Foreword

On behalf of the Government of Jordan, it gives me great pleasure to introduce Jordan's Second National Communication (SNC) to the United Nations Framework Convention on Climate Change (UNFCCC) which is directed to all policy makers, researchers, practitioners and the general public interested in climate change issues. This report is the result of the long, tedious and creative work of many Jordanian experts who together have reflected the most comprehensive outlook about climate change in the Jordanian context and outlined Jordan's efforts in addressing the phenomena and the impacts of climate change. Whether in greenhouse gas inventory, adaptation and mitigation options the readers of this report will find answers about Jordan's minor contribution in emissions and major vulnerability to climate change impacts.

Although Jordan does contribute a mere 20.14 million tons of Carbon dioxide equivalent, it maintains strong commitment to the objectives developed by the international community for the integrated environmental and economic response to the threat of climate change. Global Climate scenarios developed by the IPCC have also indicated that Jordan and the Middle East will suffer from reduced agricultural productivity and water availability among other negative impacts. The nationally compiled findings of this SNC further reiterate the scientific evidence of the IPCC and show the dynamics of Jordan's greenhouse emissions and where direct mitigation measures should be implemented. The vulnerability and adaptation sections define Jordan's priorities in linking adaptation to national policies for sustainable development.

At the heart of our climate change mitigation measures lies the issue of energy, which is considered as a challenge and an opportunity. Jordan is currently undergoing a paradigm shift in terms of energy policy planning. A combination of both necessity and conviction has worked together to drive a much needed vision for the development of renewable energy as a major contributor to the energy mix. The National Energy Strategy 2008-2020 identifies a target of 10% of renewable energy by the year 2020 comprising a ten-fold increase from the share of 1% in 2007. This transition will require capital investments, technology transfer and human resources development to produce a solid base to maintain and enhance this positive change pursued through the modified energy policy. The success of Jordan's mitigation portfolio will highly depend on a smooth system of technical and financial support to deploy the best available technologies in sectors of energy, transport and waste management, in particular.

At the adaptation front Jordan is facing a severe challenge in water scarcity to be magnified by the impacts of Climate Change. Jordan is statistically the fourth most water scarce country in the world with a per capita share of 145 Cubic meters per year. In a harsh natural environment with limited surface water and heavy demand on groundwater, lack of adequate financial resources for desalination Jordan is at the front line in the regional fight for innovative solutions to water scarcity problems. The scarcity of water in Jordan is the single most important constrain to the country growth and development as water is not only considered a factor for food production but a very crucial factor of health, survival and social and economical development.

The findings of Jordan's second national communication show how serious and urgent are the challenges we face in the water sector where water resources are expected to decrease based on suggested scenarios. Jordan is currently undergoing a comprehensive assessment and planning process to enhance the adaptive capacity of the water sector to the potential impacts of climate change. Priority actions and choices will be developed within the context of integrated water resource management and the focus on providing adequate water to meet the Millennium Development Goals and national water and environment objectives.

The SNC is a combination of sound scientific research and creative practical recommendations. It sets the national priorities for climate change related actions and guide our future efforts to be a part of the global effort to combat climate change and ensure the right to sustainable development at the national level.

The SNC is the product of a fruitful partnership between the Ministry of Environment and the UNDP that has utilized the full potential of national expertise and human resources with technical support from UNDP/GEF's Global Support Programme. The expertise gained during the preparation of this report will have a sustainable impact on the creation, dissemination and enhancement of knowledge about climate change in Jordan. It will also contribute significantly to the enhancement of knowledge-based decisions for our development and environmental management options.

I wish to thank and congratulate all those who were involved in the preparation of this landmark report and feel proud that such country-driven effort has culminated in a scientifically sound reference that has helped us to gain in-depth understanding of the complex dynamics of climate change in Jordan.

Khalid Irani
Minister of Environment

The Second National Communication
to the United Nations Framework Convention on Climate Change (UNFCCC)

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Abbreviations

AS	Activated sludge
bcf	billion cubic feet
BF	Bio-filter
CDM	Clean development mechanism
CEGCO	Central Electricity Generating Company
CERs	Certified emission reductions
CFC	Chlorofluorocarbons
CIS	Climate Information System
COP or C.P	Conference of Parties
CSIROMK3	Commonwealth Scientific and Industrial Research Organization Model
DOS	Department of Statistics
DSSAT	Decision Support System for Agrotechnology Transfer
DSWLF	Domestic solid waste landfill
ECHAM5OM	The 5th generation of the ECHAM general circulation model
ENPEP	Energy and Power Evaluation Package
ETc	Crop Evapotranspiration
EU	European Union
FAO	Food and Agriculture Organization
GAM	Greater Amman Municipality
GCMs	Global Climate Models or General Circulation Models
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GWP	Global Warming Potential
HADGEM1	HADley Center Global Climate Model
HFCs	Hydrochlorocarbons
HFO	Heavy fuel Oil
IFAD	International fund for Agricultural Development
IMIS	Irrigation Management Information System
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
IPCC-TGCIA	IPCC Task Group on Scenarios for Climate Impact Assessment
JD	Jordanian Dinar
JOMET	Department of Meteorology (Jordan)
KTD	King Talal Dam
LPG	Liquefied Petroleum Gas
LULUCF	Land Use Land Use Change and Forestry

MEMR	Ministry of Energy and Mineral Resources (Jordan)
MMRA	Ministry of Municipalities and Rural Affairs
MMT	Monthly Maximum Temperature
MoA	Ministry of Agriculture (Jordan)
MoEnv	Ministry of Environment (Jordan)
MoH	Ministry of Health (Jordan)
MOPIC	Ministry of Planning and International Cooperation (Jordan)
MoT	Ministry of Transport (Jordan)
MP	Maturation ponds
MWI	Ministry of Water and Irrigation (Jordan)
NCARE	National Centre for Agricultural Research and Extension
NERC	National Energy Research Center
NG	Natural gas
PMU	Project Management Unit
PV	Photovoltaic
QAIA/P	Queen Alia International Airport
R	Correlation Coefficient
R2	Coefficient of Determination
RBC	Rotating biological contactors
RCMs	Regional Climate Models
RJGC	Royal Jordanian Geographic Center
RMS	Root Mean Square
RMSE	Residual Mean Square of Error
SNC	Second National Communication
TDS	Total dissolved solids
UN	United Nations
UNDP	United Nations Development Programme
UNFCCC	United Nation Framework Convention on Climate Change
WHO	World Health Organization
UNEP	United Nations Environmental Program
V&A	Vulnerability and Adaptation
WASP	Wein Automatic System Planning Model
WEAP	Water Evaluation and Planning System
WSP	Waste stabilization ponds
WUAs	Water Users' Associations
WWTP	Wastewater Treatment Plant
YADP	Yarmouk Agricultural Resources Development Project
YRB	Yarmouk River Basin
ZRB	Zarqa River Basin

Symbols

CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2 eq.	Carbon dioxide equivalent
CH_4	Methane
N_2O	Nitrous oxide
NOx	Nitrogen oxides
NMVOC	Non Methane Volatile Organic Compounds
SO_2	Sulphur dioxide

Units

ºC	Degree celcius
Du	Dunum
Gg	Gigagram
ha	hectare
Kg	Kilogram
km	kilometer
kt	Kilo tonne
KW	Kilowatt
MCM	Million cubic meter
mm	Millimeter
MMSCM/Y	Million standard cubic meters per year
Mt	Mega (million) tonne
MW	Megawatt
m^3/s	cubic meter per second
ppm	Parts per million
TJ	Tera Joul
TOE (toe)	Tonne of oil equivalent

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

1. NATIONAL CIRCUMSTANCES

The Hashemite Kingdom of Jordan is a constitutional monarchy with a representative government. It is bordered by Syria to the north, Iraq to the east, Saudi Arabia to the east and south and the Palestinian territories and Israel to the west. The area of land mass is approximately 88,778 km2. The climate of Jordan is predominately of the Mediterranean type, which is characterized by a hot dry summer and rather cool wet winter.

Jordan's demographic profile is a major factor affecting development opportunities. In the year 2006, the total population of Jordan exceeded 5.6 million living mostly in urban areas. About 40 percent of Jordanians are less than 15 years old. Such a high percentage imposes heavy economic burden on Jordanian families.

Jordan is classified by the World Bank as a "lower middle income country". In the year 2006, the per capita Gross Domestic Product (GDP) was JD 1785. The main three sectors contributing to the GDP are: (1) finance, insurance, real estate and business services; (2) transport, storage and communications; and (3) manufacturing.

Jordan suffers from a severe water scarcity problem. Jordan's Water Strategy for the period of 2008-2022 states that Jordan is one of the four driest countries in the world. Despite the Government efforts in managing the limited water resources and its relentless search for alternative supply, the available water resources per capita are falling as a result of population growth. It is projected that the population will continue to grow from about 5.87 million in the year 2008 to over 7.8 million by the year 2022. Annual per capita water availability has declined from 3600 m3/year in the year 1946 to 145 m3/year in the year 2008; this is far below the international water poverty line of 500 m3/year. Jordan's remarkable development achievements are under threat due to the crippling water scarcity, which is expected to be aggravated by climate change. The scarcity of water in Jordan is the single most important constrain to the country growth and development as water is not only considered a factor for food production but a very crucial factor of health, survival and social and economical development.

Jordan has extremely limited primary energy resources and is forced to depend to a large extent on the imported petroleum, petroleum products and natural gas from neighboring Arab countries. Primary energy consumption reached 7.187 million toe in the year 2006, compared with 5.1 million in the year 2001, reflecting an overall growth of almost 40 percent. Over the same period, consumption of renewable energy has increased by a similar rate, growing from 76,000 toe in the year 2001 to 83,000 toe in the year 2005 and 111,000 toe in the year 2006.

The electricity consumption in the year 2006 was 9,579 GWh compared to 6,392 GWh in the year 2001. The average growth rate of consumption was 7.7 percent for the period 2001-2006, and 10 percent for the period 2005-2006. The transport sector is by far the leading final energy consumer in the country. The end users energy consumption in the year 2006 was distributed as follows: transport sector 37 percent, households 22 percent, industry 24 percent, and other sectors 17 percent (including services 7 percent).

Due to economic growth and increasing population, energy demand is expected to rise by at least 50 percent over the next 20 years. The provision of reliable energy supply at reasonable cost is thus a crucial element of economic reform and sustainable development. Although the demand will be increasing, however, the dependency on conventional oil sources is expected to decrease.

The sustainability of human development in Jordan is dependant on the availability of secure, adequate and clean energy sources and threatened by the decline in both the quantity and quality of water resources; and degradation in the quality and availability of arable land due to urbanization and poor land-use policies. To address these challenges that threaten sustainable efforts in Jordan; the Government in the year 2005 developed a national agenda; an action plan for achieving sustainable development through a programme of reforms in prevailing policies and practices.

2. NATIONAL GREENHOUSE GAS INVENTORY

Jordan's anthropogenic (human-induced) emissions by sources, and removals by sinks, of all greenhouse gases (GHGs) not controlled by the Montreal Protocol have been estimated for the base year 2000 using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories.

The GHG emissions and removals from the following sectors were estimated: energy, industrial processes, agriculture, land use, land-use change and forestry (LULUCF), waste and solvents.

The direct GHGs whose emissions have been estimated in this national inventory are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs). Emissions of the following indirect GHGs have also been estimated and reported in this inventory: oxides of nitrogen (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC); and sulphur dioxide (SO_2).

Jordan's 2000 Greenhouse Gas Inventory by Sector and by Gas

In the year 2000, Jordan contributed about 20140 gigagrams (Gg) or 20.14 million tonnes (Mt) of CO_2 equivalent (CO_2 eq.) of GHGs to the atmosphere. A sectoral breakdown of Jordan's total emissions of GHGs is as follows:

- Energy (14911 Gg CO_2), 74.0%;
- Industrial processes (about 1594 Gg CO_2 eq.), 7.9%;
- Agriculture (183 Gg CO_2 eq.), 0.9%;
- Land use, land use change and forestry (730 Gg CO_2 eq.), 3.7%; and
- Waste (2713 Gg CO_2 eq.), 13.5%

A breakdown of Jordan's total emissions on a GHG basis is as follows:

- Carbon dioxide (about 17047 Gg CO_2), 84.6%;
- Methane about (2745 Gg CO_2 eq.), 13.6%; and
- Nitrous oxide (about 347 Gg CO_2 eq.), 1.7%.

The Jordan's emissions of the fluorinated gases of sulphur hexafluoride, perfluorocarbons and hydrofluorocarbons were negligible in the year 2000.

The following paragraphs present the results of GHG inventory by sector.

Energy Sector

The total emissions from the energy sector were 14911 Gg CO_2 eq., i.e., 74% of the total GHG emission of Jordan in the year 2000. Carbon dioxide was the largest contributor (14714 Gg) at a percentage of 98.7% of the total energy sector emissions.

On a per gas basis, the contribution of the energy sector in the year 2000 was 86.3% of the total CO_2 emissions of the country, 4.7% of the CH_4 emissions, 19.6% of the N_2O emissions, 41.2 of the NMVOCs emissions and more than 99% of the total emissions of each of NOx, CO and SO_2.

On a per sub-sector basis, the largest contributor to emissions in the energy sector is the energy industries sub-sector, which accounted for 37.5% of energy emissions, followed by the transport sector which contributed 24.3% of the energy emissions.

Industrial Processes Sector

In the year 2000, emissions from industrial processes sector category were 1594 Gg CO_2 at 7.9% of Jordan's total GHG emissions. These CO_2 emissions originated mainly from cement production (1588.7 Gg CO_2). The industrial processes sector was the largest source of NMVOC emissions and accounted for 62.86 Gg at around 49% of Jordan's total NMVOC emissions in the year 2000. In addition to CO_2 and NMVOC, this sector generated negligible emissions of NOx, CO, SO_2 and HFCs.

Solvents and Other Products Use Sector

In the year 2000, NMVOC emissions generated from the solvents and other products use sector were only 13.34 Gg at around 10% of Jordan's total NMVOC emissions. The key source of NMVOC emissions in this sector was the application of oil and water based paints (8.57 Gg). Other sources within the chemical products, manufacture and processing sub-sector were pharmaceuticals production, printing industry, glue use, edible oil extraction and paint production.

Agriculture Sector

The GHG emissions of the agriculture activities were very small and accounted only for 0.9% (183 Gg CO_2 eq.) of Jordan's total GHG emissions in the year 2000. These emissions were composed of methane and nitrous oxide. Emissions of indirect GHGs of CO and NOx were negligible.

Land Use Change and Forestry Sector

The land-use change and forestry sector was a net source of CO_2. The emissions were estimated to be 739 Gg of CO_2 at 3.7% of Jordan's total GHG emissions in the year 2000. The net CO_2 emissions from soil were calculated to be around 960 Gg and the net CO_2 removals were estimated to be 221 Gg.

Waste Sector

In the year 2000, GHG emissions from the waste sector totaled 2713 Gg CO_2 eq. at 13.5% of Jordan's total GHG emissions. Most of the emissions originated from disposal of domestic solid waste which accounted for 12.5% (2515 Gg CO_2 eq) of the total GHG emissions, while wastewater handling accounted for 1% (199 Gg CO_2 eq) of the total GHG emissions. In the current national inventory the key source of methane was from the managed domestic solid landfill sites at around 96 % (around 120 Gg CH_4) of the total methane emissions in this sector.

3. GREENHOUSE GAS MITIGATION ANALYSIS

Greenhouse gas mitigation analysis aims at assessing potential measures to reduce GHG emissions and enhance GHG sinks. For this purpose, two types of scenarios were constructed; the baseline and mitigation scenarios.

The baseline scenario is constructed based on the trends, plans and policies prevailing in the Jordanian context. The development of this scenario required a projection of current levels to future levels of each type of activity for the time period of 2000-2033. Such projection draws on assumptions made about population growth, GDP, and other macro variables, which were obtained from official institutions

The mitigation scenario assessment was structured according to a set of criteria reflecting country-specific conditions such as potential for large impact on greenhouse gases, direct and indirect economic impacts, consistency with national development goals, potential effectiveness of implementation policies, sustainability of an option, data availability for evaluation and, other sector-specific criteria. Emission reductions and financial analysis have been conducted for the selected options.

Baseline Scenarios for the Different Sectors

Baseline scenario for energy sector

A most probable scenario based on National Energy Strategy was constructed. The major assumptions underlying this were:

- Introduction of oil shale based power plants into the national power system in the years 2014, 2015, 2017, 2018 and 2021(5 × 300MW)
- Introduction of nuclear power plants into the national power system starting 2020, 2024 and 2030 (3 × 400 MW).
- Limited natural gas supply availability.
- Medium demand scenario for petroleum products and for electricity.
- Limited renewable energy contribution to the energy mix.
- Limited energy conservation and energy efficiency activities.

Baseline scenario for wastewater

The wastewater baseline scenario is based on:

- Water Authority of Jordan will continue to construct the necessary domestic wastewater treatment plants to cover all cities and governorates throughout the country.
- Wastewater quantity is increasing with the increase in population.
- Wastewater is not managed as "waste" but is collected, treated, and used in an efficient and optimized manner.

Baseline scenario for domestic solid waste

The domestic solid waste baseline scenario is based on:

- Ministry of Municipal and Rural Affairs strategy is to establish environmental friendly landfills by the year 2010.
- The necessary transition stations will be opened for the domestic solid wastes to enhance the collection of the solid waste.
- A second cell in Al-Ghabawi landfill will be opened and a leachate treatment plant will be constructed.
- Solid waste quantities increase proportionally with population, the expected amounts of domestic solid waste generated were calculated based on a

generation rate of 0.9 Kg/capita/day.

- No methane recovery from sanitary landfills (due to investment barriers).

Baseline scenario for agriculture

The baseline scenario for this sector is based on plans, policies and strategies announced and adopted by the government of Jordan. It is based on conservation of land, water and natural vegetation, conservation of Jordan's biodiversity, monitoring environmental changes, combating desertification, and restoring degraded ecosystem of rangelands and forests.

GHG emissions in baseline scenario

Out of the 20140 Gg CO_2 equivalents of total emissions in the year 2000, CO_2 emissions represented 84.6 percent. This percentage is expected to grow according to the baseline scenario to reach 93 percent out of 70377 Gg by the year 2033. Methane emissions on the other hand represented 13.6 percent in the year 2000, and are expected to drop to about 6.5 percent in the year 2033. The N_2O emissions account only for 1.7 percent in base year and are expected to decrease to 0.3 percent by the 2033.

Mitigation Scenario

Thirty eight GHG mitigation projects were proposed in the areas of primary energy, renewable energy, energy efficiency, waste, and agriculture. The cost, benefits and CO_2 emission reduction are analyzed for each proposed project.

Results of mitigation analysis show that the major areas that should receive the most attention are fuel switch and introducing natural gas to the national energy system, renewable energy especially wind energy and energy efficiency.

Emissions reduction

The investigated mitigation projects, if executed, will lead to annual reductions of 2,761 thousand tonnes of CO_2 eq. in the year 2009; and are expected to increase to 12345 thousand tonnes of CO_2 eq. in the year 2033, representing 9.7 percent and 17.5 percent from baseline emissions; respectively.

4. VULNERABILITY ASSESSMENT AND ADAPTATION OPTIONS

Jordan's assessments of vulnerability and adaptation (V&A) to climate change under the second national communication have two principal parts: detailed analysis of possible scenarios of future climate, and analysis of V&A for agriculture, water resources, socio-economic, and health sectors. Zarqa River Basin (ZRB) and Yarmouk River Basin (YRB) were chosen as the study areas for the V&A to climate change. The findings are summarized below.

Observed Climate Variability and Change in Jordan

The spatial and temporal characteristics of the climatological variables in the different climatic regions were analyzed. Trends in the available longest time series (1961-2005) of various climatological variables were investigated all over the country. Climate change and climate variability in Jordan in general, and in the study area in particular were addressed.

Temperature: Both maximum and minimum temperature time series in the selected 19 meteorological stations have shown significant increasing trends. Increasing trends in the annual maximum temperature range between 0.3 and 1.8°C. The increasing trends in the annual minimum temperature range between 0.4°C and 2.8°C, which are obviously greater than maximum temperature trends.

Precipitation: Decreasing trends in the annual precipitation by 5-20 percent in the majority of the stations are apparent evidence of climate change in Jordan during the last 45 years. But very few stations, such as Ruwaished in the extreme east and Ras Muneef in the northwest, experienced an increase in the annual rainfall amount by 5-10 percent.

Baseline climate scenario: A 45 year (1961-2005) baseline of the daily mean air temperature and daily precipitation were developed using data from 9 synoptic meteorological stations distributed in the study area. The purpose of selecting a baseline spanning over the last 45 years of the climatological record is to construct a projection of climate change for the next 45 year period, 2005-2050.

Climate Change Projections for Jordan

The temperature and precipitation baseline scenarios were compared to the baselines extracted from 13 Global Climate Models (GCMs). The most comparable 3 GCMs to the observational data were selected to construct climate change scenarios for the projection period 2005 – 2050. These models are: the Australian model CSIROMK3, the German model ECHAM5OM and the British model, HADGEM1. The outputs of these models were combined with the baseline climate data to produce climate scenarios that served as inputs for the vulnerability assessment studies.

All the scenarios show an increase in temperature of less than 2°C by the year 2050. Warming was found to be stronger during the warm months of the year while less warming is projected to occur in the cold months of the year. However, the climate change scenarios for precipitation are highly variable. In addition to the GCMs, twenty incremental scenarios of temperature and precipitation were developed for each station in the study area. These scenarios were projected for the period 2005–2050.

Assessment of Vulnerability and Adaptation in Different Sectors

Agricultural sector

Agriculture in Jordan is one of the most vulnerable sectors to climate change because the available water and land resources are limited as most of the country's land is arid and is used as open range. The impact of climate change on rainfed agriculture was investigated using a Decision Support System for Agrotechnology Transfer (DSSAT) model on two main crops, wheat and barley.

Results of the vulnerability assessment for agricultural sector showed that climate change could have significant impacts, in particular on rainfed agriculture. Livestock sector and the overall food production in the country were identified as most significantly impacted by the adverse impacts of climate change on rainfed cultivation and on the arid and semi-arid rangelands.

The DSSAT had been used to simulate the impact of the different climate change scenarios on barley and wheat. Results showed variations in response between wheat and barley. For both crops, however, it has been found that the reduction of rainfall by 10 to 20 percent had a negative impact while the increase in rainfall by 10 to 20 percent had a positive impact on grain yield for both barley and wheat at the different temperature regimes. The maximum predicted losses of yield were 423 Kg/ha and 523 Kg/ha for wheat and barley; respectively. Generally, the increase in rainfall amount would not compensate for the adverse impacts of the temperature increase on barley. The trend for wheat was different from barley, as the increase of temperature was more advantageous for yield if rainfall would increase. The maximum increase of yield was 1667 Kg/ha for wheat under the scenario of 4 °C increase in temperature and 20 percent increase in rainfall, while barley was adversely affected by all scenarios.

The adaptation measures were divided into two main groups following the framework of Food and Agriculture Organization (FAO). The main adaptation measures at farm level included conservation agriculture, improvement of water use efficiency, implementation of water harvesting techniques, supplemental irrigation with treated wastewater and community-based management of rangeland resources. Planned adaptation measures included policy and legislation options, capacity building for mitigation and adaptation assessment and monitoring of vulnerability, early warning and risk management systems, knowledge management and technology transfer, and rehabilitation of livestock systems and rural livelihoods.

Water resources

The effect of climate change on water resources is expected to be significant as a result of decrease in precipitation and projected changes in its spatial and temporal distribution.

The analysis of the incremental scenarios had shown that change in precipitation and temperature will highly affect the amounts of monthly surface runoff. For both basins, surface runoff amounts would decrease when precipitation was kept unchanged and the mean annual temperature increased by 1, 2, 3 and 4 °C. It was also noticed that the most vulnerable scenarios to climate change impact on water resources are those when temperature will be increased by more than 2 °C and precipitation will not be increased. Even in some scenarios, the increase in precipitation by 20 percent does not compensate the increase in temperature by 2 °C.

The results from analyzing GCMs scenarios yielded different findings for both watersheds. For Zarqa Basin, the CSIROMK3 results show that the amount of surface runoff will decrease for the rainy season which extends from October to February. The highest decrease is expected to take place in January (about 25 percent) which is the rainiest month of the year. While the other two models show no or very little impacts of climate change on surface runoff.

For Yarmouk Basin, CSIROMK3 model shows that there will be a slight increase in the surface runoff amount during the rainy season. While ECHAM5OM simulation results show that there will be no change in surface runoff as a result of precipitation in January, and there will be a decrease in the other months.

The HADGEM1 simulation predicated a major increase in surface runoff values in March accompanied by a decrease in October and November. While other months show no change in surface runoff values. The three models shows slight or no change in surface runoff values for January, February, May and October.

In the last two decades a range of acts, regulations and measures, policies and strategies directly related to water scarcity were developed and some were even adopted. The current policies and strategies including the recently published water strategy for the period of 2008-2022 do not consider the stress that will be added to the available water resources due to climate change. The adopted measures or those suggested in the current strategies include water conservation, finding additional water sources (desalination and wastewater reuse) and water demand management; these measures will serve as future adaptation measures to climate change as well.

Health sector

A series of impacts on public health are expected as a result of the likely changes of climate system. General effects on human health of increased temperatures and changes in rainfall patterns include physiological disorders, skin rashes and dehydration, eye cataracts, and damage of public health infrastructure, deaths and injuries. Indirectly, climate change affects also ecological systems. For example, incidents of diseases transmitted by water such as cholera may increase. Vector borne diseases may also be affected by changes in climatic conditions. Moreover, the indirect impacts are perceived to include factors like demographic dislocations and socio-economic disruptions.

Environmental and health data sets are poorly matched at the international level and methods for analyzing the relationships between them have not been locally carried out. In the health sector study, surveillance records and logbooks from health centers (HC) were reviewed for climate sensitive diseases and rate of attendees to HC retrospectively. Time series analysis was performed to correlate maximum monthly temperature (MMT) to the number of admissions and deaths from public hospitals (PH), and to respiratory, cardiovascular and digestive tract diseases from HC.

Analysis of the collected data showed that there is a positive correlation between diarrhea rate and the MMT. Weak correlations were observed between MMT and typhoid fever, respiratory and hepatitis A. The study emphasized the need for detailed investigations of the impact of climate change on human health in Jordan's vulnerable regions.

The health study identified several adaptation measures to climate change on health sector including:

- Strengthening surveillance and establishment of highly sensitive alert system by the development of health forecast system for climate sensitive diseases.
- Prevention and control of emerging and re-emerging vector- borne diseases.
- Strengthening the existing emergency preparedness and disaster management
- Improving data collection on diseases related to climate change and establishing database for the collected data.

Socio-economic impacts

There are no published data on socio-economic factors affected by climate change for the study areas. As a result, the study relied on the subjective analysis, in general, and on a short field survey of selected areas. The survey was conducted to understand the attitudes of respondents to climate change. The main effect of climate change factors on the respondents (according to their perspective) in the urban areas is shortage of water which affects the sanitary conditions in the households; leading to an increase in some kinds of diseases such as diarrhea, and the increase of cost of living. The farmers, on the other hand, mainly rainfed farmers are affected by the high temperature and low rain in their farming practices, leading to a decrease in their income.

The socio-economic study recommended several measures and programs for adaptation to climate change, including enhancing the knowledge of the poor on adaptation measures to enhance their resilience to climate change, implementing some adaptation measures in agriculture and food security, establishing a "National Disaster Fund" for farmers and developing institutional capacity through provision of better infrastructure and more personnel training.

NATIONAL CIRCUMSTANCES

1. NATIONAL CIRCUMSTANCES

This chapter includes a short description of Jordan's governmental structure, and geographical, climate, population, and economic profiles of the country. In addition, this chapter describes the transport, health, water, waste, and agricultural sectors and presents the basic elements constituting Jordan's actual energy profile.

1.1 GOVERNMENT STRUCTURE

The Hashemite Kingdom of Jordan is a constitutional monarchy with a representative government. His Majesty King Abdullah II is the Head of State. The king exercises his executive authority through the Prime Minister and the Council of Ministers, or Cabinet. The Cabinet is accountable to a two-house parliament. The Upper House (the Senates) is appointed by the King, while the deputies of the Lower House are elected by popular vote.

Administratively, Jordan is divided into 12 governorates, each headed by a governor appointed by the King through the Ministry of Interior. They are the sole authorities for all government departments and development projects in their respective areas. Each governorate is divided into smaller administrative sub-regions. The district government acts as the executive organ for carrying out cabinet decisions on the local level. These district governments are thus essentially an extension of the central government, and are supervised by the Ministry of Interior.

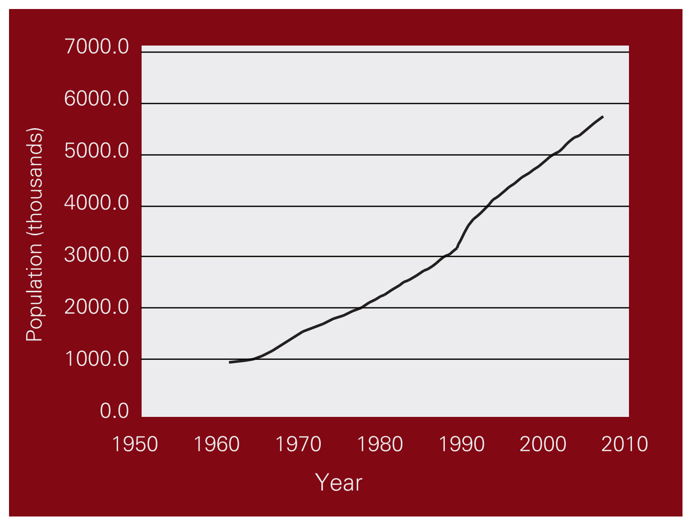
In contrast to the appointed district governors, mayors are elected. The only exception to this rule is the mayor of Amman, who is appointed directly by the King. Mayors supervise the day-to-day affairs of towns and cities, and grievances against mayors can be appealed to the Ministry of Municipal and Rural Affairs.

The Ministry for Environment (MoEnv) is the main governmental body concerned with the development and implementation of environmental policy in Jordan. The MoEnv was established in the year 2003 and functions within the mandate of Environmental Protection Law No: 1/2003 (MoEnv, 2008). The Ministry's responsibilities include developing government guidelines and policies concerning the environment, and then managing and coordinating their implementation and enforcement. The MoEnv is responsible for the coordination of climate change activities through the country's climate change unit.

1.2 DEMOGRAPHIC PROFILE

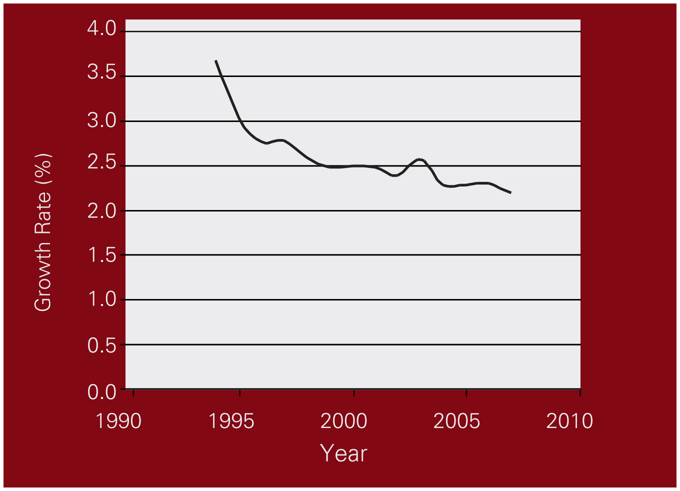
Jordan's demographic profile is a major factor affecting development opportunities. In the year 2006, the total population of Jordan exceeded 5.6 million. As shown in Figure (1.1), this represents a five- fold increase since the 901,000 registered in 1961 (DOS, 2008).

Figure 1.1: Population of Jordan



Since its establishment, the Kingdom has experienced a succession of in-migrations, augmenting its indigenous population with waves of Palestinian refugees displaced by conflicts in years 1948 and 1967. Hundreds of thousands of expatriate Jordanians and Palestinians returned to Jordan from the Arab Gulf states especially Kuwait during the Gulf crisis of 1990-1991, and more recently many Iraqis. The considerable growth in population is also attributed to the high population growth rate especially until the end of the 1970s. The average population growth rate was 4.3 percent between the years 1952 and 1979 (MoEnv, 2006). The current population growth rate is 2.3 percent which has decreased from 3.6 percent in 1996, as shown in Figure (1.2).

Figure 1.2: Population growth rate in Jordan



Due to the high population growth rate, large percentage of the Jordanian citizens is concentrated in the age group of less than 9 years (27.6 percent). Those who are less than 15 years comprise more than 40 percent of the population (DOS, 2008). Such a high percentage imposes heavy economic burden on Jordanian families.

The population of Jordan is highly urban. In the 1952, only 39.6 percent of Jordan's population lived in urban areas. By the 2006, the figure had reached 82.6 percent. This increase is largely a result of internal rural-to-urban migration, combined with the influx of refugees and migrants. The urban population within Amman, Irbid and Zarqa governorates now account for four millions of people, which constitutes 71.5 percent of the total population of Jordan (DOS, 2008).

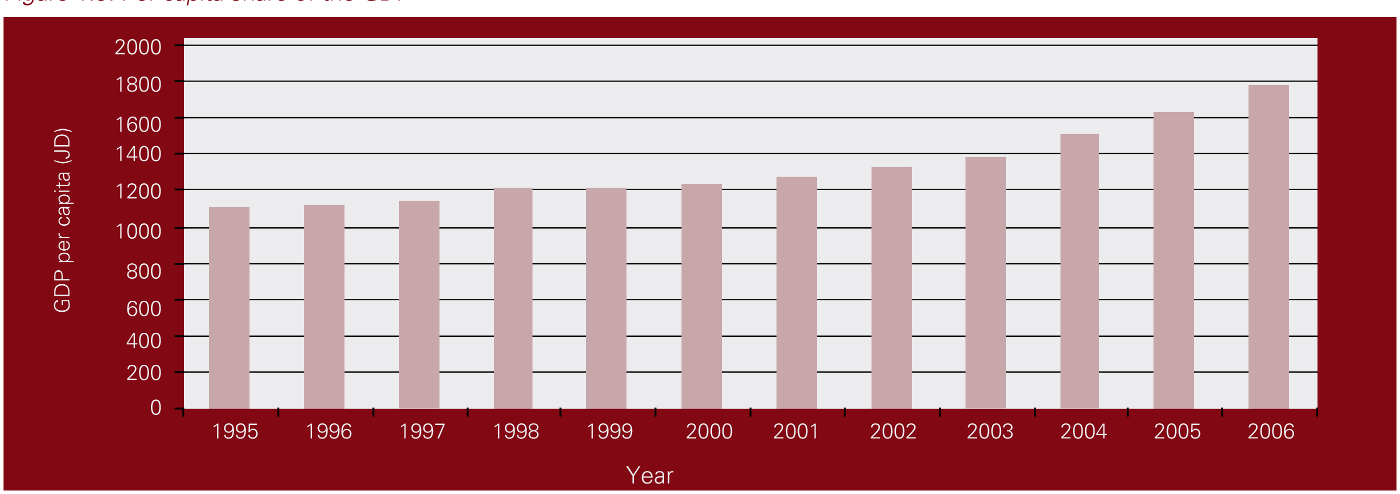
1.3 ECONOMIC PROFILE

Jordan is classified by the World Bank as a "lower middle income country". In the year 2006, the per capita Gross Domestic Product (GDP) was JD 1785 rising from JD 1106 earned in the year 1995, this is shown in Figure (1.3) (DOS, 2008).

According to Jordan's Department of Statistics, 13 percent of the economically active Jordanian population residing in Jordan was unemployed in the year 2007, although unofficial estimates cite a 30 percent unemployment rate. The rate of inflation in 2007 was 5.7 percent. The Jordanian currency has been stable with an exchange rate fixed to the U.S. dollar since 1995 at JD 0.708-0.710 to the dollar. In the year 2007, Jordan negotiated a Paris Club debt buyback agreement to retire at least 2 billion USD. This buyback will reduce the percentage of external debt to GDP from 51.3 percent in 2006 to 32 percent.

Since the late 1980s, with the firm encouragement of the International Monetary Fund and World Bank, Jordan has made sustained efforts to reform its economy. These reform measures included removing public subsidies (including those on fuel), controlling public-sector payrolls, reforming the state pension system, and introducing a general sales tax in the year 2004 (MoEnv, 2006).

Figure 1.3: Per capita share of the GDP



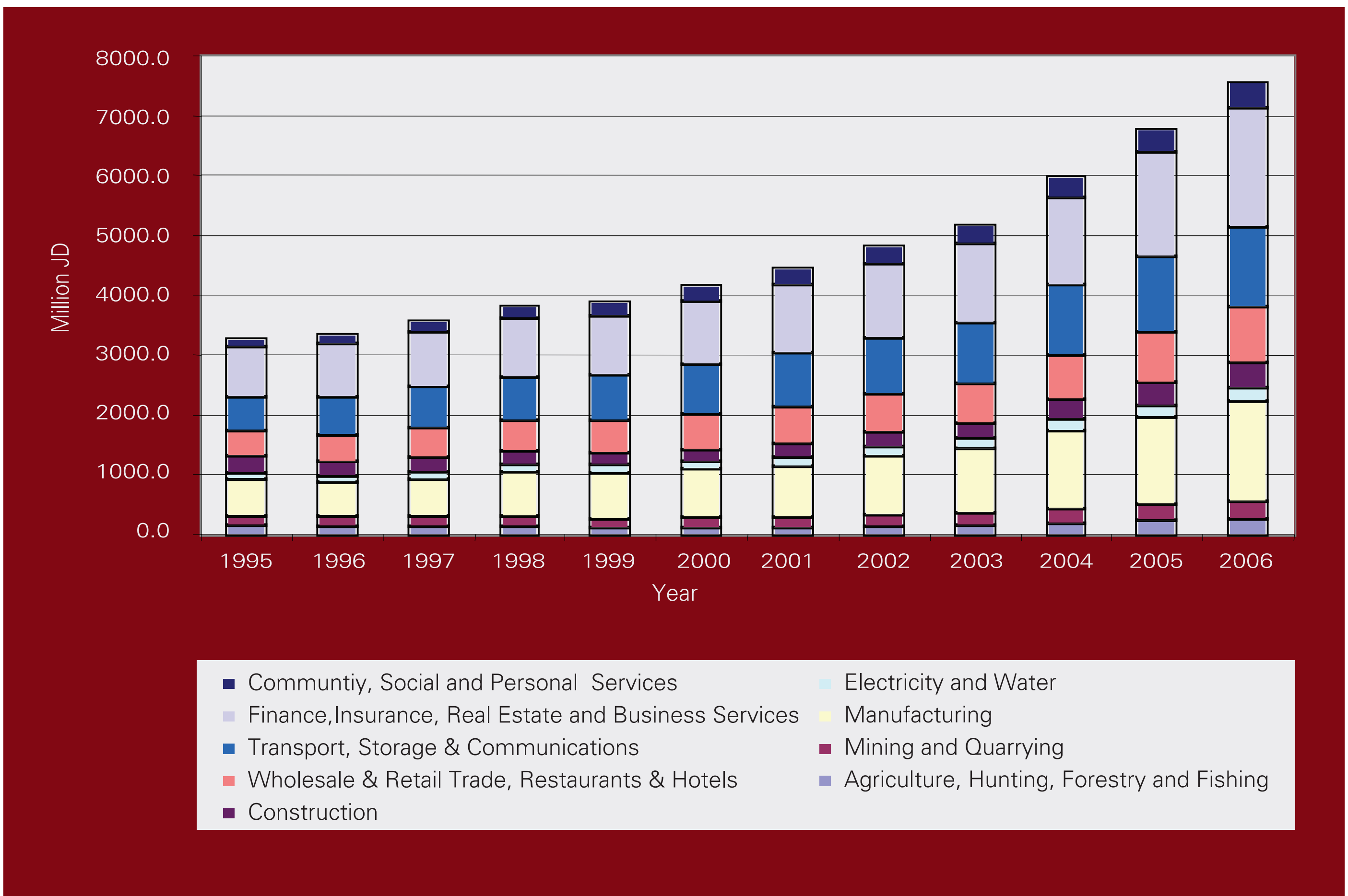
By the year 2000 the economy was growing at an average annual growth rate of 5 percent (compared with less than 3.5 percent on average for the period 1996-2000); real GDP growth reached 7.7 percent in the year 2004 and 8.4 percent in the year 2005. Remarkably, this growth occurred despite a recession in the year 2003 caused by the Iraq war, which caused the loss of heavily-subsidized oil supplies from Iraq forcing Jordan to purchase crude oil at global market prices (UN, 2006).

