adaptation plan is needed to reduce such detrimental health impacts in Kuwait. These include:

- Inclusion health outcomes into Kuwait's national climate change adaptation plans and programs,
- Specific adaptation plans targeting vulnerable groups is needed to create and implement prevention measures toward climate health impacts such as heat-related conditions,
- It was noted that there is a lack of research and scientific studies toward local climate health impacts in Kuwait. Future studies are greatly needed to assess further public health impacts at local levels in relation to heat waves, extreme temperatures, ambient air pollution, humidity, droughts and sea level rise,
- Enhance data collection system through electronic filing systems at health care centers to correctly measures the climate health impacts,
- Equip health care workers with the right skills and knowledge on how to identify, assess and treat such health effects such as heat stress and heat exhaustion. This needs to be coupled with sufficient resources in terms of medical equipment and human resources given the estimated increase in number of admissions and emergency presentations,
- Since climate change is a cross-sectoral issue involving several areas including environment, health, agriculture, and more, a multi-sectoral and multidisciplinary collaboration is essential to the development of a national health adaptation strategy,
- Due to the health effects of dust events and extreme temperature as highlighted in the report, a review of national working conditions should be made to adjust to the current and future climate change impacts. Additionally, a nation-wide early warning system must be developed further in case of extreme weather events such as heat waves or sand and dust storms

3.7. List of references

Abdulrazzak, D. and Pauly, D. 2013b. Managing fisheries from space: Google Earth improves estimates of distant fish catches. *ICES J Mar Sci*. 71 (3): 450–454.

Abou-Seida, M. M., and Al-Sarawi, M. A., 1990. Utilization and management of coastal areas in Kuwait. *Coastal Management*. 18(4): 385-401.

Al, B., Bogan, M., Zengin, S., Sabak, M., Kul, S., Oktay, M., Bayram, H., and Vuruskan, E. 2018. Effects of Dust Storms and Climatological Factors on Mortality and Morbidity of Cardiovascular Diseases Admitted to ED. *Emergency Medicine International*. Vol: 2018, Article ID 3758506.

Al Bakri, D., and Kittaneh, W. 1998. Physicochemical Characteristics and Pollution Indicators in the Intertidal Zone of Kuwait: Implications for Benthic Ecology. *Environmental Management*. 22(3): 415-424. doi: 10.1007/s002679900116.

Al-Abdulrazzak, D. and Pauly, D. 2013a. From dhows to trawlers: A recent history of fisheries in the Gulf countries, 1950 to 2010. *Fisheries Centre Research Reports 21*. University of British Columbia, Pp.: 61.

Al-Baz, Ali & Al-Husaini, Mohsen & Al-Foudari, Hussain. 2013. *Fisheries Status and Research Developments in Kuwait*.

Al-Dousari, A., Doronzo, D., and Ahmed, M. 2017. Types, Indications and Impact Evaluation of Sand and Dust Storms Trajectories in the Arabian Gulf". *Sustainability*. 9: 1526; doi:10.3390/su9091526.

Al-Essa, W. 2000. Wastewater management in Kuwait. In: Al-Sulaimi, J. and Asano, T. (Eds.). *Proceedings of the Workshop on Wastewater Reclamation and Reuse. Arab School for Science and Technology*. Kuwait Foundation for the Advancement of Science, Kuwait.

Al-Gabandi, A. 2011. Boubyan Port: The Eastern Gate of Kuwait. Beatona. Pp.: 16- 25.

AlHarbi, M., Abbas, H., AlHoulan, N., and AlAbdulrazzaq, F. 2018. Summary Report: Climate Change and Water Resources in State of Kuwait. Vulnerability and Adaptation Group Vulnerability & Adaptation Team, August.

Al-Hasem, A. M., 2002. *Coastal morphodynamics of an open-ended tidal channel in an arid and mesotidal environment: Al-Subiya Tidal Channel, Kuwait*. Ph.D thesis, The University of Queensland.

Alhazeem, S. 2007. *An ecological study of the coral reefs of Kuwait islands*. School of Ocean Sciences. University of Wales, Bangor, UK.

Alhazeem, S., Gholoum, M., and Bahzad, J., 2018. Summary Report: Climate Change and Marine Ecosystem in State of Kuwait. Vulnerability and Adaptation Group Vulnerability & Adaptation Team, August.

Al-Husaini, M & M Bishop, J & M Al-Foudari, H & Al-Baz, Ali. 2015. A review of the status and development of Kuwait's fisheries. *Marine Pollution Bulletin*. 100.

10.1016/j.marpolbul.2015.07.053.

Al-Marzouk, A., Duremdez, K., Sameer, Y., Al-Gharabally, H. and Munday, B. 2005. Fish kill of mullet Liza klunzingeri in Kuwait Bay: The role of Streptococcus agalactiae and the influence of temperature. In: . P. Walker, R. Lester, and M. G. Bondad- Reantaso, (Eds). *Diseases in Asian Aquaculture.* Pp.: 143-153. Manila.

Al-Mutairi, Nawaf & abahussain, Amsa & El Battay, Ali. 2014. Environmental Assessment of Water Quality in Kuwait Bay. *International Journal of Environmental Science and Development*. 5. 10.7763/IJESD. 2014.V5.539.

Al-Rashed, M, Al-Senafy, M. N, Viswanathan, M. N, and Al-Sumait, A. 2010. Groundwater Utilization in Kuwait: Some Problems and Solutions. *International Journal of Water Resources Development*. 14(1): 91-105.

Al-Rashidi, T., El-Gamily, H., Amos, C., and Rakha, K. 2009. Sea surface temperature trends in Kuwait Bay, Arabian Gulf. *Natural Hazards*. Vol. 50: 73-82.

Alsahli, M., Hassan, A., and Altheyabi, N., 2018. Summary Report: Climate Change and Coastal Zones in State of Kuwait. Vulnerability and Adaptation Group Vulnerability & Adaptation Team, August.

Alshatti, A., AlQodmani, L., and AlSeaidan, M. 2018. Summary Report: Climate Change and Health Outcomes in State of Kuwait. Vulnerability and Adaptation Group Vulnerability & Adaptation Team, August.

Al-Yamani, F. Y., Bishop, J., and Ramadhan, E. 2004. *Oceanographic atlas of Kuwait's waters*. Kuwait Institute for Scientific Research.

Al-Yamani, Y, Bishop, J, Ramadhan, E, Al-Husaini, M & Al-Ghadban, A. 2004. Oceanographic Atlas of Kuwait's Water", Environmental Public Authority-Kuwait and Kuwait Institute for Scientific Research, Kuwait. Pp.: 203.

Baby, S., 2014. Assessing morphological landscape carrying capacity for coastal areas in Kuwait. *Indian Journal of Geo-Marine Sciences*. 43(8): 1- 16.

Basu, R., 2009. High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008. *Environ Health*. 8 (1): 40.

Basu, Rupa & Pearson, Dharshani & Malig, Brian & Broadwin, Rachel & Green, Rochelle. 2012. The Effect of High Ambient Temperature on Emergency Room Visits. *Epidemiology*. 23: 813-820. 10.2307/41739678.

Batista, P. P., Clemesha, B. R., Tokumoto, A. S., and Lima, L. M. 2004. Structure of the mean winds and tides in the meteor region over Cachoeira Paulista, Brazil (22.7°S,45°W) and its comparison with models. *Journal of Atmospheric and Solar-Terrestrial Physics.* 66: (6–9), 623-636. doi: http://dx.doi.org/10.1016/j.jastp.2004.01.014.

Benzoni, F., Pichon, M,. Alhazeem, S., and Galli, P., 2006. The Coral Reefs of the Northern Arabian

Gulf: Stability over time in extreme environmental conditions? *Proceedings of the 10th International Coral Reef Symposium*.

Bhadra, A., Choudhury, S., and Kar, D. 2011. Flood Hazard Mapping in Dikrong Basin of Arunachal Pradesh (India). *World Academy of Science, Engineering and Technology*. 60: 1614 - 1619.

Coles, S., and Jokiel, P. 1992. Effects of salinity on coral reefs. In: *Pollution in Tropical Aquatic Systems*. Connell, D & Hawker, D (eds), CRC Press, Cleveland, USA. Pp.: 2-25.

Done, T. 2011. Corals: Environmental Controls on Growth. In: Hopley, D (ed), *Encyclopedia of Modern Coral Reefs*. Springer Netherlands. Pp.: 281-293.

Downing N., 1985. Coral reef communities in an extreme environment: The Northwestern Arabian Gulf. *5th International Coral Reef Congress*, Tahiti, Pp.: 343-348.

Ebrahimi, S., Ebrahimzadeh, L., Eslami, A., and Bidarpoor, F. 2014. Effects of dust storm events on emergency admissions for cardiovascular and respiratory diseases in Sanandaj, Iran. *Journal of Environmental Health Science & Engineering*. 12:110.

El-Ghareeb, R., El-Sheikh, M. A. E., & Testi, A. 2006. Diversity of plant communities in coastal salt marshes habitat in Kuwait. *Rendiconti Lincei*. 17(3): 311-331. doi: 10.1007/BF02904769.

Förster, H., Förster, A., Oberhänsli, R., and Stromeyer, D., 2009. The steady-state thermal structure of the Arabian Shield prior to the Read Sea rifting. Paper presented at the EGU General Assembly Conference Abstracts.

Glibert, P & H Landsberg, Jan & Evans, Joyce & A Al-Sarawi, Mohammad & Faraj, Muna & A Al-Jarallah, Mohammad & Haywood, Allison & Ibrahem, Shahnaz & Klesius, Phil & Powell, Christine & Shoemaker, Craig. 2002. A fish kill of massive proportion in Kuwait Bay, Arabian Gulf, 2001: The roles of bacterial disease, harmful algae, and eutrophication. *Harmful Algae*. 1: 215-231. 10.1016/S1568-9883(02)00013-6.

Gornitz, V., White, T., and Cushman, R. 1991. Vulnerability of the U.S. to future sea-level rise. Coastal Zone. In: *Proceedings of Seventh Symposium on Coastal and Ocean Management*. 91: 2354-68. ASCE.

Hennige, S., Smith, D., Walsh, S., McGinley, M., Warner, M., and Suggett, D. 2010. Acclimation and adaptation of scleractinian coral communities along environmental gradients within an Indonesian reef system. *Journal of Experimental Marine Biology and Ecology*. Vol. 391 (1-2): 143-152.

Hume, Benjamin & D'Angelo, C & Burt, John & Baker, Andrew & Riegl, Bernhard & Wiedenmann, J. 2013. Corals from the Persian/Arabian Gulf as models for thermotolerant reef-builders: Prevalence of clade C3 Symbiodinium, host fluorescence and ex situ temperature tolerance. *Marine Pollution Bulletin*. 72. 10.1016/j.marpolbul.2012.11.032.

Khadadah, M. 2012. The cost of asthma in Kuwait. *Med Princ Pract*. 22:87–91.

Khalaf, F., 1988. Quaternary calcareous hard rocks and the associated sediments in the intertidal and offshore zones of Kuwait". *Marine Geology*. 80(1): 1-27.

Lokier, S. W., Bateman, M. D., Larkin, N. R., Rye, P., and Stewart, J. R. 2015. Late Quaternary sea-level changes of the Persian Gulf. *Quaternary Research*. doi: http://dx.doi.org/10.1016/j.yqres.2015.04.007.

McLaughlin, S., & Cooper, J. A. G. 2010. A multi-scale coastal vulnerability index: A tool for coastal managers? *Environmental Hazards*. 9(3): 233-248. doi: 10.3763/ehaz.2010.0052

Ministry of Electricity and Water (MEW). 2010. *Statistical Yearbook*. Ministry of Energy, Kuwait.

Ministry of Public Works (MPW). 2010. Statistical Yearbook", Sanitary Engineering Sector, Kuwait. Moberg, F., and Folke, C., 1999. Ecological goods and services of coral reef ecosystems. *Ecological Economics*. Vol. 29 (2): 215-233.

Mohamad, M. F., Lee, L. H., and Samion, M. K. H. 2014. Coastal Vulnerability Assessment towards Sustainable Management of Peninsular Malaysia Coastline. *International Journal of Environmental Science and Development*. 5(6): 533.

Palmer, B., Van der Elst, R., Mackay, F., Mather, A., Smith, A., Bundy, S., and Parak, O. 2011. Preliminary coastal vulnerability assessment for KwaZulu-Natal, South Africa. *J Coastal Res*. 64(S1): 1390-1395.

Paul, G. C., and Ismail, A. I. M. 2012. Tide–surge interaction model including air bubble effects for the coast of Bangladesh. *Journal of the Franklin Institute* 349 (8): 2530-2546. doi: http://dx.doi.org/10.1016/j.jfranklin.2012.08.003.

Qasem, J., Nasrallah, H., Al-Khalaf, B., Al-Sharifi, F., Al-Sherafyee, A., Almathkouri, S., and Al-Saraf, H. 2008. Meteorological factors, aeroallergens and asthma-related visits in Kuwait: a 12-month retrospective study. *Ann Saudi Med*. 28 (6), November-December.

Quinn, N., Atkinson, P. M., and Wells, N. C. 2012. Modelling of tide and surge elevations in the Solent and surrounding waters: The importance of tide–surge interactions. *Estuarine, Coastal and Shelf Science*. 112 (0): 162-172. doi: http://dx.doi.org/10.1016/j.ecss.2012.07.011.

Ramadan, E., Aldousiri, A., Al Dashti, H., Alnassar, M. 2018. Climate of Kuwait (Future Projections). *Vulnerability and Adaptation Group Climate Modeling Team*, August.

Riegl BM, Purkis SJ (Eds). 2012. *Coral Reefs of the Gulf: Adaptation to Climatic Extremes*. Springer, 389pp, ISBN 978-94-007-3007-6.

Riegl, B., and Purkis, S., 2012b. *Environmental Constraints for Reef Building in the Gulf*. Springer Netherlands, Dordrecht.

Sabbah, I., Arifhodzic, N., Al-Ahmad, M., Al-Enizi, A., Al-Haddad, A., and Al-Ajmi, N. 2014. Influence of Air Quality Conditions on Asthmatic Patient Visits in Kuwait. *J Allergy Ther*. 5:6, DOI: 10.4172/2155-6121.1000197

Schoepf, V., Stat, M., Falter, J., and McCulloch, M. 2015. "Limits to the thermal tolerance of corals adapted to a highly fluctuating, naturally extreme temperature environment. *Scientific Reports*. 5: 17639.

Sheppard, Charles & Al-Husiani, Mohsen & Al-Jamali, F & Al-Yamani, Faiza & Baldwin, Rob & Bishop, James & Benzoni, Francesca & Dutrieux, E & Dulvy, Nicholas & Rao V. Durvasula, Subba & A. Jones, David & Loughland, Ronald & Medio, David & Manickam, Nithyanandan & Pilling, Graham & Polikarpov, Igor & Price, A & Purkis, Sam & Riegl, Bernhard & Zainal, Khadija. 2010. The Persian/Arabian Gulf: a young sea in decline. *Marine Pollution Bulletin*. 60: 13-38. 10.1016/j.marpolbul.2009.10.017.

Sissakiam, V., Al-Ansari, N., and Knutsson, S. 2013. Sand and dust storm events in Iraq. *Natural Science*. Vol.5 (10): 1084-1094.

Stevens, T., Jestico, M. J., Evans, G., and Kirkham, A. 2014. Eustatic control of late Quaternary sea-level change in the Arabian/Persian Gulf. *Quaternary Research*. 82(1): 175-184. doi: http://dx.doi.org/10.1016/j.yqres.2014.03.002.

Tawatsupa, B., Lim, L., Kjellstrom, T., Seubsman, S., Sleigh, A., et al., 2010. "The association between overall health, psychological distress, and occupational heat stress among a large national cohort of 40,913 Thai workers. *Global Health Action*. 3, PMC2871739.

Thalib, L. and Al-Taiar, A. 2012. Dust storms and the risk of asthma admissions to hospital in Kuwait. *Science of The Total Environment*. 433:347-51.

Thoppil, P. G., & Hogan, P. J. 2010a. A Modeling Study of Circulation and Eddies in the Persian Gulf. *Journal of Physical Oceanography*. 40(9): 2122–2134. doi:10.1175/2010JPO4227.1

Turner L., Connell D., and Tong S. 2013. The effect of heat waves on ambulance attendances in Brisbane, Australia. *Prehosp Disaster Med*. 28(5): 482–487.

Wang, X., Lavigne, E., Ouellette-Kuntz, H., and Chen, B., 2014. Acute impacts of extreme temperature exposure on emergency room admissions related to mental and behavior disorders in Toronto, Canada. *J Affect Disord*.155: 154-61.

Wright, J.M., 1988. Recruitment patterns and trophic relationships of fish in Sulaibikhat Bay, Kuwait. *J Fish Biol*. 33: 671– 687.