GDP composition by sector for the period from 1995 to 2006 is shown in Figure (1.4). The main three sectors contributing to the GDP are:

- Finance, insurance, real estate and business services
- Transport, storage and communications
- Manufacturing

Jordan's ranking improved substantially in the Global Competitiveness Index (from 44/80 in the year 2002 to 34/102 in the year 2003), and in the Business Competitive Index (from 53/80 in the year 2002 to 41/101 in the year 2003). The main strengths of the Jordanian economy lie in the quality of the educational system (27/102); the availability of scientists and engineers, where Jordan outranks Singapore (12/102); infrastructure quality, where Jordan outranks Israel (23/102); judicial independence (23/102); efficiency of legal framework (29/102); protection of minority shareholder interests (19/102); and intellectual property protection (22/102) (MoEnv, 2006). Despite these achievements, Jordan's economy remains vulnerable to external shocks, as was seen in various ways during the 1990s, particularly in terms of trade with Iraq and the Gulf states.

Figure 1.4: Contribution of different sectors of economy to the GDP



1.4 GEOGRAPHIC PROFILE

Jordan is located about 80 kilometers east of the Mediterranean Sea between 29° 11' to 33° 22' north, and 34° 19' to 39° 18' east. It is bordered by Syria to the north, Iraq to the east, Saudi Arabia to the east and south and the Palestinian territories and Israel to the west. The area of land mass is approximately 88,778 km^2 while area of water bodies is approximately 482 km^2 that includes both the Dead Sea and the Gulf of Aqaba. Altitude ranges from about -415 m (below mean sea level) at the surface of the Dead Sea up to 1845 m at top of Jabal Um Ad Dani (RJGC, 2008).

Jordan has three distinct ecological zones (Al-Bakri et al., 2008): (i) Jordan Valley which forms a narrow strip located below the mean sea level, and has warm winters and hot summers with irrigation being mainly practiced in this area; (ii) the western highlands where rainfall is relatively high and climate is typical to the Mediterranean areas; and (iii) the arid and semiarid inland to the east, known as the "Badia", where the annual rainfall is below 200 mm. Badia is an Arabic word describing the open rangeland where Bedouins (nomads) live and practice seasonal grazing and browsing.

The Jordan rift valley lies in the western part of the country and extends from Lake Tiberias in the north to the Gulf of Aqaba in the south with a length of about 400 km and with a width that varies from 10 km in the north to 30 km in the south. The Jordan Valley, the Dead Sea and Wadi Araba are located in this zone.

To the east of Jordan rift valley, the Mountainous Region, forming the eastern boundary of the Rift Valley and extending from Lake Tiberias to the Gulf of Aqaba. Mountains in this zone have elevations ranging from 1,200 in the northern parts to 1,500 meters in the southern part of the country with highest peak in the extreme south (MoEnv, 2006).

1.5 CLIMATE PROFILE

The climate of Jordan is predominately of the Mediterranean type, which is characterized by a hot dry summer and rather cool wet winter, with two transitional periods the first starts around October and the second around mid of April. Most of the precipitation falls in the form of rain or drizzle, snow may fall on highlands and hail is frequent during thunderstorms. Precipitation falls during rainy season (October-May), but about 75 percent of precipitation falls during winter season, which extends from December to March.

In general, the annual precipitation in the Jordan valley is less than that over mountainous regions located west or east of the Valley. The annual precipitation in the northern parts of the valley is the highest at the north, decreasing gradually southward. The annual precipitation ranges from 394 mm in the northern parts (Baqura) to 74 mm in the southern parts (Ghore Safi) (JOMET, 2008). The amount of annual precipitation in Mountainous Region is the highest. It exceeds 550 mm in Ajloun and Balqa Mountains, decreasing gradually southward to about 339 mm in Rabba/Karak, 294 mm in Shoubak and 238 mm in Tafeeleh. In the Steppes Region, the amount of rainfall is about 100-200 mm. The mean annual rainfall is 158 mm in Mafraq and 148 mm in Wadi-Dhalail. In the Badia, it is about 75-110 mm in the north decreasing to about 60-mm in the south. In the Jordanian Desert (southeast of Jordan) the annual rainfall is less than 35 mm, and is only 12 mm in Mudawara at the extreme southeast of Jordan borders.

The northwestern part of Jordan has the greatest annual rainfall amount with 572 mm in Ras Muneef (1150 m above see level). The total rainfall decreases eastward, and southward to minimum values as in the extreme southern parts, 32 mm in Aqaba, and in the southeastern parts 33 mm in Jafr. In spite of the higher elevations in the southern region, it has rainfall amounts less than the lower northern heights. Shoubak with 1365 m above sea level has a total annual rainfall of 288 mm while the northern mountains are totally lower than 1150 m, and have annual rainfall of more than 400 mm. In the eastern desert (arid) area and in the south, the rainfall occurrences are of small scale and rather random. Jordan can be divided into three obvious homogenous precipitation regions as follows (Freiwan and Kadioglu, 2008):

(i) The first region includes the northern heights, western Amman, Irbid and the extreme northern Jordan Valley (Baqura). The total annual rainfall amount in this region varies from 400 to 600 mm. The seasonal rainfall distribution is 63, 23, and 14 percent in winter, spring and fall; respectively.

(ii) The second region includes the central part of Jordan (Amman), the southern heights (Shoubak and Rabba), and the northern Jordan Valley (Deir Alla). This region has a total rainfall amount between 250 and 350 mm with a temporal rainfall distribution of 63, 24, and 12 percent in winter, spring and fall; respectively.

(iii) The third region consists of the lower locations among and besides the northern and southern heights (Queen Alia International Airport (QAIA) ,Wadi Duleil and Mafraq), the eastern parts (Safawi and Ruwaished), southern and southeastern parts (Ma'an and Jafr) and southern Jordan Valley that extends to Aqaba. The total annual rainfall amount in this region varies from 140–170 mm in the central west to 70–90 mm in the east to 30–50 mm in the south, and the seasonal rainfall distributions are 54, 25 and 21 percent in winter, spring and fall seasons; respectively.

The mean annual maximum temperature produces a great spatial variability in Jordan depending on the topographic nature of the country. Winter maximum temperature has a characteristic increasing gradient from 9–13 °C in northern and southern heights to 14–16 °C in the desert area to 19–22 °C in Jordan Valley. Maximum mean temperature is inversely proportional to the elevation; it varies from 20 to 23 °C in mountainous areas and increases to 26 °C in the desert region. In Jordan Valley, annual maximum temperature increases southward and varies from 29 to 31 °C.

In summer, high averages of maximum temperature prevail and reach 38–39 °C in Jordan Valley, 35–37 °C in desert region and decrease to 26–29 °C in the mountainous region, causing a large spatial variation from west to east and south.

Minimum temperature is an important climatic element due to its deterministic relation to agricultural activities. Mean annual minimum temperature differs from mean annual maximum temperature by having the lowest values not in the northern heights, but in southern heights and in some of the arid areas. Shoubak has the lowest mean annual minimum temperature (5.6 °C), which is followed by the QAIA (7.8 °C), Mafraq (9 °C), and then the northern heights and the desert area. The warmest region in the country is Jordan Valley where the mean annual minimum temperature ranges between 15.7 °C in the north and 19.5 °C in the southern part of the Valley (Freiwan and Kadioglu, 2008).

During summer the Jordan Valley is very hot, and the mean daily maximum is 39 °C. The highest observed temperature is 51.2 °C near the Dead Sea. During winter the mean minimum temperature is about 9 °C, the temperature is pleasant and frost is rare. In the mountainous region it is rather cold during winter, and the mean daily minimum temperature is about 4 °C. The lowest recorded temperature at Amman Airport is -7.5 °C, and at Shoubak is -12 °C. The annual number of days with air frost is 10-15 days. During summer it is pleasant, and the mean daily maximum temperature is about 26 °C to 30 °C.

Amman, the capital of Jordan, is a mountainous city which enjoys four seasons of excellent weather when compared to other places in the region. Summer temperatures range from 28 °C to 35 °C, but with very low humidity and frequent breezes. Spring and fall temperatures are extremely pleasant and mild. The winter sees nighttime temperatures frequently near 0 °C, and snow is known in Amman. As a matter of fact, it usually snows a couple of times per year.

1.6 WATER RESOURCES

The 2006 UNDP Human Development Report classified Jordan as one of the ten most water scarce countries in the world while Jordan's Water Strategy for the period of 2008-2022 states that Jordan is one of the four driest countries in the world (MWI, 2009). The National Agenda that sets Jordan's development vision till 2015, as well as the United Nations Development Assistance Framework for Jordan from the year 2008-2012 (UN, 2007), stress that Jordan's remarkable development achievements are under threat due to the crippling water scarcity, which is expected to be aggravated by climate change. The scarcity of water in Jordan is the single most important constrain to the country growth and development because water is not only considered a factor for food production but a very crucial factor of health, survival and social and economical development. The Initial National Communication (INC) to the United Nations Framework Convention to Climate Change (UNFCCC) foresees that over the next three decades, Jordan will witness a rise in temperature, drop in rainfall resulting in reduced water availability.

Recognizing the magnitude of threat of water scarcity, the Government of Jordan developed a comprehensive water strategy entitled "Water for Life" for the period 2008 to 2022. The water strategy for Jordan was prepared by a royal committee and was approved and published in May,

2009. The strategy defines the long term goals that the government of Jordan seeks to achieve in the water sector. It mainly focuses on effective water demand management, effective water supply operations, and a well developed institutional reform (MWI, 2009).

Despite the Government efforts in managing the limited water resources and its relentless search for alternative supply, the available water resources per capita are falling as a result of population growth. It is projected that the population will continue to grow from about 5.87 million in 2008 to over 7.8 million by the year 2022 (MWI, 2009). Annual per capita water availability has declined from 3600 m^3/year in the year 1946 to 145 m^3/year in the year 2008; this is far below the international water poverty line of 500 m^3/year. As a result of scarcity, the demands and uses of water are far exceeding renewable supply. The deficit is made up by the unsustainable use of groundwater through overdrawing of highland aquifers, resulting in lowered water table in many basins and declining water quality in some. In addition to that, the deficit is overcome also by supply rationing to the domestic and agricultural sectors.

In the year 2007, water resources were 867 MCM while the demand was 1505 MCM, thus the deficit was 638 MCM. The distribution of water supply (allocations) in the year 2007 was as follows; 30 percent for municipal use, 1 percent for tourist use, 5 percent for industrial use, 32 percent for highland irrigation and 32 percent for irrigation in Jordan Valley (MWI, 2009).

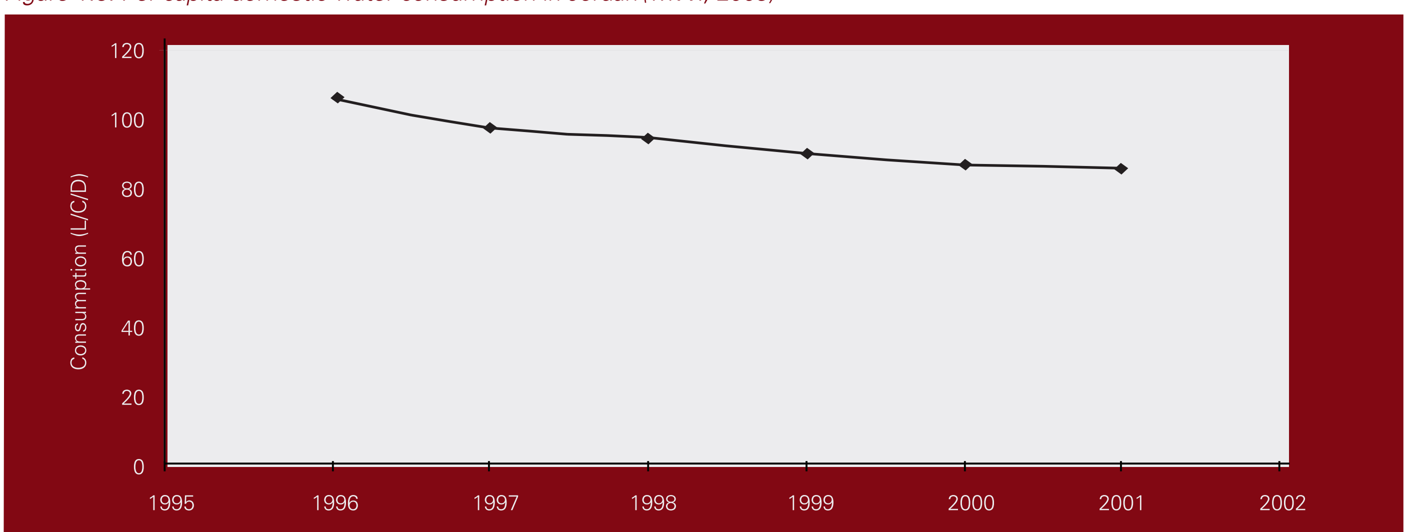
The municipal water demand is growing rapidly faster than the population growth but due to system capacity and limited supply, the actual demand has never been met. To overcome the shortage and gap between supply and demand, water consumption is rationed by rotating supplies and providing intermittent services during most of the dry months (June - August). The average per capita per day share of drinking water is continuously falling as shown in Figure (1.5).

The water resources should be developed to 1632 MCM by the year 2022. The Dissi is planned to be operational by the year 2013, the Red Dead conveyance is expected to be operational by the year 2022 and treated wastewater should be fully utilized by the year 2022. Extraction from ground water should be drastically reduced (MWI, 2009).

Jordan water is derived from surface and underground sources. Developed surface water in Jordan is estimated at 295 MCM in 2007 at approximately 37 percent of Jordan's total water supply. The contribution of the groundwater is estimated at 54 percent of the water supply. Other water sources include treated wastewater which is used for irrigation in addition to desalinated water from some springs (MWI, 2009).

Treated wastewater emanating from twenty three existing wastewater treatment plants is an important component of the Kingdom's water resources. About 100 MCM per annum of treated wastewater is primarily used

Figure 1.5: Per capita domestic water consumption in Jordan (MWI, 2003)



for irrigation, mostly in the Jordan Valley. Wastewater quantity is increasing with the increase in population, increasing water use and development of the sewerage systems. Thus, by the year 2022 about 256 MCM /year of wastewater is expected to be generated (MWI, 2009).

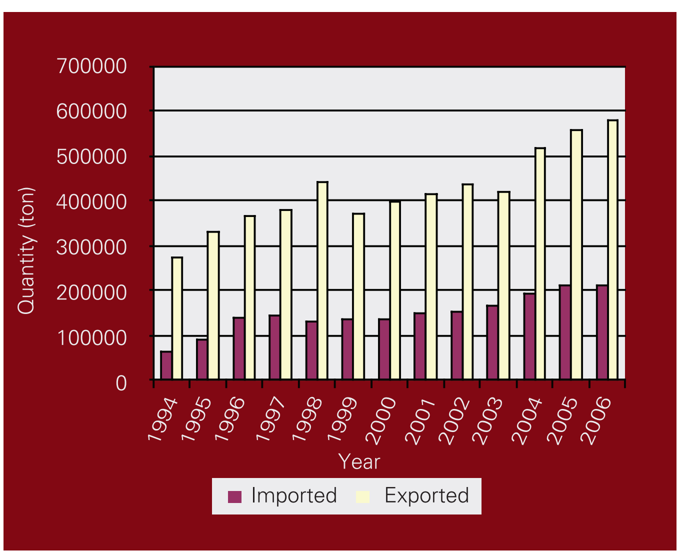
Several brackish springs have been identified in various parts of the country. Estimates of stored volumes of brackish groundwater for the major aquifers suggest huge resources, but not all of these quantities will be feasible for utilization. The main environmental concern for all desalination projects is the disposal of the brine.

Sea water desalination is viewed in conjunction with the execution of the Red Sea- Dead Sea canal project. If this project could be implemented, an amount of 500 MCM of desalinized sea water would be available for Jordan. The available energy to produce this amount is through utilization of about 400 m head difference between the Red Sea and the Dead Sea and flow of 40-60 m^3/s of sea water in order to restore the Dead Sea to its original elevation of 395 m below sea level.

1.7 AGRICULTURE

Agriculture contributed substantially to the economy at the time of Jordan's independence, but it subsequently suffered a decades-long steady decline. However, farming remained economically important and production

Figure 1.6: Quantities of imported and exported crops in Jordan (MoA, 2006)



grew in absolute terms. Even with increased production, the failure of agriculture to keep pace with the growth of the rest of the economy, however, resulted in an insufficient domestic food supply. Jordan thus needed to import such staples as cereals, grains, and meat. Between the years 1982 and 1985, the total food import bill averaged about JD180 million per year, accounting for more than 15 percent of total imports during the period. At the same time, cash crop exports generated about JD40 million per year, yielding a net food deficit of JD140 million.

The suffering of the agricultural sector continued in the 1990s into the present time despite the increase in production and exported crops as shown in Figure (1.6). However, observers expected food imports to remain necessary into the indefinite future. Much of Jordan's soil was not arable even if water were available. Estimates show that between 6 percent and 7 percent of Jordan's territory was arable, a figure that was being revised slowly upward as dry-land farming techniques became more sophisticated. Only about 20 percent of Jordan's geographic area received more than 200 millimeters of rainfall per year, the minimum required for rain-fed agriculture.

The high rainfall areas, however, suffered from urbanization and land fragmentation which resulted in permanent loss of these lands. Much of the country's land therefore can be classified as unsuitable for agriculture. Moreover, rainfall varied greatly from one year to another, so crops were prone to be ruined by periodic drought.

In 1986 only about 5.5 percent (about 500,000 hectares) were under cultivation. Fewer than 40,000 hectares were irrigated, almost all in the Jordan River Valley. Because arable, rain-fed land was exploited extensively, future growth of agricultural production depended on increased irrigation. The cropped area decreased in the 1990s into the new millennium as shown in Figure (1.7). In the year 2006, only about 80,000 hectares were irrigated out of around 250,000 hectares of the total cultivated land (DOS, 2006). The most profitable segment of Jordan's agriculture is fruit and vegetable production (including tomatoes, cucumbers, citrus fruit, and bananas) in the Jordan Valley. The rest of crop production, especially cereal production, remains volatile because of the lack of consistent rainfall.

Figure 1.7: Cropped area in Jordan (DOS, 2008)

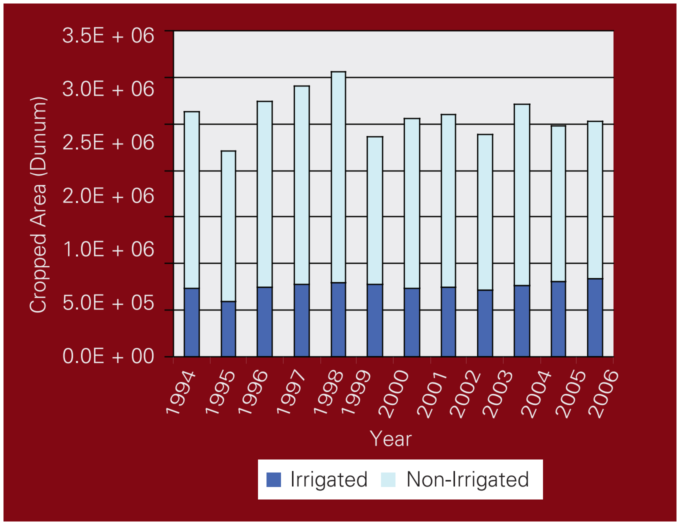


Table 1.1 Field crops in Jordan in the year 2005 (Annual report; MoA, 2006)

Crops	Planted area (000 du)	Harvested area (000 du)	Production (000 tonnes)
Wheat	385.8	292.9	34.4
Barley	713.3	361.5	81.8
Lentil	12.7	12.7	00.8
Chickpeas	14.0	14.0	03.9
Corn	13.2	13.2	30.8
Tobacco	0.4	0.4	00.1
Green clover	47.7	47.7	264.6
Vetches	18.9	17.7	02.2
Others	5.6	5.6	06.2
Total	1211.6	765.7	374.8

The suffering of the agricultural sector is aggravated by the increase in demand for water and depletion of available resources. In the year 2003, about 506 MCM of water was consumed for irrigated agriculture which comprised 62.5 percent of Jordan's total water consumption (DOS, 2003). Only 3 percent of the country's work force is skilled agricultural workers. The agricultural sector contributed 2.3 percent of GDP in the year 2004 (down from 8.5 percent in the year 1994). Economics will play an increasingly important role in future water allocation decisions. As a result, farmers in Jordan Valley and the highlands will soon find it difficult to justify their priority claim over water resources. Although irrigated agriculture is the largest user of water in Jordan, however, most of the available water resources for irrigation come from treated wastewater. Therefore, the key challenges to irrigated agriculture are the improvement of water use efficiency and the alleviation of adverse environmental impacts resulting from the reuse of treated wastewater. On the other hand, rainfed agriculture will face the challenge of climatic variability and change.

Generally the country's soils are calcareous and poor in organic matter, nitrogen and the other essential nutrients. So in order to have high crop production, the farmers apply fertilization and adding soil amendments which are considered among the activities that add to the GHG emissions mainly nitrous oxides. Table (1.2) shows the amounts of fertilizers imported by the country between 2001 to 2006.

The livestock is one of the main components of the agriculture sub-sector, it adds significantly to the GDP at around 50 percent over the past decade. The livestock sub sector provides a major source of income to about 250 thousand people. The contribution of different sub-sectors of livestock to the total produce is variable. The poultry sub-sector occupies the highest rank, followed by dairy cattle (Friesian), where as the sheep and goats have special importance due to its social significance (Table 1.3).

Table 1.2: Total quantity of fertilizer imported, 2001-2006 (tonnes)

Fertilizer type	2001	2002	2003	2004	2005	2006
Nitrogen	40576	39526	42246	35286	61.8	32416
Phosphorous	255	1999	599	352	432	25
Potassium	851	9861	706	451	498	2995
Compound	7883	-	10291	11519	13149	13345
Total	49565	49305	54042	47608	61781	48781

(Annual report; MoA, 2006)

Table 1.3: Livestock sector (000 heads)

Year	Cows			Sheep	Goats			Camels
	Friesian	local	Total		Syrian type (Shami)	Local	Total	
2001	63.60	3.20	66.80	1456.9	10.88	415.02	425.90	14
2002	67.20	2.60	69.80	1433.3	17.90	539.38	557.25	13
2003	61.78	4.49	66.27	1476.50	10.41	537.06	547.47	12
2004	64.79	4.47	69.26	1539.9	9.57	491.54	501.11	13
2005	67.59	4.21	71.80	1901.16	8.41	507.72	516.13	13
2006	68.25	3.20	71.45	1971.54		473.80	473.80	13

(Annual report; MoA, 2006)

Table 1.4: Poultry sector (number of farms)

year	Farm for Eggs	Farm for Broilers	Farm for Hens	Farm for Chicks
	Farm capacity (thousand)	Farm capacity (thousand)	Farm capacity (thousand)	Farm Capacity (million)
2001	6377	24209	2666.48	264.1
2002	6730	29181	3150.97	277.1
2003	6597	29145	3241.00	292.0
2004	6620	26044	3484.06	285.3
2005	7580	27520	3369.81	341.6
2006	7600	26750	3369.81	341.6

(Annual report; MoA, 2006)

Around 30 percent of red meat consumption is produced within the country, 50 percent for milk and dairy products, while the production of poultry meat and eggs satisfies the consumption need with periodic surpluses. (Annual agriculture report, 1999-2001)

1.8 LAND-USE

Land use/cover in Jordan falls into five broad categories (Table 1.1) which reflect climate, topography, soils and the availability of water resources. In general, availability of water resources is the most important factor controlling land use. Discrepancy is observed between figures on existing land use/cover coming from different sources. However, most of studies and figures have shown that agricultural areas form small proportion of the country. According to the Department of Statistics, land use shows that most of the country is dominated by non-cultivated areas, classified as rangeland (DOS, 2003).

Land use in Jordan is dynamic with obvious changes among the different types of use. The root cause of land use change is the high growth rate of population which resulted in putting high pressure on the limited natural resources of the country, particularly water.

Table 1.5: Land use in Jordan in 2005

Type of Land Use	% of total area
Pastures	80.8
Urban	11.0
Forest lands	0.9
Afforestation projects	0.9
Water area	0.5
Agricultural lands	5.9

(Annual report; MoA, 2006)

1.9 ENERGY PROFILE

Energy security is a major challenge facing Jordan's sustainable development. In response, the Ministry of Energy and Mineral Resources (MEMR) has developed an integrated and comprehensive energy master plan for the development of the energy sector over the next 20 years. The plan was approved by the Council of Ministers on December 7, 2004. Implementation of the plan should yield a net increase in GDP of $250 million per year for the Jordanian economy and will create a number of investment opportunities, which will be structured to encourage and promote private sector participation. On January 28, 2007, The Royal Energy Committee was formed to undertake the following tasks: (1) review and modernize the national energy strategy, (2) reconsider restructuring of the energy sector in Jordan and to recommend ways to provide the needed energy, particularly the alternative and renewable energy resources, and (3) draw a work program with clear mechanism and specified cost and time frame.

1.9.1 Energy Efficiency and Conservation

Jordan has made significant progress in improving energy efficiency on the supply side mostly through the introduction of natural gas as a major source of primary energy for electricity production using combined cycle technology; its overall energy intensity is higher than in most Middle East and North Africa (MENA) countries. There is therefore considerable scope for demand-side management and energy efficiency measures. Key barriers to energy efficiency are (1) lack of knowledge by energy users of the benefits of energy efficiency, (2) lack of expertise to develop energy efficiency projects, (3) high initial implementation cost, (4) lack of suitable financing mechanisms, as banks lack experience and awareness in energy efficiency and need assistance on risk analysis and mitigation to achieve bank ability, and (5) lack of consistent institutional frameworks.

The Government decided to establish an energy efficiency fund and agreement was reached with the World Bank to have a combined energy efficiency and renewable energy fund. Energy consumption for the year 2020 is estimated to reach 16,773,000 tonne oil equivalent (toe), and if it is assumed that approximately 20 percent of the energy consumption can be saved from the total energy consumed in the year 2020 (as anticipated by MEMR studies), then the estimated energy saved will be around 3,355,000 toe when implementing the energy efficiency programs.

The Government of Jordan has adopted a national strategy for improving energy efficiency in all sectors in the Kingdom, where several measures and actions are needed to be implemented throughout this strategy. The main goals of this strategy are (1) to reduce energy consumption without negatively affecting the size of production or the standard of living; which will lead to a lower national imported oil bill and also reduce the national emissions of greenhouse gases (GHG), (2) to improve the standard of living, (3) to achieve balance between imports and exports, (4) to reduce production cost and enhance competitiveness of the local industries and other sectors, and (5) to reduce investment in the equipments used for production, conversion, transmission and distribution of electrical energy.

1.9.2 Energy Resources

Jordan has extremely limited primary energy resources and is forced to depend to a large extent on the imported petroleum, petroleum products and natural gas from neighboring Arab countries.

Oil and gas

Jordan has very limited oil and natural gas resources. As of the beginning of the year 2007, Jordan's oil reserves are estimated to stand at one million barrel. In the year 2006, the country produced 1,200 tonnes of crude oil from the Hamza petroleum site near the Saudi Arabian border, and imported 4,258 thousand tonnes of crude oil from neighboring Arab countries.

Reserves of natural gas are estimated to stand at 213 billion cubic feet. Some 8.9 billion cubic feet of natural gas were produced in the year 2006 from 13 wells at Risha gas field in the eastern desert near the border with Iraq. The produced gas (about 24 million cubic feet/day) was used to fuel the 150-MW Risha gas turbine station. In the same year, total final consumption of natural gas amounted to 81 billion cubic feet.

In the year 2006, Jordan's local crude oil and natural gas production was 186.5 thousand tonnes oil equivalent (toe) which represents only 3 percent of the total primary energy consumption of 7,187 thousand toe in that year (MEMR, 2006).

In view of the limited local resources, Jordan has depended on imports to meet its energy needs. Crude oil

Table 1.6: Imports of crude oil and petroleum products (000 tonnes) (MEMR, 2008)

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Crude oil	3444	3559	3501	3763	3875	3926	4023	4244	4602	4258
Fuel oil	611	796	773	626	647	758	570	100	19	-
LPG	105	103	138	133	138	155	171	179	178	182
Diesel	213	246	191	239	182	230	292	543	785	509
Gasoline	-	7	-	-	-	25	40	135	93	65
Jet Fuel								1	1	1
Total	4373	4711	4603	4761	4842	5094	5096	5202	5678	5015

and oil products imported in the year 2006 were around 5015 thousand tonnes. As shown in Table (1.6), crude oil constitutes about 80 percent of the total imports. The quantities of natural gas imported from Egypt via the natural gas pipeline were around 1935 million cubic meters.

Imports of crude oil are received by Jordan's single refinery, at Zarqa city. The refinery has a capacity of 90,400 barrel/day and was designed to produce a product mix skewed toward heavy fuel oil, which was needed at the time it was built to run electric power plants (MoEnv, 2006). However, the local market is now in need of additional gasoline and diesel, while electric power generation is switching over to natural gas. The facility is in need of major upgrades, and its owner, the Jordan Petroleum Refining Company, is currently studying its options. The MEMR strategy recommends seeking partnership with private investors to expand and upgrade the refinery.

Oil shale

Oil shale is available in large quantities and is of good quality in the central and north-western region of the country. There are 24 known outcrops and near-surface oil shale deposits with estimated reserves of nearly 40 billion tonnes containing about 4 billion tonnes of oil with a calorific value ranging from 5000 to 6000 kJ/Kg (MoEnv, 2006).

Jordan signed five memoranda of understanding with international companies, including Shell and Petrobras for shale oil production and the other three for electric power production (direct firing).

Renewable energy

The government of Jordan has set policy goals and objectives which formed the framework of the renewable energy target set in the year 2004; which aims for 5 percent share in the primary energy mix by the year 2015. The policy goals include (1) enhancing energy security and saving foreign currency from reduced utilization of imported energy, (2) attracting foreign and private investments on renewable energies, (3) promoting the local manufacturing of renewable energy technologies and the development of the local manufacturing industry, (4) reducing the country's emissions of GHGs and optimizing the emission reduction benefits through the sale of emission reduction credits in the global carbon markets, (5) reducing emissions of airborne pollutants, and (6) enhancing access to energy services in remote communities.

A draft renewable energy law was prepared by the Ministry of Energy which serves two main purposes: (1) to identify areas of high wind and solar resources potential and to protect such areas from random development, and (2) to provide a set of incentives to the developers to bring the kWh cost down. The Ministry has publicly tendered a wind farm during the year 2007, with a nominal capacity of 30-40 MW in Kamsha area, a second wind farm will be tendered in the near future with a nominal capacity of 60-70 MW in Showbak area.

The General Electricity Law of the year 2002 opened up the electricity market to private investments and introduced enabling framework to allow private sector's access to the market and electricity grid. Renewable energy projects can be developed through the following: (1) large scale (above 5 MW) through competitive tendering, (2) small-scale (below 5 MW) through direct negotiations, and (3) very small scale (below 1 MW) for auto-generation and serving peak demand not exceeding 100 kW. For large-scale projects, a generation license is required, small-scale projects may be exempted from obtaining a license, while projects with rated capacity below 1 MW are exempted from licensing requirement. The government is also elaborating a standard power purchase agreement for solar and wind energy projects.

Solar energy

Jordan is blessed with an abundance of solar energy, with high average daily solar radiation of 5 to7 kWh/m2, which is one of the highest in the world. The average sunshine duration is more than 300 days per year. National Energy Research Centre (NERC) is conducting a long term project for collecting and evaluating solar radiation to have new solar data. For this purpose, 14 measurement stations were installed around the country.

However, solar energy is not widely used, except for solar water-heaters, which are used for heating of domestic water. In addition to the economic benefit, the use of solar radiation instead of conventional fuels reduces the level of air pollutants; including greenhouse gas emissions. In the year 2002, the total area of installed solar collectors in Jordan was more than 1,135,000 m^2. There are some other pilot applications in place. These include: solar desalination using solar heat pipe principle, solar desalination using solar still method, and parabolic trough desalination system in the city of Aqaba, photovoltaic brackish water reverse-osmosis desalination facility at Aqaba international industrial estate, and photovoltaic water pumping systems.

Wind energy

Jordan enjoys also good wind energy potential. The first wind atlas for Jordan was prepared in the year 1989 jointly by the Ministry of Energy and Mineral Resources (MEMR), Jordan Meteorological Department (JMD) and the Danish Riso Institute. The atlas was prepared based on data collected at 36 meteorological stations. All data analyses were performed using the Wind Atlas Application Program (WAsP) in which the wind areas were identified for potential wind energy. The great potential areas are the northern area of the country with an average annual wind speed between 6.5-7.5 m/s. In addition, the southern areas enjoy good wind speed, while the eastern regions have significant wind potential. Most attractive sites are Hofa, in the northwestern corner and Fjeij, near Showbak, and Wadi Araba in the south.

The national energy research center is executing a long term project for wind data collection and evaluation to have new wind data that can be evaluated according to the international standards utilizing WAsP program. For this purpose, eighteen measurement stations were installed around the country to collect wind speed and wind direction data at different heights. Wind profile in different places of the country is also being studied.

Jordan's first wind farm, with a gross capacity of 320 kW in Ibrahimyya close to Hofa, was commissioned in the year 1988. This pilot project generated about 650 MWh of electricity. A new wind-electric power generator was installed in Hofa with 1125 kW nominal capacity. The project was connected to the national grid in the year 1996 and became fully operational in the year 1997. In addition, there are many other wind energy water pumping stations especially in remote areas (MoEnv, 2006).

After the new electricity law was enacted in the year 2002, it is now expected that new wind farms will be installed. Wind farms with rated power of 100 MW have been studied and identified as suitable for implementation at the north and south of Jordan. Local industries have the potential of manufacturing a considerable percentage of wind farm components.

Bio energy

Biomass energy includes all fuels derived from biological sources, such as agricultural, animal and municipal wastes. In Jordan, potential source of energy from biomass is significantly arising from municipal waste. Preliminary studies carried out by NERC show that biogas from animal and domestic waste can save up to 4 percent of imported oil which equivalent to 130,000 toe per year.

A project which was funded by Global Environment Facility (GEF) started its operation in the year 2000 in Russifeh landfill site. The project has two objectives: (1) demonstrating the environmental and energy benefits from using municipal and industrial organic wastes for producing biogas and then electricity, and (2) collecting the biogas generated from Russifeh landfill to produce electricity via electrical generators. The total amount of biogas generated from the landfill is around 2000 m^3/hr where 50 - 60 percent of the biogas is methane. The project is owned by the Greater Amman Municipality (GAM) and Central Electricity Generating Company. The plant receives 60 tonnes of pure organic waste daily. The waste consists mainly of blood from slaughterhouses that are managed by GAM, and food waste from restaurants and hotels.

The total amount of electricity generated from the project in the year 2006 is estimated at 6239 MWh. The total electricity generated since the start of the project is 36.1 GWh which is connected to the national electricity grid. As a pilot project, the lessons and experience learned from operating this plant can contribute greatly to the decisions of expanding the plant in the future and replicating it in other landfill sites in the country.

Underground (Geothermal) energy

Jordan is among countries with moderate potential in geothermal energy. Several studies have been conducted and it concluded that there is a significant evidence of geothermal activity almost all along the Dead Sea rift at two levels; medium energy 110 - 114 °C and low energy 30 - 65 °C.

There are 108 hot springs in Jordan discharging about 25 million cubic meters of hot water each year into the Dead Sea. Some ambitious projects do exist, which utilize geothermal energy for refrigeration by absorbing technology to conserve fruits and vegetables and to desalinate water from deep aquifers at Azraq. The relatively low temperatures of the hot springs make this source not economically suitable for electric power generation, however; they are useful for a wide spectrum of applications, from evaporation of brines to home and greenhouse heating.

On the other hand, Jordan has a shortage of expertise in geothermal development. An emphasis on scientific and engineering expertise for exploration and management of commercial systems should be considered.

Hydropower

Hydropower sources are limited in Jordan due to scarcity of surface water resources, such as rivers and falls. However, currently there are three small hydropower schemes. The first one is King Talal Dam spanning the river Zarqa, with a rated electricity-generating capacity of 5 MW. The second scheme is at the Aqaba thermal power station, where the hydro-turbine utilizing the available head of returning cooling seawater with a capacity of 5 MW. The third is the hydropower turbine rated 350 kW which was installed at Wadi Arab Dam with the generated electricity being used to pump water for irrigation purposes.

However, there is a great possibility to generate electricity, using hydropower stations, by exploiting the elevation difference between the Red and Dead Seas. If seawater is allowed to flow from the Gulf of Aqaba into the Dead Sea (400 m below sea level) through a canal system at predetermined rates, it will produce electrical power from hydropower stations and potable water from seawater desalination plants. Preliminary prefeasibility reports showed that it is possible to build hydropower stations with a total capacity of 600 MW. However, the required capital investment is extremely high due to necessary infrastructure (about 200 km long canal). Other future potential hydropower sources are the pumping storage at the King Talal Dam (50 MW) and Al-Wehda Dam (200 MW).

If all Hydropower potential mentioned above is exploited, this may amount to 855 MW or 21 percent of the year 2015 required capacity. This assumption is extremely ambitious.

1.9.3 Consumption of Energy and Electricity

Jordan is a country with limited oil and natural gas resources. For a long time the country imported petroleum and petroleum products from Iraq at prices determined according to bilateral agreements between the two countries. The war in Iraq in the year 2003 marked the end of that period, where Jordan started to get its supplies from Saudi Arabia. The cost of consumed energy, driven by higher fuel prices in an expanding economy, has been increasing ever since, putting considerable strains on Jordan's balance of payments and competitiveness.

Significant changes are underway in the oil sector: almost two-thirds of Jordan's thermal power plants have already been switched to natural gas, the Government plans to complete conversions for all other oil or diesel-operated stations, and increasingly more industrial companies are also aiming to do the same. Imports of natural gas have been relatively more convenient than oil, but it is likely that their price will increase in the future. The second stage of the Arab Gas Pipeline, designed to provide Egyptian natural gas to Jordan, Syria, Turkey and ultimately Europe, was completed in the year 2006, and involved a 393-km connection stretching across Jordan, from the Red Sea port of Aqaba to Rehab near the Syrian border.

Primary energy consumption as indicated in Table (1.7) reached 7.187 million toe in the year 2006, compared

Table (1.7): Primary Energy Consumption (000 TOE)

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Crude Oil & Products	4316	4385	4491	4471	4815	4803	4954	5031	5012	5325	4953
Renewable Energy	63	65	67	68	75	76	79	77	82	83	111
Natural Gas	211	223	226	216	213	206	188	431	1196	1382	1999
Imported Electricity	-	-	-	-	11	65	78	235	199	238	124
Total	**4590**	**4673**	**4784**	**4755**	**5114**	**5150**	**5299**	**5774**	**6489**	**7028**	**7187**

with 5.1 million toe in the year 2001, reflecting an overall growth of almost 40 percent over the past six years. Over the same period, consumption of renewable energy has increased by a similar rate, growing from 76,000 toe in 2001 to 83,000 toe in 2005 and 111,000 toe in the year 2006. Consumption of natural gas has grown sharply since the year 2003, coinciding with increased imports from Egypt as the pipeline was extended from Aqaba to the northern part of the country. Figure (1.8) shows Jordan's final energy consumption breakdown by sector during the period 2001-2006. It can be seen that the transport sector is by far the leading energy consumer in the country. In the year 2006, energy consumption was distributed as follows: transport sector 37 percent, households 22 percent, industry 24 percent, and other sectors 17 percent (including services 7 percent).

Whereas in regard to electricity consumption most of the electricity consumed is produced locally using thermal power plants, which have been increasingly switched from oil to natural gas.

In the year 2006, Jordan's power stations reached a total installed capacity of 2,104 MW and produced 11,349 GWh of electricity. Table (1.8) provides a summary of key statistics for installed capacity and electricity generation in Jordan during the period 2001 to 2006.

In April 2007, the MEMR inaugurated the development of Jordan's first independent power producer project; a 370 MW gas-fired combined cycle power plant in Al-Manakhir (east of Amman). The Al-Manakhir plant will increase Jordan's power generation by about 20 percent.

Table 1.8: Installed capacity and electricity generation, 2001-2006

	2001	2002	2003	2004	2005	2006
Installed Capacity (MW)	1,657	1,784	1,784	1,784	2,014	2,104
Yearly Growth Rate	-0.18%	7.66%	0.00%	0.00%	12.89%	4.47%
Peak Load (MW)	1,255	1,410	1,428	1,555	1,751	NA
Reserve Margin	32.03%	26.52%	24.93%	14.73%	15.02%	NA
Electricity Generation (GWh)	7,543	8,132	7,995	8,968	9,654	11,349
Yearly Growth Rate	2.28%	7.81%	-1.68%	12.17%	7.65%	17.56%

The electricity consumption in the year 2006 was 9,579 GWh compared to 6,392 GWh in the year 2001. The average growth rate of consumption was 7.7 percent for the period 2001-2006, and 10 percent for the period 2005-2006. Figure (1.9) shows the electricity consumption by different sectors.

Due to economic growth and increasing population, energy demand is expected to rise by at least 50 percent over the next 20 years. The provision of reliable energy supply at reasonable cost is thus a crucial element of economic reform and sustainable development. Although the

Figure 1.8: Final energy consumption by different sectors in Jordan (MEMR, 2008)

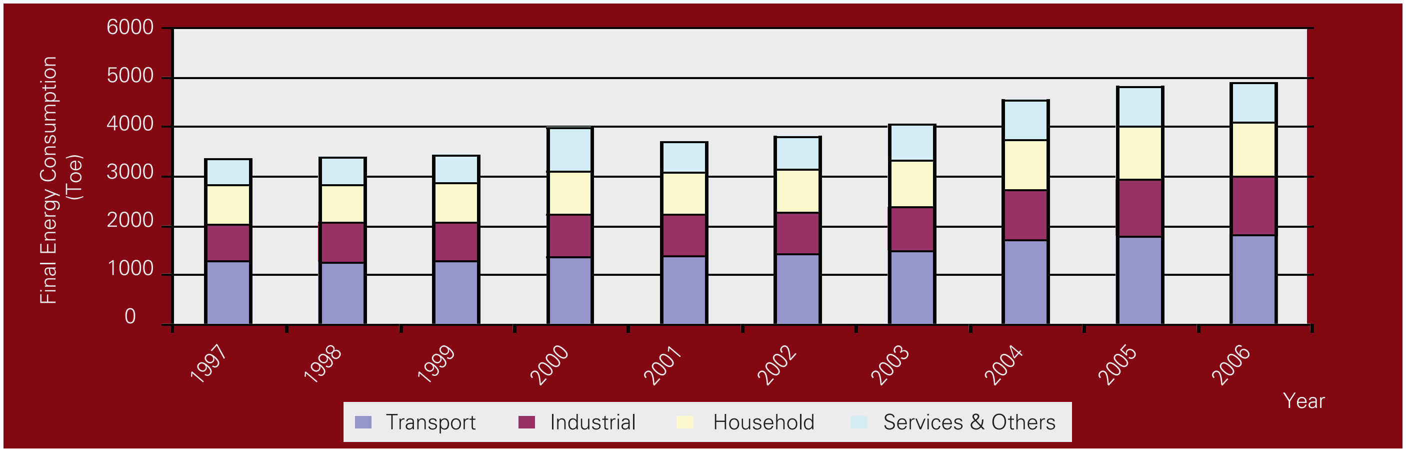
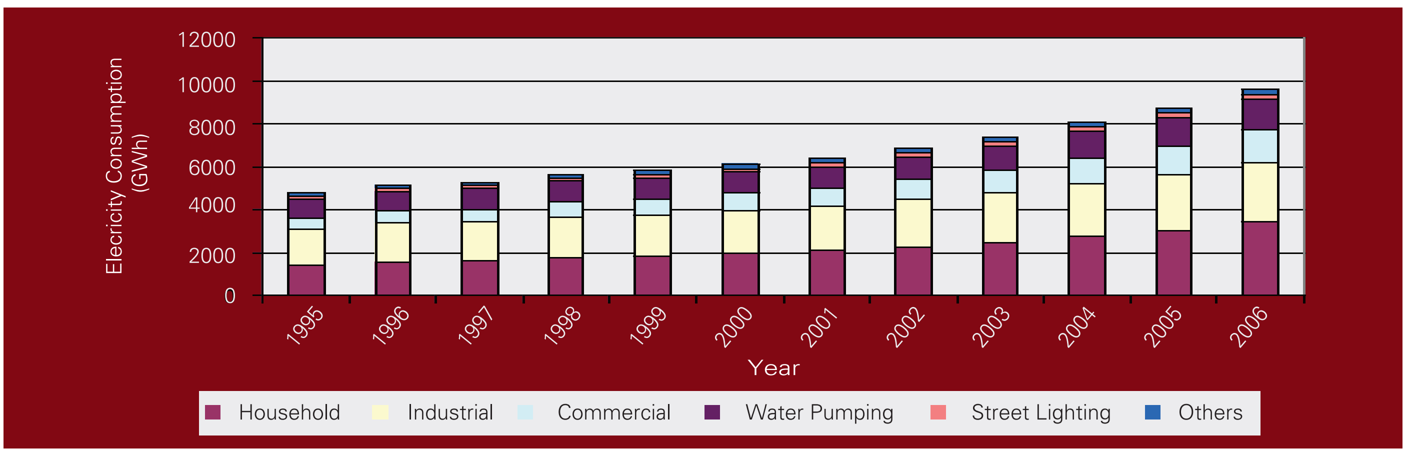


Figure 1.9: Electricity consumption by different sectors in Jordan



demand will be increasing, however, the dependency on conventional oil sources is expected to decrease.

1.10 TRANSPORTATION

Transportation sector is of crucial importance to Jordan's further economic development. Its contribution to the national economy was about JD 911,815 millions in the year 2006; constituting 9 percent of the GDP in that 2006.

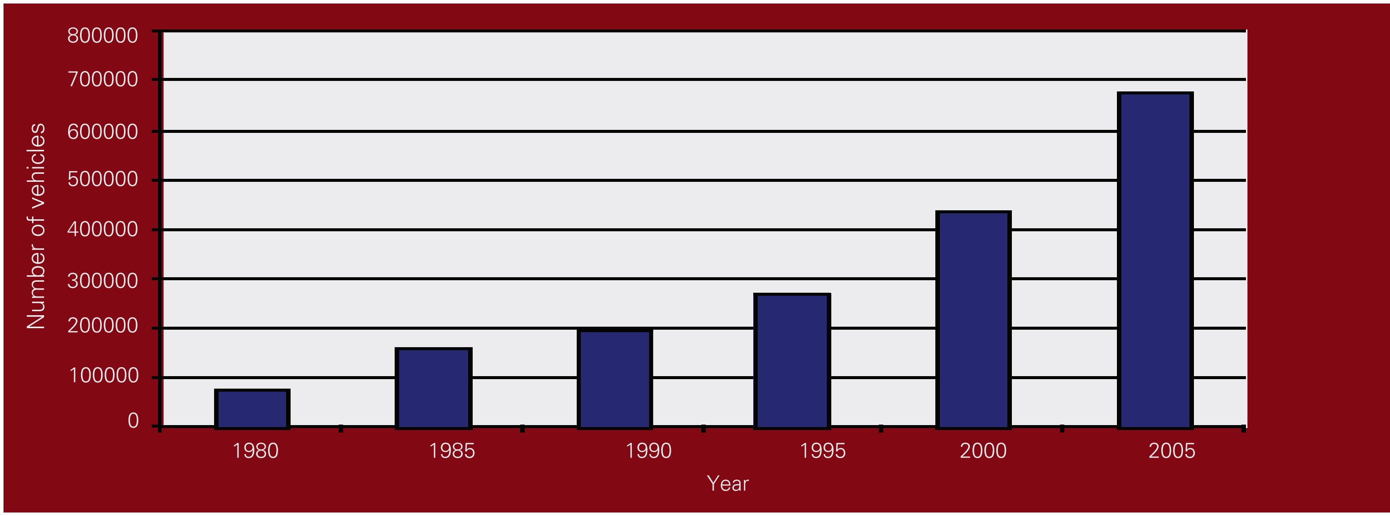
The Ministry of Transport (MoT) prepared a national strategy for the transportation sector which includes a number of strategic goals that the ministry aims to achieve. Among these goals are the construction of a statistical database for the transport sector, improvement of the road freight transport, and expansion of the rail transport network to connect Jordanian cities (MoT, 2008).

Jordan has a single seaport at Aqaba in the far south. The port serves as the main conduit for foreign trade and also for transit traffic to neighboring countries, in particular Iraq. In the year 2006, the volume of cargo handled by the Port of Aqaba reached 17.2 million tonnes through 2884 vessels. The exports and imports during that year were 7 and 9.5 million tonnes; respectively (MoT, 2006).

The main airport in Jordan is Queen Alia International Airport located about 30 km south of Amman. In the year 2006, about 3.8 million passengers arrived to or departed from this airport. The aircraft movements in the year 2006 were 54266 flights and the air cargo movement was 97734 tonnes (MoT, 2006).

The road network in Jordan has expanded over the past years with the construction of highways between the

Figure 1.10: Number of vehicles in Jordan



cities and extension of the roads to the newly developed areas. In the year 2006, the lengths of the main roads, side roads, and rural roads were 3187 km, 2112 km, and 3395 km; respectively.

The number of vehicles increased significantly to coincide with population growth and economic development. As shown in Figure (1.10), the number of vehicles reached 841,933 in the year 2007 compared to 77,202 and 435,393 vehicles in the years 1980 and 2000; respectively.

Rail transport in Jordan includes the Hijaz railway, which was built in the year 1901 to connect Damascus in Syria with Al-Medina in Saudi Arabia. The Amman-Damascus route was reactivated in the year 2001 but has not attracted passenger traffic due to the long travel of six hours. However, in the year 2004, the railway announced a 600 percent increase in goods traffic over the preceding two years. In the south, the Aqaba railway serves the export of phosphate. As a part of its strategy to encourage investors in the railway system, the MoT has announced plans to privatize the Aqaba Railway Corporation. Currently, the MoT is preparing a railway master plan as one of its strategic objectives (MoT, 2008).

In order to improve public transport in the Amman metropolitan area, Jordan has invited proposals to build and operate a 25 km light rail system between Amman and Zarqa cities. By the year 2010, this system is expected to carry some 50,000 passengers in each direction daily.

1.11 WASTE SECTOR

1.11.1 Solid Waste

The volume of municipal solid waste (MSW) has increased in the last decade. This was the result of the population pressure, industrial development, new consumption patterns and life style. Solid waste management is the responsibility of the Common Services Councils of the Ministry of Municipal and Rural Affairs and the Greater Amman Municipality (GAM) for Amman and its suburbs. The Ministry of Environment which is considered as the authority for the regulations pertaining to management of solid waste in addition to taking a coordinating role with national and international parties. The Ministry of Environment has listed solid waste management as an urgent priority and is in the process of preparing a detailed master plan for solid waste management.

It has been estimated that municipal solid waste reaches a gross annual production rate of approximately 1.5 million tonnes. The daily average per capita generation rate of municipal solid waste stands at 0.6 Kg and 0.9 Kg in rural and urban regions; respectively. In Jordan, there are about 21 solid waste disposal sites distributed in the country. Al-Ghabawi landfill site is the largest site which replaced the Russifeh landfill site that was closed in the year 2003. The site serves Zarqa and Amman governorates and is managed by GAM. It receives about 2500 tonnes of solid waste per day. Table (1.9) shows the domestic landfill sites, location, area and the amount of solid waste received for each site.

Table 1.9: Domestic landfill sites in Jordan

#	Site name	Operation date	Governor-ate	Site area (Dunum)	Quantity (tonnes / day)
1	Al-Ekader	1980	Irbid	806	800
2	Husaineat	1986	Mafraq	180	170
3	North Badia	2003	Mafraq	360	43
4	Al-Ruaished	2003	Mafraq	179	4
5	Al-Hamra	1990	Al Salt	275	450
6	Al-Ghabawi	2003	Amman	1947	2500
7	Madaba	1974	Madaba	87	500
8	Dhulil	1991	Zarqa	270	295
9	Dair Alla	1998	Balqa	363	290
10	Azraq	1983	Zarqa	-	17
11	North Shuneh	1983	Irbid	200	67
12	South Shuneh	1988	Al-Balqa	-	55
13	Ghor Al-Mazra'a	1997	Karak	205	22
14	Lajoon	1995	Karak	485	190
15	Ghor Al-Safi	1997	Karak	153	25
16	Tafilah	1990	Tafilah	450	65
17	Al-Shoubak	1983	Ma'an	26	45
18	Eyil Neimat	1984	Ma'an	274	42
19	Ma'an	1994	Ma'an	502	90
20	Al-Quaira	2000	Aqaba	270	25
21	Aqaba	2000	Aqaba	60	115

1.11.2 Wastewater

Domestic wastewater

The environmental and health problems associated with domestic wastewater have changed over the years. In the past, the cities, towns and villages collected their domestic wastewater in cesspits which resulted in environmental problems. By the end of the year 1960, the first sewer system was established in Amman. Nowadays, around 57 percent of the households are connected to the sewer system. The first domestic wastewater treatment plant was established and commissioned in the year 1968 in Ein Ghazal to serve a population of 300,000. Nowadays, there are 23 domestic wastewater treatment plants in the country. Water Authority of Jordan (WAJ) is the responsible authority for operation and conducting the necessary routine and emergency maintenance for most of the domestic wastewater treatment plants. Table (1.10) shows the domestic wastewater treatment plants along with the treatment type, design values and the average daily inflow.

Industrial wastewater

Amman-Zarqa region is the largest urban center in Jordan and is the largest industrial congregation, where the majority of Jordan industry is located. The Jordanian standards (JS) (JS 202/2006) define the maximum allowable concentrations of treated industrial wastewater effluents to be discharged to wadis and rivers, and to be reused for irrigation and groundwater recharge (JISM, 2006). Additionally, the Jordanian regulation number 18/1998 (WAJ, 1998) defines these limits for effluents to be connected to sanitary sewer system. Industries that can not treat their generated industrial wastewater may collect and dispose of that wastewater into an authorized dumping site (such as Al-Ekader dumping site). Unfortunately, some of these industries dispose of their wastewater to wadis (an Arabic word for ephemeral water courses) and open areas.

1.12 DEVELOPMENT PRIORITIES AND CHALLENGES

Human development is a high priority in Jordan. Between the years 1997 and 2002, its Human Development Index (HDI) score increased from 0.715 to 0.747. Although Jordan's HDI values ranked it ninth out of 19 countries in the Arab region, however seven of the eight higher-ranking countries were the beneficiaries of huge revenues from oil and gas exports.

The sustainability of Human Development including educating its young population and providing basic social services for all and social security for the most vulnerable, is threatened by the availability of secure, adequate and clean energy sources; the decline in both the quantity and quality of water resources; and degradation in the quality and availability of arable land due to urbanization and poor land-use policies.

To address these challenges that threaten sustainable efforts in Jordan; the Government in the year 2005 developed a national agenda; an action plan for achieving sustainable development through a programme of reforms in prevailing policies and practices. Much of its focus, and many of its recommended reforms, will be in the area of

Table 1.10: Domestic wastewater treatment plants with their characteristics

Treatment plant name	Treatment type	Design flow (m^3/day)	Actual flow (m^3/day)	BOD_5 in (mg/l)	BOD_5 out (mg/l)	Efficiency (%)
As-Samra	WSP and AS	68000	224175	745	173	76.7
Aqaba Tertiary	AS	12000	7296	407	5.1	98.7
Aqaba Natural	WSP	9000	6229	403	24.5	93.9
Irbid	AS and BF	11023	6354	1037	28.4	97.2
Salt	AS	7700	4322	919	25.8	97
Jerash	AS	3250	3312	1208	68	94
Mafraq	WSP	1800	1866	602	187	69
Baqa'a	BF	14900	10978	877	27.5	96.8
Karak	BF	785	1618	536	61	88.6
Abu Nuseir	AS and RBC	4000	2309	538	18	96.6
Tafila	BF	1600	1013	655	41	94
Ramtha	AS	5400	3492	750	13	98
Ma'an	WSP	1590	2644	800	190	76
Madaba	AS	7600	4584	1356	24	98
Kufranja	BF	1800	3387	1160	73	93.7
Wadi Al Seer	WSP	4000	2718	494	30	94
Fuhis	AS	2400	1684	607	22	96
Wadi Arab	AS	22000	9960	764	11.4	98.5
Wadi Mousa	AS	3400	1670	320	8.2	97.4
Wadi Hassan	AS	1600	1099	802	4.5	99.4
Tall Al-Mantah	AS and BF	400	274	2742.8	30.6	98.8
ALEkader	WSP	4000	2872	2000 Design	221	88
Alljoon	WSP	1000	502	1500 Design	238	84

public administration including legislative, legal and social initiatives, the national agenda also has as a key aim to "develop human and economic resources, upgrade the production base and expand development benefits".

1.13 HEALTH PROFILE

Jordan health care system has improved dramatically over the last two decades placing it among the top ten countries of the world in reducing infant mortality. In achieving universal child immunization by the year 1988, Jordan surpassed the average rate of the world by two years. Major health indicators in Jordan are:

- Crude birth rate of 28.1 per 1000 population,
- Total fertility rate 'Mean number of children born alive to women between the ages 15 – 49' is 3.6,
- Crude death rate of 7 per 1000 of the population,
- Infant mortality rate of 19 per 1000 live births,
- Under five mortality rate of 21 per 1000 live birth,
- Life expectancy at birth is 73 years.

Source: (DOS, 2006), (MoH 2006, 2007), and (DHS, 2007).

The Jordanian health care system provides a wide range of health services to suite all income levels. Estimates indicate that 40 percent of Jordanians are not covered by a health insurance program. However, this does not mean that they cannot obtain health care services. The Ministry of Health (MoH), through its wide spreading hospitals and health centers, provides subsidized health care services at a very low expense. In addition, the MoH provides free health services such as vaccination, health care for children under five years, health care services for pregnant women, cancer treatment, and kidney dialysis.

The number of qualified health care personnel in Jordan is low which reflects negatively on the quality and cost of health care. Table (1.11) provides the numbers of health care personnel in Jordan for each 1000 people.

Table 1.11: Health care personnel rate per 1000 people, Jordan, 2007

Occupation	Rate per 1000 people
Physicians	2.6
Dentists	0.8
Pharmacists	1.4
Nurses and medwives	3.3

The current health care system in Jordan is faced by many challenges that hinder its development. These include continuous increase in population, increase in the health care cost, unorganized expansion of the health care system, absence of a comprehensive health coverage system, lack of institutional planning for health services, and increase in the migration of qualified health care employees (MoH, 2006).

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NATIONAL GREENHOUSE GAS INVENTORY

2. NATIONAL GREENHOUSE GAS INVENTORY

This chapter presents the anthropogenic (human-induced) emissions by sources, and removals by sinks, of all greenhouse gases (GHGs) not controlled by the Montreal Protocol for Jordan in the year 2000.

2.1 INTRODUCTION

As per Article 4, paragraph 1, and Article 12, paragraph 1 of the United Nations Framework Convention on Climate Change (UNFCCC), each party is required to report to the Conference of Parties (COP) information on its emissions by sources and removals by sinks of all Greenhouse Gas Emissions (GHGs) not controlled by Montreal Protocol.

Jordan has ratified the convention in the year 1993. As a non-Annex I country, the inventory information to be provided by Jordan is according to the guidelines for Parties not included in Annex I as required by decision 17/CP.8, the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997) has been used. In addition, and as encouraged by decision 17/CP.8, the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Inventory (IPCC 2000), and the IPCC Good Practice Guidance on Land Use, Land Use Change and Forestry (IPCC 2003) have been also used specially in the uncertainty estimation. The UNFCCC software for Non Annex I countries has been used for the preparation of this inventory.

Sectoral (bottom-up) approach has been used to estimate the GHG emissions and removals from the following sectors:

- Energy;
- Industrial processes;
- Agriculture;
- Land use, land-use change and forestry (LULUCF);
- Waste; and
- Solvents.

Furthermore, GHG emissions from bunker fuels have also been estimated and reported as a memo item (these emissions are not included in the national total).

In addition to the sectoral approach, the reference approach has also been used for the estimation of CO_2 emissions from the overall fuel consumption figures for the time series of 1995-2000.

The direct GHGs whose emissions have been estimated in this national inventory are:

- Carbon dioxide (CO_2);
- Methane (CH_4);
- Nitrous oxide (N_2O);
- Sulphur hexafluoride (SF_6);
- Perfluorocarbons (PFCs); and
- Hydrofluorocarbons (HFCs).

Emissions of the following indirect GHGs have also been estimated and reported in this inventory:

- Oxides of nitrogen (NOx);
- Carbon monoxide (CO);
- Non-methane volatile organic compounds (NMVOC); and
- Sulphur dioxide (SO_2).

However, as the indirect GHGs have not been allocated global warming potential, they are not included within Jordan's aggregate emissions.

The GHG inventory has been compiled by a team of fifteen local experts from different relevant ministries and institutions who worked on a part-time basis. The engagement of those stakeholders has benefited in dissemination and validation of the project's results in addition to facilitation in data and information collection.

Primary activity data for the various sectors covered in the inventory have been collected from the annual reports, surveys, studies and brochures of the concerned ministries (Ministry of Environment, Ministry of Energy and Mineral Resources, Ministry of Agriculture, etc) and public and private institutions (Department of Statistics, Amman Chamber of Industry, Greater Amman Municipality, Jordan Petroleum Refinery, Civil Aviation Authority, National Energy Research Centre, etc). The collected information of the industrial sector has been complemented by a field survey of selected Jordanian industries. Wherever possible, activity data have been verified from multiple sources including government documents, publications of industrial chambers, and technical reports of research institutions, publications of international institutions and United Nations organizations, and data collected directly from the industry.

In the current inventory tier 1 method has been used except for the estimation of emissions from domestic and international aviation where tier 2 methods was used based on the number of landing and take-off (LTOs), types of aircrafts and total fuel consumption.

2.2 JORDAN'S 2000 GREENHOUSE GAS INVENTORY

In the year 2000, Jordan contributed about 20140 gigagrams[1] (Gg) or 20.14 million tonnes (Mt) of CO_2 equivalent (CO_2 eq.) of GHGs to the atmosphere. Table (2.1) summarizes Jordan's emissions of CO_2, CH_4 and N_2O for all sectors presented in terms of CO_2 equivalent, and Table (2.2) summarizes Jordan's direct and indirect GHGs emissions with proper notations as required by decision 17/CP.8.

1. One Gigagram is equivalent to One kilotonnes (kt) and One Megatonnes is equivalent to One million tonnes

Table 2.1: Jordan's GHG Emissions Summary (by Sector and Gas) for the Year 2000

	GHG Source and Sink Categories	CO_2	CH_4	CH_4	N_2O	N_2O	Total
	Global Warming Potential	1		21		310	
		Gg	Gg	Gg CO_2 eq	Gg	Gg CO_2 eq	Gg CO_2 eq
1.	**ENERGY**						
a.	Fuel Combustion						
	Energy Industries	5573.01	0.21	4.41	0.04	12.4	5590
	Manufacturing industries and construction	1858.38	0.05	1.05	0.02	6.2	1866
	Transport	3564.02	0.90	18.9	0.13	40.3	3623
	Other sectors (Residential, commercial, Agricultural)	2779.84	0.40	8.4	0.02	6.2	2794
	Other	938.23	0.06	1.26	0.01	3.1	943
	Fuel Combustion Subtotal	**14713.48**	**1.62**	**34.02**	**0.22**	**67.6**	**14815**
b.	Fugitive Emissions	0.52	4.53	95.13	-	-	96
	ENERGY TOTAL	**14714.00**	**6.16**	**129.36**	**0.22**	**67.6**	**14911**
2.	**INDUSTRIAL PROCESSES**						
	Mineral Production	1594.31	-	-	-	-	1594
	INDUSTRIAL PROCESSES TOTAL	**1594.31**	**-**	**-**	**-**	**-**	**1594**
3.	**AGRICUTURE**	**-**	**0.03**	**0.63**	**0.59**	**182.6**	**183**
4.	**LULUCF**						
	Changes in forest	-221.52	-	-	-	-	-222
	CO_2 emissions and removals from soil	960.51	-	-	-	-	961
	LULUCF TOTAL	**738.99**	**-**	**-**	**-**	**-**	**739**
5.	**WASTE**						
	Solid waste disposal on land	-	119.77	2515.17	-	-	2515
	Wastewater handling	-	4.76	99.96	0.32	99.2	199
	WASTE TOTAL	**-**	**124.53**	**2615.13**	**0.32**	**99.2**	**2713**
	TOTAL	**17047.30**	**130.72**	**2745.12**	**1.12**	**347.2**	**20140**

Table 2.2 (A): National greenhouse gas inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol and greenhouse gas precursors

Greenhouse gas source and sink categories	CO_2 emissions (Gg)	CO_2 removals	CH_4	N_2O	NO_x	CO	NMVOCs	SO_x
Total national emissions & removals	17047.30	NA	130.72	1.12	75.56	225.33	129.55	186.40
1. Energy	**14714.00**	**NA**	**6.16**	**0.22**	**75.47**	**224.81**	**53.36**	**185.20**
A. Fuel combustion	14713.48		1.62	0.22	75.43	216.37	52.47	184.91
1. Energy Industries	5573.01		0.21	0.04	14.68	1.18	0.38	121.19
2. Manufacturing industries and construction	1858.38		0.05	0.01	4.89	0.24	0.12	39.54
3. Transport	3564.02		0.90	0.13	40.37	200.12	48.96	11.83
4. Other sectors	2779.84		0.40	0.02	4.89	1.58	0.36	8.72
5. Other (please specify)	938.23		0.07	0.01	10.59	13.24	2.65	3.62
B. Fugitive emissions from fuels	0.52		4.53		0.04	8.43	0.89	0.30
1. Solid fuels			NO		NO	NO	NO	NO
2. Oil and natural gas			4.53		0.04	8.43	0.89	0.30
2. Industrial processes	**1594.31**	**NA**	**NA**	**NA**	**0.08**	**0.30**	**62.86**	**1.20**
A. Mineral products	1594.31				NA	0.00	35.96	0.83
B. Chemical industry	NO		NO	NO	NO	NO	NO	NO
C. Metal production	NO		NO	NO	NO	NO	NO	NO
D. Other production	NA		NA	NA	0.08	0.30	26.90	0.37
G. Other (please specify)	NE		NE	NE	NE	NE	NE	NE
3. Solvent and other product use	**NA**			**NA**			**13.34**	
4. Agriculture			**0.03**	**0.59**	**0.01**	**0.22**	**NA**	**NA**
A. Enteric fermentation			0.02					
B. Manure management			0.00	0.00			NA	
C. Rice cultivation			NO				NO	
D. Agricultural soils			NA	0.59			NA	
E. Prescribed burning of savannahs			NO	NO	NO	NO	NO	
F. Field burning of agricultural residues			0.01	0.00	0.01	0.22	NA	
G. Other (please specify)			NE	NE	NE	NE	NE	
5. Land-use change and forestry [1]	**738.99**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

A. Changes in forest and other woody biomass stocks	NA	-221.52						
B. Forest and grassland conversion	NO	NO	NO	NO	NO	NO		
C. Abandonment of managed lands		NO						
D. CO_2 emissions and removals from soil	960.51	NE						
E. Other (please specify)	NE	NE	NE	NE	NE	NE		
6. Waste			**124.53**	**0.32**	**NA**	**NA**	**NA**	**NA**
A. Solid waste disposal on land			119.77		NA		NA	
B. Waste-water handling			4.76	0.32	NA	NA	NA	
C. Waste incineration					NO	NO	NO	NO
D. Other (please specify)			NE	NE	NE	NE	NE	NE
7. Other (please specify)	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
Memo items								
International bunkers	**541.56**		**0.04**	0.02	2.88	1.82	0.67	0.43
Aviation	541.56		0.04	0.02	2.88	1.82	0.67	0.43
Marine	NE		NE	NE	NE	NE	NE	NE
CO_2 emissions from biomass	**NO**							

[1] If you have completed the LUCF section of Table 7As, these data will appear here automatically. If, however, you have used the IPCC Good Practice Guidance and Categories therein, apply the mapping back procedure for this sector and insert the corresponding numbers here manually.
NA: Not applicable
NE: Not estimated
NO: Not occurring

Table 2.2 (B): National greenhouse gas inventory of anthropogenic emissions of HFCs, PFCs and SF_6

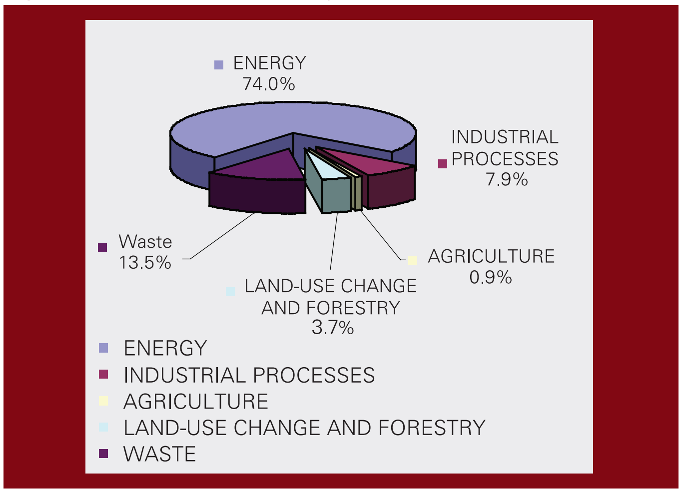
Greenhouse gas source and sink categories	HFCs (Gg)		PFCs (Gg)		SF_6 (Gg)
	HFC-23	HFC-134	CF_4	C_2F_6	
Total national emissions & removals	NO	0.00	NO	NO	0.00
1. Energy					
A. Fuel combustion					
1. Energy Industries					
2. Manufacturing industries and construction					
3. Transport					
4. Other sectors					
5. Other (please specify)					

B. Fugitive emissions from fuels					
2. Industrial processes	**NO**	**0.00**	**NO**	**NO**	**0.00**
A. Mineral products					
B. Chemical industry					
C. Metal production	NO	NO	NO	NO	NO
D. Other production					
E. Production of halocarbons and sulphur hexafluoride	NO	NO	NO	NO	NO
F. Consumption of halocarbons and sulphur hexafluoride	NO	0.00	NO	NO	0.00
G. Other (please specify)					
3. Solvent and other product use					
4. Agriculture					
A. Enteric fermentation					
B. Manure management					
C. Rice cultivation					
D. Agricultural soils					
E. Prescribed burning of savannahs					
F. Field burning of agricultural residues					
5. Land-use change and forestry					
A. Changes in forest and other woody biomass stocks					
B. Forest and grassland conversion					
C. Abandonment of managed lands					
D. CO_2 emissions & removals from soil					
E. Other (please specify)					
6. Waste					
A. Solid waste disposal on land					
B. Waste-water handling					
C. Waste incineration					
D. Other (please specify)					
7. Other (please specify)	**NO**	**NE**	**NO**	**NO**	**NE**
Memo items					
International bunkers					
Aviation					
Marine					
CO_2 **emissions from biomass**					

A sectoral breakdown of Jordan's total emissions of GHGs as shown in Figure (2.1) is as follows:

- Energy (14911 Gg CO_2), 74.0 percent;
- Industrial processes (about 1594 Gg CO_2 eq.), 7.9 percent;
- Agriculture (183 Gg CO_2 eq.), 0.9 percent;
- Land use, land use change and forestry (730 Gg CO_2 eq.), 3.7 percent; and
- Waste (2713 Gg CO2 eq.), 13.5 percent

Figure 2.1: GHG Emissions by Sector

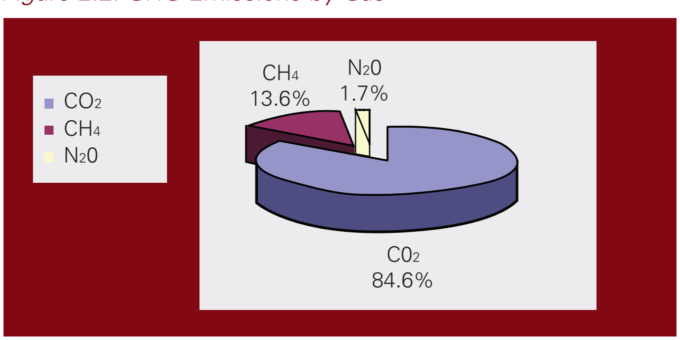


A breakdown of Jordan's total emissions on a GHG basis as shown in Figure (2.2) is as follows:

- Carbon dioxide (about 17047 Gg CO_2), 84.6 percent;
- Methane about (2745 Gg CO_2 eq.), 13.6 percent; and
- Nitrous oxide (about 347 Gg CO_2 eq.), 1.7 percent.

The Jordan's emissions of the fluorinated gases of sulphur hexafluoride, perfluorocarbons and hydrofluorocarbons were negligible in the year 2000.

Figure 2.2: GHG Emissions by Gas



2.3 GREENHOUSE GAS EMISSIONS BY SECTOR

2.3.1 Energy Sector

Energy-related activities have the dominant share of GHG emissions in Jordan. Emissions from this sector are classified into two main categories:

- Emissions from fuel combustion, and
- Non-combustion (fugitive) emissions.

The total emissions from the energy sector were 14911 Gg CO_2 eq., i.e., 74 percent of the total GHG emission of Jordan in the year 2000. Carbon dioxide was the largest contributor (14714 Gg) at a percentage of 98.7 percent of the total energy sector emissions.

On a per gas basis, the energy sector contributed in the year 2000 with 86.3 percent of the total CO_2 emissions of the country, 4.7 percent of the CH_4 emissions, 19.6 percent of the N_2O emissions, 41.2 percent of the NMVOCs emissions and more than 99 percent of the total emissions of each of NOx, CO and SO_2.

On a per sub-sector basis, the largest contributor to emissions in the energy sector is the energy industries sub-sector, which accounted for 37.5 percent of energy emissions, followed by the transport sector which contributed 24.3 percent of the energy emissions. Table (2.3) depicts the emissions of the energy sub-sectors and their shares to the total energy emissions and to the total national GHG emissions (see Table (A1): energy sectoral report, Appendix (A)).

Table 2.3: GHG emissions of the energy sub-sectors

Energy sub-sectors	GHG emissions (Gg CO_2 eq.)	Percent of the total energy emissions	Percent of the total national emissions
Energies industries	5590	37.5	27.7
Manufacturing industries and construction	1866	12.5	9.3
Transport	3623	24.3	18.0
Other sectors (Commercial/ institutional, residential, and Agriculture/ forestry/fishing)	2794	18.7	13.9
Other	943	6.3	4.7
Fugitive emissions	96	0.6	0.6

Emissions from Fuel Combustion

Energy Industries

According to the 1996 Revised IPCC Guidelines, the sub-sectors of energy industries are:

- Public electricity and heat production;
- Petroleum refining; and
- Manufacturing of solid fuels and other energy industries.

In this inventory, fuel combustion emissions from public electricity generation and petroleum refining activities were only included as there was no manufacturing of solid fuels in Jordan in the year 2000.

The energy industries are the largest source of emissions and accounted for (5590 Gg CO_2 eq.) at 27.7 percent of Jordan's GHG emissions in the year 2000.

The public electricity generation accounted for 4911 Gg CO_2 eq. at 87.9 percent of the energy industries sub-sector while petroleum refining accounted for 679 Gg CO_2 eq. at 12.1 percent of this sub-sector. As there are no nuclear power and hydro power in Jordan, fossil fuel is used for power generation. Heavy fuel oil with high sulphur content of about 4 percent by weight was the main fuel used for public electricity generation in the year 2000. In fact about 88 percent of the total electricity generated during the year 2000 was produced using heavy fuel oil. Thus the energy industries sub-sector contributed 121.2 Gg SO_2 out of the total SO_2 national emissions in the year 2000 of 186.4 Gg at 65 percent.

Manufacturing Industries and Construction

Emissions from the Manufacturing industries and Construction sub-sector include the combustion of fossil fuels for generation of electricity (autogeneration) and for heat production. Industrial categories that should be included in this sub-sector according to the 1996 Revised IPCC Guidelines are:

- Iron and steel;
- Non-ferrous metals;
- Chemicals;
- Pulp, paper and print;
- Food processing, beverage and tobacco; and
- Other: emissions from fuel combustion of the remaining industries including emissions from construction.

The main industrial companies that were considered in this sub-sector included Potash Company, Phosphate Mines Company and Cement companies. Emissions from fuel combustion in non-ferrous metals industries and in coke ovens (within the iron and steel industry) were not considered as there were no such industries in Jordan in the year 2000.

The manufacturing industries and construction sub-sector occupies the fourth place in GHG emissions among all sub-sectors. In the year 2000, GHG emissions from this sub-sector totaled 1866 Gg CO_2 eq. at 12.5 percent and 9.3 percent of the energy sector emissions and the total national GHG emissions respectively. This sub-sector also occupies the second place in its SO_2 emissions; these emissions were 39.5 Gg at 21.2 percent of Jordan's total GHG emissions in the year 2000.

Transport

Transport is a major sub-sector contributing to GHG emissions from fuel combustion for the passenger and freight. It includes the following subcategories:

- Domestic aviation;
- Road transport;
- Rail transport;
- National Navigation; and
- Pipeline transport.

The first three subcategories were included in the inventory as there was no pipeline transport in the year 2000. In addition, national navigation activities were limited and, thus, were also excluded.

The transport was the second largest source of emissions; it accounted for (3623 Gg CO_2 eq.) at 24.3 percent and 18 percent of the energy sector emissions and the total national GHG emissions in the year 2000; respectively. Among all energy sub-sectors, transport had the largest contribution to the emissions of N_2O, NOx, CO and NMOVCs at 59.1 percent, 53.5 percent, 89.0 percent, and 91.7 percent of the total energy emissions; respectively. Among transport sub-sectors, road transport is dominating in Jordan, as shown in table (A1)) in the energy sectoral report, Appendix (A). Domestic aviation is limited to relatively small number of trips between Amman and Aqaba cities. Only around 1 percent of jet fuel was used for domestic aviation in Jordan in the year 2000. Rail transport is also limited to one train transporting phosphate from Al Shadiya mine to the only Jordanian port of Aqaba.

International Bunkers
International bunkers include aviation and navigation. However, emissions from marine were not estimated due to lack of data. Emissions of CO_2 from international aviation accounted for 541.56 Gg, while emissions of other gases were insignificant. These emissions are not counted in national totals.

Other sectors
The other sectors category comprises fuel combustion emissions from the following subcategories:

- Commercial/institutional;
- Residential; and
- Agriculture/Forestry/Fishing.

Fuel combustion from the first two subcategories in addition to the agriculture subcategory was estimated, while emissions from forestry and fishing were excluded as they were negligible.

In the year 2000, emissions from other sectors category were 2794 Gg CO_2 eq. at 18.7 percent and 13.9 percent of the energy GHG emissions and of Jordan's total GHG emissions; respectively. This other sectors subcategory was the third largest source of CO_2 emissions as shown in the sub-sector report. However, the emissions of the non CO_2 emissions were insignificant.

The fuels consumed by this category are LPG (for cooking), Kerosene (mainly for space heating and cooking) and diesel (mainly for space heating). The residential activities accounted for 66.9 percent (1858.3 Gg) of the total CO_2 emission of this other sectors category (2779.8 Gg), followed by the commercial/institutional activities which accounted for 19.4 percent and finally agriculture fuel combustion activities which accounted for 13.7 percent.

Other (not elsewhere specified)
This category covers all sectors that are not included elsewhere in estimating GHG emissions from fuel combustion. The total emissions of this category were estimated to be 943 Gg CO_2 eq. at 6.3 percent and 4.7 percent of the energy GHG emissions and of Jordan's total GHG emissions respectively.

Fugitive Emissions from Fuels
According to the Revised 1996 IPCC Guidelines, the following sub-sectors should be considered:

- Methane emissions from coal mining and handing;
- Methane emissions from oil and natural gas activities;
- Ozone precursors and SO_2 from oil refining including:
- Ozone precursor and SO_2 from catalytic cracking
- SO_2 from sulphur recovery plants
- NMVOC emission from storage and handling.

The methane emissions from coal mining and handling, and ozone precursors and SO_2 from sulphur recovery plants were excluded as there were no such sub-sectors in Jordan in the year 2000.

As the oil and natural gas activities were very limited, the fugitive emissions were insignificant. The estimated CH_4 emissions were 4.53 Gg out of 6.16 Gg of the energy sector.

2.3.2 Industrial Processes Sector
This sector comprises emissions from industrial processes where GHGs are by-products of those processes. Thus, this sector accounts for emissions generated from non-energy related activities as all energy activities in the industries are covered in the previous section under energy sector.

Industrial processes GHG sources in industrial processes sector according to the revised 1996 IPCC Guidelines are shown in Table (2.4) together with their status in Jordan in the year 2000. The inventory results show that only two sub-sectors were sources of GHG's in the industrial processes sector in Jordan in the year 2000; mineral production and food and drink manufacture. Mineral production mainly includes cement production, limestone and dolomite production, and use of asphalt for roofing and paving. Food and drink manufacture includes production of beer and other alcoholic drinks, bread, cakes and biscuits, processed meats and coffee roasting.