Wright, J.M., 1989. Diel variation and seasonal consistency in the fish assemblage of the non-estuarine Sulaibikhat Bay, Kuwait. *Marine Biology*. 102: 135–142.

Xiang, J., Bi, P., Pisaniello, D., and Hansen, A. 2014. Health Impacts of Workplace Heat Exposure: An Epidemiological Review. *Ind Health*. 52(2), PMC4202759.

4. Greenhouse Gas Mitigation

Kuwait is committed to efforts that harmonize economic growth with a low-carbon, climate-resilient development. Domestically, it has already undertaken several strategic projects to reduce its carbon footprint. Internationally, it has expressed through its Nationally Intended Contribution a commitment to explore future GHG emission reduction policies and measures in the energy sector (State of Kuwait, 2015).

Such actions will reflect practical ways to promote clean energy initiatives, introduce new low-carbon technologies, and develop long-term partnerships to exploit sustainable energy opportunities. Progress toward such actions is already underway, and when fully implemented, will eventually lead to substantive greenhouse gas mitigation in an increasingly carbon-constrained world.

The rest of this section is based on an analysis of potential GHG reductions in the energy sector by KEPA (2018). The energy sector was selected at it represents the largest share of GHG emissions in Kuwait. The section concludes with a proposed set of strategic mitigation actions for achieving deeper GHG reductions in the future.

4.1. Goal, scope, methodology, and data sources

The goal of the GHG mitigation assessment was to establish annual and cumulative GHG emission reductions due to the implementation of several promising GHG mitigation options. The scope of the assessment focused on fugitive emissions from oil & gas operations and combustion-related emissions associated with electricity and desalinated water production. Together, these activities accounted for between 76% and 81% of emissions over the 1994-2016 period (see Figure 4-1).

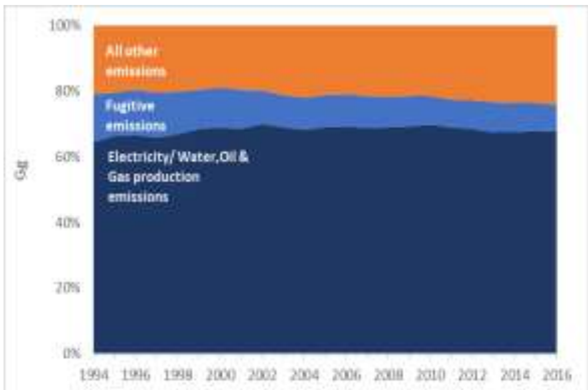

Figure 4-1: Share of oil & gas and electricity water production emissions, 1994-2016

While there are other GHG reduction opportunities in the next largest-emitting sector, transportation, which accounted for roughly 18% of emissions in 2016, a tactical decision during initial mitigation planning was made to limit the scope of the assessment solely to the way that electricity is produced and efficiency improvement in upstream oil & gas operations.

Two emission scenarios were considered; a Baseline Scenario which assumed the continuation of historical trends in energy supply and demand and a Mitigation Scenario which assumes the implementation of measures to reduce fugitive emissions, enhance supply side efficiency in electricity production and introduce renewable energy. Due to resource and time constraints, the assessment was limited to GHG reductions only (i.e., costs were not considered). The Baseline scenario incorporated activities that have taken place to date to reduce emissions. A 19-year planning horizon was considered, from 2016 through 2035.

A linear regression model was developed to project Baseline Scenario emissions to 2035. Population and GDP data over the 1994-2016 were used to establish trends between these variables and national CO_2e emissions. The model was developed using simple regression and analysis of variance (ANOVA) techniques. Box 4-1 provides details of the final form of the model. Most of the data required to undertake the assessment was acquired from governmental sources.

Average annual growth rates of 2.65%, 1.8%, and 2.0% were used for population, GDP, and inflation, respectively. Physical properties of fuels (e.g., GHG emission factors, energy densities) are based on IPCC default factors used in the development of the GHG inventory.

Box 4–1: Regression model used to project Baseline Scenario emissions through 2035 The final form of the econometric model for year t is as described below. All regressions statistics confirm that the model adequately produces actual GHG emissions over the 1994-2016 period (e.g., R^2 over 0.96).

$$CO_2e_t = 6.3E{+}03 + 0.018178*(P)_t + 3.17E{-}08*(GDP)_t$$

Where:

CO_2e_t = national GHG emissions in year t P

= national population in year t

GDP = Gross domestic product in nominal US dollars in yeart

4.2. Baseline scenario

The Baseline Scenario incorporates emission reductions associated with several recent projects that have been implemented as part of the Clean Development Mechanism (CDM) to stimulate sustainable development and emission reduction targets under the Kyoto protocol. A brief overview of these projects is provided in the bullets below.

- *Flare gas recovery at the Mina Al Ahmadi Refinery.* This project aims to recover gases that are currently flared at one of the refineries operated by the Kuwait National Petroleum Company. The project involves the installation of a Flare Gas Recovery Unit (FGRU) to recover gases for subsequent commercial uses. Annual GHG emission reductions are about 54.4 Gg.
- *Flare gas recovery at the Mina Abdullah Refinery:* This project aims to recover gases that are currently flared at another of the refineries operated by the Kuwait National Petroleum Company. The project involves the installation of an FGRU to first cool and then compress the recovered gases. After the cooling and compression steps, the gases are treated in an amine absorber to remove hydrogen sulfide and then reused for thermal heat generation. Annual GHG emission reductions are about 89.5 Gg.
- *Solar photovoltaics.* This project introduces a 10 MW solar photovoltaic farm in western Kuwait partially meet electricity demand at 29 oil wells and related infrastructure in the region. The major electrical load at oil wells consists of electric submersible pumps which would otherwise be met by the central grid. Annual GHG emission reductions are about 13.7 Gg.
- *Improved electric distribution efficiency*. This project introduces capacitor bank technologies at various 11/0.433 KV substations to improve the power factor in the electric distribution system. Capacitor banks were implemented in 632 transformers around Kuwait City and showed substantial improvement in the average power factor, leading to a reduction in distribution losses. Annual GHG emission reductions are about 112.7 Gg.

Baseline scenario trajectories of GHG emissions, CO_2e emissions per capita and CO_2e emissions per$ of GDP are illustrated in Figure 4-2. The left side of the figure shows that GHG emissions are projected to grow from about 86,000 Gg in 2016 to over 142,00 Gg by 2035, an average annual increase of about 2.67% per year. The right side of the figure shows historical and projected trends for CO_2e emissions as a function of population and GDP. Notably, per capita emissions showed sharp increases over the 1994-2002 period and declining per capita emissions over the 2002-2016 period, suggesting that efficiency and co to conservation measures have been effective in counteracting steady population growth. Additionally, while CO_2e emissions as a function of GDP show inter-year volatility, there is a noticeable downward trend from 3.6 in 1994 to about 1.0 in 2016 - suggesting that the economy is becoming more efficient from a carbon footprint perspective.

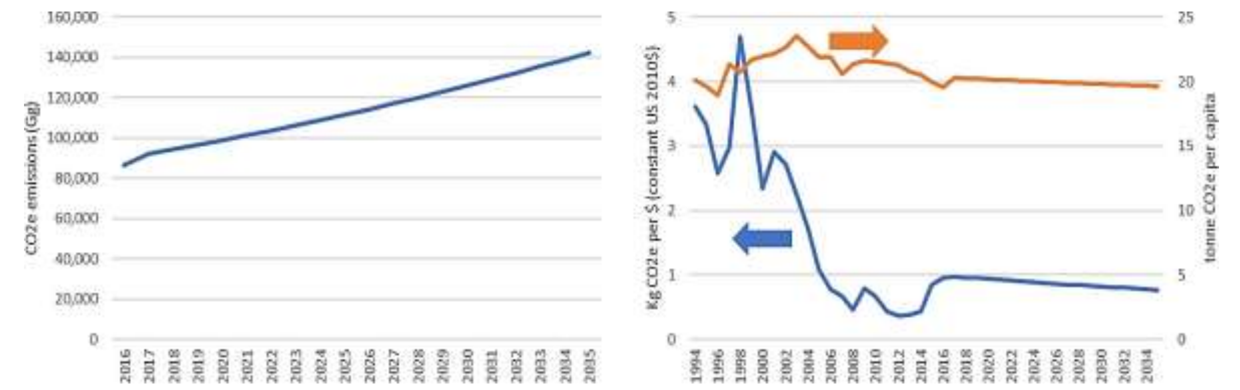

Figure 4-2: Left: Projected CO2e emissions in the Baseline Scenario; Right: Historical trends and projections for CO2e emissions per capita and per constant US$ of GDP

4.3. GHG Mitigation scenario

The GHG Mitigation Scenario incorporates emission reductions associated with several projects that have been proposed as expansions to the distribution efficiency and solar photovoltaic projects described above. A brief overview of these projects is provided in the bullets below.