In the year 2000, emissions from industrial processes sector category were 1594 Gg CO_2 at 7.9 percent of Jordan's total GHG emissions. These CO_2 emissions came mainly from cement production (1588.7 Gg CO_2). The industrial processes sector was the largest source of NMVOC emissions and accounted for 62.86 Gg at around 49 percent of Jordan's total NMVOC emissions in the year 2000. The main sub-sectors contributors to

Table (2.4): Status of industrial processes in Jordan in the year 2000

Greenhouse Gas Source Categories in the Industrial Sector	Status in Jordan in 2000
A. Mineral Products	
1. Cement Production	Present
2. Lime Production	Not Present
3. Limestone and Dolomite Use	Not Present
4. Soda Ash Production	Not Present
5. Asphalt Roofing	Present
6. Road Paving with Asphalt	Present
7. Other	
- Glass Production	Not Present
- Concrete Pumice Stone	Not Present
B. Chemical Industry	
1. Ammonia Production	Not Present
2. Nitric Acid Production	Not Present
3. Adipic Acid Production	Not Present
4. Carbide Production	Not Present
C. Metal Production	
1. Iron and Steel Production	Not Present
2. Ferroalloys Production	Not Present
3. Aluminum Production	Not Present
4. SF6 Used in Aluminum and Magnesium Foundries	Not Present
D. Other Production	
1. Pulp and Paper	Present
2. Food and Drink	
- Production of Beer, Wine, Spirits	Present
- Production of Meat, Poultry	Present
- Production of Bread and Biscuits & Cakes	Present
- Production of Animal Feed	Not Present
- Production of Margarine & Solid Fats	Present
- Coffee Roasting Process	Present
E. Production of Halocarbons and Sulphur Hexafluoride	
1. By-product Emissions	Not Present
2. Fugitive Emissions	Not Present
F. Consumption of Halocarbons and Sulphur Hexafluoride	
1. Refrigeration and Air Conditioning Equipment	Present
2. Foam Blowing	Not Present
3. Fire Extinguishers	Not Present
4. Aerosols	Not Present
5. Solvents	Not Present

the NMVOC emissions within the industrial processes sector were road paving with Asphalt (around 36 Gg) and food and drink (around 27 Gg).

In addition to CO_2 and NMVOC, this sector generated negligible emissions of NOx, CO, SO_2 and HFCs (see Table (A2): sectoral report for industrial processes, appendix (A)).

2.3.3 Solvents and Other Products Use Sector

This category covers mainly NMVOC emissions resulting from the use of solvents and other products containing volatile compounds. According to the 1996 Revised IPCC Guidelines, this sector includes the following sub-sectors:

- Paint application;
- Degreasing and dry cleaning;
- Chemical products, manufacture and processing; and
- Other: includes use of N_2O as a carrier gas, anaesthetic, and propellant in aerosol products.

There are no methodology and emission factors in the 1996 Revised IPCC Guidelines to estimate GHG emissions from solvents and other products use sector. The estimations for this sector are based on other countries experiences and emission factors, namely; Bulgaria (CORINAIR), Czech Republic (local studies) and Poland (research in Polish industries). Two sub-sectors were covered in this inventory: the paint application, and chemical products, manufacture and processing.

In the year 2000, NMVOC emissions generated from the solvents and other products use sector were only 13.34 Gg at around 10 percent of Jordan's total NMVOC emissions. The key source of NMVOC emissions in this sector was the application of oil and water based paints (8.57 Gg), other sources within the chemical products, manufacture and processing sub-sector were pharmaceuticals production, printing industry, glue use, edible oil extraction and paint production (see Table (A3): sectoral report for solvent and other product use, Appendix (A)).

2.3.4 Agriculture Sector

Emissions from all anthropogenic activities within the agriculture sector, excluding fuel combustion and sewage, are covered in this sector. According to the 1996 Revised IPCC Guidelines, this sector includes the following sub-sectors:

- Enteric fermentation;
- Manure management;
- Rice cultivation;
- Agricultural soils;
- Prescribed burning of savannas;
- Field burning of agricultural residues; and
- Other

As there is no rice cultivation or savanna in Jordan, these sub-sectors were excluded.

The GHG emissions of the agriculture activities were very small and accounted only for 0.9 percent (183 Gg CO_2 eq.) of Jordan's total GHG emissions in the year 2000. These emissions are composed of methane and nitrous oxide. Emissions of indirect GHGs of CO and NOx were negligible. Emissions of methane from agriculture sector were insignificant, and were estimated at 0.03 Gg. Almost two thirds of these methane emissions came from herbivores as a by-product of enteric fermentation and from the manure decomposition under low oxygen or anaerobic conditions. The remaining one third of methane emissions came from field burning of agricultural residues.

Almost all nitrous oxide emissions in agriculture sector were emitted from agricultural soils (0.5867 Gg), while the contributions of manure management and field burning of agricultural residues were negligible.

Emissions of N_2O from agricultural soils are primarily due to the microbial processes of nitrification and de-nitrification in the soil. Three types of emission can be distinguished:

- Direct soil emissions of N_2O: they are the result of nitrogen input to soils through: synthetic fertilizers, nitrogen from animal waste, biological nitrogen fixation and nitrogen from crop residues. The contribution of these emissions was around 72 percent of the total N_2O emissions from agricultural soils.
- Direct soil emissions of N_2O from animal production induced by grazing animals. The contribution of these emissions to the total was negligible.
- Indirect N_2O emissions take place after nitrogen is lost from the field as NOx, NH_3 or after leaching or runoff. These emissions were estimated at a percentage of around 28 percent of the total N_2O emissions from agricultural soils.

Emissions of NOx and CO resulted mainly from field burning of agricultural residues. The field burning of residues accounted for in this inventory was mainly from the burning of fruit trees pruning residues. The rest of the agricultural residues were either used as a source of energy in the rural areas (could not be estimated) or used as a feed for the national livestock. These emissions were negligible and were estimated to be 0.01 Gg and 0.2 Gg of NOx and CO; respectively (see Table (A4): sectoral report for Agriculture, Appendix (A)).

2.3.5 Land Use Change and Forestry Sector

The GHG emission/removals for the year 2000 were calculated for the Land Use Change and Forestry sector (LULUCF). According to the Revised 1996 IPCC Guidelines, the following key sources should be covered:

- Changes in forest and other woody biomass stock;
- Forest and grassland conversion;
- Abandonment of managed lands;
- Carbon dioxide emissions and removals from soil; and
- Other.

The CO_2 emissions in this national inventory were calculated for the following relevant and applicable sub-sectors:

- Changes in forest and other woody biomass stock
- CO_2 emissions or uptake by soil from Land-Use Change and Management
  - ◊ Change in soil carbon for mineral soils
  - ◊ Agriculturally impacted lands
  - ◊ Agriculturally impacted soils

The land-use change and forestry sector was a net source of CO_2; contrary to what is expected. The emissions were estimated to be 739 Gg of CO_2 at 3.7 percent of Jordan's total GHG emissions in the year 2000. The net CO_2 emissions from soil were calculated to be around 960 Gg, and the net CO_2 removals were estimated to be 221 Gg. This number is considered modest due to the relatively small area of forests in Jordan; which is around 1 percent of the total area of the country (see Table (A5): sectoral report for LULUCF, Appendix (A)).

2.3.6 Waste Sector

According to the 1996 Revised IPCC Guidelines, this sector includes the following sub-sectors:

- Solid waste disposal on land;
  - ◊ Managed waste disposal on land
  - ◊ Unmanaged waste disposal on land
- Wastewater handling
  - ◊ Industrial wastewater
  - ◊ Domestic and commercial wastewater
  - ◊ other
- Waste incineration; and
- Other

As there was no waste incineration in Jordan in year 2000, the related section is not included in this report.

Methane is produced from anaerobic decomposition of the organic matter in solid waste and wastewater while N_2O is released from human sewage.

In the year 2000, GHG emissions from the waste sector totaled 2713 Gg CO_2 eq. at 13.5 percent of Jordan's total GHG emissions. Most of the emissions were from disposal of domestic solid waste which accounted for 12.5 percent (2515 Gg CO_2 eq) of the total GHG emissions, while wastewater handling accounted for 1 percent (199 Gg CO_2 eq) of the total GHG emissions.

In the current national inventory, the key source of methane was from the managed domestic solid landfill sites at around 96 percent (around 120 Gg CH_4) of the total methane emissions in this sector. Whereas the contribution of the domestic and commercial wastewater was estimated to be around 4 percent of the total (around 4.7 Gg CH_4) generated methane nation-wide. This 4 percent was generated at As-Samra treatment plant, which at that time was operated as natural wastewater stabilization ponds. This plant used to receive around 75 percent of Jordan's domestic wastewater.

As for the industrial wastewater plants, two main industrial wastewater treatment plants were considered; King Abdullah Industrial Zone and Prince Hassan Industrial Zone. Methane emissions from these plants were negligible as there operation mode is activated sludge.

Nitrous oxide emissions were estimated within the domestic wastewater sub-sector at 0.32 Gg, and the calculations were based on protein consumption per capita (see Table (A6): sectoral report for waste, Appendix (A)).

2.4 GAS BY GAS EMISSION INVENTORY

This section presents a brief description of emissions by greenhouse gas type of Jordan's inventory in the year 2000. Greenhouse gases included are CO_2, CH_4, N_2O, NOx, CO and NMVOC.

2.4.1 Carbon Dioxide

Net CO_2 emissions were estimated to be 17047 Gg at 84.6 percent of Jordan's total greenhouse emissions in the year 2000. These emissions arise from energy, industrial processes and LULUCF sectors at 86.3 percent, 9.4 percent and 4.3 percent of the total CO_2 emissions; respectively.

Thus, the main source of CO_2 is combustion of fossil fuels. The largest single contributor to CO_2 emissions was energy industries sub-sector (mainly power generation which relied on heavy fuel oil in the year 2000), followed by road transport at 32.7 percent and 20.9 percent out of the total CO_2 emissions in the year 2000 respectively.

The industrial processes sector (mainly cement production) contributed 9.4 percent of the total CO_2 emission in the year 2000. The CO_2 emissions from Land Use, Land Use Change and Forestry were 960.5 Gg. This was partially offset by the CO_2 sink of 221.5 Gg. This resulted in net CO_2 emissions of 739 Gg at 4.3 percent of the total CO_2 emissions. Figure (2.3) shows the contributions of the sub-sectors in CO_2 emissions in the year 2000.

2.4.2 Methane

Methane has the second largest share of Jordan's greenhouse gas emissions. CH_4 emissions were estimated to be 130.7 Gg at 13.6 percent of Jordan's total greenhouse emissions in the year 2000.

The largest contributor to CH_4 emissions in the year 2000 was the waste sector. Methane emissions generated from domestic solid waste landfills and wastewater accounted for 91.6 percent and 3.6 percent of the total CH_4 emissions; respectively. The energy sector contributed 4.7 percent of the total CH_4 emissions. The contribution of agriculture sector to CH_4 emissions was negligible. Figure (2.4) shows the contributions of the different sub-sectors in CH_4 emissions in the year 2000.

Figure 2.3: CO_2 emissions by sub-sectors

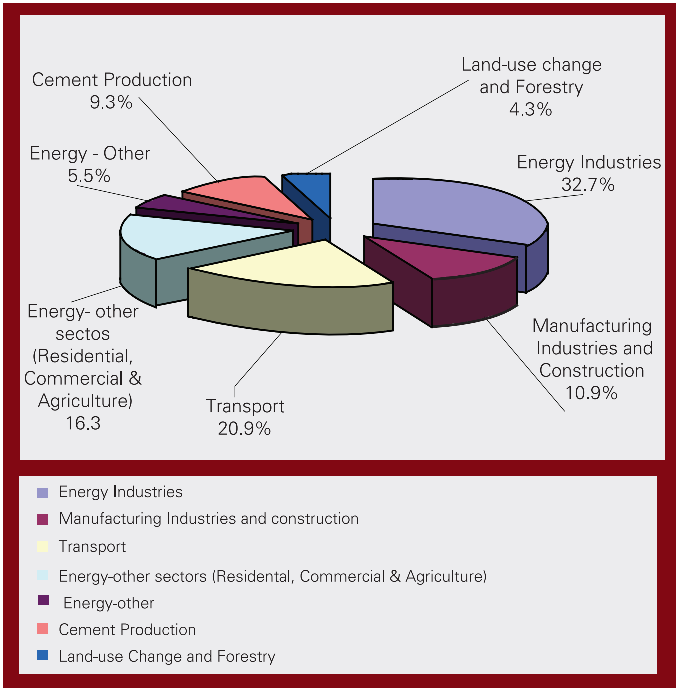
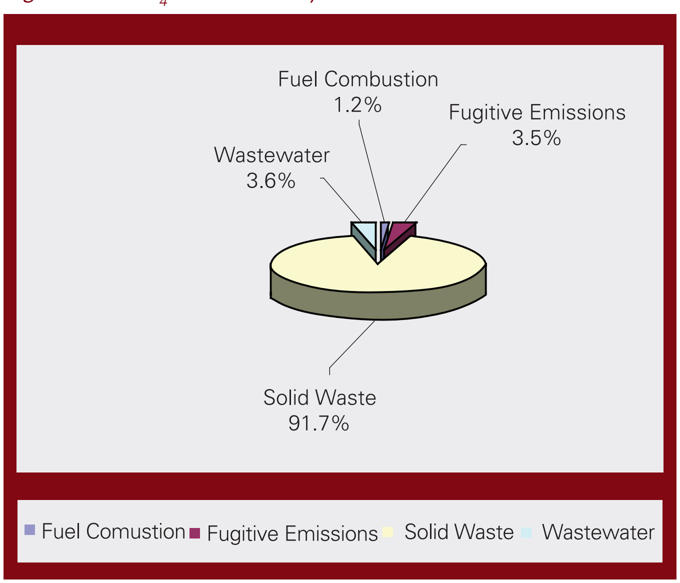


Figure 2.4: Ch_4 emissions by sub-sectors



2.4.3 Nitrous Oxide

Emissions of nitrous oxide were small and estimated to be 1.1 Gg or around 1.7 percent of Jordan's total greenhouse emissions in the year 2000. Nitrous oxide emissions were generated from energy, agriculture and wastewater (human sewage) at 19.6 percent, 52.7 percent and 28.6 percent of the total N_2O emissions.

2.5 CARBON DIOXIDE EMISSIONS FROM THE ENERGY SECTOR USING THE REFERENCE APPROACH

Reference approach was used to estimate the CO_2 emissions of the energy sector based on the Revised 1996 IPCC Guidelines for the years 1995-2000. The results are depicted in Table (2.5) and Figure (2.5). The results of CO_2 emissions in the year 2000 using sectoral approach was 14714 Gg which is very close to the CO_2 emissions of 14207 Gg calculated using the reference approach.

Figure 2.5: CO_2 emissions for the year 1995 - 2000

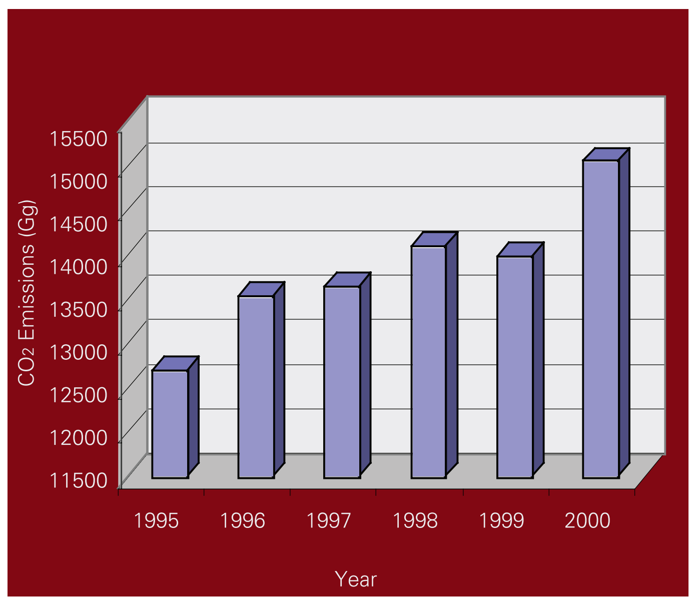


Table 2.5: CO_2 emission from the energy sector for the years 1995 – 2000 using reference approach

Year	1995	1996	1997	1998	1999	2000
CO_2 Emission	12703.34	13534.08	13644.75	14097.89	13983.85	14207

2.6 COMPARISON BETWEEN THE CURRENT AND PREVIOUS INVENTORIES

The previous national GHG inventory was prepared for the base year of 1994 as part of Jordan's initial national communication (INC). Three direct GHGs were included in the INC (CO_2, CH_4, and N_2O) compared to six direct GHGs estimated in the current inventory (CO_2, CH_4, N_2O, SF6, HFC, and PFC). In addition to the indirect GHGs of NOx, CO, HMVOC estimated in the INC, SO_2 was estimated in the current inventory. With regard to sectors, the current inventory included for the first time the solvents sector. Additionally, the industrial processes sector included all relevant sub-sectors compared to the INC inventory which included emissions from cement production only.

The estimated GHg emissions using bottom-up approach for the year 1994 were as follows:

- CO_2: 13390 Gg;
- CH_4: 403.8 Gg; and
- N_2O: 0.40 Gg.

In 2005, the Ministry of Environment carried out a project of "Add on Funds", the two component of this project were:

- Review the Initial National Communication; and
- Assessment of Technology Needs and Technology Transfer.

The main finding of the review was that methane emissions from municipal solid waste in the year 1994 were overestimated at 371 Gg compared to the correct estimated figure of only 79 Gg. The difference is 292 Gg CH_4 or 6132 Gg CO_2 eq.

2.7 UNCERTAINTY

The IPCC Good Practice Guidance (IPCC, 2000) characterizes determination of uncertainties as a key element of a complete inventory. The purpose of uncertainty estimate is not to dispute the validity of the inventory estimate, but to help prioritize efforts and resources allocation to improve the accuracy of inventories in future, in addition to guiding decisions on methodological choice. The Tier 1 uncertainty analysis for Jordan's GHG inventory for the year 2000 gives an overall uncertainty of 6.7 percent (excluding LULUCF from CO_2 emissions). The level of uncertainty associated with total CO_2 (excluding LULUCF), CH_4 and N_2O emission estimates are 3.52, 35.3, and 128.3 percent respectively. The uncertainty in CO_2 emissions is 23.85 percent if LULUCF is included.

Energy sector's overall uncertainty estimate is relatively low at 2.29 percent. CO_2 emissions from energy industries contributed the highest share to energy sector GHG emissions and their combined uncertainty is estimated at 3.17 percent. CO_2 from transport, the next largest contributor, has an uncertainty of 5.14 percent. The overall uncertainty level for the industrial processes is 30 percent. For both the agricultural and waste sectors, uncertainty estimates based on source category analysis are 38.3 and 43 percents; respectively. LULUCF sector's uncertainty is estimated to be the largest at 545 percent. Emission factor uncertainty was estimated from the available ranges of emission factors and default uncertainty estimate in the IPCC 1996, 2000 and 2006 guidelines as appropriate, while the activity data uncertainty was determined by expert judgment. Appendix (B) provides details of source level uncertainty estimates.

Jordan understands that measuring some country specific emission factors, especially for key sources, will reduce uncertainty in emission estimates. Activity data uncertainty could be reduced by regularly collecting it as a consistent time-series, and reconciliation of differences in national and sectoral data. Jordan plans to develop further in these directions. In order to improve the quality of uncertainty estimates, agencies that provided information for inventory estimation need to be sensitized to the importance of uncertainty estimate. In addition, using Tier 2 method for estimating uncertainty (Monte-Carlo simulation technique) in future can reduce the uncertainty since it deals with the asymmetrical uncertainty ranges.

2.8 REFERENCES

IPCC, 1997. Revised 1996 Guidelines for National Greenhouse Gas Inventories.

IPCC, 2006. Guidelines for National Greenhouse Gas Inventories.

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

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

GREENHOUSE GAS MITIGATION ANALYSIS

3. GREENHOUSE GAS MITIGATION ANALYSIS

3.1 INTRODUCTION

The purpose of this chapter is to provide an analysis of measures to limit and reduce GHG emissions and enhance GHG sinks as part of the Second National Communication of Jordan. It also describes the followed mitigation methodology, and discusses issues that came up during conducting mitigation assessments for the specified sectors. Two types of scenarios were constructed during the analysis; the baseline scenario and mitigation scenario.

The baseline scenario is constructed based on the trends, plans and policies prevailing in the Jordanian context. This baseline scenario is different from a business-as-usual scenario since the government of Jordan has committed itself to long term plans which introduce major changes to the existing structure of the economy. Some of these changes may be considered as mitigation options; therefore, the effort to construct the baseline scenario had to carefully distinguish between actions dictated totally or partly by environmental considerations and actions irrelevant to environmental considerations. As an example, environmental aspects were a major factor in designing renewable energy, while oil shale development was entirely driven by strategic considerations such as energy supply security.

The baseline scenario was constructed in close cooperation with the concerned institutions. The required data on the activities that produce GHG emissions were collected from sources identified through the literature review phase. Data sources included the periodical reports issued by concerned institutions, specialized sectoral and sub-sectoral studies, surveys, relevant technical papers and domestic and international standards and specifications. Development of scenarios required a projection of current levels to future levels of each type of activity. Such projection in turn draws on assumptions made about population growth, GDP, and other macro variables, which were obtained from official institutions such as Ministry of Planning and International Cooperation (MOPIC) and Ministry of Energy and Mineral Resources (MEMR) as available. Where these projections were not available, the mitigation team worked in close cooperation with the relevant institutions to develop coherent and politically accepted sets of projections to facilitate the mitigation assessment. This was necessary especially due to the relatively long time period considered in the assessment activity (2000 – 2033), which surpasses normal planning horizons considered by the official Jordanian institutions.

The mitigation assessment activity was structured according to a set of criteria reflecting country-specific conditions such as potential for large impact on greenhouse gases (GHGs), direct and indirect economic impacts, consistency with national development goals, potential effectiveness of implementation policies, sustainability of an option, data availability for evaluation and, other sector-specific criteria. Once options have been selected for analysis, it was necessary to characterize technologies and mitigation options with respect to their cost and benefits. Various models and methods were used to assist in this evaluation, depending on the sector that is being analyzed. Data gathering for evaluation of options also provided general data on technologies, which can be incorporated into scenarios. As for the energy sector, the Energy and Power Evaluation Package (ENPEP) was employed to construct the baseline scenario and assess different mitigation scenarios on different levels; including policy, program and individual project levels in the energy sector. Individual mitigation projects in other sectors were also assessed using proper financial and economic tools (combinations of cost-benefit and other complementary environmental and social effects). Strategies approved and adopted by the government of Jordan in different sectors formed the basis for the baseline scenario. Ongoing programs and measures directly affecting the GHG emissions are considered as part of the mitigation scenario. For example, several projects are already under development as Clean Development Mechanism (CDM) projects. Additionally, programs to enhance renewable energy technologies and energy conservation are well underway. These programs are at least partially driven by environmental concerns and stipulate taking advantage of CDM opportunities.

Projects undergoing development as CDM projects at the time of this report are:

- Aqaba thermal power station, conversion from fuel oil to natural gas.

- Rahab and Samra power stations, converting from simple to combined cycle.
- Ruseifeh and Gabawi landfills, gas collection for power generation.
- Rashadieh cement factory, clinker use optimization by maximizing additives use.
- Akider landfill, gas collection for power generation.
- Al-samra wastewater treatment plant, gas collection for power generation.

Projects listed above are at different stages in the CDM project cycle and all are incorporated in the mitigation analysis below.

3.2. BASELINE SCENARIOS FOR THE DIFFERENT SECTORS

3.2.1 Baseline Scenario for Energy Sector

As illustrated in the review presented earlier in the National Circumstances Chapter, the energy sector of Jordan received maximum attention from the government of Jordan. A long term energy sector strategy was prepared and reviewed on several levels of the State and was finally adopted. The major actions recommended by this strategy are:

- Maximizing private sector involvement in all aspects of energy,
- Maximizing foreign investment in all aspects of energy,
- Maximizing contribution of indigenous energy sources to the energy mix,
- Introducing new technologies in different stages of the energy cycle, and
- Adopting energy pricing policies which reflect actual cost to the economy and elimination of all types of subsidies.

These actions are well underway and concrete steps were undertaken to materialize the goals and objectives of the energy strategy; which include:

- Restructuring Jordanian Petroleum Refinery Company by unbundling its current activities (refining, logistical facilities, distribution) and termination of the concession (in progress),
- Oil-market liberalization and opening to competition (in progress),
- Gradual phasing out of subsidies of prices of oil products and adopting a pricing policy which reflects changes in international prices of oil products on local process periodically (completed), and
- Diversifying sources and types of primary energy mainly through exploitation of oil shale resources in the country for shale oil production and power production on the medium term, introducing nuclear power technology on the long term, and maximizing renewable energy contribution in the energy mix on the short and medium terms (in progress).

The Ministry of Energy and Mineral Resources (MEMR) in cooperation with other related energy entities prepared a comprehensive energy demand forecast studies covering several scenarios with different demand growth profiles and different availability of fuels especially the natural gas. The supply of natural gas from Egypt through the Arab Natural Gas Pipeline is subject to contractual and technical complications which render the future quantities of natural gas available to Jordan uncertain. The relevance of this fact will be illustrated when discussing the assumptions underlying the most probable scenario.

The planning period considered for the purposes of these studies was 2006 - 2020 for primary energy and 2006 - 2030 for electricity. These were periods dictated by models applied during the studies. The mitigation team complemented the results of these studies by adding actual figures for the period 2000 – 2005 and extrapolation of available figures over the future period up to the year 2033 in consultation with the involved entities and personnel. A special electricity system expansion exercise was conducted by the mitigation team using Wein Automatic System Planning Model (WASP). The exercise was based on the assumptions adopted by the most probable scenario. This scenario was extracted from the different scenarios considered in the studies conducted by the energy institutions as part of the energy strategy of Jordan. These scenarios varied according to future energy demand levels (low, medium and high) and according to the availability of natural gas (domestic and imported). Sensitivity analysis covering the effects of other important variables such as fuel cost was also carried out.

Out of these scenarios considered by the MEMR, a most probable scenario was constructed for the purposes of this study. Major assumptions underlying this most probable scenario are:

- Introduction of oil shale based power plants into the national power system in the years 2014, 2015, 2017, 2018 and 2021. A total of 1500MW (5 × 300 MW) to be installed in the planning period.
- Introduction of nuclear power plants into the national power system starting 2020, 2024 and 2030 (3 × 400 MW). The nuclear power units are considered as committed in the WASP run. This is a strategic decision made by the State at the highest levels and efforts to prepare the necessary infrastructure are in progress.
- Limited natural gas supply availability (reaching a peak of 3000 million metric standard cubic meters per year (MMSCM/Y) in the year 2011 as per the year 2004 agreement. This is the most probable case adopted for the baseline scenario considering the contractual complications prevailing between Jordan and Egypt (the supplier) in addition to the Egyptian plans to maximize the use of its natural gas domestically. Three optimistic scenarios regarding the availability of natural gas are considered by the national energy strategy, where domestic supply of natural gas from Risha field increases significantly and the quantities of imported natural gas are also increased which will be considered in the mitigation scenario
- Medium demand scenario for petroleum products by all sectors. This level of demand is the result of combining optimistic growth rates of the economy with the sharp increase in international oil prices which is reflected on domestic energy prices through the new pricing mechanism adopted recently by the government of Jordan.
- Medium demand scenario for electricity. This level of demand is also dictated by the same arguments as above.
- Limited renewable energy contribution to the energy mix. This assumption is based on the history of renewable energy in Jordan where this contribution never exceeded 2 percent of total energy mix. It is assumed that the already under tendering 40 MW wind power plant at Kamsha area will come on line in the year 2010, a load factor of 20 percent is assumed. Existing wind turbines will remain in service with the historical average performance.
- Modest role of the Photovoltaic (PV) solar technology is assumed. The present 30 toe being produced is projected to increase up to 100 toe by the year 2010 and remains constant since this is justified by the fact that PV applicability in Jordan is extremely limited, 99.9 percent of the population is connected to the grid and very few remote areas may benefit from PV technology.
- As for the thermal solar energy applications, the historical growth in penetration rate of solar heaters (2.3 percent per year) in household and commercial sectors is considered to prevail over the period of the study.
- In the biogas field, the Jordanian experience is limited to the 3.5 MW biogas power plant at the Rusaifeh municipal waste disposal site. This plant was financed largely by foreign grants and proved to be uneconomical unless the project is registered as a CDM project and preferential financing is guaranteed. Therefore, the baseline scenario does not contemplate any new similar projects.
- No additional hydro power sources are available in Jordan except for the two main sources already exploited (King Talal Dam and Cooling Water Hydro Turbine in Aqaba Thermal Power Station).
- Limited energy conservation and energy efficiency activities. This is also based on the prevailing historical trend in Jordan. Since interest in the fields of renewable energy and energy efficiency has increased considerably in the past few years due to the introduction of CDM in Jordan, future projects in these two fields are considered as part of the mitigation scenario even though the importance of these fields is recognized by the national energy strategy. The delineation between baseline scenario and mitigation scenario is based on the convention that CDM is a major driving force towards implementing energy efficiency activities.

Table (C1) in Appendix (C) summarizes the primary and final energy demands (excluding electricity) for the period 2000 - 2033 for the baseline scenario. The demand for primary energy types by the electricity sector is a result of the optimal expansion plan for the electric system; demand for final energy by other sectors is generated by the application of the DEMAND Model which is part of the ENPEP. This program was designed for calculating the growth rate of oil product demand for any form of energy form based on several macroeconomic variables; such as:

- GDP in constant prices,
- added value for economic sectors separately,

- population growth rate, and
- any factor related to the consumed energy in certain sectors which can affect directly the trend of energy consumption.

Table (C2) in Appendix (C) summarizes demand forecast for electricity by different sectors; domestic, commercial, services, industrial, water pumping and public lighting sector. The approach adopted in this study requires defining and analyzing the factors that affect the energy consumption of each sector. Concerning the economical sectors, the value added factor has a major influence on electricity consumption of the industrial, commercial and service sectors. As for residential, and medium and small industries, the per capita income is a key driving variable in the residential sector, while the price of electricity and the value added are significant driving factors in the medium and small industries sector. The electricity demand forecast is considered the first step in the planning activity, and is a complicated process which involves the interaction of socio-demographic, statistics, economics and engineering activities, in addition to the application of professional sense and professional judgment of planners.

The role of demand forecasting is to serve as the basis for long term system development, long term financial plans (tariff studies) and developing corporate strategies. This forecast is based on the medium scenario, and is consistent with the assumptions underlying demand forecast for other types of energy presented above.

3.2.2. BASELINE SCENARIO FOR WASTE SECTOR

3.2.2.1 Domestic and industrial wastewater

Water Authority of Jordan (WAJ) is the responsible entity for managing the domestic wastewater including constructing the necessary domestic wastewater treatment plants to cover all cities and governorates throughout the country. Wastewater quantity received by the treatment plants is increasing with the increase in population, water use and the development of sewer system (Table (C3), Appendix (C)).

As available freshwater resources become increasingly limited in Jordan, treated wastewater will play an ever more important role in the sector. WAJ will ensure that appropriate wastewater collection systems and treatment facilities are provided for all sources of wastewater. It will also ensure that wastewater is not managed as "waste" but is collected, treated, and used in an efficient and optimal manner. WAJ will also ensure that treated effluent complies with the recent established national standards for reclaimed domestic wastewater (JS 893/2006) and that all treatment is to a quality appropriate for use in agricultural activities and other non-domestic purposes, including groundwater recharge (JISM, 2006).

Appropriate wastewater treatment technologies shall be adopted with due consideration to sustainability, economy in energy consumption and quality assurance of the effluent. In light of this, WAJ will establish targets for providing wastewater collection systems and treatment facilities to areas not served throughout the country.

Industries will be encouraged to recycle part of their wastewater and to treat the rest to acceptable standards before it is discharged into the sewer systems or elsewhere. This will help to ensure that the treated effluent quality for the exiting wastewater treatment plants conforms to water quality standards for reuse. WAJ will consider the plans and studies for power generation from the sludge if technically, economically and financially feasible otherwise the use of sludge as fertilizer and soil conditioner will be considered. Table (C3) in Appendix (C) shows the baseline scenarios for domestic wastewater for the period 2001-2033 (Wastewater Management Policy, Water Authority of Jordan).

3.2.2.2 Domestic solid waste

Solid waste management is the responsibility of the Joint Services Councils of the Ministry of Municipal and Rural Affairs and the Greater Amman Municipality (GAM) for Amman and its suburbs.

Joint Services Councils were established according to Joint Services Councils regulation 17 for the year 1983 issued based on Municipal Law No. 29 for the year 1955. There are 21 Joint Services Councils in Jordan, 16 of them supervise domestic solid waste landfills that receive 3500 tonnes of solid waste daily (Ministry of Municipal and Rural Affairs (MMRA)).

The most important concern for the MMRA is to meet the increasing demand in solid waste disposal. Also, the Ministry's strategy is to establish environmental friendly landfills by the year 2010 and to set up projects for recycling and producing energy. A special viable strategy has been set up to achieve this vision through shrinking landfills in the Kingdom to preserve environment. Additionally, the Ministry built transfer stations to transfer waste into main landfills by compactors and locomotives and all modern transfer station requirements.

The special strategy aims to develop and modernize working styles of landfills. This will be achieved through provision of necessary machinery for the successful construction and operation of plants and acquire needed equipments to modernize waste disposal techniques and preserve surrounding environment. The strategy also aims at institutional capacity building for those who work in landfills through training and rehabilitation in using health-imbedding styles for solid waste in order to preserve local environment and underground water (Strategic Plan for the years 2006-2010, MMRA, 2005).

The GAM is responsible for municipal affairs in Amman and its suburbs with a population of over 2 millions. Zarqa, which is located to the northeast of Amman, has a population of around 0.8 million. Population of both cities is growing rapidly due to the high normal growth rate and migration from rural areas. The municipalities of Amman and Zarqa share Al-Ghabawi landfill; which is considered the largest landfill in Jordan, and replaced the Russifeh landfill site which was closed in the year 2003. The site receives about 2500 tonnes of domestic solid waste per day. It consists of many cells; however, only one cell is currently open.

Greater Amman Municipality has a strategy that aims at protecting the environment. To achieve the strategy, the necessary transfer stations for the domestic solid waste will be established to enhance the collection and handling of the solid waste. A second cell in Al-Ghabawi landfill will be opened to receive the solid waste and house a leachate treatment plant. GAM will install domestic solid waste incinerators to produce energy and to reduce the volume of solid wastes by 10 - 30 percent (GAM, 2004). Table (C4) in Appendix (C) shows the projected amounts of domestic solid wastes generated which were calculated based on a generation rate of 0.9 Kg/capita/day.

3.2.3 Baseline Scenario for Agriculture Sector

The baseline scenario for this sector is based on plans, policies and strategies announced and adopted by the government of Jordan. The macroeconomic and demographic variables adopted in the scenario are similar to those of other sectors. Although the contribution of agriculture sector in GDP is only 3 percent (MWI, 2009), it has an extremely important role in the environmental plans.

As part of the National Agricultural Strategy, the environmental aspect was given due attention. The following objectives were common for both environmental planning and agricultural planning and were pursued in full coordination among relevant institutions:

- Conserve land, water and natural vegetation, and utilize them within their production capacity to ensure sustainable and long term agricultural production.
- Conserve Jordan's biodiversity and utilize it in supporting agricultural development.
- Improve the technical capacities of the people working in the agricultural sector to cope with probable climate and environmental changes.
- Combat desertification and monitor environmental changes.
- Ensure a sound monitoring system when using treated wastewater in irrigation.
- Establish green belts to combat desertification.
- Introduce organic farming practices.
- Control urban expansion on agricultural and forest lands.
- Drought prediction and desertification control through the establishment of a center for monitoring, predication and assessment.
- Restore degraded ecosystem of rangelands and forests through community based rangeland rehabilitation.

The following are general guidelines that directed the predictions in the agricultural activities:

Field crops production activities

- Increase productivity per unit area,
- Maintain productivity under predicted fluctuations in rainfall rates,
- Occurrence of drought and frost,
- Expansion of urban areas on agricultural lands,
- Increase use of modern technology in agriculture, and

- Promote the usage of drought tolerant plant species.

Animal production activities

- Promote the private sector involvement,
- Control overgrazing of rangelands,
- Increase in prices of fodder, veterinary services, and other production inputs,
- Increase in prices of fuel,
- Promote high productive animal species, and
- Improve animal diseases control programs.

Fodder production activities

- Reclamation of rangelands
- Introduce species with high productivity under drought conditions,
- Promote wastewater reuse in fodder production,
- Encouraging private sector investments in fodder production, and
- Promote water harvesting projects to expand planting areas.

Forestry Conservation activities

- Maintain the forests under predicated continuity of drought cycles,
- Urban and rural expansion,
- Enforcement of the land use policy (regulation),
- Expected fire occurrences,
- Trees cutting for fuel,
- Fluctuations in rainfall rates,
- Promote soil conservation,
- Establishment of natural reserves, and
- Anticipated growth in forest areas of 0.3 percent.

The adopted strategy is to be implemented through special committees for the following main activities:

- Rainfed agriculture.
- Irrigated agriculture in the Jordan Valley and the highlands.
- Animal production and rangeland conservation and rehabilitation.
- Marketing of the national agricultural products.

Tables (C5, C6, C7, C8 and C9) in Appendix (C) show the projections of crop production, poultry production, fertilizers imports, animal production and forestry area for the period of 2001 to 2033.

3.2.4 GHG Emissions in Baseline Scenario

Out of the 20140 Gg CO_2 equivalents of total emissions in the year 2000, CO_2 emissions represented 84.6 percent. This percentage is expected to grow according to the baseline scenario to reach 93 percent out of 70377 Gg by the year 2033. Methane emissions on the other hand represented 13.6 percent in the year 2000, and are expected to drop to about 6.5 percent in the year 2033. The N_2O emissions account only for 1.7 percent in base year and are expected to decrease to 0.3 percent by the 2033 (see Tables (C10 and C11), and Figures (C1 and C2), Appendix (C)).

3.2.4.1 Emissions from energy related activities

Within the energy strategy of Jordan, a new expansion of the existing refinery is contemplated where an increase of 70 percent in refining capacity is expected to be achieved by the year 2012. Future emissions from refining activities were estimated based on this assumption.

As for the electricity generation sector, the emissions are calculated with the help of the IMPACT Model based on the baseline expansion plan developed by WASP model, both being part of the WASP Package.

The energy sector is the dominant source of GHG emissions in Jordan as could be seen from Table (C10) and Figures (C3 and C4) in Appendix (C).

The role of the energy sector as the leading emitter of GHGs will be enforced in the future as its share will grow from 74.0 percent of total emissions in the year 2000 to 86 percent in the year 2033. Therefore, it is logical to focus the mitigation efforts on the energy sector.

By sub-sector, the energy transformation industry (refinery and electricity generation) is the leading emitter, and its share from energy sector emissions ranges from 40 percent to 53 percent during the planning period (see Table (C10) and Figure (C5), Appendix (C)) followed by the transport sector with emissions ranging from 22 percent to 29 percent. The third place is shared by the manufacturing sector and residential sector; each ranging from 10 percent to 12 percent. Commercial and agricultural sectors are marginal contributors to energy related GHG emissions; ranging from 2 percent to 4 percent.

The electricity generation sector will witness moderate growth rate in emissions up to the year 2014; where a somewhat sharp growth rate will start to dominate the sector's emissions until the year 2020 due to the introduction of oil shale based power generation. By the year 2020 and beyond; the emission's growth rate will decrease again as a result of introducing nuclear power stations in the national electrical system. This is shown in Figure (C6), Appendix (C).

Fugitive emissions

The major part of fugitive emissions originates from natural gas related activities. Therefore, the baseline scenario calculates future emissions as a direct function of natural gas quantities consumed in the future. Fugitive emissions from oil products are considered constant since there are significant improvements planned in the handling system. Compared to other sectors, the fugitive emissions are negligible.

3.2.4.2 Emissions from industrial activities

Cement manufacturing in Jordan is the major source of GHG emissions from industry where the two existing cement factories which operate at near maximum capacity produce around 1594 Gg of CO_2 yearly. As for the future, several companies expressed interest in building new cement factories in Jordan due to the excessive demand for this product at home and in the region. One of these companies already started construction activities and is expected to start commercial production in the year 2010. Based on the information available regarding this new factory and other planned factories, the baseline scenario assumes a 50 percent addition to the cement production capacity every 6 years. Other industries emitting CO_2 are expected to follow the same trend with a 20 percent increase in their activities every 6 years. The sector's share in total emissions will drop from around 8 percent in the year 2000 to 6 percent in the year 2033.

3.2.4.3 Emissions from agriculture

The agriculture sector's contribution to the overall economic activity in Jordan has been historically modest (3 percent of GDP in the year 2007, (MWI, 2009)). No major changes are expected to take place in the sector except for a modest increase in its constituent activities over this study time horizon. The major two sources of GHG emissions are enteric fermentation and manure management.

For the baseline scenario, activities in these two domains are not expected to change; therefore the future emissions were calculated as a direct function of the activity levels contemplated in related tables (Tables (C5 - C7), Appendix (C)). The underlying assumption is that the present self sufficiency degree in animal production is preserved, and a modest annual increase of 1.0 to 1.5 percent in animal production is assumed.

As for the GHG emissions, the sector's contribution is negligible as can be seen from Table (C10), Appendix (C).

3.2.4.4 Emissions from land use, land use change and forestry

Emissions from this sector are estimated based on the optimistic scenario adopted by the Ministry of Agriculture regarding forestation and rangelands conservation projects.

This sub sector being a net emitter as per the year 2000 GHG Inventory; emissions are expected to gradually drop.

The overall contribution of this sector in the total GHG emissions is modest (3.7 percent in the year 2000) and it decreases gradually to a mere 1 percent in the year 2033 (see Table (C10) and Figures (C3 and C4), Appendix (C)).

3.2.4.5 Emissions from waste sector

In the commercial and domestic wastewater treatment sub-sector, WAJ converted all wastewater treatment units to aerobic mode by the end of the year 2008, therefore reducing methane emissions considerably. On the other hand, interest in CDM projects is escalating and several specialized companies have expressed interest in exploiting the potential methane emissions from wastewater treatment plants to generate electricity and achieve reductions in GHG emissions. This line of development will be presented in detail in the mitigation part of the report.

Nitrous Oxide emissions from human sewage was calculated based on the expected population growth in Jordan as published by the Department of Statistics and based on the per capita protein consumption factor approved and published by Food and Agriculture Organization (FAO).

As for the methane emissions from solid wastes, the recovered methane part was limited to the Ruseifeh landfill which is already recovering methane and producing electricity. The future expansion of this landfill is also considered as part of the baseline scenario. Potential methane recovery projects from other landfills are part of the mitigation scenario. Emissions from the waste sector represent 13.5 percent of total emissions in the year 2000 and are expected to decrease to 6 percent in the year 2033; mainly due to the assumption that WAJ will adopt aerobic treatment plants in the near future which leads to minimizing methane emissions considerably.

3.3 MITIGATION SCENARIO

The mitigation team proposed a total of thirty eight GHG mitigation projects (see Table (C12), Appendix (C)) in the following areas:

- Primary energy,
- Renewable energy,
- Energy efficiency,
- Waste, and
- Agriculture

The cost, benefits and CO_2 emission reduction are analyzed for each proposed project. Net present value method was used in the financial calculations, by converting all of the present and future revenues and cost over the period of the project to a base of today's cost. The same approach was also followed in calculating the CO_2 emission reductions over the lifetime of the proposed projects. A discount rate of 8 percent was used in all calculations. The discounted unit cost of reduced emissions is the quotient of the discounted net cash flow to the discounted emission reductions.

The results of the analysis are presented in the following sub-sections.

3.3.1 Proposed Mitigation Projects in Primary Energy

Among the applicable options that can be applied in Jordan to mitigate CO_2 emissions are shifting from oil to natural gas in electricity generation sector, employing efficient technologies that consume less fuel; such as combined cycle, and demand side management.

Natural gas combustion emits 1.2 times less CO_2 than that of oil, which indicates that using natural gas in industries as an alternative for diesel and fuel oil will mitigate a good quantity of CO_2 emissions. Using the natural gas in a distribution networks in Amman, Zarqa, and Aqaba, will mitigate about 7.8 millions tonnes of CO_2 emissions in the next 30 years.

Utilizing combined cycle technology in Samra power plant will be very efficient. This technology will add 100 MW to the plant without any extra cost for additional fuel. This can lead to significant reduction in fuel consumption and CO_2 emissions in the 30 years life time of the plant.

Demand side management (DSM) includes all actions implemented to reduce the contribution to system peak load or reduce the overall energy consumption. Applying DSM in Jordan will mitigate about 1.4 millions tonnes of CO_2 emissions through the next 30 years.

The cost and the CO_2 emission reductions are analyzed for the five proposed projects. A summary of the results is shown in Table (3.1).

Table 3.1: Emission reductions and emission reduction unit cost for Primary Energy Projects

Project name	Total emission reductions (thousand tonnes $CO_{2\,eq}$)	Reduction unit cost (JD/t CO_{2eq})
Demand side management	8174.13	-28
Natural gas network/Aqaba	3201.02	-5.5
Natural gas network/Zarqa	7469.05	-4.7
Natural gas network/Amman	10670.07	-6.5
Conversion of Samra power plant to combined cycle	9791.92	-25.5
Total	39306.21	

3.3.2 Proposed Mitigation Projects in Renewable Energy

The following foreseen renewable energy projects were investigated based on the recommendations that were adopted by the Royal Committee of national energy strategy. The execution of wind farm projects is based on build-own-operate (BOO), so the source of finance is private. For simplicity, no loans were considered for these projects. In the national energy strategy, it was decided to promote the utilization of solar water heaters in 50 percent of houses in Jordan by the year 2020; while the current numbers for the year 2008 are about 14 percent. Since this program was considered as a project in total, the initial cost of the project was considered as the total cost of the total installed solar water heaters (SWH) in the year 2008, and the cost of the newly installed ones is the yearly cost. The operation and maintenance cost is assumed to be 2 percent of the yearly cost.

Table 3.2: Emission reductions and emission reduction unit cost for renewable energy projects

Project name	Total emission reductions (thousand tonnes $CO_{2\,eq}$)	Reduction unit cost (JD/t CO_{2eq})
Aqaba wind farm	2,064,613.50	89.3
Kamsha wind farm	2,124,232.50	87.5
Al-Hareer wind farm	12,989,114.50	70
Ibrahimya wind farm	1,940,840.50	101
Fujaij wind farm	2,915,563.00	98
Ma'an wind farm	8,209,391.00	95
Solar water heaters	33,769,358	-189
Total	64,013,113.00	

3.3.3 Proposed Mitigation Projects in Energy Efficiency

A global consensus on climate change mitigation has established energy efficiency as a key priority to address this growing problem. The present proposed projects investigate the potential of energy saving and the resulting emission reduction for a selected spectrum of local energy consuming sectors. Most of the proposed energy saving projects resulted from local and international field studies carried out by MEMR and NERC in local energy consuming sectors.

The energy saving projects discussed in this report covered three local energy consuming sectors; industrial, commercial and residential. Most of the selected energy saving projects were focused on the industrial sector due to the fact that this sector has a high degree of diversity in energy consumption modes and processes involved, which expands the scope of energy saving measures and projects in this sector.

In the industrial sector, the industries covered in the study included ceramic, food and canning, paper, steel, plastic, chemical and mining industries. In the commercial sector, the study covered hotels and a medical facility. Most of the fuel types used locally were covered in this study; and include diesel (gas oil), heavy fuel oil, and gasoline. The corresponding emission reduction factors used in these fuels expressed as carbon emission factor are as follows: 20.2 tonnes of carbon/ TJ for diesel (gas oil), 21.1 tonnes of Carbon/ TJ for heavy fuel oil, and 18.9 tonnes of carbon/ TJ for Gasoline. For electrical energy it was assumed that each 1 MWH of electrical energy produced corresponds to 0.67 tonnes of carbon dioxide.

In the financial calculations, no escalation rate was included, especially in the fuel prices. This assumption was adopted because it would be very complicated to forecast the fuel prices due to the high rate of change of these prices globally and locally.Table (3.3) summarizes the emission reductions and emission reduction unit cost for each energy efficiency project.

Table 3.3: Emission reductions and emission reduction unit cost for energy efficiency projects

Project name	Total emission reductions (thousand tonnes CO2 eq)	Reduction unit cost (JD/t CO2eq)
Ceramic factories	5004	-245
Food factory	1819	-125
Insulation/food factory	1164.75	-251
Waste heat rec./hotel	385.5	-251
Winter pool/hotel	485	-259
Medical factory/ballast	5120	-160
Canning factory/compressed air	2145	-68
Solar heating/hotel	3940	-234
CF lamps/residential	1980000	-55.2
Variable speed drive (VSD) in pumps/paper factory	2261.25	-73.5
Steel factory/reg. burners	36925	-98
Mining industry/heat recovery	14740	-61
Total	2053990	

3.3.4 Proposed Mitigation Projects in Waste Sector

3.3.4.1 Proposed projects for domestic solid waste landfills

The following tables show the summary results for the most important domestic solid waste landfills (DSWLFs) in Jordan.

Table 3.4: Emission reductions and emission reduction unit cost for municipal solid waste projects

Project name	Total emission reductions (thousand tonnes CO2 eq)	Reduction unit cost (JD/t CO2eq)
Aldulail DSWLF	2,109,323	-3.77
AL-Ekaider DSWLF	4,218,646	-4.48
Al-Karak DSWLF	5,274,102	-4.43
Al-Salt DSWLF	1,758,563	-3.51
Maddaba DSWLF	3,339,365	-4.3
Total	16,670,000	

3.3.4.2 Mitigation projects in wastewater treatment plants

Table (3.5) summarizes the emission reductions and emission reduction unit cost for each domestic wastewater treatment Plant (DWWTP) project.

Table 3.5: Emission reductions and emission reduction unit cost for DWWTP projects

Project name	Total emission reductions (thousand tonnes CO2 eq)	Reduction unit cost (JD/t CO2eq)
Aqaba tertiary DWWTP	296,877	32.12
As-Samra DWWTP	14,115,146	5.51
Baqa’a tertiary DWWTP	741,016	19.29
Madaba DWWTP	288,316	29.38
Ramtha DWWTP	397,842	25.05
Salt DWWTP	305,676	30.06
Wadi Arab DWWTP	1,716,800	13.75
Total	17,861,673	

3.3.5 Proposed Mitigation Projects in Agriculture

The agriculture sector in Jordan represents around 3 percent of GDP (MWI, 2009) due to the arid climate and the domination of the desert on most of the Jordanian lands. This sector contributes little to the overall GHG emissions and at the same time provides little opportunities for mitigation. Two projects are presented in Table (3.6), and were considered by the mitigation team as most promising.

Table 3.6: Emission reductions and emission reduction unit cost for agriculture projects

Project name	Total emission reductions (thousand tonnes CO2 eq)	Reduction unit cost (JD/t CO2eq)
Growing perennial forages in the Badia region	34.467	182
Awareness program for applying best management practices in irrigated farming fertilization applications	152.250	-287

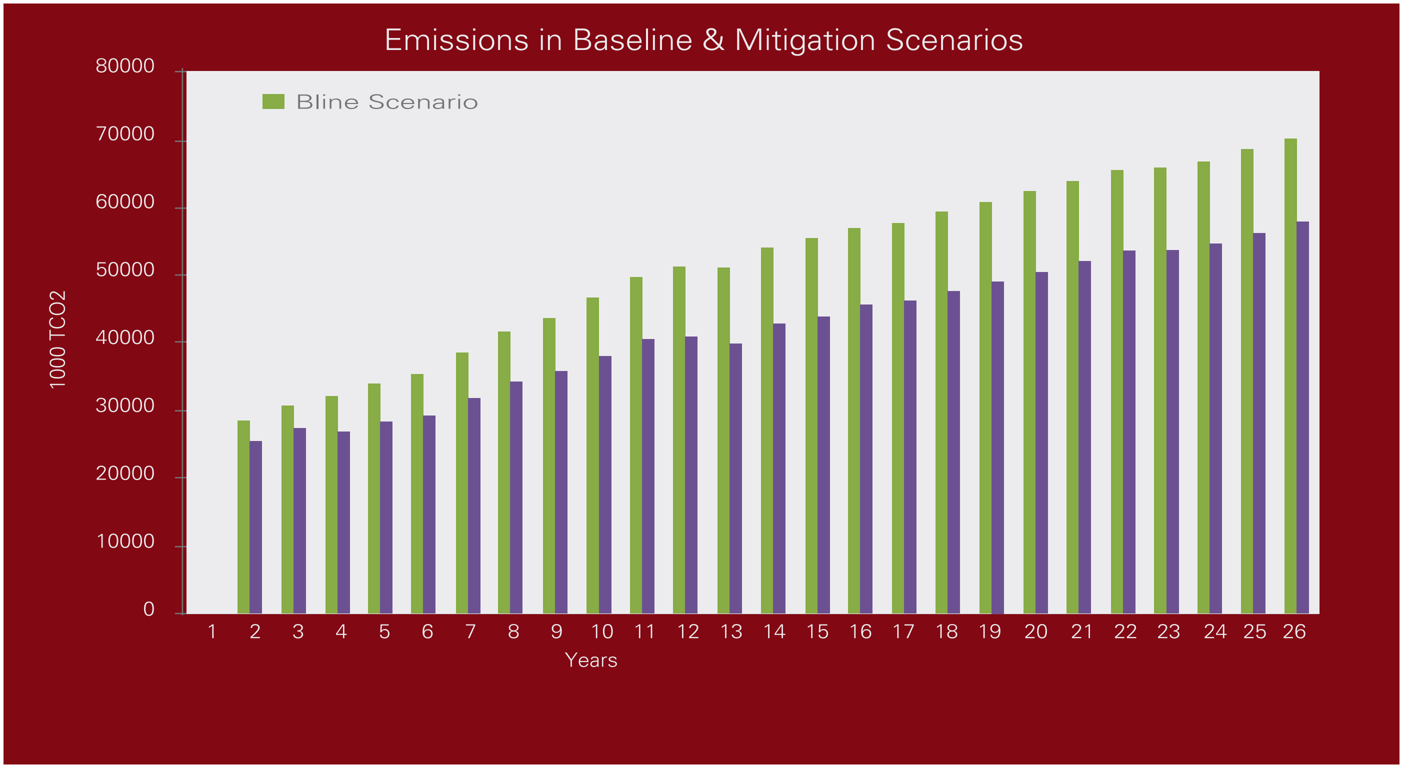
3.3.6 Emissions Reduction

Yearly emission reductions from all proposed mitigation projects over the period of 2009 to 2033 are shown in Table (C13), Appendix (C). The investigated mitigation projects if executed, will lead to annual reductions of 2,761 thousand tonnes in the year 2009; and are expected to increase to 12345 thousand tonnes in the year 2033, which represents 9.7 percent and 17.5 percent from baseline emissions; respectively. Table (3.7) and Figure (3.2) provide a comparison between baseline scenario emissions and mitigation scenario emissions.

Table 3.7: Baseline and mitigation scenarios emissions (000 tonnes $CO_{2\ eq}$.)

Years	2009	2015	2020	2025	2030	2033
Baseline scenario emissions	28441	41788	51249	59474	65934	70377
Mitigation scenario emissions	25679	34451	40012	47878	53899	58031.23
Reductions	2761	7335	11236	11595	12034	12345
Reductions (%)	9.7	17.5	22	19.5	18.2	17.5

Figure 3.1: Emissions in Baseline & Mitigation Scenarios



3.3.7 Main Results of the Mitigation Analysis

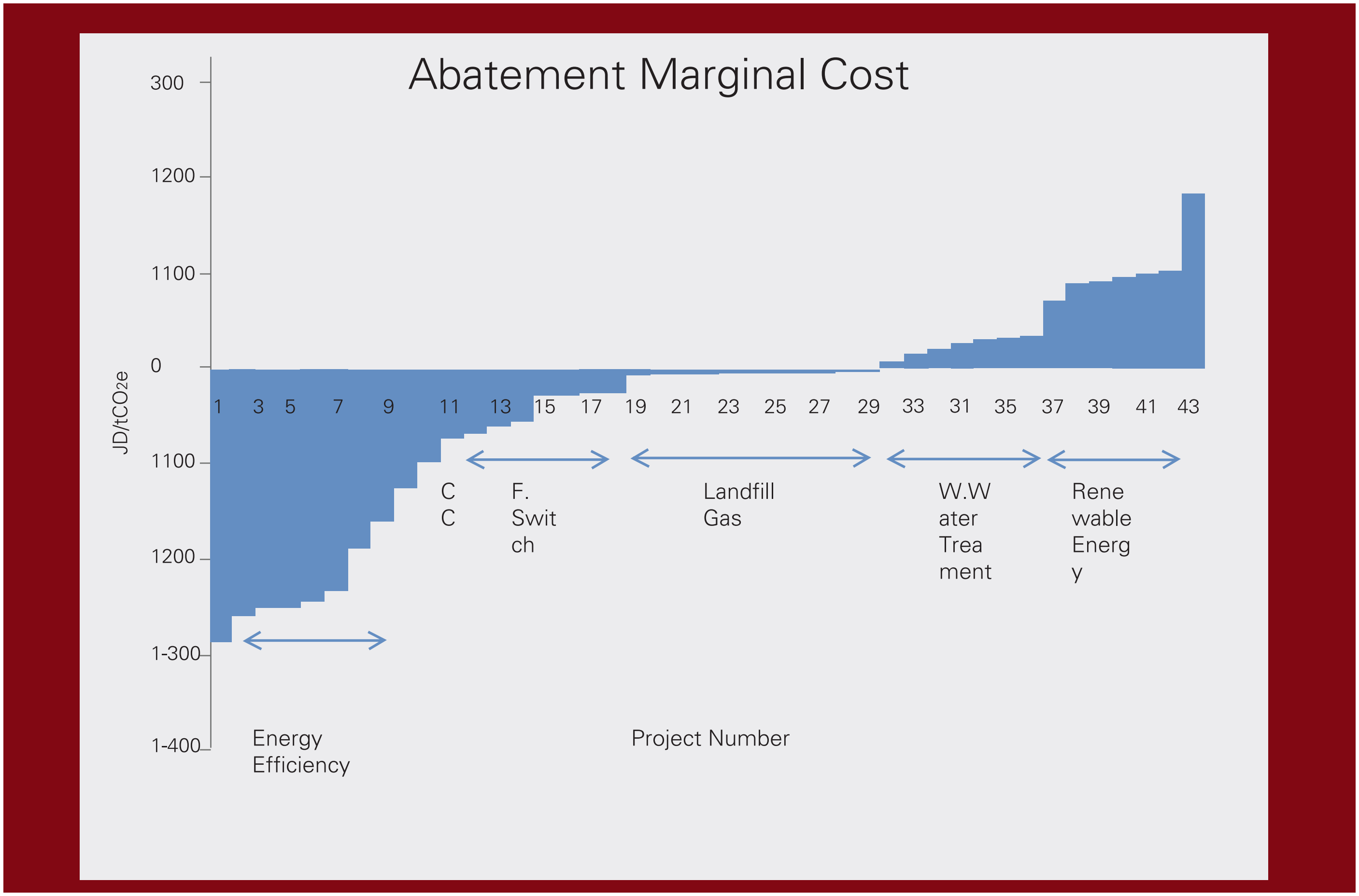
A priority order may be established for executing the above mentioned projects. (See the abatement marginal cost curve, Figure 3.2). Based on unit abatement cost, the most feasible options obviously are energy efficiency projects where unit cost range is -61 to -245 JD/t CO_2. In light of recent developments in the global energy markets and the unprecedented increases in energy prices, this result is not surprising. What is surprising actually is the reluctance in performing these projects. There should be minimum barriers facing the financing of these projects in light of their feasibility, an effort to raise the awareness of both project owners and financial institutions must be a priority to the government.

Second on the priority scale is projects of demand side management with abatement unit cost of -28 JD/t CO_2 which are energy conservation measures. Converting simple cycle power plants to combined cycle also presents a feasible option (-25.5 JD/t CO_2) for obvious reasons of higher efficiency and lower natural gas prices in the Jordanian case. Fuel switch to natural gas projects are also a feasible option with an abatement unit cost around -5.5 JD/t CO_2. This marginality can be enhanced under CDM through CERs sales revenues.

Third on the priority scale is projects based on landfill gas collection and utilization for power generation. The abatement unit cost for these projects is around -4 JD/t CO_2. This marginality of project feasibility is enhanced under the CDM, through revenues from CERs sales.

As for domestic wastewater projects, it is obvious that developing these projects only for the purpose of producing

Figure 3.2: Abatement Marginal Cost Curve



power is not feasible. These projects may have a chance under CDM if limited to the capture and incineration of methane. Wind power plants are less attractive compared to commercial power plants using fossil fuels. CDM may improve the situation somewhat (with less than 1 US cent/ KWh in the case of Jordan) but other forms of subsidy are still required to encourage wind farm technology.

Results of mitigation analysis show that the major areas that should receive the most attention are:

- *Fuel switch and introducing natural gas to the national energy system. This option is actively pursued by the government of Jordan, where licenses are already issued to natural gas companies to install natural gas networks to supply commercial and residential consumers.*
- *Renewable energy, which is being encouraged by getting the proper attention from the government of Jordan. The Kamsha wind farm project (40 MW) was tendered for private companies and offers are already under evaluation. The Government of Jordan has an ambitious plan to expand wind farms up to 600 MW by the year 2020, and tenders for relevant farms are under preparation.*
- *Energy efficiency which suffers from inherent problems that are being addressed by the new energy law and the introduction of the new law of energy efficiency fund. The objective of this action is to facilitate energy efficiency, and provides for financial incentives for energy efficient appliances.*

The implementation of these mitigation options will enhance sustainable development through minimizing dependence on imported energy, maximizing security of supply through energy source diversification, minimizing energy cost to the economy, creating new employment opportunities, and improving local environment.

3.4. REFERENCES

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VULNERABILITY ASSESSMENT AND ADAPTATION MEASURES

4. VULNERABILITY ASSESSMENT AND ADAPTATION MEASURES

4.1 INTRODUCTION

This chapter assesses the expected impacts of climate change on Jordan and provides a survey of activities performed in implementing Article 4.1 of the UNFCCC Convention with emphasis on adaptation. The analysis was based on the Technical Guidelines for Assessing Climate Change Impacts and Adaptations of the Intergovernmental Panel of Climate Change (IPCC, 2001) and on the United Nations Environmental Program (UNEP) Handbook of Methods for Climate Change Impact Assessment and Adaptation Strategies (UNEP, 1998). The carried out analyses have focused on the sectors of water resources, agriculture and health and on selected socio-economic factors.

Estimates of the impacts of climate change were based on methods of impact projection using biophysical, empirical-statistical and process models. In addition, empirical analogue studies and expert estimates were employed. Validation and sensitivity analyses were also used for the models. The climatic conditions in Jordan during the period 1961-2005 were employed as starting points.

Climate change is not only a major global environmental problem, but also an issue of great concern to a developing country like Jordan (Abdulla and Al-Omari, 2008). The earth's climate has demonstrably changed on both global and regional scales since the pre-industrial era, with some of these changes attributable to human activities. The changes observed in the regional climate have already affected many of the physical and biological systems and there are indications that social and economic systems have also been affected. Climate change is likely to threaten food production, increase water stress and decrease its availability, result in sea-level rise that could flood crop fields and coastal settlements, and increase the occurrence of diseases, such as malaria. Given the lack of resources, and access to technology and finances, developing countries such as Jordan have limited capacity to develop and adopt strategies to reduce their vulnerability to climate change.

Jordan's vulnerability and adaptation study (V&A), which was carried out as part of the activities of the Second National Communication (SNC), focused on two issues: climatology and the assessment of (V&A) for the relevant sectors: agriculture, water resources, socio-economic and health. These sectors as well as the study sites were selected based on a national meeting of main stakeholders.

An assessment of the impact of projected climate change on natural and socio-economic systems is central to the whole issue of climate change. Climate change impact assessment methodology followed in this study is consistent with the seven step analytical framework developed by the IPCC. The approach begins with the definition of the scope of the problem and the assessment process. Steps 2 and 3 of the IPCC are selecting and testing methods. Step 4 is concerned with selection of climate change scenarios. Steps 5 and 6 are concerned with conducting the climate change assessment process which includes assessment of biophysical impacts, and assessment of socioeconomic impacts. The last step is concerned with evaluating the adaptation strategies.

4.1.1 Vulnerability Issues

Jordan like other developing countries is vulnerable to the impacts of climate change. Given the nature of scientific knowledge and the problems associated with the availability, accuracy and reliability of data in the country, the task of a scientifically sound basis for impact and vulnerability assessments becomes all the more daunting. Furthermore, the difficulties of differentiating between impacts caused naturally as a process of climate change from the ones emanating as a result of human induced activities pose additional difficulties in framing the appropriate policy responses.

Vulnerability and impact assessment studies were conducted for key sectors as part of the research undertaken for Jordan's SNC. These studies were undertaken to evaluate the effects of climate change and to understand the long term impacts that changes in climate variables such as temperature and precipitation can have on key sectors of the economy.

4.1.2 Vulnerability and Adaptation Study Objectives

The objective of this study is to determine potential implication of climate change on water resources, agricultural, health and socio-economic sectors in Jordan and to suggest appropriate adaptation measures and then to incorporate the results into related national policies and strategies.

The specific objectives and outputs are:

1. Define trends in existing records of temperature, precipitation, evaporation, sunshine, and stream flow for selected locations in Jordan.
2. Develop climate change scenarios. There are two main types of scenarios:
    a. Scenarios based on the General Circulation Models.
    b. Incremental scenarios.
3. Investigate, analyze and evaluate the impact of climate change on agriculture, water resources and health sectors as well as socio-economic systems.
4. Identify potential adaptation responses that are required to be adopted to face the predicted changes and impacts on these sectors.

4.1.3 Description of the Study Areas

Based on the meeting with the relevant stakeholders, Zarqa and Yarmouk rivers' basins were selected as the main study areas (Figure 4.1). Both are the most important basins in the country with respect to their economical, social and agricultural importance. In both sites, rainfed and irrigated agriculture is practiced (Figure 4.2).

Zarqa River Basin (ZRB) is the second main tributary to River Jordan after Yarmouk River Basin (YRB), and thus one of the most significant basins in the country with respect to its economical, social and agricultural importance. The Basin is located in the central part of Jordan and extends from Jabal Druz in the east to River Jordan in the west. The ZRB is located between 213 to 319 East and 140 to 220 North and covers an area of 3567 km^2 from the upper northern point to its outlet near King Talal Dam (KTD). And the ZRB covers parts of five governorates, namely; Amman, Balqa, Jarash, Mafraq and Zarqa, and it hosts three major cities (Amman is the largest) where about 40 percent of the country population lives. The ZRB is also considered as one of the major productive groundwater basins in Jordan. The natural wadis included in this study area are five major sub-catchments: Wadi Abdoun, Wadi Ain Ghazal, Wadi Al-Sukhnah, Wadi Rumeimin and Wadi Jerash

The ZRB is the most complex resource system in Jordan. At the lower end of the basin King Talal Dam (KTD) is located, with a capacity of 85 million cubic meters (MCM). The stream flow conditions of the river are governed by torrential discharge characteristic with very low base flow that ranges from 0.5 to 1.0 m^3/s contrasted with irregular flood caused by rain storms of about 54 MCM. The groundwater safe yield of the basin is about 90 MCM while the abstraction rate amounts to about 158 MCM. Part of the deficit in Baqa'a and Amman-Zarqa aquifers may be compensated from seepage due to leaks in pipe network or excess irrigation. Amman area receives about 40 MCM from the basin groundwater for municipal uses. Industries in the basins pump about 8 MCM. Extractions for irrigation are estimated at 110 MCM. The annual effluent of the wastewater treatment plants totals about 85 MCM where most of it flows into KTD while only about 5 MCM are used in the basin and along the river banks for restricted irrigation. Municipal use, including that of Amman, totals about 180 MCM/yr.

Yarmouk River basin (YRB) has a drainage area of about 6790 km^2 of which 1384 km^2 lie within Jordan. The natural wadis included in the study area are four major sub-catchments: Wadi Hamra, Wadi Shallala, Wadi Al-Shomar and Wadi Abyad. The maximum elevation is 1150 m above mean sea level at Rass Munif and the minimum elevation is -200 m below mean sea level at the Jordan Valley and at the end of the catchment.

The western parts of Yarmouk basin are mainly rainfed areas where olive trees and wheat are planted, in addition to other crops of fruit trees and summer crops of vegetables. The eastern parts of Yarmouk basin extend in the low rainfall zone of the country where open grazing is practiced and rainfed barley is cultivated to support the grazing herds. Irrigation is taking place in different parts of the Yarmouk basin using groundwater.

Detailed studies were conducted on this basin and subsequently many datasets were developed and compiled for the basin. Recently, a European Union (EU) funded project entitled: "optimization for sustainable resources management" (OPTIMA, 2006) was implemented to optimize water resources in the basin. Different data were generated by the project including land use and digital elevation model. Land use/cover of both study sites is shown in Table (4.1). Generally, intensive rainfed agriculture is taking place in Yarmouk while more irrigation is practiced in Zarqa. In both sites, open grazing is a dominant land use.

Figure 4.1: Location of the Zarqa and Yarmouk basins (note: study was limited to the Jordanian parts of the basins)

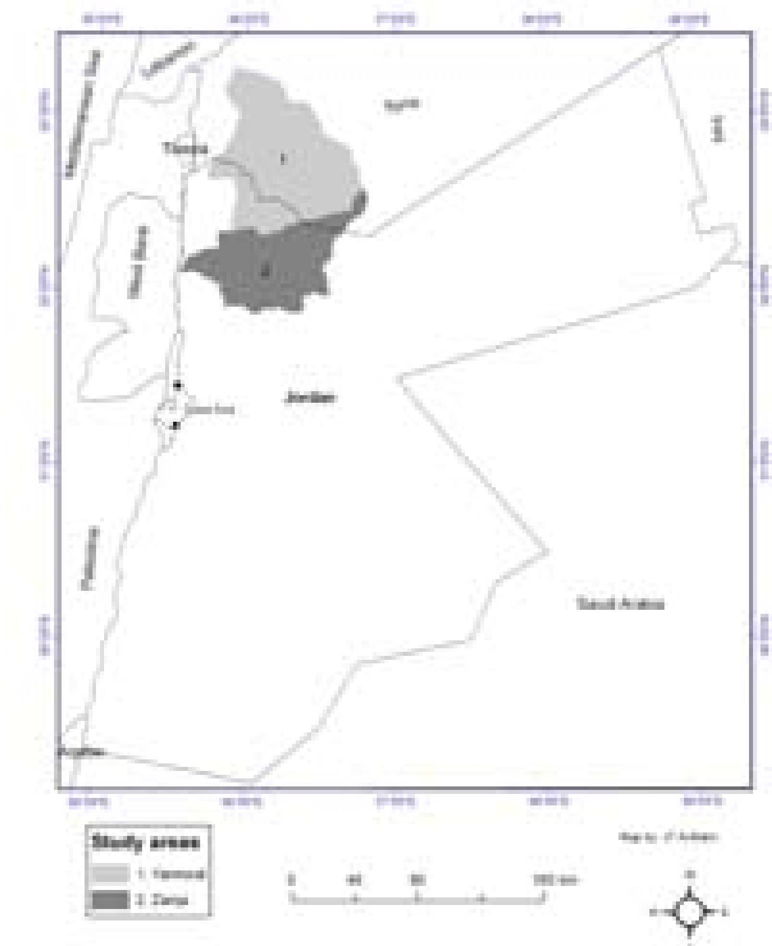


Figure 4.2: Current land use/cover of the Zarqa (bottom) and Yarmouk (top) basins (adapted from Salameh 2006 and Kharabsheh 2008)

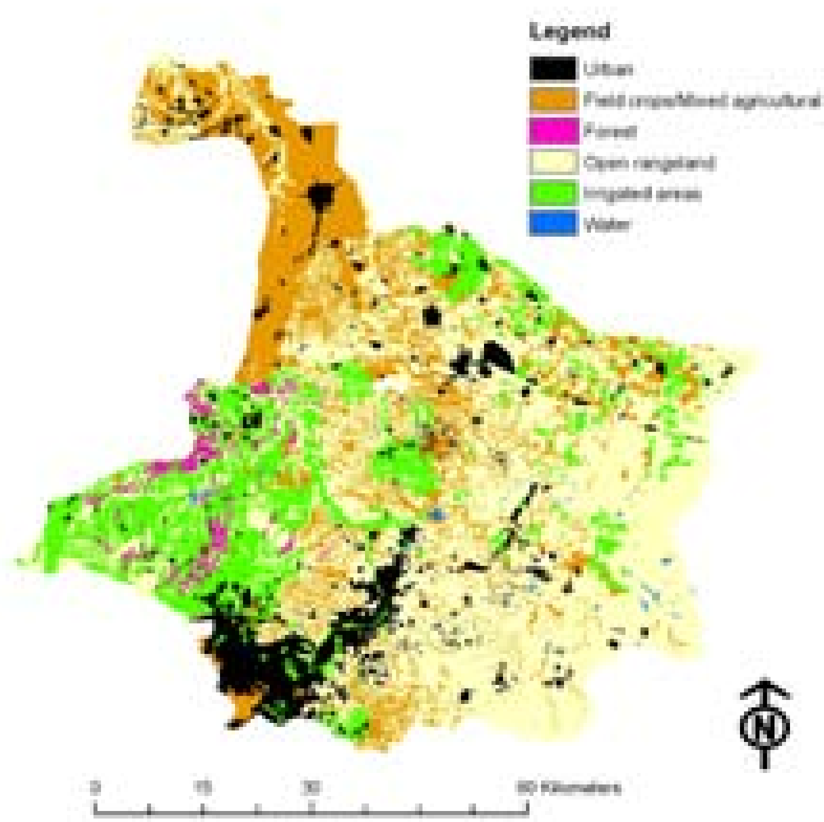


Table 4.1: Land use/cover percent in both study sites (Salameh 2006 and Kharabsheh 2008)

Land use/cover (Description)	Yarmouk	Zarqa
Urban (residential, commercial and industrial)	8.6	9.8
Rainfed field crops/mixed agricultural areas	49.2	12.2
Irrigated areas (farms of vegetables and fruit trees)	7.4	20.1
Open range (non cultivated areas used for browsing)	34.7	55.5
Forest (recreational forest and parks)	--	2.0
Water bodies (KTD, small earth dams and wastewater treatment plant (WWTP))	--	0.4

4.2 CLIMATE, CLIMATIC TRENDS AND CLIMATE CHANGE SCENARIOS

Emission of pollutants increases the concentration of the long-lived greenhouse gases in the atmosphere and leads to global warming. Global surface temperature has increased by about 0.3 – 0.6°C since the late 19th century and about 0.2 – 0.3°C over the last 40 years in the 20th century (Houghton et. al, 1995). The global temperature has risen rapidly during the period beyond the year 1970 up to the end of the second millennium and similarly during the first few years of the third millennium. The surface temperatures do not increase uniformly. Therefore the regional and local consequences of the global climate change differ from one place to another over the planet's surface. Studies show that the minimum temperature has increased in a rate higher than twice the rate of maximum temperature increase (Freiwan and Kadioglu, 2008). Also it is found that the rate of warming varies from one region to another on the earth surface and the precipitation shows either increasing or decreasing rates in various regions on the earth's surface.

In the following sub-sections, the climatic trend of important climatic factors mainly; temperature and precipitation are presented. This is followed by a description of the baseline and climate change scenarios.

4.2.1 Trend Analysis of Climatic Variables

The climatic trend is defined as a monotonic increase or decrease in the average value between the beginning and the end of an available time series. Therefore, the linear trends are not the correct tool to detect the start of the trend. Among some nonparametric trend tests is the sequential version of the "Mann-Kendall rank trend test" which has the ability to detect the beginning and/or the end of the trend. The Mann-Kendall test is widely used for trend testing, particularly when many time series need to be analyzed at the same time (Sneyers, 1990; DeGaetano, 1996; Freiwan and Kadioglu, 2008).

In this study, the available longest (1961-2005) monthly time series of precipitation, mean temperature, maximum temperature, minimum temperature, relative humidity, Class A-Pan evaporation, number of rainy days and sunshine duration are analyzed. This was carried out to identify meaningful long-term trends by making use of the Mann-Kendall statistics in addition to the linear trend statistics. The Mann-Kendall trend and the linear trends of the time series of the above mentioned eight meteorological variables at the 19 locations (Figure 4.3) are evaluated. For example, Figure (4.4) shows the Mann-Kendall trend values versus the linear trends of the time series of the above mentioned eight meteorological variables at Irbid station.

The Mann-Kendall statistics' values out of ± 1.96 (approximately 2.0) and the values out of ± 2.54 (approximately 2.5) are considered statistically significant at the 5 percent and the 1 percent confidence levels; respectively. The Mann-Kendall trend statistics of the above mentioned climatological variables at the selected stations have been calculated and summarized in Table (4.2). In order to identify the spatial variation of increasing or decreasing Mann-Kendall trends of the climatological variables mentioned above, the results have been illustrated in maps using kriging techniques. The Surfer software was employed to generate illustration figures and maps using the kriging method (Davis, 1986).

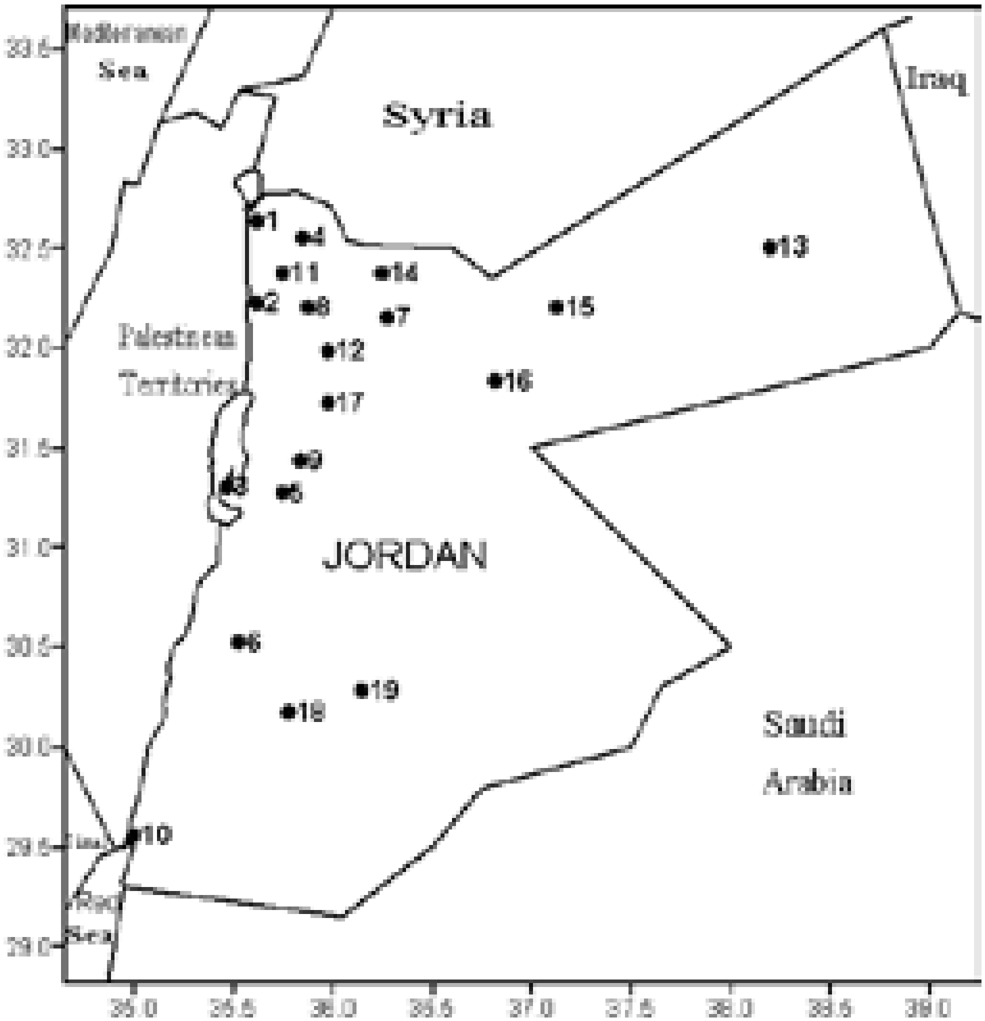
Decreasing trends in the annual precipitation by 5-20 percent in the majority of the stations are apparent evidence of climate change in Jordan during the last 45 years, but very few stations such as Ruwaished in the extreme east and Ras Muneef in the northwest experienced an increase in the annual rainfall amount by 5-10 percent. Larger rainfalls associated with a decrease in the number of rainy days may lead to an increase in the daily rainfall intensity and, thus, increase in the chance of recording extreme precipitation values. On the other hand, many other stations experienced increasing number of rainy days associated with decreasing annual precipitation amounts. In this case a smaller amount of precipitation will spread over a longer period of time and consequently the daily rainfall intensity may be reduced. This has been observed in stations such as Wadi Dhuleil, Irbid and Al–Rabba. Increasing trends in relative humidity of about 4–13 percent during the last three decades in the majority of the study locations are observed.

The significantly increasing trends in relative humidity mainly started to occur at the end of the decade 1970's. The yearly total of evaporation shows significant decreasing trends in all locations, and started to occur in the 1960's and 1970's. Most of the stations experienced significant decreasing trends of sunshine duration. The decrease in sunshine hours ranged between 2 percent and 8 percent and started in the decades 1960's and 1970's. This decrease may be attributed to the increase in cloud cover.