- *Expansion of improved electric distribution efficiency.* This project expands the introduction of capacitor bank technologies at additional outdoor and indoor 11/0.433 KV substations to improve the power factor in the electric distribution system. Online years are 2019 and 2020 for outdoor and indoor substations, respectively. Annual GHG emission reductions are about 219.8 Gg for outdoor substations and 351.8 Gg for indoor substations, or total annual reductions of 571.6 Gg.
- *Expansion of renewable-based electricity production.* The Shagaya Renewable Energy Master Plan represents a 3-phase national vision to meet 15% of electricity requirements by renewable energy by 2030. The Plan incorporates solar thermal, solar photovoltaic and wind technologies. Phase I of the Plan introduces 50 MW of concentrated solar power, 10 MW of solar photovoltaics and 10 MW of wind in 2018. Phase II introduces an additional 1,500 MW of solar photovoltaics by 2022. Phase III of the Plan introduces an additional 200 MW of concentrated solar power, 1,200 MW of solar photovoltaics and 100 MW of wind by 2030. By its completion, the Plan will have introduced a total renewable energy capacity of 3,070 MW. Annual GHG emission reductions are about 5,000 Gg, equivalent to a displacement of 12.5 million barrels of oil equivalent.

The results of the GHG Mitigation scenario are illustrated in Figure 4-3. The left side of the figure shows projected CO_2e emission reductions by measure. The right side of the figure shows the resulting annual GHG emissions in the Baseline and GHG Mitigation scenarios. By 2030, total annual emission reductions are about 5,600 Gg, representing a reduction of about 4% of Baseline scenario emissions in that year. Cumulatively, nearly 60,000 Gg of CO2e is avoided over the entire planning period by the measures.

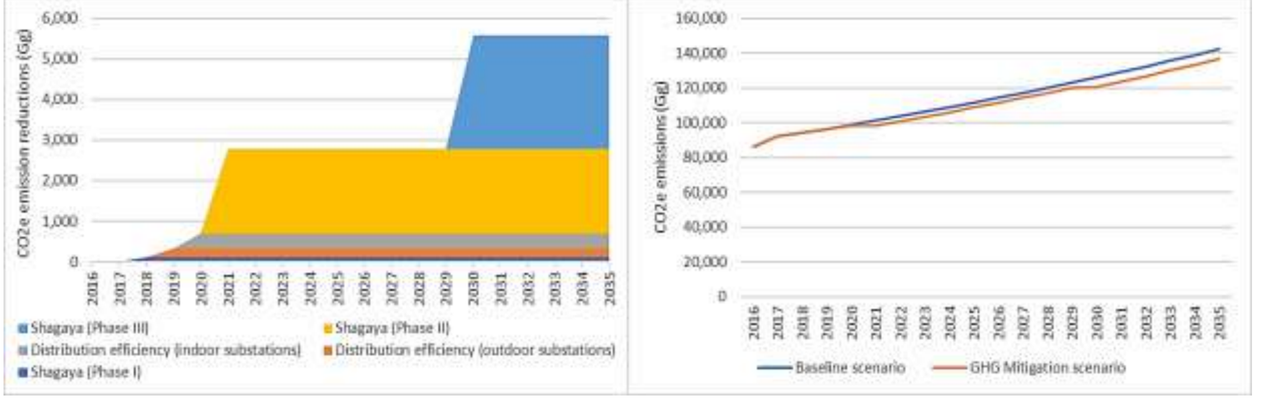

Figure 4-3: Left: Projected CO2e emission reductions in the GHG Mitigation Scenario; Right: Projected CO2e emissions in the Baseline and GHG Mitigation Scenarios

4.4. Future GHG mitigationopportunities

Going forward, there are several priority strategies that are being considered for achieving additional reductions, as outline in the bullets below.

- *Power supply*. Supply side combustion efficiency can be increased by shifting from current technologies to combined cycle gas turbines and maximizing the use of reverse osmosis over multi-stage flash technology in seawater desalination. Moreover, emissions can be further decreased by fuel switching (i.e., replacing liquid fuels in existing thermal power plants with natural gas) and
- *Transport.* There are several promising mitigation options for transport sector that are strategic for Kuwait. These include fuel efficiency improvements for vehicles, alternative clean fuel, transportation infrastructure improvement, as well as tariff and subsidy redistribution.
- *Industry*. The industrial sector in Kuwait covers chemicals, manufacturing fertilizers, cement industry, metallic products and food processing. Waste heat recovery from industrial processes is an important GHG reduction measure. Furthermore, adoption of more advanced plants, technologies, and processes are effective mitigation options leading to reduced electricity demand.
- *Waste.* Mitigation options in waste sector are based on the objectives of the National Development Plan in improving the efficiency of waste management by developing a safe waste management system for Solid, liquid and hazardous waste (Ensures the reduction of pollution levels resulting from traditional waste handling). Encourage the rehabilitation of landfill and gas utilization. Utilization of biogas from waste-water treatment. And, encourage waste recycling (Through providing all scientific consultations and provide incentives for investors to carry out recycling activities).

Going forward, Kuwait plans to build up its mitigation assessment capacities especially those related to human resources. Additionally, in order to improve the quality of future mitigation assessments, there is an urgent need to develop a national database for monitoring and reporting information related to GHG emissions and mitigation projects.

4.5. List of references

Kuwait Environment Public Authority, Kuwait, 2018.

State of Kuwait, 2015. Intended Nationally Determined Contributions. November. Kuwait.

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.

According to the regulations of the UNFCCC, parties are supposed to submit an assessment of their country's technological needs. In 2012, the State of Kuwait submitted the Initial National Communications under the UNFCCC, which included initial technological needs assessment. In 2018, Kuwait developed the second Technology Needs Assessment (TNA) report, which is part of the Second National Communications (SNC) Report.

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.

Enhancing technology development, transfer, deployment and dissemination is a key pillar of the international response to climate change. As a result, and to support the implementation of the UNFCCC Paris Agreement, Parties to the UNFCCC initiated the elaboration of the technology framework to further promote and facilitate enhanced action on technology development and transfer. The work on technology needs assessment (TNA) will play a key role in the implementation of climate technologies.

With reference to the aforementioned, the UNFCCC executed the Technology Needs Assessment (TNA) project. The Technology Needs Assessment (TNA) project assists developing country Parties to the UNFCCC determine their technology priorities for the mitigation of greenhouse gas emissions and adaptation to climate change. TNA is a set of country-driven activities leading to the identification, prioritization and diffusion of environmentally sound technologies for mitigation and adaptation to climate change.

In early 2017, Kuwait Environment Public Authority (KEPA) signed an agreement with the Regional Office for West Asia of the United Nations Environment Program (UNEP) to supervise the preparation of technical tasks implementation of the SNC project and the first periodic report of the State of Kuwait on the UNFCCC. To achieve main objective of this project, KEPA executed the SNC project in cooperation with several governmental organizations involving oil, power, industry, transportation, agriculture, waste, and research and education fields. All the efforts that has been taken by KEPA were to serve all the SNC aspects; in addition, a sure a successful completion of the report.

This report introduces an updated assessment of Kuwait's technological needs by referring to nationally active different sectors in the country. Priority given to the tools and technologies that will serve the sectors with the highest share in Green House Gases (GHG) emissions. The ultimate goal of the United Nation Framework Convention on Climate Change (UNFCCC) is to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic [i.e., human-induced] interference with the climate system". UNFCCC is the main international treaty on climate change.

TNA is important part of all country's national communications and so Kuwait's SNC. The TNA team of experts worked on a process that identifies the country's development priorities. Surveying ongoing policies, programs and projects as well as strategies that work for the favor of climate change mitigation and adaptation was part of the process. Figure (5-1) represents the TNA process that parties has to apply follow during the path of the assessment. This TNA report will bring to light the specific technologies that are the most appropriate to Kuwait, which will facilitate achieving its targets for the mitigation of greenhouse gases and adaptation to climate change.

Figure (5-1): Technology Needs Assessment process

Technologies that were identified during initial stakeholder consultations were then assessed in a collaborative fashion among stakeholders relative to a set of four 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.