Table 4.2: Mann-Kendall trend statistics of climatological time series of precipitation, mean maximum and minimum temperatures, relative humidity, evaporation and sunshine duration. (* sign indicates significant trends at the 5 percent confidence level, ** sign indicates significant trends at the 1 percent confidence level, the $ sign indicates that the meteorological element is not measured in the related station and the € sign indicates that the time series is too short)

No.	Station name	Precipitation	Mean Temp.	Max. Temp.	Min. Temp.	Relative Humidity	Evaporation	Sunshine Duration
1	Baqura	-0.05	1.4	3.98**	-0.72	-0.37	-0.03	-1.12
2	Deir Alla	0.31	2.42*	0.52	5.15**	1.48	-0.75	-3.21**
3	Ghor Safi	-0.36	3.73**	3.44**	3.16**	3.55**	-2.27**	-4.52**
4	Irbed	-0.44	1.2	-0.09	3.28**	2.55**	-3.53**	-1.95
5	Al-Rabbah	0.2	1.34	2.09*	0.1	1.05	-7.06**	-0.36
6	Al-Shoubak	-2.85**	2.63**	3.61**	1.32	-1.73	-2.67**	-2.36*
7	Wadi Dhulail	-1.29	3.96**	3.64**	3.69**	1.99	0.03	-0.16
8	Jordan Univ.	0.67	4.69**	2.15*	4.71**	-1.86	$	$
9	Madaba	-1.93	1.97	1.38	3**	3.02**	$	$
10	Aqaba A/P	-0.32	0.75	-0.28	2.65**	3.51**	-5.27**	-2.08*
11	Ras Muneef	0.71	1.66	2.06*	0.83	4.98**	0.11	-0.52
12	Amman A/P	-1.14	1.03	-1.27	3.04**	0.94	-3.75**	-8.21**
13	Ruwaished	1.68	2.74**	1.22	4.5**	2.16*	-3.88**	-2.69**
14	Mafraq	-0.83	2.58**	1.34	3.49**	1.55	-2.99**	-2.67**
15	Safawi	0.6	3.74**	3.53**	1.48	2.94**	-3.35**	-2.76**
16	Azraq South	-2.08*	3.37**	1.45	3.27**	0.68	€	€
17	Q.A.I.A/P	-0.22	5.48**	5.34**	4.76**	-0.8	-3.27**	0.71
18	Ma'an	-0.22	1.88	0.61	2.57**	1.27	-4.79**	-3.4**
19	Al-Jafr	-0.05	4.29**	1.66	4.12**	2.45*	€	-4.3**

Figure 4.3: Location of the selected meteorological stations



NO	Station Name
1	Baqura
2	Deir Alla
3	Ghor Safi
4	Irbid
5	Al–Rabba
6	Al–Shoubak
7	Wadi Duleil
8	Jordan Univ.
9	Madaba
10	Aqaba Airport
11	Ras Muneef
12	Amman Airport
13	Rwaished
14	Mafraq
15	Safawi
16	Azraq South
17	Q.A.I.A./P.
18	Maan
19	Al Jafr

Figure 4.4: Linear trend (left) and Mann-Kendall trend (right) of rainfall, number of rainy days, relative humidity, class A–Pan evaporation, sunshine duration, maximum temperature, minimum temperature and mean temperature time series in Irbid

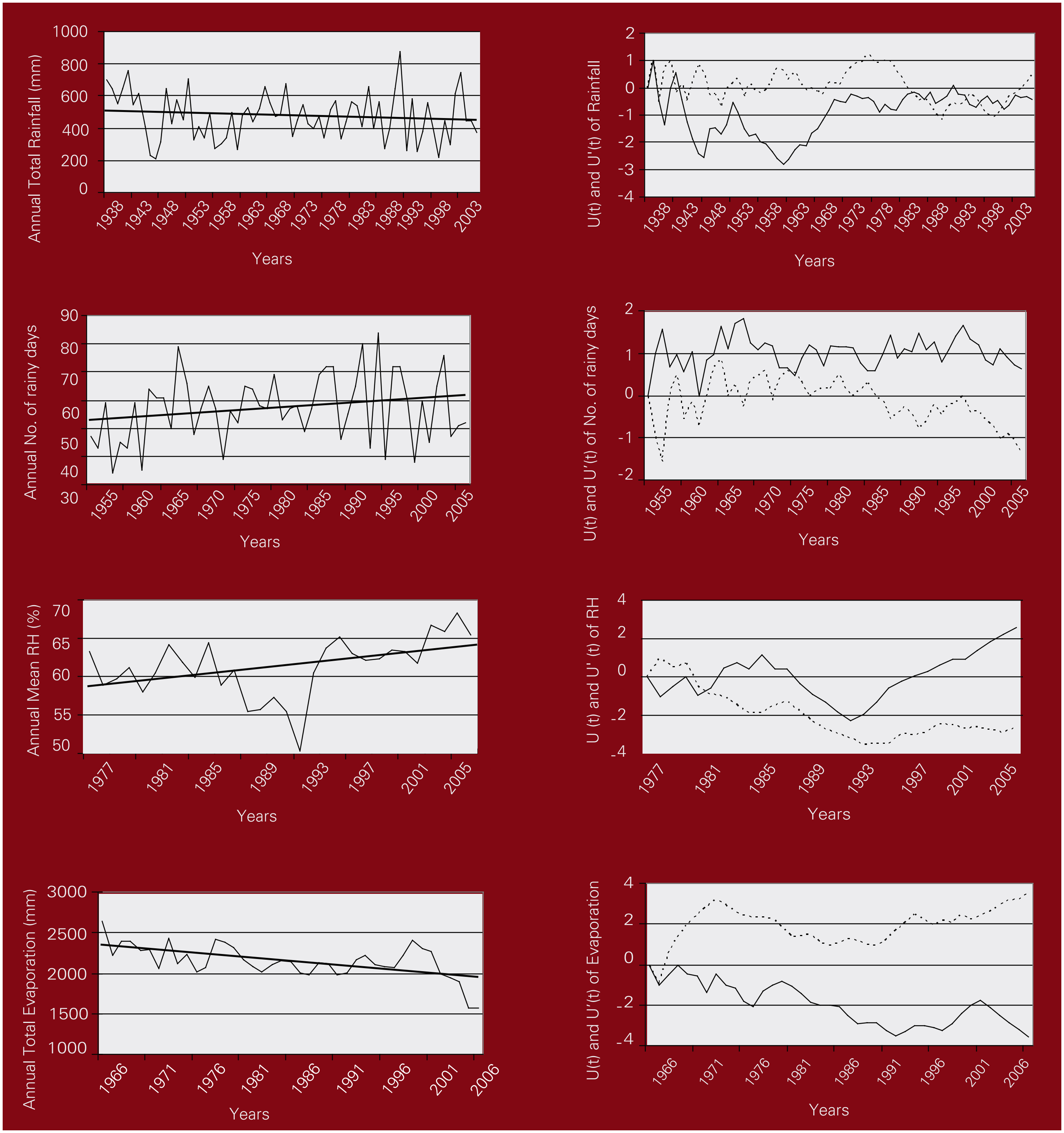
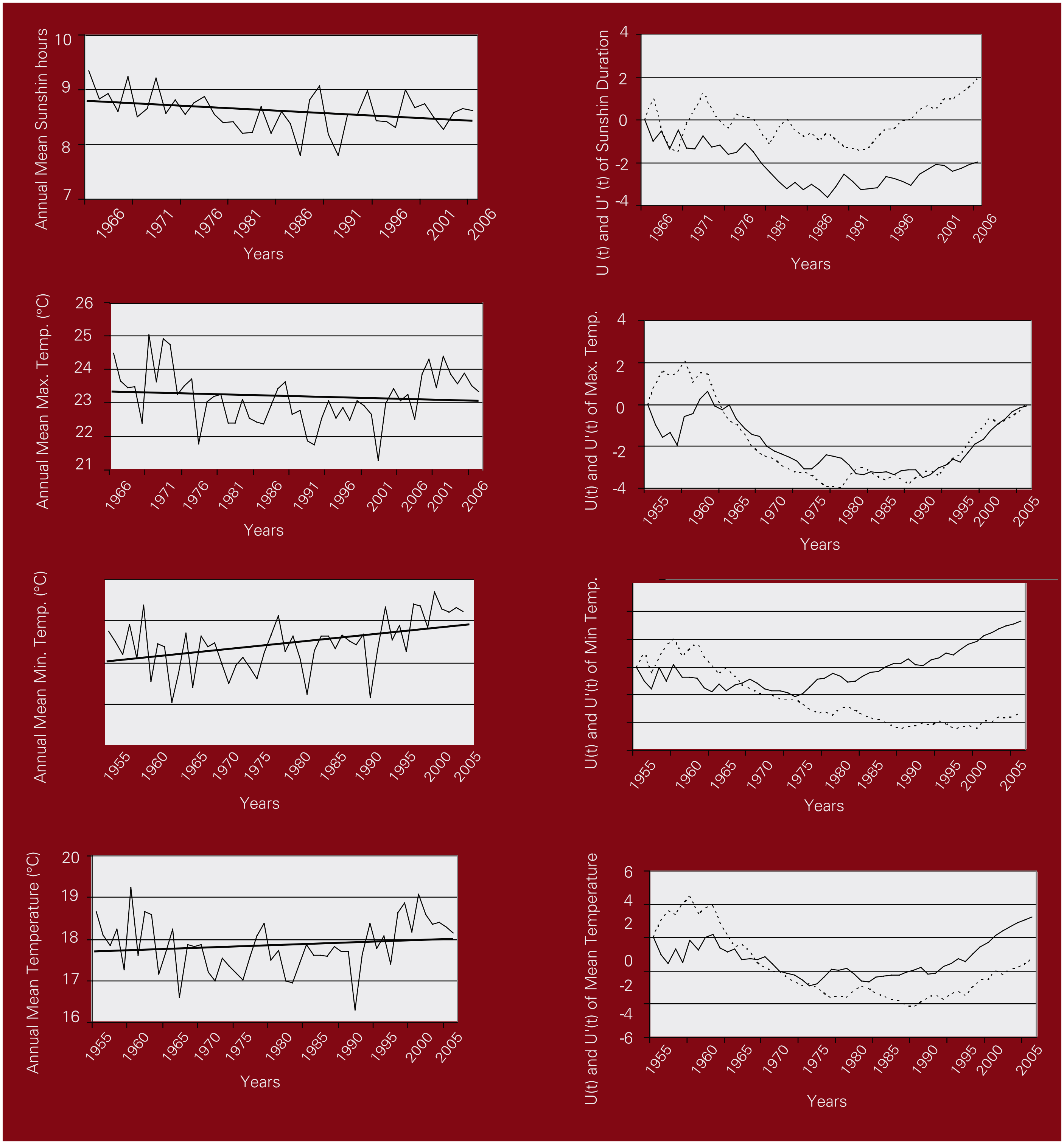


Figure 4.4: Continued



4.2.2 Baseline Climate Scenarios

A baseline climate is the climatic conditions that are representative of recent prevailing climatic trends for a given period of time in a specific geographic area. A baseline climate describes average conditions, spatial and temporal variability and anomalous events over the baseline period. The baseline climate should provide sufficient information on those present-day conditions that will be characterized in the scenarios under a changing climate at the appropriate temporal and spatial scales. It also provides a benchmark that helps measure future changes in climatic variables and assesses the impacts of future changes. In addition, impact assessors might use baseline climate data to calibrate and test impact models. Good quality observed climatological data are often required to define a baseline climate (IPCC-TGCIA, 1999).

In this study, the climate baselines are constructed to cover the period 1961-2005. The climatological data used to develop the baseline scenarios were obtained from the Jordanian Meteorological Department. Baselines of the daily mean air temperature and daily precipitation are developed in 9 synoptic meteorological stations distributed over the whole study area. These stations are Baqura, Deir Alla, Wadi Al-Rayyan, Irbid, Ras Muneef, Ramtha, Mafraq, Wadi Dhulail and Amman Airport.

The V&A assessment studies in various sectors require the climate data at daily time intervals. The purpose of selecting a baseline scenario that covers the last 45 years of the climatological record in the study area is to construct a projection of climate change scenarios for the next 45 year period; 2005-2050.

4.2.3 Climate Change Scenarios

Climate change scenarios describe plausible future changes in climate variables and are usually measured with respect to baseline climate conditions. Climate scenarios usually (although not always) combine observed baseline climate with estimates of future climate changes. These possible changes are often (although not always) derived from climate model outputs (Abdulla et al., 2008).

The most common approach to deriving climate change scenarios is to make use of climate model outputs. Three types of climate models have been developed to provide projections of future climate changes, each with progressively higher resolution: (i) Simple Climate Models, (ii) General Circulation Models, or Global Climate Models (GCMs) and (iii) Regional Climate Models (RCMs).

In this study, temperature and precipitation outputs of 13 GCMs for a period of 45 years (1961-2005) were extracted from the IPCC Data Center. These outputs were compared to the observed climatological data in order to select the most appropriate models and consequently to construct climate change scenarios.

Of the 13 GCMs, 10 models have been excluded from the analysis because they have too coarse resolution and no single grid point of the models' grid points has lied within the territory of Jordan. The remaining 3 models are:

1. CSIROMK3: Commonwealth Scientific and Industrial Research Organization (CSIRO) Model, Australia.
2. ECHAM5OM: The 5th generation of the ECHAM general circulation model, Max Planck Institute for Meteorology, Germany.
3. HADGEM1: HADley Center Global Climate Model, UK.

The resolution of the first two models (CSIROMK3 and ECHAM5OM) is 1.875° Lat. × 1.875° Lon. which is approximately equal to 200 × 200 km. One of the models' grid points lies exactly on the Baqura meteorological station at the northwestern corner of the country and also at the northwestern edge of the study area. The next grid points are 200 km to the east and to the south, and that is approximately double the dimensions of the study area.

The spatial resolution of the third model (HADGEM1) is slightly finer than the first two models; it is 1.25 Lat. × 1.875 Lon. But the distribution of the grid points over the country is different; one of the grid points lies to the east of Amman at the southeastern corner of the study area and the next grid points to the north and west are outside the study area.

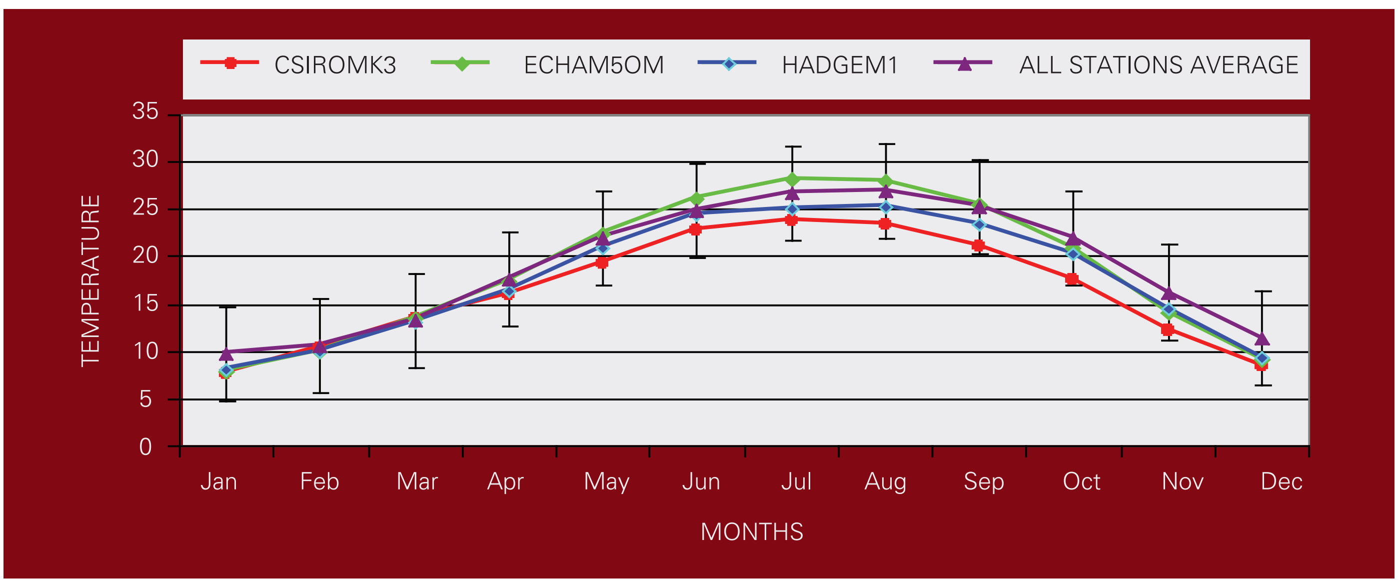
The typical grid resolution in state-of-the-art GCMs is still too coarse to examine effects of local topography and land use, and to assess climate change impacts in local sites. As a result, it was necessary to apply spatial interpolation to produce sufficient number of grid points in the study area. Increasing the number of grid points does not necessarily increase the accuracy of the model projections but increases the coincidence probability of grid points and selected single sites which may facilitate the use of the GCMs projections in these sites.

In this study, the GCMs baseline scenarios of mean air temperature are interpolated for the 4 corners then for the center of the study area and are compared to the observed average mean air temperature calculated from the 9 meteorological stations that represent the study area, which is shown in Figure (4.5). The figure apparently shows that the temperature baselines of the three models are in good agreement with the observed temperature of the study area. Furthermore, the models' monthly temperatures are within the range of the monthly values of the observed temperature in the 9 meteorological stations.

General circulation models are considered the best source for developing climate change scenarios. The outputs of the three models were combined with the baseline climate data to produce climate change scenarios that could serve as inputs for vulnerability assessments. The GCM climate change scenarios are developed by adding the difference between the future projections and the baselines of the GCMs to observed values (for temperature) and by multiplying the ratios of the future projections to the baselines of the GCMs by the observed values (for precipitation).

The adjustment statistics of the difference between the equilibrium GCM outputs for monthly mean air temperature and precipitation are presented in Table (4.3).

Figure 4.5: Comparison of the mean temperature baseline scenarios of the selected 3 models and the average mean temperature at the observation stations in the study area



All the scenarios show an increase in temperature of less than 2°C. As a rule, warming should be stronger during the warm months of the year while less warming is projected to occur in the cold months of the year. The climate change scenarios for precipitation are highly variable. The annual precipitation projections of the three models; CSIROMK3, ECHAM5OM and HADGEM1, are expected to be 100 percent, 90 percent and 82 percent of the observed annual precipitation; respectively. CSIROMK3 model expects an increase in precipitation in the rainy season from October to May and a decrease in the summer months. Additionally, ECHAM5OM model shows a decrease in precipitation in the rainy season from November to April. The third model HADGEM1 exhibits an increase in the months February to May as well as December and a decrease in the rest of the other months.

Table 4.3: Adjustment statistics (precipitation ratio and temperature difference between the future projections and the baselines of the GCMs) generated by the three General Circulation Models

Model	CSIROMK3		ECHAM5OM		HADGEM1	
Month	Average precipitation ratio	Average temperature difference	Average precipitation ratio	Average temperature difference	Average precipitation ratio	Average temperature difference
Jan.	1.03	1.43	0.89	0.91	0.94	0.95
Feb.	1.06	0.60	0.94	0.45	1.13	0.85
Mar.	1.03	0.83	0.71	0.84	1.75	0.67
Apr.	1.26	0.85	0.37	0.98	1.40	1.38
May	1.39	0.95	1.04	1.02	1.23	1.18
Jun.	0.76	1.49	1.10	0.53	0.26	1.27
Jul.	0.78	1.17	0.56	1.22	0.04	1.65
Aug.	0.77	1.12	1.93	1.22	0.07	1.49
Sep.	0.80	1.32	0.65	0.78	0.20	1.52
Oct.	1.02	1.67	1.09	0.93	0.70	1.45
Nov.	1.00	1.17	0.69	0.98	0.71	1.37
Dec.	1.12	0.34	0.85	0.89	1.43	1.46

The Australian model; CSIROMK3, predicts an increase in precipitation over the whole year except for the summer months where usually no precipitation occurs in Jordan. The British model; HADGEM, predicts an increase in precipitation in the cold and rainy months of the year and a decrease in the rest. While the German model; ECHAM5OM, predicts a decrease in precipitation in the cold and rainy months and an increase in the summer hot months.

In conclusion, it can be said that the GCM climate change scenarios estimate a general increase in temperature in Jordan of approximately 1.0 to 1.3 °C by the year 2050 and that summer warming is more substantial than winter warming. But the GCM climate change scenarios of precipitation do not agree with each other.

4.2.4 Incremental Scenarios

Developing incremental scenarios is the simplest way to obtain climate change scenarios. They provide a wide range of potential regional climate changes and help identify sensitivities to changes in temperature and precipitation (Abdulla et al., 2008). For the study area, increases in temperature of +1°C, +2°C, +3°C and +4°C were combined with no change, and with –20 percent, –10 percent, +10 percent, and +20 percent changes in precipitation. As a result, 20 incremental climate change scenarios were developed, as shown in Table (4.4).

The main disadvantage of using incremental scenarios is that they may not be physically plausible. Also, uniform climate changes throughout a year are not realistic. For instance, the estimated warming in summer should be much greater than in winter. Despite these concerns, incremental scenarios are appropriate for Jordan, which has great spatial and temporal variability in precipitation; warm and rainy years as well as hot and dry years.

Table 4.4: Increments used to construct the 20 incremental climatic change scenarios

Dry Scenarios							
– 20%				– 10%			
+ 1 °C	+ 2 °C	+ 3 °C	+ 4 °C	+ 1 °C	+ 2 °C	+ 3 °C	+ 4 °C
Normal Precipitation Scenarios							
0%							
+ 1 °C		+ 2 °C		+ 3 °C		+ 4 °C	
Wet Scenarios							
+ 20%				+ 10%			
+ 1 °C	+ 2 °C	+ 3 °C	+ 4 °C	+ 1 °C	+ 2 °C	+ 3 °C	+ 4 °C

The twenty incremental scenarios have been constructed for each selected station in the study area as monthly and daily scenarios. The incremental adjustments shown in Table (4.4) were combined with the 45-year climatological time series (1961-2005) of daily mean temperature and daily precipitation amounts to construct the daily incremental scenarios for the period 2006-2050 in each of the 9 stations of the study area.

These incremental scenarios as well as the GCMs daily scenarios were used in the vulnerability assessment of the selected sectors to climate change.

4.2.5 Obstacles, Constraints and Limitations of Climate Scenarios

The natural variability of climate could be as large as the changes that have been actually observed. In the case of Jordan, the data time series are usually too short to identify a definite long-term climatic trend. But it might be a good indication of the direction of recent climate variability and to series behaviors. Although the baseline period is selected to cover the period 1961 – 2005, the record period of the climatological data at some of the meteorological stations in the study area is shorter than the baseline period. It ranges between 30 and 45 years. There are missing data in the daily and monthly climatological time series at the majority of stations. The missing data were estimated before the use of the time series in trend analysis and in construction of the climate change scenarios.

Several major constrains and gaps were identified during preparation of the thematic studies on vulnerability assessment. The most persisting one is the problem in data availability, consistency and transparency. Existing monitoring of climate and water resources conducted by Meteorology and Hydrology Services in the country is facing permanent problems in operation, slow modernization of equipment, reduction of monitoring network, etc. Therefore, improvement of the hydrological and meteorological monitoring stations, improvement of data processing, and implementation of predictive models in real time and modernization of equipment (in field, laboratory, software and hardware) are of highest importance in the near future. Soil monitoring does not exist, as well as ground water monitoring. Basic maps and data bases are hardly available. There is a need for increasing technical capacities for monitoring and updating of basic data sets. Modern tools for vulnerability assessment are needed. In the field of climate change and climate change scenarios there is a need to establish regional models and downscaling models.

Typical limitations are summarized as follows:

- Due to incomplete observational records, proxy data have to be used (e.g., data from a neighboring station or weather generator used to fill in the gaps in the record, etc.),
- Due to time and resource constraints, uncertainties related to emission scenarios and climate models are not adequately represented in scenarios, and
- Coarse spatial and temporal resolutions, or the "wrong" time frame of climate scenarios, do not match the requirements of policy-oriented applications.

Although it does not resolve the limitations, explicit documentation could be helpful to inform potential users and enable them to place scenario information into proper perspectives. Good reporting and documentation will also help highlight major knowledge and/or data gaps to individual government agencies and international bodies. This is an important first step in addressing unresolved information needs.

4.2.6 Conclusions

The most important conclusions can be summarized as follows:

- The majority of stations exhibit slight decreasing trends in precipitation time series. While some other stations, such as: Ruwaished, Safawi, Deir Alla, Jordan University and Ras Muneef, exhibit insignificant increasing precipitation trends.

- The number of rainy days reveals decreasing trends of about 3 percent-10 percent in most of the stations, but it is significant only in few of them. The change in the number of rainy days has an adverse impact on the temporal distribution of rainfall over a season. This feature is discussed in the agricultural sector.
- If the increasing rainfall amount in a particular location is accompanied by a decreasing number of rainy days, the rainfall intensity will accordingly increase and the probability of recording extreme values of rainfall will also increase. Ruwaished, Ras Muneef and Jordan University are typical examples of such locations.
- The maximum, minimum and mean temperatures reveal significant warming trends at 99 percent confidence level in most of the stations. The significant warming trends of minimum temperature are greater than that of maximum temperature. As a result, the mean temperature shows significant warming trends in all stations.
- Relative humidity is one of many factors affecting evaporation. Evaporation and relative humidity are inversely proportional. In the absence of other factors, lower relative humidity results in greater evaporation. This is the case with the majority of stations. The relative humidity exhibited significant decreasing trends, leading to significant increasing trends in evaporation.
- A great coincidence of the significant decreasing trends of both evaporation and sunshine duration is noticed. Which means that the decrease in sunshine duration leads to a decrease in evaporation.
- All of the GCMs future scenarios for the period 2005-2050 show an increase in temperature of less than 2°C. The warming was found to be stronger during the warm months of the year while less warming is projected in the cold months of the year.
- The climate change scenarios for precipitation are highly variable. The Australian model; CSIROMK3, predicts an increase in precipitation over the whole year except the summer months where usually no precipitation occurs in Jordan. The British model; HADGEM1, predicts an increase in precipitation in the cold and rainy months of the year and a decrease in the rest of the months. Additionally, the German model; ECHAM5OM, predicts a decrease in precipitation in the cold and rainy months and an increase in the summer hot months.

4.3 VULNERABILITY AND ADAPTATION OF AGRICULTURE SECTOR

Climate change is seen as the most important change that will affect agricultural sector in developing countries, as vulnerability of this sector is high and adaptation measures are restricted by the limited resources of these countries. In Jordan, agriculture is one of the most sensitive sectors to climate change induced impacts. Due to urban expansion in the high rainfall zones, rainfed agriculture had expanded towards the marginal lands of arid and semiarid areas that receive less than 200 mm of annual rainfall. For many years, rainfed agriculture in these areas suffered from droughts and accelerated soil degradation and overgrazing of natural vegetation. In these areas, barley is usually cultivated to support the grazing herds whose stocking densities are too high, although in many years grain production is not guaranteed.

The shift towards irrigated agriculture to meet the country's need of food is not possible as the country's water resources are scarce. Currently, irrigated agriculture consumes less than 64 percent of the country's water resources. This share is expected to decrease as water will be prioritized for domestic and industrial uses. According to the first national communication report of Jordan to the UNFCCC, an increase of temperature by 2 ºC would increase irrigation demand by 18 percent while a 10 percent reduction in precipitation would result in an increase of approximately 5 percent in irrigation demand. These combined effects would aggravate the problems of agricultural sector and would emphasize the need for adaptation measures. As climate change is expected to have significant impacts on water supplies in Jordan, the competition on water among different sectors will be exacerbated. This will leave low quality water for agriculture and will result in creating serious challenges of soil and water management.

This section includes analysis of baseline scenarios and analysis of projected scenarios and their impact on rainfed cultivation in two important surface water basins in the country; ZRB and YRB.

4.3.1 Selection of Crops

In order to assess the vulnerability of agriculture sector to climate change, the sub-sectors of plant and animal production were analyzed using the data from Department of Statistics (DOS) for the period 1996-2006. This period was only used to analyze agricultural sector (baseline conditions) and not to assess the impact of climate change, which was assessed by the use of longer period of data (27 years). The trends and variations among years were evaluated in relation to rainfall.

Data from DOS showed that during 1996-2006, the irrigated area was about 75 thousands ha while the total rainfed area was about 132 thousands ha. Most of agricultural areas in Jordan are rainfed, with 93 percent being cultivated with field crops. On average, 33 percent of rainfed areas were cultivated with wheat while 58 percent were cultivated with barley. Both crops formed important source of feed for sheep and goats whose numbers were estimated at 2.7 million heads. Data showed that the harvested areas for both wheat and barley were less than the cultivated ones, which was attributed to crop failure due to drought conditions and erratic rainfall distribution. Therefore, both crops were selected to assess the impact of climate change on rainfed agriculture in Jordan.

Both ZRB and YRB are characterized by intensive agricultural activities of rainfed and irrigated cultivation. In addition, open grazing and browsing of natural vegetation and barley are practiced in both sites. Figures of livestock showed that the study areas had considerable number when compared with total number in the country. Both study areas had 73 percent of the country's sheep, 61 percent of the country's goats and 84 percent of the country's cattle. Most of the sheep and goats are found in Mafraq governorate, while most of the cattle are found in Zarqa. Data of plant production showed variation in the cultivated and harvested areas in both study areas. Generally, Yarmouk basin had the highest total yield of wheat, barley, lentil and chickpea. In both study areas, the total yield was extremely low in the year 1999, the driest year during the period of 1996-2006. Also, the ratio of harvested to cultivated areas was lower for barley than for wheat. This could indicate that barley was more sensitive to drought conditions and inter annual variations of climatic conditions. Finally, both study areas are important contributors to agricultural sector of the country, particularly in cultivating rainfed field crops and breeding of livestock. Therefore, both should be prioritized in terms of adaptation measures and plans.

4.3.2 Methodology

The methodology included the analysis of existing data of crop production in both study areas and application of a crop model to predict crop yield under different scenarios of climate change. The trends of yield in both study areas were investigated for both wheat and barley during the period 1996-2006. Daily weather data for the period 1970-2005 were used to simulate crop yield in the baseline scenario. Also, these data were modified according to the climate change scenario to predict the yield of both wheat and barley.

Following the IPCC guidelines, the Decision Support System for Agrotechnology Transfer (DSSAT), crop simulation model was selected (Boote et. al, 1998; Ritchie et al., 1998; Tsuji et al., 1994). This model was used to predict the impact of climate change on the two main rainfed crops; wheat and barley. The model has been widely used in the US and worldwide over the last two decades because it is reasonably accurate, process-oriented, and simple (Kalra et al., 2007). The model requires daily weather values of solar radiation, maximum and minimum temperatures and precipitation. The simulation models, including DSSAT, are usually preferred over production function models which test crop yield under one variable while assuming optimum conditions and inputs for crop growth.

4.3.3 Crop Modeling

Daily weather data for the period 1970-2005 were acquired from the meteorological department. While data of crop yield were retrieved from the official website of DOS. Additional data for yield of wheat was obtained from the annual reports of the National Center for Agricultural Research and Extension (NCARE) for Maru agricultural research station, located within Yarmouk basin. Irbid was selected as the reference for model application because it was considered to be the main rainfed area in the Yarmouk basin.

DSSAT model was run for wheat and barley for a period of 10 years (1996-2005) using the weather data of Irbid. Output was compared with the data of DOS. For most years, the absolute difference between the DSSAT predicted grain yield of wheat and the observed one was less than 530 Kg/ha (45 percent of the DOS average) with a residual mean square of error (RMSE) of less than 586 kg/ha. For barley, the average yield obtained from the model was very close to the average of the DOS data with a difference of about 5 Kg/ha (< 0.5 percent of the DOS average).

Based on the initial results, the model was inter-calibrated and refined assuming different varieties of wheat. By this, the RMSE decreased to 319 Kg/ha and the mean of the simulated grain yield for the ten years was only 30 Kg/ha different from the DOS ten-year average of grain yield. The model predicted an average yield of wheat of 1176 Kg/ha which was rather close to the DOS average of 1173 Kg/ha.

After model calibrating, climatic data were prepared to run the model for the years 1971-1999. Modifications were applied to temperature and rainfall according to the proposed 20 incremental scenarios of climate change that combine temperature change (+1, +2, +3 and + 4 oC) with changes in precipitation (no change, +10 percent, +20 percent, -10 percent, and -20 percent). In addition, the model was applied for three GCM scenarios that were scaled and implemented to project possible changes in temperature and rainfall in the next fifty years. The average value for yield was calculated and used as the predicted level of yield under each scenario. After examining the weather data, three vernalization periods of 40, 50 and 60 days were used to assess the impact of climate change on wheat. Vernalization periods are periods of low winter temperature that are needed to initiate flowering; as different winter wheat varieties have different vernalization requirements.

4.3.4 Results and Discussions

4.3.4.1 Trends of yield in the period 1996-2006

Analysis of rainfed and cultivated areas in the study area showed a slight increase during the period of 1996-1999 (Table 4.5). After the year 2000, irrigated areas started to decrease as water resources were prioritized for domestic and industrial uses. A similar trend was observed in rainfed cultivation which was affected by the dry season of the year 1999 which did not encourage farmers to cultivate their lands in the subsequent years. After the year 2000, the rainfed area fluctuated without an obvious increase or decrease. This could be also explained by the non-changed policy of forage subsidy during the period 2000-2006 which did not enforce farmers to expand barley cultivation in the low rainfall areas.

Results showed variations in the cultivated and harvested areas within the study areas during the period 1996-2006. Generally, an inconsistent trend of average yield of wheat and barley was observed among years and among the

Table 4.5: Summary of cultivated area, harvested area, total and average yield for wheat and barley in both study areas

	Wheat				Barley			
Year	Cultivated area (ha)	Harvested area (ha)	Total yield (tonne)	Average yield (Kg/ha)	Cultivated area (ha)	Harvested area (ha)	Total Yield (tonne)	Average yield (Kg/ha)
1996	6,252	5,383	8,261	7,031	26,293	7,525	6,233	580
1997	19,850	13,232	9,642	885	34,836	10,647	8,601	314
1998	16,544	8,651	9,637	432	45,823	9,498	6,950	411
1999	21,232	935	628	1,691	65,150	1,438	1,272	2076
2000	12,694	6,084	8,006	1,600	20,431	2,839	2,242	864
2001	16,953	6,328	9,020	879	43,826	10,879	7,240	325
2002	14,730	11,246	12,028	635	30,109	21,204	18,331	750
2003	13,226	9,899	13,052	754	19,956	7,615	9,214	1024
2004	12,349	3,774	2,778	160	39,026	12,067	4,521	215
2005	13,334	9,605	10,960	692	28,054	12,051	9,053	530
2006	12,341	8,200	7,381	310	22,824	10,985	3,174	200

governorates located within both study areas. For both study areas, the total yield was extremely low in the year 1999, the driest year during the period of 1996-2006. The average yield of wheat in both study areas was less than 1100 Kg/ha while the average yield of barley was 867 Kg/ha. It should be noticed that the data from the NCARE for wheat species (ACSAD 65 and Horani 27) showed higher yield (2260 Kg/ha) than the average yield obtained from DOS (1100 Kg/ha). This could be attributed to the supervised management practices followed in these stations. Therefore, these levels of productivity would be useful in suggesting adaptation plans following the practices of agricultural research stations.

Analysis of crop data also showed differences between cultivated and harvested areas for all rainfed crops in the study areas. These differences could be attributed to crop failure which would mainly result from droughts during the growing seasons. This fact emphasized that rainfed cultivation would be the most vulnerable sector that might be affected by adverse climatic impacts. The average ratio between harvested and cultivated area was 0.52 for wheat and 0.28 for barley (lowest among crops) which was mainly cultivated for hay.

4.3.4.2 Modeled yield

Results from the model showed variations in response between wheat and barley. For both crops, however, it was found that the reduction of rainfall by 10 to 20 percent had a negative impact on yield while the increase in rainfall by 10 to 20 percent had a positive impact on grain yield for both barley and wheat at the different temperature regimes. This would be attributed to water as the main limiting growth factor for wheat and barley under rainfed agriculture. The warming (increase in temperature by 1 °C to 4 °C) had negative impact on barley grain yield while it had a positive impact on grain yield of wheat (Figure 4.6).

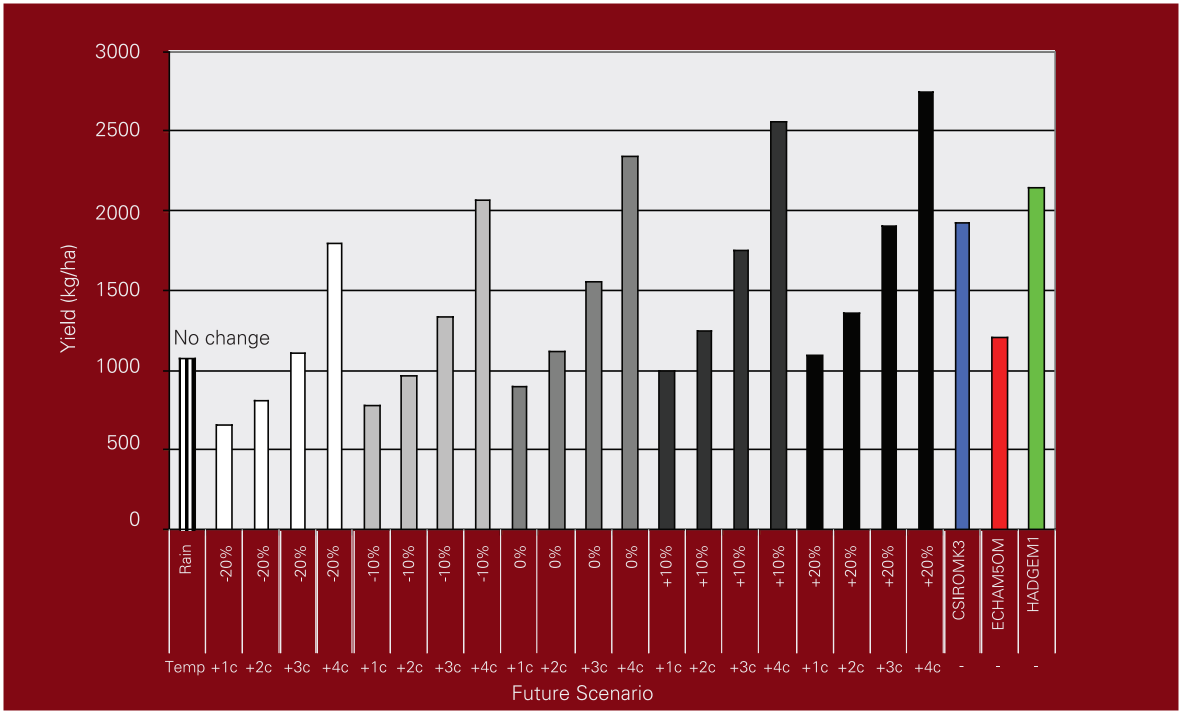
Interestingly enough, all scenarios had negative impacts on barley. However, an increase in rainfall amount would result in less reduction in the yield of barley, provided that the increase of temperature would not be more than 1 °C. At this point, the overall reduction in yield (200 Kg/ha) would be within the errors of prediction (RMSE of 476 Kg/ha). Generally, the increase in rainfall would not compensate for the adverse impacts of temperature increase.

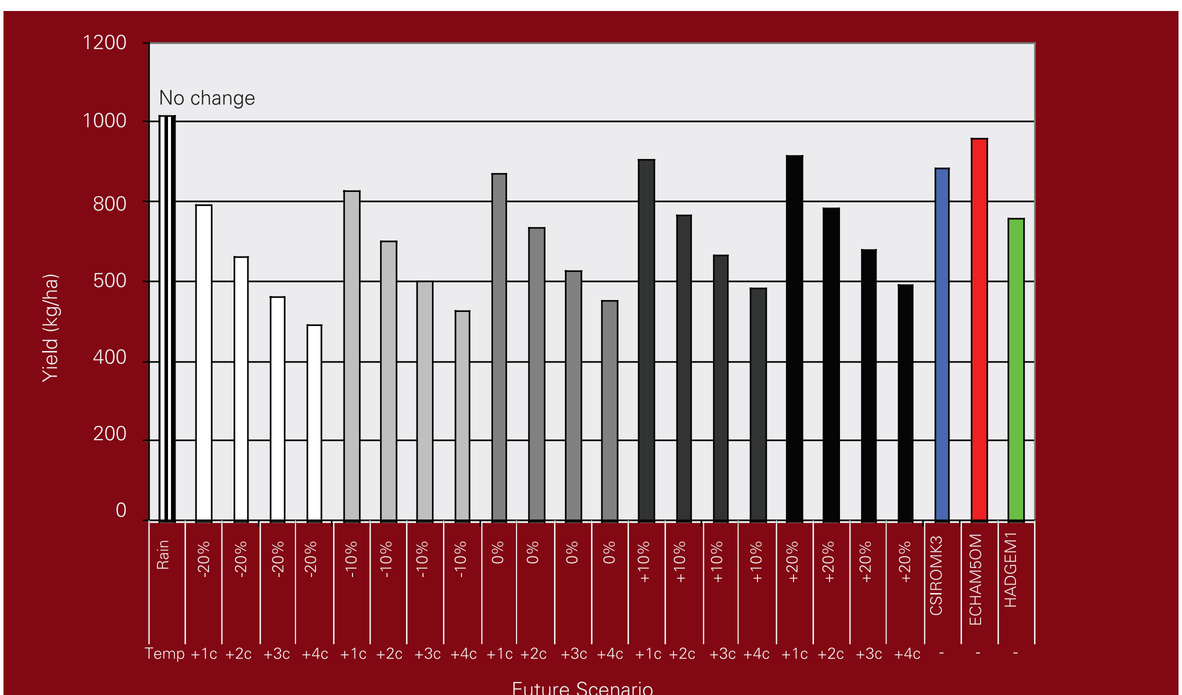
The trend for wheat was different from that of barley, as the increase of temperature would be more advantageous for yield if rainfall increased. The increase of temperature by 1 °C to 2 °C for wheat had adverse impacts on yield for dry scenarios, while it had positive impacts under no changes or increase in rainfall scenarios. These findings can be attributed to the fact that most rainfall was occurring in the period of December-February. This indicates that in mid-to-high-latitude regions, moderate warming would benefit cereal crop and pasture yield. These findings were also indicated by Parry et al. (2007).

Generally, any increase in temperature was expected to reduce the length of the growing season as a whole, as well as the grain filling period. Reducing the length of the growing season would reduce the crop water requirements and that should reduce the water stress under rainfed agriculture. Although this was expected to improve yield production, however reduction of grain filling period had a negative impact on grain yield because it would result in smaller grains. In the case of barley, this could be the main reason for grain yield reduction as temperature increased by 1 °C to 4 °C. In the case of wheat, although the length of growing season decreased, the length of grain filling period did not decrease significantly. This is because a decrease in the length of growing season results in shifting the grain filling period to colder days. This was more evident in wheat because it is usually harvested in June, while barley is usually harvested in May.

Results showed that the average modeled yield without climate change was 1083 Kg/ha for wheat and 1017 Kg/ha for barley. Results also showed that barley was always adversely affected under all scenarios. The reduction in barley yield would range from 52 Kg/ha under one of the GCM scenarios (ECHAM5OM model) to 523 Kg/ha under the extreme incremental scenario of a temperature increase of 4 °C and 20 percent decrease in rainfall. The maximum reduction in the yield of wheat reached 423 Kg/ha under a rainfall decrease of 20 percent and a temperature increase of 1 °C. The possible increase in the yield of wheat reached 1667 Kg/ha under the extremely wet scenario of 20 percent increase in rainfall and +4 °C in temperature. Results from DSSAT showed that the impact of temperature and rainfall on rainfed wheat and barley could not be separated. In addition, the trend of yield for wheat was opposite to that of barley for all incremental scenarios.

Figure 4.6: Simulated grain yield of wheat (top) and barley (bottom) under the different Incremental and GCMs climate change scenarios

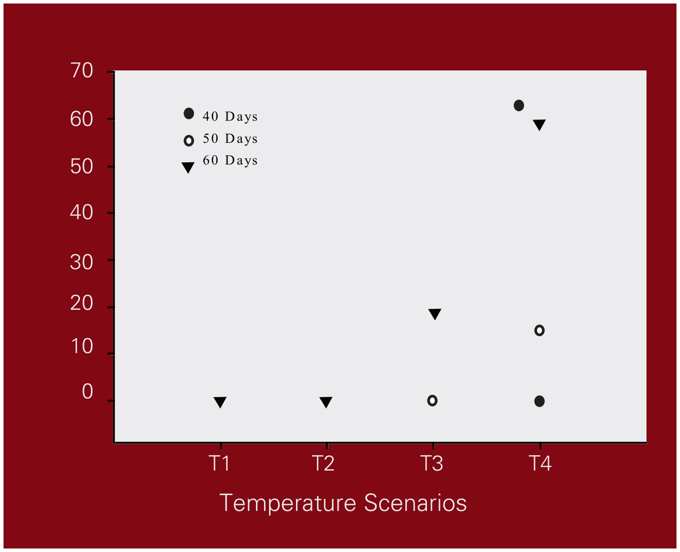




The DSSAT model predicted an increase in wheat production under the three GCM based scenarios, particularly for HADGEM1. Oppositely, an obvious decrease in barley yield was predicted for HADGEM1, and a slight decrease was observed for ECHAM5OM. Applying the three GCM models on the data of the 27 years of climatic records showed that both CSIROMK3 (+7 percent) and HADGEM1 (+19 percent) had a positive impact on wheat grain yield while ECHAM5OM resulted in about 33 percent reduction in yield compared to the 27-year average. The three GCM scenarios predicted negative impacts of barley yield, particularly the HADGEM1 which showed an average decrease of 33 percent when compared with the 27-year average. These results could be explained by the relatively high temperature difference and average precipitation ratio of this scenario when compared with the other two scenarios.

Implementing the DSSAT model for wheat with different vernalization showed that the percent of crop failure would be high under temperature scenarios of increase of 3 and 4 °C (Figure 4.7). Also, the percent of crop failure would increase with increasing the number of required days of vernalization; which implied higher crop failure in Zarqa than in Yarmouk study area. The use of crop varieties with 50 days of vernalization requirements in Yarmouk area would result in less crop production and in lower variation among the different climate change scenarios.

Figure 4.7: Simulated crop failure of wheat with 40, 50 and 60 days of vernalization requirements under the different climate change scenarios of temperature (Tx corresponds to an increase of x °C)



4.3.5 Adaptation, Alternatives and Evaluation Methodologies

Based on the previous analysis, adaptation measures are suggested for both rain-fed and irrigated agriculture in Jordan. Many of these adaptation measures were proposed by literature and research in similar environment. The measures, mainly proactive, are modified according to the components and inputs of agricultural sector in Jordan. The framework of FAO (2007) was followed to classify adaptation measures into two levels; farm level (autonomous adaptation) and at decision-maker level (planned adaptation). Some of these adaptations are seen as autonomous in the sense that no other sectors (e.g. policy, research) are needed in their development and implementation. In Jordan, both levels of adaptation are interrelated and can not be implemented without the integration of a top-down and bottom-up approaches. For example, the use of treated wastewater as a source for supplemental irrigation can not be achieved without a governmental plan that provides reclaimed water with high standards.

4.3.5.1 Autonomous adaptation

Several measures can be proposed to adapt the agricultural sector at farm level for both plant and animal subsectors. Farm level analyses have shown that large reductions in adverse impacts from climate change are possible when adaptation is fully implemented (Mendelsohn and Dinar, 1999). Therefore, the proposed measures mainly include:

1. Improvement of water use efficiency

The implementation of soil management and supervised irrigation practices is one of the important adaptation measures, as these practices are expected to increase crop yield per unit of water applied or stored in the soil. The problem of water shortage in Jordan requires the implementation of irrigation management information system (IMIS) at the farm level. This system shall provide the farmer with the exact crop water requirement, which in turn saves huge amounts of water that can be utilized to expand the irrigated area and reduce the return flow of water. Increasing irrigation system efficiency is also needed to improve water use efficiency at the farm level.

2. Implementation of conservation agriculture
The sector of rainfed agriculture needs to incorporate crop rotations and appropriate soil tillage that maintain soil organic matter and soil moisture through crops, crop residues or cover crops. The use of no-tillage or minimum-tillage in the arid areas, where soils are crusted and fragile, is very crucial to conserve a good soil structure with good pore size distribution for fauna and related macrospores. The use of surface mulch cover protects soil from excess temperatures and evaporation losses and can reduce crop water requirements by 30 percent (FAO, 2007). The conservation agriculture also implies the selection of crops and cultivars with tolerance to abiotic stresses of high temperature, drought, high salt content in soil, pest and disease resistance.

Many studies, carried out in Jordan, have shown that conservation practices are promising adaptation options that should be promoted. This is because of their ability to increase soil moisture storage and soil organic carbon, reduce mineral fertilizers use and reduce on-farm energy cost. The impact of these practices was evident in the levels of yield obtained from Maru Agricultural station. Technology transfer, however, is needed to enhance the adoption of these practices by farmers. The farmers also need to understand soil, water, and plant nutrient relationship to determine optimum growth conditions and management practices that maximize yield and adapt the crop to climate change.

3. Implementation of water harvesting
Results from the DSSAT model showed that barley is to be adversely affected by projected future climate change. In Jordan, this crop is usually cultivated in low rainfall areas where soil surface crust is dominant and evaporation rates are high. Under these conditions, crop failure rate is usually high and grain is usually obtained in one year out of five. This was indicated by the ratio of harvested to planted areas which was only 0.28 for barley. Therefore, a national strategy is needed to promote the use of proper water harvesting techniques that will reduce the risk of crop failure.

The use of small earth dams in arid areas was investigated by the Badia Program in Jordan and showed that these techniques are not efficient as the annual evaporation loss might reach 3 m. Therefore, the proposed interventions may include contour furrow and water spreading. By the implementation of these interventions, the area cultivated with barley can be increased by at least 10 to 25 thousand ha. It should be noticed that water harvesting techniques can be applied for indigenous and locally-adapted plants which form important component of forage. Several studies (e.g. Abu-Zanat et al., 2004; Al-Bakri et al., 2008) have shown that the use of these interventions for native plants proved to increase range production and improve rangeland conditions.

4. Supervised irrigation with treated wastewater
Due to scarcity of water resources, treated wastewater seems to be the main source for irrigating some forage crops like barley. Results from DSSAT model showed that reduction in rainfall amounts or increase of crop evapotranspiration (Etc) would result in reducing grain yield of barley. The short growing season of barley in arid areas might require careful scheduling of one or two irrigation events that would maintain enough soil moisture and crop development to reach maturity and produce grain. Therefore, transfer of this knowledge is important to implement supplemental irrigation with reclaimed water. However, the use of this type of water requires environmental auditing to prevent soil degradation. Also, it requires upgrading of the existing wastewater treatment plants (WWTP) to ensure good quality of treated wastewater which will improve the quality of yield and reduce the possibility of soil and crop pollution. The whole approach shall be participatory and implemented at farm levels.

5. Community-based management of rangeland resources
The use of indigenous and locally-adapted plants combined with the selection and breeding of crop varieties and races adapted or resistant to adverse conditions are among the most important adaptation measures to preserve rangeland resources. In Jordan, rangeland rehabilitation is an important priority that should be included in the national agenda. Efforts and actions made to reduce pressure on rangeland resources did not succeed as they were following top-down approach without involving local communities in the process. The policy of forage subsidy contributed to this problem as it encouraged farmers to increase livestock numbers above the carrying capacity of rangelands. All of these factors accelerated degradation of rangeland resources and resulted in reduction of yield in arid and semiarid areas. Therefore, the community-based management of rangeland resources is urgently needed as a key adaptation measure for climate change. This will require strengthening the capacity of local communities to implement plant breeding programs and develop locally-adapted crops, and to implement sustainable

interventions of water harvesting and controlled browsing.

This adaptation measure is cross-cutting with planned adaptation of rural livelihood. Most studies showed that farmers who live in insecure places need to build their resilience to cope with climatic changes. This is an important challenge in adapting to increasing climate variability and climate change. The livelihood-based approach to promote climate change adaptation processes at grass root level builds on the assumption that most rural communities work on the basis of day-to-day priorities rather than longer-term ones (FAO, 2007). Therefore, successful adaptation policy shall take this issue into consideration and shall empower and strengthen these vulnerable communities.

This adaptation measure also targets livestock system. It is expected that climate change has direct effects on livestock productivity as well as indirect ones through changes on the availability of fodder and pastures. Climate changes will also affect nomadic and transhumant livestock systems. The early greening of arid pastures which may result from warming during late winter will enhance the early browsing of these pastures and will enhance their degradation. Therefore, the policy of subsidy shall be modified accordingly to reduce pressure on these fragile pastures.

4.3.5.2 Planned adaptation

1. Program one: Climate change legislation and policy
The current policies of agriculture and water do not tackle the issue of climate change explicitly. A framework needs to be in place to support and implement adaptation policies and programs that sustain agricultural and natural resources. This program shall support the incorporation of adaptation in the existing policies through reviewing and updating of policies as well as capacity building for related institutions in the areas of mitigation and adaptation.

2. Program two: Assessment and monitoring of vulnerability
Assessing the vulnerability of ecosystems and planning food security and humanitarian programs are essential for identification of the most affected areas that require urgent actions. However, there is still a lack of reliable or comparable baseline data to carry out this task. Therefore, road maps of different data on natural resources and local communities are needed. Furthermore, more detailed studies are still needed at large scale to assess vulnerability and to identify areas and sectors with high priorities. This program shall include the following projects:

Mapping and assessment of agroecological zones project
Adaptation practices require extensive high quality data and information on climate, and on agricultural, environmental and social systems affected by climate, to carry out realistic vulnerability assessments. Detailed data on the country's natural resources is still lacking and scattered among institutions. The need for spatial database has been emphasized by different researchers on climate change. Therefore, this project aims at building a spatial database of different data sets on soil, vegetation, climate, socio-economic and demography. This project is crosscutting with desertification information system (DIS), proposed in the country's Desertification National Action Plan. Therefore, both projects can be interlinked and integrated to exchange data which is particularly related to arid and semi-arid areas; most vulnerable zones.

Early warning and risk management systems project
The knowledge and technology required for adaptation include understanding patterns of variability of current and future climate, seasonal forecasts, land use planning, and resource management. Vulnerability assessment relates to impacts of variability and changes in climate (inter-annual and intra-seasonal variability) on agricultural systems which are dynamic. Therefore, adaptation in itself may include a real time reaction towards erratic rainfall distribution and drought. Some of the autonomous adaptations were focused on soil moisture and land management. This will require an early warning system that provides information in real time to farmers.

3. Program three: Knowledge management and technology transfer
Documentation of traditional knowledge of local community on soil and water conservation is needed to understand their adaptation to harsh physical conditions in dry seasons. Since changes are relatively slow, there is a need to rely more on continuous observations and experience of farmers and their local knowledge. The ability of old farmers to select tolerant species of crops and fodder shrubs shall be respected and transferred in an extension package. At the same time, unsupervised practices of plowing, seeding, harvesting and grazing shall be discouraged and replaced by alternative packages of supervised land use.

Results from the DSSAT model showed that vulnerability of barley is more than wheat under most scenarios. Vulnerability of wheat to increased temperature was less than that of barley. However, wheat vernalization requirement should be considered and selection of adapted cultivars shall be enhanced. Also, data of wheat showed relatively low levels of yield at farmers' level when compared to the level of yield inside the agricultural research station of Maru, Irbid. This could indicate that the supervised practices followed in this station and other ones should be transferred to farmers.

4.3.5.3 Farm level adaptation

The main adaptation measures for rainfed wheat would include the use of crop varieties with appropriate vernalization. In both basins and most likely in other areas of the country, barley will be adversely affected by climate change. Therefore, implementation of soil management and supervised irrigation practices, adoption of conservation agriculture, implementation of water harvesting, supervised irrigation with treated wastewater and community-based management of rangeland resources were seen as the main adaptation measures that would sustain and increase yield at farm level under the conditions of climate change.

Within the framework of FAO, the main adaptation measures would include change of sowing dates and use of different variety or species. Replacing wheat with barley, however, should not be recommended as results of crop model showed that wheat was positively affected by many of the climate change scenarios.

4.3.5.4 Research and development

Results from DSSAT model should emphasize the need for more research on vulnerability of other crops under rainfed and irrigated conditions. This would require the calibration of DSSAT and other models to simulate crop yield under different scenarios of climate change. Also, high levels of yield obtained from the agricultural research station showed that development of technology transfer and intrusion of high technology in agricultural sector should be among the main adaptation measures. A successful implementation of adaptation measures would require a wide range of tools. This might include capacity and financial resources, institutional framework, technology transfer and information.

4.3.6 Limitations, Difficulties, Gaps and Constraints

The main limitations and difficulties for adaptation of agriculture sector would include the lack of national strategies and plans for adaptation. The sector needs more initiative programs to mitigate the adverse impacts of climate change. In addition, agricultural extension and communication systems are among the most important limitations. Currently, scientific research in this area at the country level is insufficient for precise quantification of adverse impacts and vulnerability. The main constraints that need alleviation are technology transfer, availability of data, commitment at society level, adaptation programs at the governmental level, and most important is the lack of financial resources that could strengthen research and adaptation.

4.4 VULNERABILITY AND ADAPTATION OF WATER RESOURCES SECTOR

The effect of climate change on water resources is expected to be significant. An analysis of changes in the hydrological regime can provide a basis for estimating the impacts of climate change on water resources, and can be used as a tool to recommend changes in water management regimes. Climate change is projected to cause significant changes in spatial and temporal distribution of precipitation (Abdulla and Al-Omari, 2008). This can be expected to cause a wide range of health effects, particularly in communities within or at the edge of deserts where water is scarce, highly polluted or salinated, and in communities where there are competing demands from household consumption, agriculture and other industrial sectors.

The main objectives of the vulnerability assessment of water resources sector to climate change are:

- To investigate the impact of climate change on water resources of two major river basins in Jordan, namely ZRB and YRB.
- To identify possible adaptation measures (policies, strategies, action plans and sustainable water resources environment) in response to potential climate change.

4.4.1 Methodology

The general methodology followed to achieve the above objectives can be divided into the following steps:

1. Data collection: all data concerning this work were collected from the Ministry of Water and Irrigation (MWI). Collected Data included; hydrological and meteorological data for the period 1960 - 2006. All data obtained was stored in a digital database created using ESRI ArcMAP and Microsoft Access 2007.

2. Hydrological modeling: Water Evaluation and Planning system (WEAP) software that was developed by Stockholm Environment Institute (SEI) was used to simulate surface runoff in both ZRB and YRB. The model was first calibrated against the observed stream flow in both basins.
3. Assessing the impacts of climate change on surface runoff: The calibrated model was then used to simulate monthly runoff under the proposed incremental and GCM climate change scenarios.
4. Suggestion of adaptation measures: in this step, climate change adaptation measures for water sector were identified.

4.4.2 Modeling of Runoff

WEAP model was used to estimate the monthly surface runoff resulted form precipitation. It was also used for the assessment of climate change impacts on surface runoff. The hydrology module in WEAP is spatially continuous, with a study area configured as a continuous set of sub-catchments that cover the entire extent of the river basin.

4.4.2.1 Hydrological modeling of Zarqa basin

The basin was divided into five sub catchments using ArcHydroTool within ArcGIS environment. These sub-catchments with their areas are:

- Mafraq: 721.13 km^2
- Wadi Duhlil: 861.56 km^2
- Jerash: 1074.22 km^2
- Zarqa: 586.73 km^2
- Amman: 663.27 km^2

The base scenario runoff for Zarqa sub-catchments was considered for the period from 1970 to 2000 (Table 4.6). The modeling requirements for the Rainfall Runoff Method (FAO method) are daily precipitation amounts (mm) and evaporation (mm)

Automatic calibration for the model was carried out for the period 1/1/1970 to 31/12/2000. Data available from Jerash Bridge gauging (AL0060) was used for this process. The main objective of this process was to ensure that results obtained from modeling process match the measured ones. This is an essential process before considering the model for future prediction.

Figure (4.8) shows a comparison between simulated runoff values for Jerash Bridge gauging (at the outlet of Zarqa Basin) and the observed data. As can be seen from the figure, results obtained from the model are very comparable to the observed data from gauge station. The WEAP model is suitable for monthly and daily time intervals. However, yearly time series are not supported by WEAP and the results shown here represent the average monthly or daily values over the base scenario interval.

Table 4.6: Simulated monthly average runoff for Zarqa sub-catchments (cubic meter /second (CMS))

Month	Amman	Jerash	Mafraq	Wadi Duhlil	Zarqa	Total
Jan.	1.52	2.82	0.96	0.25	0.66	7.16
Feb.	1.59	2.54	0.96	0.28	0.61	6.73
Mar.	1.06	1.87	0.74	0.24	0.61	5.03
Apr.	0.35	0.58	0.23	0.08	0.14	1.55
May	0.06	0.10	0.05	0.02	0.00	0.26
Jun.	0.00	0.00	0.00	0.00	0.00	0.01
Jul.	0.00	0.00	0.00	0.00	0.00	0.00
Aug.	0.00	0.00	0.00	0.00	0.00	0.00
Sep.	0.00	0.01	0.01	0.00	0.00	0.03
Oct.	0.19	0.34	0.15	0.01	0.16	1.00
Nov.	0.64	1.58	0.56	0.05	0.39	3.69
Dec.	1.20	2.11	0.79	0.12	0.55	5.52
Total	6.61	11.95	4.44	1.07	3.14	30.97

Figure 4.8: Simulated surface runoff values versus observed stream flow values

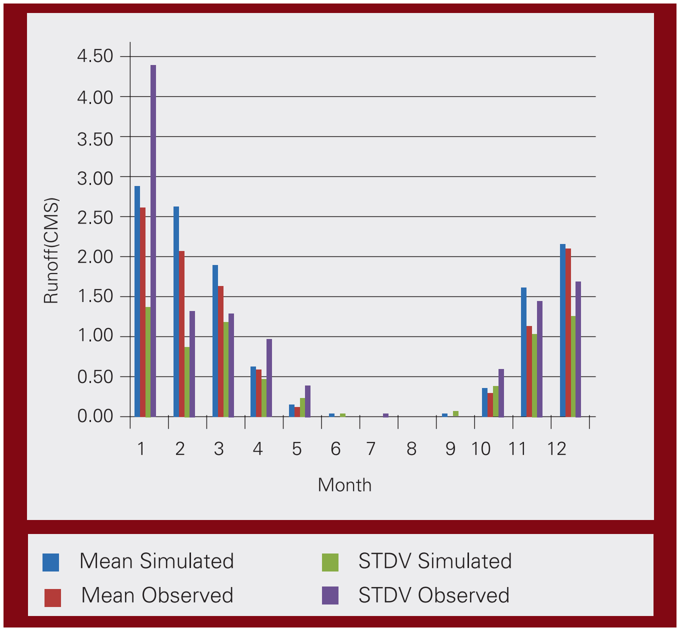
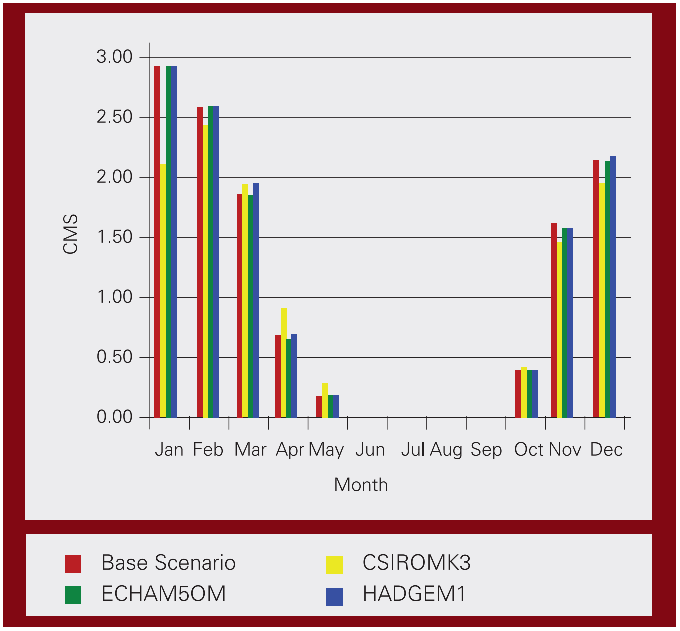


Figure 4.9: Results obtained for base scenario and GCMs



4.4.2.2 Impacts of climate change on surface runoff of ZRB

The impact of climate change on monthly surface runoff of ZRB was investigated through application of WEAP model and using the twenty incremental and three GCMs climate change scenarios.

Results of analysis carried out on incremental scenarios can be summarized as follows:

1. Runoff is expected to increase by about 5 percent when precipitation is increased up to 10 percent and mean temperature is increased by not more than 2 °C. Monthly runoff is also expected to increase by 30 percent and 22 percent when precipitation is increased by about 20 percent and mean temperature is increased by 1 °C and 4 °C; respectively.
2. Runoff is expected to decrease by more than 20 percent when mean temperature values increase by up to 4 °C and precipitation remains unchanged.
3. The incremental scenario which combines precipitation increase by 10 percent and mean temperature increase by 3 °C shows slight or no change on surface runoff amounts especially in the rainy season (months of January, February and March).

Figure (4.9) shows results obtained from WEAP modeling process for the base scenario and the selected GCMs scenarios. Additionally, Table (4.7) summarizes these results. By referring to Figure (4.9), the impacts of climate change on water resources can be summarized as follows:

1. CSIROMK3 scenario

This scenario predicted that the amount of surface runoff will decrease for the rainy season which extends from October to February. The highest decrease is expected to take place in January (about 25 percent) which is the rainiest season of the year. During the rest of the year, it was noticed that there will be less or no decrease of surface runoff as these months always receive little or no rain during the year.

2. ECHAM5OM and HADGEM1 Scenario

This scenario predicted that there will be no or very little impacts of climate change on surface runoff.

Table 4.7: Zarqa monthly runoff vulnerability to climate change under different GCMs (CMS)

Month	Base Scenario	CSIROMK3		ECHAM5OM		HADGEM1	
		Value	Change	Value	Change	Value	Change
Jan	2.82	2.03	-0.79▼	2.82	0.00	2.82	0.00
Feb	2.54	2.43	-0.11▼	2.54	0.00	2.55	0.00
Mar	1.87	1.90	0.03▲	1.85	-0.02▼	1.90	0.03▲
Apr	0.58	0.74	0.16▲	0.57	-0.01▼	0.59	0.01▲
May	0.10	0.18	0.08▲	0.10	0.00	0.10	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.01	0.00	0.00	0.01	0.00	0.01	0.00
Oct	0.34	0.36	0.03▲	0.34	0.00	0.34	0.00
Nov	1.58	1.43	-0.16▼	1.57	-0.02▼	1.57	-0.01▼
Dec	2.11	1.92	-0.19▼	2.12	0.00	2.13	0.01▲

▲: Runoff decreased ▲: Runoff increased

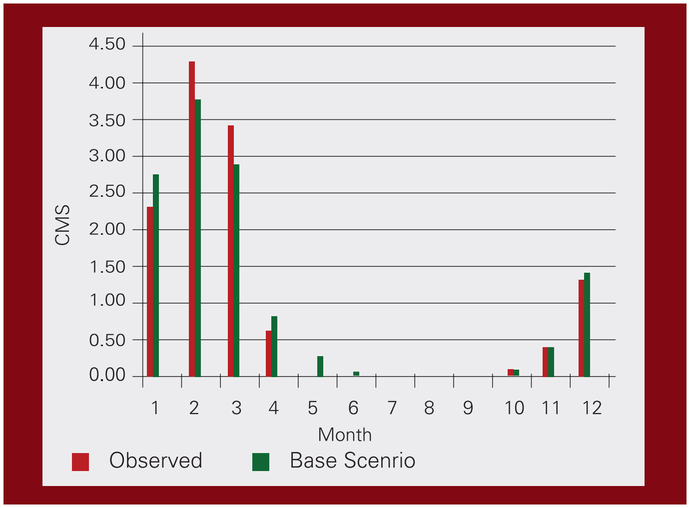
4.4.2.3 Hydrological modeling of Yarmouk basin

Similar approach was followed as in the case of ZRB. The YRB has been divided into three major sub-catchments. These sub-catchments with their areas are:

- Hawsha: 377.44 km^2
- Ramtha: 414.88 km^2
- Irbid: 599.18 km^2

Figure (4.10) shows the simulated mean daily runoff values obtained for base scenario (1970-2000) which has been automatically calibrated against observed flood measured at Adasiya gauge station (AD0032). A good agreement between simulated and observed runoff was noticed. The RMS for YRB runoff simulation was about 0.3.

Figure 4.10: Simulated mean monthly surface runoff for Yarmouk Basin versus observed values



4.4.2.4 Impacts of Climate Change on Surface Runoff of YRB

The impacts of climate change using the incremental scenarios and selected GCM scenario were also applied to YRB. The results under these scenarios are summarized below:

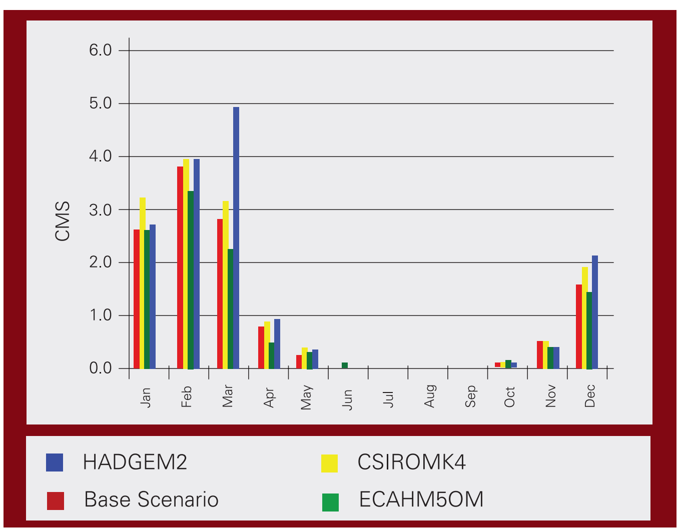
- Monthly runoff is expected to decrease under most of the incremental scenarios in the months of October to March. The reduction in surface runoff may be as high as 30 percent.
- Runoff is expected to decrease in March under all scenarios, while April runoff will not change.
- Runoff is expected to increase by about 5 percent when precipitation is increased by up to 10 percent and mean temperature is increased not more than 2 °C. Runoff also is expected to increase by more than 12 percent and 9 percent when precipitation is increased by about 20 percent and mean temperature is increased by 1 °C and 4 °C; respectively.
- Runoff is expected to decrease by more than 9 percent when mean temperature values are increased by up to 4 °C and precipitation remains unchanged.

- The largest increase in surface runoff may be noticed in January under the incremental scenario that combines precipitation increase by 20 percent and mean temperature increase by 1 °C.

The impacts of climate change on surface runoff were also assessed using the GCMs scenarios. Figure (4.11) shows the simulated monthly runoff under the 3 GCMs scenarios. The following conclusions can be derived:

1. According to CSIROMK3 model, there will be a slight increase in surface runoff amounts during the rainy season.
2. The ECHAM5OM simulation results showed that there will be no change in surface runoff resulting from precipitation in January; while there will be a decrease in the surface runoff of other months.
3. HADGEM1 simulation predicated a major increase in surface runoff values in March and a decrease in October and November. Surface runoff of other months shows no change.
4. The three models showed slight or no change in surface runoff amounts for the months of January, February, May and October.

Figure 4.11: Simulated mean monthly runoff under the GCM scenarios for YRB



4.4.3 Key Implications of the Projected Impacts on Water Resources

The vulnerability assessment study presented in the previous sections showed that ZRB and YRB are vulnerable to climate change in the sense that there is a strong relationship between infiltration rates and the amount of rainfall in Jordan. Accordingly, less precipitation will lead to less recharge; and less available water resources coupled with deterioration of surface and groundwater quality.

4.4.4 Adaptation Measures for the Water Resources Sector

Climate change studies conducted in Jordan are very limited and only focused on the impacts of climate change on one single surface water and one groundwater resources, amongst 15 surface and 12 groundwater basins existing in Jordan. Other studies conducted in Jordan showed an increase in the magnitude and frequency of extreme temperatures, reduction in runoff, shift in peak flow, and increase in sediment transport (Abdulla and Al-Omari, 2008; and Abdulla et al., 2008). Higher temperatures and lower precipitation are expected as a result of climate change. Water resources, environment and other related issues such as range land, and livestock are most likely to be vulnerable to climate change. (Jordan's Initial National Communications Report, and Vulnerability and Adaptation to Climate Change Report, 1999).

Considering the scarcity of natural water resources and their anticipated decrease resulting from climate change, the following adaptation measures can be taken:

Residential water supply:

(i) Reduce water losses in distribution pipes.
(ii) Introduce water metering.
(iii) Introduce water saving technologies such as low-flow toilets and showers, and efficient appliances.
(iv) Collection of rainwater for garden, toilets, and other applications.
(v) Promote water saving by awareness campaigns.

Irrigation:

(i) Introduce water saving technologies in irrigation schemes such as drip, micro-spray, night irrigation, etc.
(ii) Introduce new varieties of crops that use less water and are salt-tolerant.
(iii) Increase the efficiency of irrigation systems.
(vi) Reform water pricing.
(vii) Use groundwater more efficiently.

Water quality:
(i) Improve wastewater treatment plants (WWTP).
(ii) Recycle wastewater.
(iii) Develop river protection and sanitation zones.
(iv) Improve chemical and biological monitoring.

Socio-economic issues:
(i) Train people of different ages and social statuses on water saving and sanitation methods.
(ii) Increase public awareness to water related issues.
(iii) Introduce water cleaning and softening technology.
(iv) Introduce policy measures to ensure the equity in access to water.
(v) Carry out studies to estimate the impacts of hydrological disasters such as flash floods and thunderstorms.
(vi) Improve the drought prediction and mitigation system.

The above measures can be grouped in the following programs:

1. Demand management
Despite ongoing projects and plans to mobilize additional water resources, options for further resources development are very limited. Similar to other countries in the region, demand side oriented management is of increasing importance. Mobilization of additional water resources can be achieved through:

- Artificial groundwater recharge.
- Surface water reservoirs.
- Water harvesting.
- Increased re-use of treated wastewater.
- Use of non-conventional water resources.
- Desalination.
- Weather modification (cloud seeding).
- Transfer of water among different basins in Jordan.
- Various projects have been set up to reduce water consumption and to enhance water use efficiency by:
    - ◊ Reduction of losses from the supply networks.
    - ◊ Introduction of water saving technologies.
    - ◊ Public awareness campaigns on water consumption.
    - ◊ Adaptation of different cropping patterns.

The development of non-renewable water resources contradicts the idea of sustainable development and is therefore only planned to bridge the gap until sufficient alternative sustainable resources can be made available.

2. Surface water development
In Jordan, direct runoff from heavy rainfall lasts from less than an hour to very few days. This makes the management of this type of resource difficult. Possible measures are:

- Optimizing the development and use of this resource through supply-enhancing measures, including surface and subsurface storage, minimizing losses by surface evaporation and seepage, soil and water programs, and protecting surface water supplies from pollution.
- Development of sustainable management plans for surface water systems in Jordan Valley, conversion of open canal systems to a pressurized pipe system, giving priority to modernizing and upgrading systems, and precedence to water projects which make significant contributions to meeting rising municipal and industrial demands.
- Dams are required for storing flood waters during the wet winter season and releasing the water gradually during the summer season when the demand is high. Additionally, «ordinary» reservoirs, so called desert dams (water harvesting) help increase groundwater recharge and provide water for pastoral use.

3. Groundwater protection
Most groundwater aquifers are exploited at more than double of their safe yield. The sustainability of irrigation in the highlands and the Badia areas will be greatly endangered unless strict measures are taken to address this issue. As such, the development and implementation of an action plan is needed in order to ensure that plans for groundwater protection, management, monitoring and restoration are defined, integrated and managed in a cost-effective manner. However, such action plan needs:

- A strong legal basis, given by laws and by-laws of the Water Authority, 2002.
- Guidelines and legal provisions.
- An administrative structure for implementation and survey.
- Public involvement.
- Measures will also continue to be taken to protect the groundwater resources from all sources of pollution.

In order to improve groundwater situation in Jordan, the Ministry of Water and Irrigation is establishing an integrated program to assess the availability and exploitability of all resources at rates that can be sustained over long periods of time.

The mining of renewable groundwater aquifers will be checked, controlled, and reduced to sustainable extraction rates. The Ministry will further encourage the application of applied research activities, including artificial recharge to increase groundwater supplies, and the employment of new technologies that will optimize operation and development of groundwater systems and promote more efficient and feasible uses.

4. Non-conventional water resources development
Non-conventional water resources may be defined as water resources that are not readily available and suitable for direct beneficial use. These include wastewater reuse, water desalination, and weather modification. The most common source of non-conventional water in Jordan is treatment of domestic and industrial wastewater.

Currently, there are 22 operational municipal wastewater treatment plants in Jordan. Additionally, the majority of industrial plants, hospitals, universities, army units and airports possess their own wastewater treatment facilities. Effluents of these treatment plants are used directly or indirectly in irrigation, around the plants, or discharged to wadis or reservoirs where they get diluted and utilized for agriculture. Some of these plants have been overloaded and are not able to meet the standards specified by the government. Even though water-related development projects usually produce positive impacts on the environment, and are also associated with indirect negative environmental impacts.

In light of this, the Ministry is developing a wastewater master plan, which will establish targets for providing wastewater collection systems and treatment facilities to un-served areas throughout the country. Wastewater treatment involves reducing, removing, and disposing of water contaminants. It aims to process and dispose municipal and industrial liquid wastes in a manner that reduces pollution, particularly, of the aquatic environment and makes usable treated effluent for restricted reuse. Wastewater reuse is becoming more popular throughout the world, particularly in arid and semiarid regions because it can reduce environmental and health related hazards if planned properly. Wastewater reuse can also result in increasing crop yields because of supplemental irrigation and nutrients within the wastewater.

5. Brackish water
Since Jordan suffers from severe water shortages, finding alternative water resources has become a priority for the MWI, which has been studying the possibility of desalination on a large national scale. Several positive environmental impacts regarding the use of desalinated water were identified. These include improvement of physical and chemical characteristics of the soil, and decreased pressure on freshwater resources for agricultural purposes.

In order to further pursue the brackish water option, the Ministry must first assess the potential of brackish water resources in terms of sound technical, economic and environmental feasibility in all groundwater basins within the Kingdom. The Ministry then has to conduct research and studies on desalination and on optimization of brackish water use in agriculture and industry.

6. Water quality and the environment
Jordan has witnessed some deterioration in its water quality in the last two decades due to industrial pollution, overuse of agrochemicals, drainage water, overloading of wastewater treatment plants, over-pumping of aquifers, seepage from landfills and septic tanks, and improper disposal of dangerous chemicals by certain industries. The added population pressure, exacerbated by successive waves of refugees and displaced people, has further degraded the effluent from the As-Samra wastewater treatment plant and resulted in degradation of water quality in King Talal Dam.

Treated effluent from wastewater plants offers a different set of challenges. The performance of many of the plants is inadequate, resulting in an effluent of low quality. This effluent may have an adverse effect on public health due to the presence of pathogens or the accumulation of toxins in soils when used for irrigation. Furthermore, pollution of surface water and groundwater due to seepage results in the deterioration of water quality of some water resources, and will limit their use for different purposes. The quality of treated effluent and the performance of wastewater treatment plants are greatly affected by influent water quality, which may be of domestic or industrial source. Enforcing standards for wastewater discharges to sewers, treated effluent and water for other uses is essential.

Thus, the standards adopted should consider national priorities, economics, and availability of water supplies, as well as health and other environmental implications. Implementation of standards and their enforcement require facilities and expertise, which involve significant cost. Enforcement requires commitment and coordination between many agencies and at many levels within the government. Adopting and implementing guidelines for water used in irrigation, in cooperation with the Ministry of Agriculture, increases the availability of water.

7. Water resources monitoring system

Systematic water resources monitoring is mainly carried out by MWI through its monitoring network. The MWI aims to accomplish conservation and protection of water resources in the country. Regarding irrigation water monitoring, currently there are no national standards for evaluation of irrigation water quality in Jordan. The Jordan Valley Authority (JVA) is the main monitoring agency for irrigation water quality in the country. JVA therefore monitors surface water quality in the Jordan Valley. The monitoring is carried out mainly to secure a water quality suitable for irrigation purposes.

8. Domestic wastewater

The Water Authority of Jordan (WAJ) monitors wastewater at public and private wastewater treatment plants in Jordan, in order to ensure compliance with the standards. The MoH has undertaken the responsibility of quality control at wastewater treatment plants, concentrating mainly on biological parameters.

9. Industrial wastewater

Wastewater discharged from private industrial sources is sampled by WAJ and MoEnv, who coordinate in order to avoid duplication of sampling. WAJ and MoEnv communicate with each other in case of violations, warn the violators and in certain circumstances take them to court.

10. Measures to improve system efficiency

The overall efficiency of water resources system is low. This is mainly due to losses in the system, system constraints, inefficient farm practices, constraints of funds and inflow patterns. In the precipitation increase scenario, adaptation measures to increase efficiency may include adoption of better farm management and irrigation practices. Special care will have to be taken to control high waters in the root zone and results in considerable reduction of the acreage of the crop. Precision land leveling and proper field sizing may also be required.

11. Watershed management

An effective and economically beneficial adaptation option lies in the construction of dams over all potential wadis. The finite nature of renewable fresh water renders it a critical natural resource to be examined in the context of population growth and climatic changes. Fresh water availability is dictated to a large extent by climate, timing and location of precipitation, and by evaporation rates. Accordingly, available fresh water varies tremendously from one season to another. Watershed protection would also have benefits for groundwater storage and flood alleviation.