Kuwait like all the GCC countries rely heavily on fossil fuel to meet its increasing demand for electricity. One can see that more than 65% of GHG emissions are associated with the power generation, water desalination sector, and manufacturing industries, which exclusively depends on fossil fuel (Figure (5-2). The relative high consumption of electricity and water is the result of:

- Harsh hot environment
- Lack of natural potable water and
- Weak energy efficiency measures.

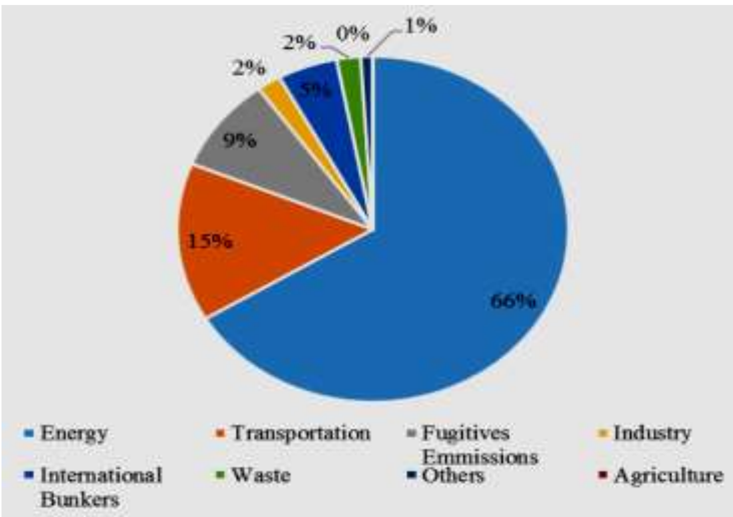

Figure (5-2): Average percentage CO2e emission by sectors from year 1994 to 2016.

The main contributors to the emission are both, the energy with a share of 66%, and transportation sector with a share of 15%. The energy is composed of the following sectors:

- Electricity
- Water and
- Manufacturing that involve fossil fuel combustion activities

Advanced fossil technologies for electricity generation

Achieving a sustainable and more competitive energy system is one of the most critical challenges for Kuwait's future. 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.

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

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

- ***Carbon capture and storage (CCS):***

This technology prevents up to 90% of CO2emissions associated with power generation from being released into the atmosphere. CCS separates CO2 emissions from the process and transports compressed CO2 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.

Carbon capture and storage (CCS) technologies, which could enable the use of fossil fuels while reducing the emissions of CO2 into the atmosphere, have yet to achieve significant cost reductions to be widely deployed.

- ***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 is in case of heating; however, district cooling is the centralized production and distribution of cooling units (refrigeration ton).Chilled water is produced by cooling plants (that re in close proximity with building to be cooled) delivered via an underground insulated pipeline to office, industrial and residential buildings. 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 operation strategy 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 SO_2 emissions, which are an indirect greenhouse gas that is included in the national GHG inventory.

To establish a successful mitigation strategy, Kuwait must promote gas in the energy mix for diversification and decarbonization. The following steps must be considered:

a) Support Kuwait Petroleum Corporation's (KPC's) target to achieve 2.5 Bcf/d of non-associated gas production capacity by 2030
b) Expedite implementation of the Al-Zour LNG import and storage facility
c) Expedite MEW's efforts to maximise gas-fired power generation
d) strategically explore the potential for regional cross-border pipeline gas imports.

Renewable technologies for electricity generation

Exploring the second primary option, Kuwait initiated serious efforts to harness renewable energy much before a worldwide awareness of global warming. Solar power generation and application of solar energy for desalination and air-conditioning were the major areas of research from mid-seventies till mid-eighties. Renewable technologies for electricity generation refer to options that rely on non-emitting energy resources such as solar and wind. Several renewable technologies represent potential opportunities for ready integration in the energy system of Kuwait. A brief overview of these priority technologies is provided the bullets below. Table 5-2 summarizes the results of the evaluation of these technologies.

- *thermal:* This technology encompasses a range of small- and large-scale, A 100 KW solar thermal power station using the parabolic dish collector was commissioned in late 70. Recently, a 50 MW solar concentrating power (CSP) with 10 hours thermal energy storage plant has been online since November 2018. This plant is part of Shegaya Phase 1 renewable energy park.

- *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 cooling systems of small and medium cooling capacity using flat plate collectors and vapor absorption chillers were installed in a solar house, kindergarten and the ministry of defense building. Several installations of photovoltaic (PV) solar systems are installed in a school, co-operative societies (supermarkets) and number of public buildings. The total combined installed capacity of these systems is about 2.0MW.

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	Yes
Solar Thermal Energy	Medium	Medium	Medium	High	Yes
Solar Ponds	High	Medium	Medium	High	No
Wind Energy	High	High	Low	High	Yes

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

- *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, therefor, several installations of photovoltaic (PV) solar systems were installed including the one of nearly 40 kW in a school. Other minor size PV units were installed for remote applications.
    - *options that harness solar thermal energy for domestic water heating.*
    - *Solar ponds*: This technology uses temperature gradients within pools of saltwater 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. Shagaya Phase-1 wind farm with capacity of 10 MW is fully operational and currently connected to the national electric grid. Its generation exceeded its guaranteed performance. There is a plan to install more wind turbines in Shagaya Phase-3 of capacity reaching 100 MW.

Shagaya Renewable Energy Power Park

Shagaya project Kuwait's first step toward energy diversification. The renewable energy power plant comes with a national objective, that is to diversify sources of power to supply a considerable part of the local demand. The RE park represents the Kuwaiti Government's long-term ambitions of securing a significant renewable energy capability by the year 2030 in order to contend with rising domestic energy demands and keep additional crude oil resources for export.

This government-funded facility is currently under the supervision of KISR who are dedicated to exhaustively testing solar thermal, photovoltaic and wind energy technologies in order to determine their feasibility for further deployments across Kuwait. Three Phases of the 3.070 GW Shagaya RE Master Plan:

- Phase I: 70 MW of RE capacity (50 MW CSP, 10 MW PV and 10 MW Wind); totally the responsibility of KISR. Figure (6-4)
- Phase II: 1500 MW, extension of the plant to a total of 1,570 MW installed RE capacity; the added 1500 MW plant is going to be totally PV technologies. Phase II will be totally under the supervision of the Kuwait Petroleum Corporation (KPC) and fund will be provided from the Kuwait National Petroleum Company (KNPC).
- Phase III: 1500MW, extension of the plant to a total of 3,070 MW installed RE capacity. The added 1500 MW will be composed of 1200 MW Solar PV, 200 MW Solar thermal and 100 MW wind energy. Phase III will be the responsibility of the Ministry of Electricity and Water (MEW).

Figure (5-3) :Shagaya (phase I) 10 MW wind turbines, total of 5 wind turbines each of 2 MW.

Technologies to reduce electricity consumption in buildings (Residential, public, and commercial buildings)

Technologies to reduce electricity consumption in 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.

Residential sector is the major consumer of electricity accounting for more than half of the total electricity exported by the power plants. Interestingly, nearly 15% of the generated electricity used in the power plants for operation of various motors and for maintaining the indoor environment. In Kuwait, Air-conditioning (A/C) is the single largest consumer of electricity as it accounts for nearly 70% of the annual peak load demand and over 45% of yearly fresh electricity consumption. Lighting, the second most important consumer of electricity accounts for 15% of peak power and 20% of annual energy consumption Both, air-conditioning and lighting are heavily used in all type of buildings, residential, public and commercial, in addition to industrial facilities. Figure (5-4) shows the percentage of electricity consumption for the major consumers of electricity.

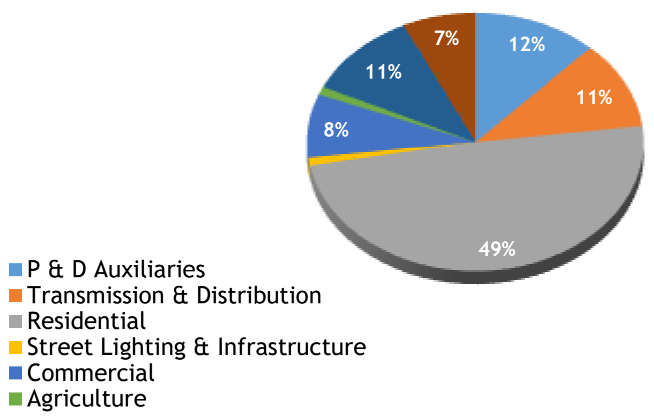

Figure (5-4): Composition of electricity consumption (%)

Reduction in the total primary energy demand, either in its direct consumption as in transport sector or improving conversion efficiency to secondary energy such as in the electricity sector is obviously the primary option to be targeted in the case of Kuwait. Accordingly, due to relevance and benefit to the national economy, energy conservation has been the essential goal, several energy efficiency and conservation measures are already being implemented in Kuwait to minimize electricity consumption from the different sectors. These measures range from regulatory, technology, economic and information measures Other measures represent new and potentially viable opportunities for improving residential, public and commercial sectors performance in Kuwait.

These measures fall under two main categories:

I. Demand side management measures

II. Supply side management measures.

Implementing energy efficiency measures in buildings sector to support a national mitigation policy:

- Update building regulations/codes to reduce AC permissible power, enhance fenestration systems, and install PV building integrated systems
- Retrofit buildings
- Implement district cooling
- Implement standardized labelling program for appliances and equipment
- Promote energy service companies.

Examples for measures from the former category include electrical load management and use of renewable energy sources to produce electricity. Examples for this category include:

- Setting energy efficiency performance standards
- Electricity tariff reforms
- Energy labelling
- Smart metering, and
- Public awareness leading to behavioral change

A brief overview of the priority technologies is provided in the bullets below. Table 6-3 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, day lighting 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.

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

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

- 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).

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.

Coastal zones

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. below summarize the results of the evaluation of these technologies.

A brief overview of these priority technologies is provided in the bullets below:

- 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 function 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.

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

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

Water resources

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.

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	Yes
Multi-Stage Flash Desalination	High	High	Medium	High	Yes
Building Retrofits	Medium	Medium	Medium	High	Yes
Irrigation Water Use Efficiency	High	High	Medium	High	Yes

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

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 6-5 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.

- 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.

- 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.

- 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.

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.

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

Table 5-6: Adaptation technology evaluation results for Public Health

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 4-7 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, CO2, H2S, SO2, O3, CH4 and non-methane hydrocarbon concentrations at various sites .The government operates and maintains an additional 15 air quality stations to monitor concentrations of SO2, NO2, CO, ground-level ozone (O3), and particulate matter less than 10 microns in diameter (PM10) and one mobile laboratory .

- *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.

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 result 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

The recent oil prices drop (since late 2104), environmental concerns and geopolitical stresses have led to accumulation of negative implications on country's socio-economic sectors. Therefore, the need for an updated sustainable energy strategy that can deal with the domestic and international challenges has become an urgent requirement.

Given the critical challenges faced by Kuwait's energy system, there is a need to draw up a national energy strategy that establishes the main goals to be pursued in the next few years and the fundamental decisions to be taken towards these goals and define the priorities of policy action. A sustainable national energy strategy needs to cover four dimensions:

- Energy security: Recognizing the fact that current energy policies (business-as-usual) are not sustainable in the medium to long term;

- Economic security: Recognizing the impact of rising domestic energy consumption and oil market uncertainty on the Kuwaiti economy;

- Environmental security: Recognizing the environmental benefits relating to air quality improvements and mitigating local pollution impacts, as well as employment and diversification opportunities that a shift to sustainable energy can provide; and,

- Engagement and collaboration with stakeholders (government and private sector): partnerships between them, can be extremely beneficial in promoting and informing policies that can facilitate the transfer of technology for mitigation and adaptation in Kuwait and implementing a successful strategy.

It is of great importance 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 promote an enabling environment, as briefly summarized in the bullets below:

- *Implement energy efficiency measures in buildings sector:* (a) update building regulations/codes to reduce AC permissible power, enhance fenestration systems, and install PV building integrated systems; (b) retrofit buildings; (c) implement district cooling; (d) implement standardized labelling program for appliances and equipment; and (e) promote energy service companies.

- *Implement transportation efficiency measures:* (a) expedite the implementation of fuel efficiency standards for passenger vehicles; and (b) expedite the construction of a modern, efficient, mass public transportation system.

- *Implement energy pricing reforms as one of the tools to alter consumer behavior:* (a) gradually replace universal subsidies with targeted compensation schemes to eligible consumers; (b) incorporate measures to protect energy-intensive firms in the economy from the effects of price increases; and (c) launch a sustained long-term public awareness campaign ahead of energy price reforms.

- *Accelerate transmission and distribution initiatives* through tariffs and supply industry restructuring, for instance, by the introduction of smart metering, distribution retrofits for power factor correction, and distributed generation.

- *Involve the private sector in power generation:* (a) develop a clear legislative and contractual framework for the protection of investors' rights; (b) ensure creditworthiness of state institutions contracting with the private sector through government guarantees; (c) empower the designated regulator to enforce decisions under a clear regulatory framework with minimal intervention from higher levels of government; and (d) provide a level playing field for private investors vis-à-vis state companies to support the development of the private sector in energy.

- *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, furthermore, expedite measures to improve the efficiency of electricity and water production.

- *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

Al-Dousari, A. "Dust Fallout Monitoring and Analysis in Al-jahra City and Surroundings." KISR Scientific Report (2006): 256-7.

Ali H, Alsabbagh M (2018) Residential Electricity Consumption in the State of Kuwait. Environ Pollut Climate Change 2: 153. 10.4172/2573- 458X.1000153.

Al-Marafie, A. M. R., R. K. Suri and G. P. Maheshwari. 1989. Energy and power management in air-conditioned buildings in Kuwait. Energy the International Journal 14(9): 557-562.

Al-Nakib D. and G.P.Maheshwari 1997. Cost-benefit analysis for energy-efficient lighting". Kuwait Institute for Scientific Research, Report No. KISR5004, Kuwait.

Buckley, R. (Editor) 1997. Turning plan into action. Understanding global issues (UGI). Published by understanding global issues limited, the Runnings, Cheltenaham GL51 9PQ, England. Pp-14.

Darwish, M. A. "Prospect of Using Alternative Energy for Power and Desalted Water Productions in Kuwait." Desalination and Water Treatment 36.1-3 (2011): 219-38. ISI Web of Knowledge.

Introduction to the United Nations Framework Convention on Climate Change (UNFCCC), Archived from the original on 8 January 2014.
https://web.archive.org/web/20131129020749/http://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf

James Haselip, Rasa Narkevičiūtė and Jorge Rogat (September 2015) A step-by-step guide for countries conducting a Technology Needs Assessment

Kuwait Institute for Scientific Research, Energy & Buildings Research Center.
http://www.kisr.edu.kw/en/facilities/energy-building/?research=1

Maheshwari, G.P; D. Al- Nakib; R.K. Suri; Y. Al-Hadban; J. Rasquina ; A. Ali Mulla; M. Sebzali and A. Al-Farhan. 1997. Energy Audit in Kuwait Port Authority. Technical report. Kuwait Institute for Scientific Research, KISR 5107, Kuwait.

Maheshwari, G.P.; K.J. Hussain; R.Alasseri 2001 Development and implementation of energy efficient operation and maintenance strategies for air-conditioning systems. Interim report. KISR No. 6213. Kuwait.

Maheshwari, G.P., M. Abdulhadi, M. Al-Ramadhan, and D. Al-Nakib. 1993. Efficiency of electricity and water sector in Kuwait. Kuwait Institute for Scientific Research, KISR 4314, Kuwait.

Maheshwari, G.P., Y. Al-Fouzan, S. Al-Ateeqi, J. Rasquinha, A.Al-Farhan. 1994. Energy monitoring in industry: National Industries Company, Cement Products Plant. Kuwait Institute for Scientific Research, KISR .Kuwait ,4194

Milutinovic, M., Eltahir, E., "Water Demand Management in Kuwait." Thesis, Dept. of Civil and Environmental Engineering, Massachusetts Institute of Technology (2006).

Statistical Yearbook (2016) Ministry of electricity and water Kuwait.

The future of Kuwait's Energy System: Mitigating Threats & Seizing Opportunities. White Paper on A Sustainable National Energy Strategy. A Technical Report, April 2017.

UNDP (2010). Handbook for conducting Technology Needs Assessment for Climate Change. United Nations Development Programme, New York

UNFCCC (2017), Enhancing Implementation of Technology Needs Assessments Guidance for Preparing a Technology Action Plan. Technology Executive Committee, UNEP DTU Partnership.

UNFCCC (2010). Handbook for Conducting Technology Needs. Assessment for Climate Change. November 2010.

6. Constraints, Gaps and Needs related to Climate Change

Inadequate capacity (technical, financial and institutional) remains one of Kuwait's significant challenges as it confronts climate change. Enhancing capacity will depend on overcoming serious institutional, financial and technical constraints and gaps that currently interfere with affective action. With adequate support, Kuwait can build climate change resilience and explore the viability of low-emission development trajectories. The subsections below outline the key constraints, gaps, and needs to facilitate compliance with UNFCCC obligations and aspirational adaptation goals.

6.1 Constraints

Several technical, institutional, legislative, and financial constraints across various levels have been identified hindering implementation of climate change adaptation and mitigation activities in Kuwait. The following bullets are examples of such constraints:

- Lack of accurate data bases, and inadequate information and data collection, analysis and dissemination;
- Weak cooperation arrangements between agencies for providing GHG inventory data, resulting in difficulties in timely data collection; and
- Lack of familiarity with current methods and tools for undertaking a quantification of climate change impacts in vulnerable sectors.

6.2 Gaps

The following outlines the key capacity gaps relative to understanding climate change impacts in Kuwait, as well as policies and measures associated with GHG mitigation:

- Lack of access to long-term climate information and associated uncertainties for use in conducting vulnerability and adaptation assessments;
- Inadequate institutional and technical capacity to plan and implement climate change adaptation measures; and
- Limited funding for climate change related research focused on Kuwait and surrounding region.

6.3 Needs

Several capacity development needs were identified during the process of preparing the SNC. The following are among the key needs:

- Build public, and policy-maker awareness on climate change;
- Strengthen institutional and technical capacities through information and knowledge management;
- Enhance coordination among stakeholders at different levels, especially as it pertains to database development for future GHG inventories;
- Better integrate climate change considerations into national and sectoral development planning and policy dialogues; and
- Promote Involvement of local media in building awareness regarding climate change impacts and risks.

7. Other information

Inadequate capacity (technical, financial and institutional) remains a critical challenge in addressing climate change in Kuwait. Hence, the core objective in the preparation of the SNC was to establish a foundation for carrying out the kinds of assessments that can enhance understanding of the climate change challenge, inform future policy dialogues, and support the process of preparing subsequent national communications and biennial update reports.

The preparation of the SNC was highly participatory in nature. A national team was recruited mostly from relevant ministries and institutions, with senior management at KEPA’s Climate Change section responsible for overall coordination and quality control. Carrying out the various assessments and analyses benefitted from inputs from experts from Kuwait University and international organizations. Staff from the West Asia regional office of the United Nations Environment Program (UNEP) provided backstopping guidance and technical support.

Preparing this SNC has been instrumental in establishing a new approach for addressing the challenge of climate change in Kuwait. There is now a network in place facilitating access to data; a system in place to account for and manage emissions data; and a framework in place to improve and upgrade information related to crosscutting components in support of climate policy. Not only have new protocols been established for improved documentation and archiving, but concreate action has begun promoting climate change education, training, public awareness, and capacity building.

7.1 Capacity building recommendations

The survey also provided an opportunity to indicate specific areas where capacity building activities should be targeted. Indeed, strengthening future capacity of stakeholders to promote and support GHG inventory development, climate change vulnerability assessment, identification of adaptation strategies, GHG mitigation analysis, and technology needs assessment is a consensus conclusion from the SNC process.

Key recommendations regarding the development of national GHG inventories are summarized in the bullets below.

- **Survey**

A survey was undertaken near the end of the SNC process to identify key issues and recommendations to inform the design of future capacity strengthening initiatives. Participation was high among all the members of the national team. Of the eight questions in the survey, two in particular were instrumental in understanding key challenges and formed the basis for subsequent recommendations for capacity building. The key questions are shown in the bullets below relative to the preparation of the national circumstances, inventory and vulnerability & adaptation chapters.

Table 7-1 summarizes the responses.

- *Difficulty*. What was the level of technical difficulty/ease experienced in completing each section of the SNC?
- *Constraints/gaps*. What were the key constraints and gaps faced in preparing each section of the SNC?

Table 7–1: Responses to capacity building questionnaire

	National circumstances	GHG inventory/mitigation	Vulnerability & adaptation
Difficulty	• Collecting & analyzing data • Difficulties in providing data • Lack of guidance	•Accuracy& lack of data •Assessment of data quality & analyzing, estimating data •Aon-cooperative authorities •Difference in fiscal & calendar year	• Difficulty in collecting data • Lack of following up • Delays in providing the necessary technology to complete the work
Constraints/ gaps	• Some essential data that was missing • Difficulty convincing some administrations to provide the required data • Gaps in data and years	•Briefing the report •Choosing method that best represents local situation •Missing data from the source due to non-recording for early years •Software requires overly detailed data •Lack of industrial classification according to energy use •Data inconsistency from different sources leading to inappropriate decisions and high uncertainty	• Inaction between members of one team • Climate data (for a long period) for Kuwait and surrounding region • Models and the gaps of the data in the whole region • Data collection of physical and fisheries • Format of the report • Some Experts have no time to meet with other members of the group

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

Key recommendations regarding the analysis of national GHG mitigation opportunities are summarized in the bullets below:

- Obtain training in methods and tools to analyze in detail the costs, benefits, and co- benefits of GHG mitigation policies and measures, starting with those included in Kuwait’s nationally determined contributions;
- Build a cost and performance database regarding energy supply and energy demand management technologies and practices; and
- Develop a centralized database for monitoring and reporting information related to GHG emissions and mitigation projects.

Key recommendations regarding the assessment of vulnerability of key sectors and systems, together with the formulation of adaptation strategies are summarized in the bullets below:

- Obtain training in modeling approaches to assess the impacts of a) rising season coastal zones, b) water efficiency/conservation policies on water demand, c) changing salinity/temperature on commercial fisheries, and d) emissions co-benefits of renewable energy investments on public health;

- Obtain training on how to establish a national framework that links the results of vulnerability assessments to ongoing policy dialogues regarding adaptation options and strategies; and
- Conduct seminars and training workshops to build awareness among managers and decision makers of the consequences of climate change and the need to incorporate adaptation considerations in utility, urban, and resource planning

7.2 Education, Training and Public Awareness

There have been substantial efforts to provide environmental education and targeted educational activities. Several initiatives and projects have been implemented to promote environmental education in schools, universities and as part of continuing professional development to increase awareness of climate change threats. Some of the major institutions and activities are summarized in the bullets below.

- *Kuwait University (KU):* At both undergraduate and graduate level KU offers many courses and degrees through its various faculties. The various undergraduate programs equips students with basic environmental knowledge and advanced applications of environmental technologies in conservation of natural resources along with the use of contemporary information systems in environmental decision-making. The graduate programs offer master's degrees in environmental science and other disciplines.
- *Public Authority for Applied Education and Training (PAAET):* This is the other major academic institution in Kuwait, in terms of number of disciplines and of enrolled students. PAAET offers bachelor's degree in two environment-related field: Industrial Hygiene and Applied Environmental Sciences. In June 2016, PAAET signed a memorandum of understanding with the Environment Public Authority to enhance coordination, unify efforts and support scientific and technical cooperation to preserve the environment and to ensure its sustainability. The MOU will encourage research by faculty members in the environmental fields and assist in educating students about the urgency to preserve the environment.
- *Global Learning and Observations to Benefit the Environment.* On the informal basis, KFAS, in collaboration with Ministry of Education has launched the international Global Learning and Observations to Benefit the Environment (GLOBE) Program. The informal education program provides students and the public worldwide with the opportunity to participate in data collection and the scientific process and contribute meaningfully to an understanding of the Earth system, global environment in general, and climate change in particular. GLOBE provides grade level-appropriate, interdisciplinary activities and investigations about the atmosphere, biosphere, hydrosphere, and soil/pedosphere, which have been developed by the scientific community and validated by teachers. GLOBE connects students, teachers, scientists, and citizens from different parts of the world to conduct real, hands-on science about their local environment and to put this in a global perspective.

- *Kuwait Society for Environmental Protection (KEPS*): This is a well-established civil society organization that has been active in environment safeguards and increasing environmental awareness in Kuwait since 1974. The Society issues a monthly bulletin, which includes studies written by leading scholars who have influenced decisions in environmental planning and management. On 28 March 2017, the Society signed a memorandum of understanding with the Public Authority for the Environment to raise awareness regarding the impacts of climate change on the State of Kuwait in various fields including health, water resources and coasts and ways of adapting them. KEPS has made notable efforts in linking education and awareness of climate change through the inclusion of educational, public schools and university institutions in its programs and activities such as its Green Schools program (see Box 6-1).
- *Marine Environment Campaigns:* National teams and organizations concerned with the marine activities have carried out several campaigns and activities concerning the various aspects of marine environment, either jointly or separately, and more recently they have been focusing on the impacts of climate change on coral bleaching. Such campaigns have been launched by the Environment Public Authority, Senyar diving team at the Volunteer Tasks Center, the Kuwaiti Dive Team of the Scientific Club, the diving team of the Kuwait Oil Company, the Coast Guard, the Marine Surveillance, the Public Authority for Agriculture and Fisheries Resources, the General Directorate of Marine Fire and Rescue, Kuwait Maritime Club, along with research-based institutions like Kuwait Institute for Scientific Research and Kuwait University.
- *Snyar Diving Team:* Snyar is a volunteer diving team working on reconstruction the country's marine environment by monitoring beaches and coasts, preventing damage to the environment, and increasing awareness of marine life. Since its inception, Snyar has accomplished several achievements in the field of environmental protection in general and the marine environment in particular.
- *The Kuwaiti Dive Team:* The Kuwait Dive Team was formed of young volunteer divers in 1991, right after the Iraq war. The main goal was to preserve the marine environment. They started with cleaning up the coastline of military wastes, and gradually assumed the responsibility of lifting objects, rescue and rehabilitation, and restoration of Kuwait's marine environment. With government support and fund from private sector, the team tasks were expanded to include rescuing marine creatures; restoring coral reefs; creating habitats for sea creatures, as well as removing waste and discarded fishing nets. They also provide diverse trainings and environmental awareness campaigns.

7.3 Research initiatives

The Paris Climate Agreement offers new challenges and opportunities for policy-related climate research. This agreement also presents the task of widening the knowledge base on climate change and its consequences. In addition, there is a need for providing data to support evidence-based decisions regarding the implementing of the global sustainable development goals, including those relating to climate change mitigation and adaptation.

Key research areas include atmospheric sciences, soil moisture, hydrologic cycle, the marine environment, ecosystems and biodiversity, and climate impacts. General expenditures on research in Kuwait is typically very low, with only US$ 30 million spent over the 2011-2016 period. Key institutions involved in these research activities are briefly described in the bullets below:

- *Kuwait Foundation for the Advancement of Sciences (KFAS):* This is a privately funded non- profit organization headed by H.H. the Emir of Kuwait, has a mission to "Stimulate and catalyze the advancement of Science, Technology and Innovation for the benefit of society, research and enterprise in Kuwait". KFAS has been active in supporting scientific research, building capacity, and funding technology application pilots. In 2017, it convened an international conference on climate impacts on coastal zones and the marine environment, oriented around a translation of a book by John Englander on sea level rise (see Box 6-1). KFAS leverages capabilities of national R&D organizations and professionals, focusing on fields of national priorities such as energy and environment sustainability in Kuwait. KFAS also funded the development of the Kuwait Emission Inventory System (KEIS) of criteria air pollutants (CAPs).

- *Kuwait Institute for Scientific Research (KISR):* This institution was established in 1967 by the Arabian Oil Company and became an independent public institution in 1981. Over the decades, KISR has amassed extensive knowledge in environmental research, surveys and management, including coastal management and atmospheric pollution; and urban infrastructure development. KISR also has a reputable capacity building programs aimed at developing skills and expertise of its manpower base (research, support and administrative), as well as providing similar opportunities to wider sectors in other governmental agencies and to the general public.

- *Kuwait Meteorological Department:* Hosted within the Directorate General of Civil Aviation, the Meteorological Department conducts research on atmospheric sciences. This department is the key institution for observing and monitoring atmospheric change. It operates extensive national observation networks, which include conventional meteorological and climatological observation stations and a network of Doppler weather radars.

Box 7–1: Example of KFAS research activities on climate change

In 2017, KFAS organized the Conference: "Our Seas: Theories, Data, and Policies" to present and discuss compelling evidence that the world's oceans – and the Arabian Gulf in particular - are already being affected by climate change. Topics addressed included sea level rise, sea acidification, sea surface temperature rise, and oxygen depletion, and their impacts on the marine and built environment.

7.4 List of references

Alsulaili, A. 2009. An Integrated Solid Waste Management System in Kuwait, 5th International Conference on Environmental Science and Technology IPCBEE vol.69. IACSIT Press, Singapore DOI: 10.7763/IPCBEE. 2014. V69. 12

Admission and Registration Department, KU Colleges Directory, 2018/2019, Kuwait University, http://kuweb.ku.edu.kw/ku/AboutUniversity/KUAdmission/index.htm
https://portal.ku.edu.kw/manuals/admission/en/colleges_manual.pdf
http://kuwebcont.ku.edu.kw/cs/groups/ku/documents/ku_content/kuw055940.pdf
http://kuweb.ku.edu.kw/ku/AboutUniversity/Colleges/KuwaitUniversityColleges/index.htm

Analysis of Hydroponic Agriculture in Kuwait - Market trend, Growth and Opportunities (2015-2020), December 2017. *Mordorintelligence*.

Annual Energy Outlook. EIA, eia.gov, June 2012.

Annual Statistical Abstract (Issues 2002 – 2016). Central Statistical Bureau, https://www.csb.gov.kw/Pages/Statistics

BioEnergy Consult is engaged in the development of Biomass Energy, Waste-to-Energy, Biogas, Solid Waste Management and Industrial Waste Management projects worldwide, https://www.bioenergyconsult.com

BirdLife International, 2012, http://www.birdlife.org

Birol F, Key World Energy Statistics, IEA publication, 2017, https://www.iea.org/publications/freepublications/publication/KeyWorld2017.pdf

College of Graduate Studies, Kuwait University, http://kuweb.ku.edu.kw/COGS/index.htm,http://kuweb.ku.edu.kw/COGS/AcademicAffairs/Preparationandpublicationdepartment/Graduateguide/index.htm

Convention on Biological Diversity, https://www.cbd.int/doc/press/2017

Environment Public Authority, https://epa.org.kw

http://elbawabah.com, a source of information on current topics and issues.

Haselip, J., Narkevičiūtė, R., and Rogat, J. 2015. A step-by-step guide for countries conducting a Technology Needs Assessment.

Kuwait Environment Protection Society, https://www.keps.org.kw/

Kuwait Institute for Scientific Research, http://www.kisr.edu.kw/ar/

Kuwait Municipality, https://www.baladia.gov.kw

Kuwait National Petroleum Company (KNPC) data, https://www.knpc.com/en/

Kuwait Petroleum Corporation, https://www.kpc.com.kw/

Kuwait Ports Authority official website, http://www.kpa.gov.kw/shuwaikh-port.html

Kuwait Times, 11 March 2017, http://news.kuwaittimes.net

Kuwait Times, 19 February 2018, http://news.kuwaittimes.net

Organization of Arab Petroleum Exporting Countries (OAPEC) Data Base, http://www.oapecorg.org/Home

Ministry of Public Works official website, http://www.mpw.gov.kw

Organization of Petroleum Exporting Countries (OPEC), Annual Statistical Bulletin, (2016/2017), https://www.opec.org/opec_web/en/.

Public Authority for Applied Education and Training, http://www.paaet.edu.kw

Public Authority for Civil Information (PACI), https://paci.gov.kw, 2018

Ramsar Convention, https://whc.unesco.org/en/tentativelists/6257.

Rising Cost Growing Demand has Prompted Drive Boost Generating Capacity and Explore Alternatives, https://oxfordbusinessgroup

Shmal AlZour Projects, https://www.aznoula.com

Site for collection of world maps, http://mapsof.net/

Statista – The portal for statistics, www.statista.com

Statistical Year Book (2016) Ministry of electricity and water Kuwait.

Tamdeen Group, http://www.tamdeen.com/projectsmadinatalhareer.shtml

The Kuwait Foundation for the Advancement of Sciences, http://www.kfas.org/

The Ministry of Electricity and Water, Statistical Year Book 2017: Electrical Energy, https://www.mew.gov.kw/

The Ministry of Electricity and Water, Statistical Year Book 2017: Water, https://www.mew.gov.kw/

UNFCCC, 1998, Kyoto protocol to United Nations framework convention on climate change

UNFCCC, 2014, Areas of convergence related to areas of cooperation on the issue of the impact of the implementation of response measures. Technical paper, FCCC/TP/2014/12

UNFCCC, 2015, Paris agreement, Decision 1/CP.21, FCCC/CP/2015/10/add.1

UNFCCC, 2016, The concept of economic diversification in the context of response measures Technical paper by the secretariat. Technical paper, FCCC/TP/2016/3

World Energy Outlook, 2017, International Energy Agency, https://www.iea.org/weo2017/

(GCC Power Market Report, 2017, www.middleeastelectricit.com