12. Urban water use

There is an urgent need to devise economic and structural policies to practice water conservation in urban areas. This is beneficial because it will result in less pressure on drainage and supply systems, as well as sewage treatment facilities. This has become essential for the preservation of water quality.

13. Water quality and environmental protection

The scenarios of temperature rise coupled with no change or decrease in rainfall will affect the quantity of inflow to dams especially in the low flow years. This will trigger environmental degradation in these areas. Techniques will have to be developed for sophisticated management of reservoir filling, reservoir and barrage releases, and canal abstraction. This will help make more effective use of available water and mitigate hazardous effects on the environment.

14. Flood control

Flash floods have varied impacts on different areas (desert wadis and rural areas). Proper risk and vulnerability analysis for each flood prone area needs to be carried out in the proper climate. For vulnerable areas, current topographic maps are needed. Flood control authorities should keep updated records of settlements and infrastructure development. A clearance from flood protection agency may be required for erection of settlements and infrastructure in the new areas.

15. Research programs

Future natural resource planning is difficult in the absence of significant and reliable data that reflect demographic variation and facilitate the understanding of phenomenological response of biological ecosystems to climatic change. There is a need for the development of mathematical models and research tools to predict phenomenological responses of various subsystems of the environment. This will help in assessing the impacts of climate change on sectors such as water resources. Water vulnerability and adaptation to climate change should therefore be part of sustainable water resources environment and integrated development policies.

The Ministry of Water and Irrigation (MWI) issued a recent water master plan coupled with related strategy and several policies to conserve water and seek alternative supplies. The following measures were reported and identified as potential measures to reduce water scarcity: increasing water use efficiency; water harvesting systems; wastewater reuse; virtual water and desalination (Ministry of Water and Irrigation, Strategy and Policies, 1998). These can also be looked at as measures of adaptation to climate change of the water resources sector.

The national water strategy was the foundation to four subsequent water policies, all of which touch on matters of environmental issues. Although these policies were not designed to address climate change issues, they all emphasize the need to study the environmental feasibility of proposed water projects. The policies also focus on public education, and emphasize awareness campaigns to educate the public on methods of water resource protection and conservation. They also emphasize the need for continuous research and development, as well as constant reviewing and updating of set standards and specifications.

4.4.5 Obstacles and Limitations

The main limitation during this assessment was data availability. Furthermore, the quality of obtained observations in some records was highly uncertain. Therefore, some records with unreliable readings were deleted from the analysis. This process was carried out by referring to some official reports and statistics from Ministry of Water and Irrigation. Some technical difficulties were encountered with the WEAP software and were reported to Stockholm Environment Institute (SEI), while other problems were solved by writing some visual basic scripts and routines.

4.5 VULNERABILITY AND ADAPTATION OF HEALTH SECTOR

4.5.1 Introduction

Both climate and weather have powerful impact on human life and health. Human physiology can handle most variations in weather, within certain limits. Certain health outcomes associated with the prevailing environmental conditions include illnesses and death associated with temperature extremes, storms and other heavy precipitation events, air pollution, water contamination, and diseases carried by mosquitoes, ticks, and rodents. As a result of the potential consequences of these stresses acting individually or in combination, it is possible that projected climate change will have measurable beneficial and adverse impacts on health.

In Jordan, the overall susceptibility of population to environmental health concerns has dropped dramatically during the past few years with the improvement in availability of health infrastructure. Referring to the likely changes of climate system, a series of impacts on public health are expected. There are general effects on human health due to increased temperatures and changes in rainfall patterns. These include physiological disorders, skin rashes and dehydration, eye cataracts, damage of public health infrastructure, deaths and injuries, an increase in the occurrence of strokes, and an increase in the incidence of non-melanoma skin cancers. Indirectly, climate change also affects ecological systems. For example, incidents of diseases transmitted by water such as cholera may increase. Vector-borne diseases may also be affected by changes in climatic conditions. Moreover, the indirect impacts are perceived to include factors like demographic dislocations and socio-economic disruptions.

Shortage of drinking water and inadequate quality could be critical especially during summer. As a consequence, an increase in cases of contagious and digestive system diseases is expected. The increase in temperature would affect the physiological and compensatory system of people. Thus, age groups like infants, children and elders where the decrease in compensatory system is common, will have changes in their health conditions. These changes would cause higher incidence of some diseases, influenced by the atmospheric changes. Infections in the respiratory system will be the most visible.

Climate change is expected to affect the quantity and quality of water resources in arid countries like Jordan. International studies, including reviews by the Intergovernmental Panel on Climate Change, have reported that regions with already scarce water resources, such as the Middle East and North Africa, will suffer even more from water scarcity. Previous regional and local studies of past weather records already show an increase in mean temperatures, and in the magnitude and frequency of extreme temperatures.

Decreasing rainfall quantities will lead to shortages, which will increase the probability of water-borne epidemics such as, cholera, dysentery, giardiasis, bilharziasis. This could also lead to reemerging of some diseases that were under control from a long time period such as malaria or emerging of new, not known diseases in Jordan such as West Nile virus fever, dengue fever or rift valley fever. Climate variables had also effects on the seasonal pattern for respiratory diseases, cardiovascular diseases and mortality.

The actual disease burden attributable to climate change in Jordan is not known. Environmental and health data sets are poorly matched and methods for analyzing relationships between them have not been applied locally. Nevertheless, it is very important to link available data, to better understand the relationships between climate variables and actual health outcomes.

As detailed region-specific scenarios are not available, predictions related to health effects of climatic changes were general and speculative. Except for a few diseases, there is insufficient data for any kind of projections. Nevertheless, when discussing the various potential health effects related to climatic change, it is necessary to present them in the context of a population because many of the conditions discussed hereafter have specific distribution patterns in the population. Population groups such as low-income households, women, children, and rural and urban slum dwellers will be at an even higher risk.

The vulnerability and adaptation study for the health sector aims at summarizing potential impacts of climate change on human health and identifying a set of adaptation measures to combat such impacts

4.5.2 Methodology

In this study, the whole population of Jordan was taken as one entity because it is difficult to detect differences of climate change on a small scale. Also the chosen ZRB and YRB are located within many health administrative directorates, so separation of the needed data for the basins was difficult.

The vulnerability assessment for health sector was designed as an ecological study which can be defined as a study in which the unit of observation is the population or community. The disease rates and exposures are measured in populations to identify correlations between them. Ecological studies are performed on a national or regional scale. The following sets of data were obtained from the MoH and DOS:

1. Monthly data from directorate of communicable diseases on water-borne diseases "hepatitis A, typhoid fever and diarrhea" and vector-borne diseases "cutaneous leishmaniasis".
2. Monthly data from public health centers logbooks on number of patients who attend the health centers for respiratory diseases, cardiovascular diseases and digestive tract diseases "including diarrhea" for the whole country.
3. Monthly data on the number of admissions and the number of deaths from public hospitals.
4. Monthly data for two specific zones from Zarqa health directorate, one located in the vicinity of a wastewater treatment plant and the other one located far from it.

The above data was then subjected to time series analysis as well as regression analysis. In the analysis of data for the above health variables, the incidents' rates were only correlated to only one climatic variable which was the monthly maximum temperature. Table (4.8) illustrates the trend for diseases included in the study. The typhoid, hepatitis A and diarrhea show declining trends while cutaneous leishmaniasis shows a rising trend.

Table 4.8: Summary of selected diseases in Jordan, 1996-2007

Population	Years	Typhoid and para typhoid		Hepatitis A		Cut. leishmaniasis		Diarrhea	
		Number	IR*	Number	IR*	Number	IR*	Number	IR*
4444000	1996	141	3	1486	33	18	0	120559	2713
4600000	1997	109	2	1612	35	53	1	109555	2382
4755750	1998	97	2	1083	23	113	2	100957	2123
4900000	1999	96	2	969	20	16	0	106114	2166
5039000	2000	46	1	947	19	5	0	102768	2039
5182000	2001	69	1	754	15	86	2	105433	2035
5329000	2002	44	1	506	9	19	0	110864	2080
5480000	2003	32	1	552	10	7	0	103737	1893
5350000	2004	155	3	342	6	192	4	104434	1952
5485000	2005	78	1	266	5	162	3	106164	1936
5600000	2006	21	0	482	9	181	3	133200	2379
5723000	2007	16	0	387	7	354	6	141210	2467

* IR: Incidence Rate = (no. of cases / population) * 100000

4.5.3 Results

Projections of the extent and direction of potential impacts of climate variability and change on health are extremely difficult to make with confidence. This is due to many confounding and poorly understood factors associated with potential health outcomes. These factors include the sensitivity of human health to elements of weather and climate, differing vulnerability of various demographic and geographic segments of the population, the movement of disease vectors, and management of anticipated health problems. In addition to uncertainties about health outcomes, it is very difficult to anticipate what future adaptive measures (for example, vaccines and the improved use of weather forecasting to further reduce exposure to severe conditions) might be taken to reduce risks of adverse health outcomes.

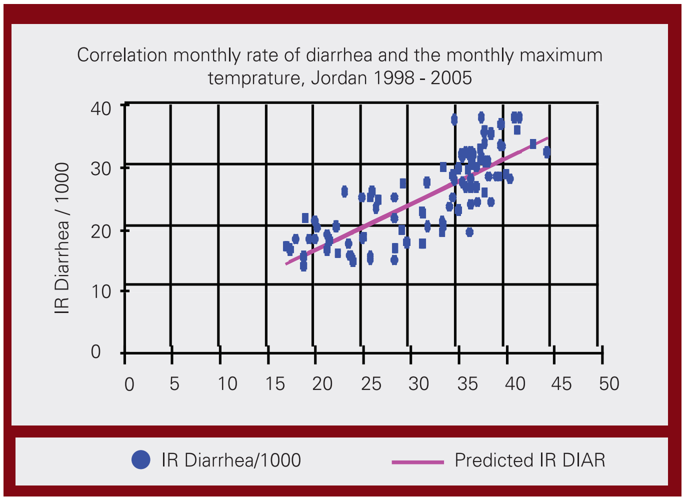
One of the most important effects of climate change in Jordan is shortage of water. Adaptation measures to cope with shortage of water include reuse of grey or treated wastewater in agriculture. This will increase the opportunity for transmission of several pathogens through contamination of crops with pathogen agents and could cause outbreaks of typhoid fever, amibiasis, giardiasis, or hepatitis A.

Another important effect of climate change in Jordan is the increase in temperature and shifting in the rainy season this may lead to changes in the vector and reservoirs mapping. This may generate new focus for some diseases that are not known to be endemic in a certain region such as leishmaniasis in south of Jordan. Also emergence of some diseases that are not known in the country such as hemorrhagic fevers, viral hepatitis E, or re-emergence of other diseases that have been under control for a long period like malaria, cholera plague poliomyelitis or typhus. Additionally, the risk of food poisoning is expected to increase due to the multiplication of pathogenic agents in high temperature environment.

In spite of the increase in temperature, incidence rates of diseases investigated continued to decrease along with secular trends through the period 1988-2007. The secular term is most often used to distinguish underlying long-term trends from seasonal variations. And the secular trend is the occurrence of diseases that are sustained or are expected to be sustained over uniform time intervals for long time period.

There is a strong positive correlation between diarrhea incident rate and the maximum monthly temperature (MMT), as shown in Figure (4.12). The relationship has a coefficient of determination (R^2) of 0.62, indicating that the variation in MMT accounts for 62 percent of the total variation in the monthly incidence rate of diarrhea. In other words 62 percent of the diarrhea cases could be attributed to the temperature. As MMT increases by 1 °C the incidence rate of diarrhea increases by one case/1000.

Figure 4.12: Relationship between monthly rate of diarrhea and maximum monthly temperature



For typhoid fever; there is an intermediary positive correlation (r) of about 0.48 between rates of typhoid fever and temperature. This means that variation in MMT can explain 23 percent of the total variation in the monthly incidence rate of typhoid fever.

For hepatitis A; there is an intermediary negative correlation of about -0.38 between rates of hepatitis A and temperature. The variation in MMT accounts for 14 percent of the total variation in the monthly incidence rate of hepatitis A. As the MMT increases by 1 °C the incidence rate of hepatitis A will decrease by one case/100000.

For leishmaniasis; there is an intermediary negative correlation of -0.49 between rates of leishmaniasis and temperature. This indicates that the variation in MMT accounts for 24 percent of the total variation in the monthly incidence rate of leishmaniasis. The results also indicate that as the monthly maximum temperature increases by 10 °C the incidence rate of leishmaniasis decreases by three cases/100000 at the national level.

For the number of admissions at public hospitals; there is an intermediary positive correlation (r = 0.53) between the number of admissions at public hospitals and temperature; with a coefficient of determination (R^2) value of 0.28. This indicates that the variation in MMT accounts for 28 percent of the total variation in the monthly number of admissions at public hospitals. In other words, 28 percent of the patients attending health centers for respiratory diseases are attributed to temperature. As the monthly maximum temperature increases by 1 °C, the number of admissions at public hospitals will increase by 97 admissions at the national level.

4.5.4 Adaptation Alternatives for the Health Sector

There are no specific guidelines for adaptation measures for the health sector due to crosscutting with all other sectors. There is a need for integrated multidisciplinary approach. In general, impacts on health depend on impacts of climate change on water resources management, transport and the infrastructure of respective country. Therefore, carrying out improvements in environmental practices, preparing disaster management plans and improving the public health infrastructure in Jordan, including disease surveillance and emergency response capabilities, will go a long way in coping with the impacts of climate change on human health.

Accordingly, adaptation strategies to climate change on health sector can be summarized as follows:

- Strengthening surveillance and establishment of highly sensitive alert system by developing health forecast system for acute respiratory and any climate sensitive diseases.
- Prevention and control of emerging and re-emerging vector-borne diseases (malaria and hemorrhagic fever).
- Strengthening the existing emergency preparedness and disaster management by implementing recognized surveillance monitoring system. Also, formulation and

implementation of policies for disaster preparedness with adaptive strategies.

- Supporting and strengthening preventative health programs and projects within public health divisions, with emphasis on community involvement projects.
- Improving monitoring systems such as permanent monitoring of the drinking water quality and permanent monitoring of water supply and sewerage systems.
- Capacity building and increasing awareness of the population through regular training workshops on sanitary education.
- Undertaking research on population and on individual level to provide a solid basis for formulation of adaptation strategies.

4.5.5 Limitations and Constraints

- Most health outcomes including water-borne and vector-borne diseases have multi factorial causes, which may be interrelated and may limit the predictability of the health outcome.
- There are no known baseline data, studies and models to verify the results and perform comparisons.
- Improvement of environmental sanitation leads to decreased incidence of diseases. This could mask the increase related to climate change leading to inaccurate prediction of its effects on health.
- Ecological studies detected associations but could not prove the causality between exposure and disease.
- Health system in Jordan uses records that are based on disease groups. As an example, group one represents all infectious diseases, group seven represents cardiovascular diseases, and group nine represents digestive tract diseases. As a result, it is difficult to gather detailed information from these registries.

4.5.6 Conclusions

Although of limited data, the vulnerability assessment of health sector to climate change identified positive or negative correlation of health outcomes with ambient temperature which ranges from weak to strong correlations.

There is a decreasing secular trend for diarrhea incidence rate in Jordan through the period 1988-2007. In spite of the increase in temperature, the incidence rate of diarrhea decreased. This could be due to sanitation improvement of the sewage system, chlorination of drinking water and development of primary health care. Also, there is a regular seasonality of diarrhea which is directly correlated to the ambient temperature.

There is a strong positive correlation between diarrhea incidence rate and temperature. Investigating results reveal that incident rate of diarrhea may increase by one case/1000 at the national level as the MMT increases by 1 °C. Weak correlation was noticed for typhoid and it was found that as the monthly maximum temperature increases by ten °C, the incidence rate of typhoid increases by two cases/100000 at the national level.

It was found that there is an intermediary positive correlation between rates of hepatitis A and temperature. It was estimated that 14 percent of hepatitis A cases are attributed to temperature increase. It was also found that as the monthly maximum temperature increases by 1 °C, the incidence rate of hepatitis A decreases by one case/100000 at the national level.

4.6 SOCIO-ECONOMIC IMPACTS

4.6.1 Introduction

The main purposes of the socio-economic scenarios in the assessment of climate impacts, adaptation and vulnerability are to characterize the demographic, socio-economic and technological driving forces underlying anthropogenic greenhouse gas emissions which cause climate change, and to characterize the sensitivity, adaptive capacity and vulnerability of social and economic systems in relation to climate change.

There is considerable uncertainty regarding the methodologies employed for conducting socioeconomic impact assessments of climate change. This is because of the absence of a universally accepted framework for analysis in this area. For the purpose of this analysis, socioeconomic impacts are largely assumed to be derived from the impacts occurring in sectors such as agriculture and livestock, forestry and land use change, among others. Some direct socioeconomic impacts are also likely to occur, primarily in the form of health impacts.

Understanding the socio-economic pattern(s) of any system(s) is essential for adapting to climate change. Vulnerability to climate change depends on the interactions between changing socio-economic conditions and climate hazards.

Successful adaptation must be accomplished through actions that target and reduce the vulnerabilities faced by poor people, as they are likely to become more prevalent as the climate changes. Adaptation tackles the issue of vulnerability reduction through their respective activities such as disaster risk reduction, climate and climate change, environmental management, and poverty reduction.

The objectives of the socio-economic study are: (1) to review social and economic scenarios relevant to climate assessments (mitigation and adaptation) in Jordan; (2) to assess the needs of different communities of users for socio-economic scenarios in climate change assessment and decision-making; (3) to tailor existing social and economic scenarios for climate assessment and decision-making; and (4) to propose further research on social and economic scenarios in climate research and policymaking.

4.6.2 Baseline Socioeconomic Scenarios

Socioeconomic variables have two basic roles in climate impact assessment. The first role is an indicator of economic and social conditions that might be influenced by climate. Climate impacts on society can be described by changes in such variables. The second role of socioeconomic variables is an indicator of socioeconomic drivers that directly or indirectly influence sensitivity and vulnerability to climate change. For example, population and income growth increase the demand for water and adequate quality, which has implications for the assessment of impacts of climate change on water quantity and quality. The socio-economic variables that could be used in analyzing the climate change effect are:

a. Demography variables:

These variables include population growth, age structure, population density, urban-rural population, mortality rates, household size, employment and unemployment rates, and migration.

b. Economic conditions variables:

These variables include GDP per capita, GDP from agriculture and GDP annual growth rate.

4.6.3 Methodology

In the conducted socio-economic study, demographic variables as well as economic condition variables were subjected to detailed regression analysis using different climatic variables. None of the socio-economic variables showed significant correlation with any climatic variables. Then, it was decided to conduct a field survey followed by qualitative and descriptive analysis. The field survey was conducted according to the following methodology:

Three groups of people were met and interviewed in the three related governorates, Irbid, Jarash and Mafraq, since these governorates are located in the two study areas. The collected data from all the interviewed people were analyzed qualitatively, where descriptive analysis was used.

1. The first group is the policy makers: the governor, head of the development department of the governorate, head of government departments in Irbid and Mafraq governorates.
2. The second group is composed of farmers in Irbid and Mafraq governorates, who were divided into two subgroups: plant production and livestock production. The focus group technique, with a pre-structured questionnaire was used and implemented for the first two groups.
3. The third group was a sample of 61 households from the community: 30 households in Irbid, 13 households in Jarash, and 18 households in Mafraq. They were selected randomly from a list of poor people who receive aid from the National Aid Fund.

4.6.4 Results

4.6.4.1 Statistical information on the study areas

The population growth rate in Zarqa River governorates during the period 1994-2006 was about 2.7 percent, which is almost equal to the average growth rate in the Kingdom. The reported average growth of income in Zarqa compared to Amman and Mafraq in the period 1997-2002 was as follows: the highest in Amman (3.9 percent), the lowest in Mafraq (1.3 percent), and a negative growth rate (-0.4 percent) in Zarqa. On the other hand, the average annual growth of consumption in Jordan was 8.7 percent, with the highest in Jarash (14 percent) and the lowest in Zarqa (1 percent).

4.6.4.2 Field survey results

Results of the focus groups and the meetings with the policy makers were discussed with the recommendations proposed by the interviewees. Data and information in the questionnaires were analyzed using the SPSS software.

The field survey showed that the highest income in Jarash and Ajlun, which are parts of Yarmouk River Basin, was the government salaries. In Mafraq, the highest income was through foreign remittances, while in Irbid the highest income originated from selling field crops. In all governorates, the largest part of the income was spent on buying clothes and social activities.

The governorate role with respect to climate conditions is to coordinate with other departments through the formation of committees to assess the extent of the damage (if any) and in the case of frost. The role of related departments is to execute the resolutions adopted by the Council of Ministers.

The Government of Jordan partially compensates farmers who are affected by frost with financial aid. Compensations are determined based on reports prepared by assessment committees. Moreover, the government partially compensates livestock owners by providing small quantities of barley at subsidized prices.

The government does not compensate for other climate hazards such as drought, snow or flood, except when general severe drought condition is declared by the Cabinet. During severe drought, the government exempts farmers, partially or totally, from interest rates on their loans from the Agricultural Credit Corporation.

The main effect of climate change factors on the respondents in urban areas is the shortage of water which affects sanitary conditions in households, thus increases some diseases such as diarrhea, in addition to the cost of living.

The impact of climate change on public health could be summarized as follows: (1) results of the study showed that climate change causes the emergence of many diseases, especially due to high temperatures, (2) there was considerable impacts of climate change on water availability for sanitary purposes in households, and (3) to address the problem of lack of clean water caused by low rainfall; the urban dwellers buy water from tankers, while some of them reduced the frequency of household cleaning, which may result in some health hazards.

The impact of climate change on the domestic use of water could be summarized as follows: (1) most residents in the cities and villages rely on the networks of the Water Authority for drinking purposes and domestic use, few rely on wells and rainwater collection tanks, and the rest purchase water from the tankers, and (2) climate change (drought) leads to lower quantity of drinking water reaching homes, and this leads to lower water consumption, while few felt that there is no impact due to drought because needed water is obtained from municipalities.

The impact of climate change is not clearly felt by residents of the urban centers, specially the employees. People whose income was affected usually depend on agriculture for living. Few of the respondents indicated that there is a decline in the purchasing power of their income due to high prices in drought years. These results pointed to the possibility of widening the proportion of poverty as a result of climate change. This is mainly due to the loss of part of the resources of the community, which leads to lower standard of living. As the income decreased, or the purchasing power of consumers decreased, some of the urban people started reducing spending on health and education to cope with rising commodity prices caused by climatic changes.

Influence on the exploitation of home gardens could be summarized as follows: (1) low rainfall causes low level of water distribution to the households, which leads to a decreasing level of production in home gardens, and (2) the water department in the different municipalities reduced the quantities of water delivered to households during drought years through reducing the frequency of distribution.

Rural households in Jordan rely heavily on climate-sensitive resources such as local water supplies and agricultural land, and climate-sensitive activities such as arable farming and livestock husbandry. Climate change can reduce the availability of those local natural resources, limiting the options for rural households that depend on natural resources for consumption or trade.

Some of the interviewed farmers indicated that they do not receive adequate climate information. The majority of those who receive information do not use it. Most of the farmers trust indigenous climate predictions more than contemporary climate forecasts. The reason they gave was that contemporary information is too general and not specific in time and space.

The most important climate information being requested by most farmers are seasonal forecasts, although shorter term forecasts are needed to support farming decisions. Farmers would like to know when the rainy season begins and ends and whether the season will have below normal, normal, or above normal rainfall. The farmers are requesting reliable forecasts and timely information delivery. Farmers also indicated that the information is often too technical.

The effect of climate change on the livestock sector could be summarized as follows: (1) it has an impact on the price and availability of fodder, since poor rain leads to higher prices of feed and low water availability which cause rising production cost, (2) lack of water for producing feed crops raises prices of these products, (3) some farmers who own livestock continued land cultivation to produce roughages to feed their animals in low-rain seasons, (4) the lack of wild grasses in drought years increases reliance on purchased fodder, which makes some herders sell part of their flocks at low price to purchase feed for the rest of the flock, and (5) in drought years the livestock owners feed their animals on the vegetable farms roughages.

The farmers and livestock owners suggested the following solution for climate change adaptation: (1) securing affordable fodder for livestock breeders, (2) the formation of associations for cultivating fodder in areas with available water to secure fodder for the rest of the Kingdom, (3) farmers should be allowed to dig boreholes to provide water for agriculture and livestock, (4) encourage the cultivation of fodder in the adjacent land to the Zarqa River which is mixed with treated wastewater, (5) support the farmer to encourage using drip irrigation to decrease irrigation water requirements, and (6) provide support to the farmers in drought years so that they can stay in business.

The effect of climate change on the plant production sector could be summarized as follows: (1) low rainfall has an impact on crop production especially for wheat and barley, (2) continuation of the crop production in low rainfall seasons is based on traditions as well as the hope that the rest of the season will be better, (3) decreasing amounts of water in the springs to be used for irrigation, (4) prices of purchased water for irrigation in drought years are high and unprofitable, and (5) lack of water harvesting practices, due to lack of finance and know-how.

4.6.4.3 Climate change and poverty

The most significant causes of poverty are high unemployment and low wages in rural areas, especially during drought seasons. International Fund for Agricultural Development (IFAD) initiated a project entitled: "Agricultural Resources Management Project (ARMP)" in two phases. The main objectives of the proposed project would be to improve food and water security for low-income levels of the target group of poor and rural households residing in the project area. The project would attempt to promote effective use of soil and water resources, and introduce better management practices for their sustainable use with particular focus on conservation of the environment. These would be achieved through: (i) providing technical and financial support to construct soil and water conservation measures and improve agricultural production through active participation of the target groups; (ii) promoting sustainable land management practices and supporting environmental monitoring; (iii) promoting rural micro-finance for on- and off-farm activities; and (iv) strengthening the capacity of existing project management unit and the agricultural directorates in the project area to provide the required technical support services and extension in line with the government decentralization plan to enhance sustainability of these services.

The adaptation procedures for climate change in the ARMP include: (1) water resources development, including construction of on-farm storage facilities such as cisterns and rehabilitation of Roman wells; off-farm reservoirs (mini earth dams) for seasonal storage of water for supplementary irrigation; protection of the springs and rehabilitation of their irrigation systems; assisting and training water users to form Water Users Associations for proper operation and maintenance of the system and for efficient use of water, and (2) a research program was funded to examine methodologies for safe and economically feasible treatment of households domestic wastewater for reuse (e.g., irrigating tree crops).

Moreover, IFAD implemented another project "Yarmouk Agricultural Resources Development Project (YARDP)". The principal objectives of the project were to improve the food security and income levels of target group (farmers) by arresting degradation and restoring soil fertility for sustainable use of land and water resources through: (i) technical and financial support for the target groups to implement soil and water conservation measures and improve agricultural production; (ii) promotion and credit-funding of on- and off-farm enterprises; and (iii) strengthening the capacity of the agricultural directorates in the project area to provide the required technical support services and extension.

The adaptation procedures for climate change in the YARDP include the following: (1) supplementary project interventions through constructing mini earth dams and small-scale water harvesting, and (2) the protection of springs, increasing water-use efficiency and preventing water logging, particularly at the sources of springs. All of these adaptation measures were implemented in the project sites.

4.6.5 Limitations, Difficulties, Gaps and Constraints

Collecting data to evaluate the above mentioned variables faced crucial problems:

1. The selected study area consists of several parts of different governorates which made it impossible to separate the included villages or towns from other places in the same governorate.
2. The data for most of the selected variables are available at the governorate level.
3. Some of the variables are not available in the form of time series data, but on interval periods which made it difficult to establish a link between the climate variables and the extrapolated socio-economic variables.

4.6.6 socio-Economic Adaptation Measures

The viability of socioeconomic adaptation to climate change is determined by the strength of the economy, the quality and coverage of health services, and the integrity of the environment. Societies with relatively greater economic resources and robust adaptive mechanisms suffer less severely from the unexpected impacts of climate change. Improvements in access to basic health care, clean drinking water, and sanitation facilities will increase the population's resilience to climate change and reduce the impact of disease vectors spreading into new areas. The study recommended the following:

- Establish Climate Information System (CIS). This system is important because most of the interviewed farmers in the study area indicated the need for such system to provide accurate temporal and spatial information on weather. Such climatic information is needed at the level of shorter forecast to seasonal forecast.
- Enhance the knowledge of the poor in adaptation methods to face the climate change through community participation.
- Given the increasing importance of poverty eradication, there is a need for measures aiming at minimizing climate's negative impacts on a country's development strategy. This could be achieved through: governments can attempt to increase the resilience of their growth strategies through implementing effective adaptation policies to both short-term and long-term impacts of climate on their economies; climate issues should be mainstreamed into national economic planning and budgetary processes; climate adaptation activities should be integrated in the budget framework of the development projects; effective adaptation strategies are facilitated by responsive and accountable public institutions.
- Follow up some adaptation measures in agriculture and food security, such as dam construction, soil fertility maintenance, and educational and outreach programs on conservation and management of soil and water.
- Provide the necessary resources to establish a "Climate Change Watch and Early Warning System" for the timely alert and preparedness of the country.
- Accord due attention and consideration to the socio-economic dimension of drought within the framework of the "Preparedness and Mitigation Plans", which should be comprehensive and integrated to address rehabilitation and development, including rangeland, livestock, forestry and crop production.
- Establish a "National Disaster Fund" for farmers.
- Institutional capacity needs boosting through provision of better equipment and more personnel training. Moreover, there is a need to improve networking among the institutions that deal with climate and drought forecasting and management.

The study suggested the following three related programs:

1- To obtain detailed analysis of the effect of climate change on the socio-economic factors, a comprehensive field survey should be conducted in a specific area, for instance in Mafraq governorate which is vulnerable to climate change. In this case, cross sectional data analysis could be conducted comparing the different socio-economic factors in different areas of the governorate with different levels of precipitation. The cost of the program depends on the size of the study area.

2- Vulnerability and adaptation to climate change workshop (training for trainers). The purpose of this workshop is to increase the participants' understanding of climate change issues, such as mitigation and adaptation, as well as their understanding of the impacts that climate change will have on development goals and vice versa. Participants will be able to identify key mitigation and adaptation options for climate change that would have the least impact on development goals. Additionally, development policies could be revised in order to lessen the compounding effects they have on areas affected by climate change. The training course components could be grouped under five modules: (i) vulnerability and adaptation: an overview, (ii) concepts, methods and tools to assess vulnerability, and adaptation strategies, (iii) vulnerability and adaptation: moving from theory to practice the basics, (iv) practical exercises, and (v) conclusions and lessons learned.

3- Strengthen national capacity to manage drought efficiently (a training course). The main objectives of this course are: (i) to improve water management planning, (ii) to reduce risks associated with drought, (iii) to improve cost effectiveness of response to drought, and (iv) to implement the drought early warning system at the provincial/regional level.

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OTHER INFORMATION: PUBLIC AWARENESS, EDUCATION AND CAPACITY BUILDING

5. OTHER INFORMATION: PUBLIC AWARENESS, EDUCATION AND CAPACITY BUILDING

This chapter provides other information considered relevant to the achievement of the objectives of the UNFCCC. In the context of addressing climate change at the national level, the following information is included; education, training, public awareness, capacity-building, steps taken to integrate climate change into relevant policies and research and studies on climate change.

5.1 PUBLIC AWARENESS

Recently awareness campaigns were carried out by the Ministry of Environment and other organizations. These campaigns focused mainly on various environmental issues like energy and water saving, waste minimization and sound waste management. During the past couple of years, a greater interest in the issue of climate change has been growing globally, regionally and nationally. During the year 2008, the Ministry of Environment and other national entities such as Greater Amman Municipality launched awareness campaigns on climate change[2]. These campaigns, which were sponsored by the private sector, used several tools and targeted different society groups including students.

After these campaigns the kingdom’s schools were more interested in the issues of climate change and consequently the Ministry of Environment participated in several activities and lectures. The lectures focused at connecting the well known environmental issues such as water and energy saving with Climate Change.

Also, the local daily newspapers published many articles on climate change and other environmental related issues. In addition, several television and radio programs addressing the climate change issues were broadcasted.

In the area of information dissemination, a project funded by the Global Environment Facility (GEF) will be executed by the National Energy Research Center aiming at promotion of widespread adoption of energy-efficient technologies and practices in the built environment.

5.2 EDUCATION

The schools curricula deal with environmental concepts and national priorities and challenges in general and climate change issues in particular at some grades. But, there is a need to re-evaluate the curricula aiming at better educating the students on climate change issues. Also, in most of the Jordanian Universities, there are special departments teaching environmental sciences and management and issues related to climate change.

5.3 CAPACITY BUILDING

Jordan has ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1993 and the Ministry of Environment (MoEnv) became the national focal point for climate change issues. The country started its efforts within the UNFCCC in 1996 with a program supported by the Global Environment Facility (GEF) and managed by the United Nations Development programme (UNDP) for national capacity building in documenting national emissions of greenhouse gases and preparing Jordan’s initial national communication (INC) to the UNFCCC. Also Jordan was the first developing country to submit is INC to the secretariat of the UNFCCC in 1998. In 2004, Phase II of the climate change enabling activity was started with the project “Building Capacity for GHG Emissions Inventory and Action Plan”. Its main objectives were to prepare national reports on technology needs assessment (TNA) and technology transfer (TT). And in 2005, the Ministry of Environment implemented another project entitled “National Capacity Self Assessment for Global Environmental Management (NCSA)”. The NCSA

2 A total of 18 articles were published on the MoEnv Climate Change Campaign during the year 2008, articles can be accessed on: <www.moenv.gov.jo>.

was a GEF initiative aiming at assessing the capacity constraints and potentials for implementing the three international environmental conventions on biodiversity, climate change and desertification.

Also, as part of the capacity building efforts, promoting the cleaner production practices is an important and ongoing effort to prevent pollution; reduce the depletion of non-renewable resources; and minimize waste in the production process, and eventually help in climate change mitigation efforts.

Additionally, the Ministry of Environment participated and organized few workshops related to Clean Development Mechanism (CDM) aiming at promoting this mechanism as a tool to mitigate climate change on the global level.

5.4 STEPS TAKEN TO INTEGRATE CLIMATE CHANGE INTO NATIONAL POLICIES

Climate change is probably one of the complex and challenging problem facing policy makers today. To effectively incorporate climate change issues into national sustainable development agendas, countries need to develop responsive policies and weigh various potential alternatives under conditions of high uncertainty and consequently recommend specific courses of actions in keeping with the country's economic and socio-political realities.

Through reviewing available published national polices and strategies of water and energy, it was clear that the climate change was not directly addressed.

The Energy Sector Master Plan prepared by the Ministry of Energy in 2004 and updated in 2007 dedicated a separate chapter to energy conservation and energy efficiency issues. However, it did not link the mentioned chapter to environmental protection nor to climate change directly. On the other hand, a National Energy Efficiency Strategy was recently issued and it was linked to environmental protection but, again, not to climate change.

A National Water Strategy for the years 2008- 2022 has been issued in May 2009. This strategy outlined needed actions and polices to overcome the shortage of water without taking into consideration the extra impact the climate change will induce.

Through the current SNC project, stakeholders from different ministries and governmental institutions were involved through the projects' different teams and committees aiming at raising their awareness so that climate change is incorporated into the future strategies and planning of these ministries.

Also, as part of the SNC work, a preliminary adaptation action plan was proposed as an initial step to develop a multi-sectoral action plan. The Ministry of Environment is considering to get high level commitment and endorsement of this action plan to help in having the issue of climate change integrated into the strategies and plans of the relevant main sectors.

Through reviewing the existing national strategies for women, poverty, childhood and early childhood development, it was clear that climate change issues were not directly addressed by them. However, it is recommended to include climate change issues in all future updates of these strategies.

5.5 RESEARCH AND STUDIES ON CLIMATE CHANGE

Jordan as a developing country has limited financial resources allocated for research. Regarding climate change, only minor research activities and studies have been carried out at universities and through funded projects; they mainly addressed the following areas;

- The effect of climate change on the water resources in Jordan.
- Contribution of solid waste disposal sites to greenhouse gas emissions in Jordan.
- Vulnerability of irrigated agriculture due to climate change in the southern Jordan River basin.
- Assessment of climate change impacts on water resources using GIS and remote sensing techniques in Yarmouk basin- northern Jordan.
- Socio-economic impacts of water allocation under climate change.
- Change in natural resources in relation to Socio-economic development.
- Vulnerability and adaptation of the water resources of Jordan to climate change.

However, more focus is needed on research directed towards implementation of adaptation and mitigation measures.

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PROBLEMS, CONSTRAINTS AND NEEDS

6. PROBLEMS, CONSTRAINTS AND NEEDS

6.1 INTRODUCTION

Constraints and gaps and related financial, technical and capacity needs identified through the preparation of the SNC are discussed hereafter. The national needs could be summarized as mainly; capacity building needs to increase the local knowledge base; mobilize financial resources to conduct studies and implement adaptation and mitigation projects, and strengthen the legislative and institutional framework.

6.2 CONSTRAINTS, GAPS AND NEEDS

6.2.1 GHG Inventory

Problems and Constraints

- Data gabs and data availability in the format and quality needed for GHG inventory preparation was one of the main identified problems faced during the preparation of SNC;
    - ◊ Lack of institutional arrangements for data collection and data sharing. Private institutions (i.e industries) are not obligated to disclose their data to the Ministry of Environment or other governmental body as there is no legal framework for reporting.
    - ◊ Data are often available in formats that suit government planning purposes, but do not cover all the information required by the IPCC methodology for inventory.
    - ◊ Lack of disaggregated activity data. Specific examples are:
        - ◊ LULUCF sector: unavailability of data of forest and non forest annual growth rates, soil types and their carbon content and land-use patterns.
        - ◊ Lack of activity data in industrial sector including fuel consumption figures.
        - ◊ Lack of up-to-date activity data in transport sector including modes of road transportation. In addition, data of local aviation and marine are not available.
        - ◊ Lack of activity data for use of energy in agriculture, forestry and fishing sub-sectors.
    - ◊ Unavailability of local emission factors, thus the IPCC default values was used.
    - ◊ Lack of IPCC methodology for solvents sector.
    - ◊ Poor documentation of the inventory of the Initial National Communication and other related studies.

Needs to Address the Identified Problems and Constraints

- Develop a GHG inventory data system aiming at collecting data in the needed quality and format. This system should include institutional arrangements to facilitate data collection and sharing among the various national institutions. Also, this system should include a legislative framework to obligate private sector to report the required data.
- Conduct surveys, studies and scientific research aiming at developing disaggregated activity data and emission factors needed for the GHG inventory estimation with special focus on key emission sources and sectors with high uncertainty.
- Conduct studies with regional cooperation aiming at developing regional emission factors.
- Develop the local capacities in using the new guidelines, methodologies, tools and software.
- Secure and mobilize financial resources to address the above mentioned needs.

6.2.2 Mitigation Analysis

Problems and Constraints

- Lack of data in sectors other than energy.
- Limited expertise in the energy models.
- Limited technical expertise in some sectors such as transport and agriculture.
- Weak awareness among decision makers on climate change in general and on financial and environmental benefits of CDM.

- Lack of legal and institutional framework to promote energy efficiency and renewable energy options.
- Improper enforcement of existing laws related to energy efficiency and renewable energy.

Needs to Address the Identified Problems and Constraints

- Develop the local capacities in using GHG mitigation methodologies, tools and software.
- Develop the local capacities in specific areas such as improvement of transport efficiency, assessment of different transport modes and application of transport mitigation methodologies.
- Secure and mobilize financial resources to implement GHG mitigation projects especially small scale CDM projects.
- Formulate legal and institutional framework to promote energy efficiency and renewable energy options as well as enforcement of exciting laws through setting bylaws and regulations.
- Raise awareness of decision makers and top management of industrial organizations on the benefits of CDM projects.

6.2.3 Vulnerability and Adaptation Problems and Constraints

- Data availability, consistency and transparency was one of the main identified problems faced during the preparation of climatic scenarios and thematic vulnerability and adaption studies;
    - ◊ There are missing data in the daily and monthly climatological time series at the majority of national meteorological stations.
    - ◊ There is also a problem in water data availability. The quality of the available data is sometimes inappropriate.
    - ◊ The existing climatic and water resources monitoring in the country is facing permanent problems in operation, slow modernization of equipment and reducing of the monitoring network.
    - ◊ Health data on climate sensitive diseases are either limited or not readily available. Current records are based on disease groups, for example group one represents all infectious diseases while group nine represents digestive tract diseases.
    - ◊ Socioeconomic data are either unavailable or available in inappropriate form. In general, data of some socioeconomic variables are available at the governorate level and not at cities, towns and villages level.
- Coarse spatial and temporal resolution of climate scenarios do not match the requirements of policy oriented applications
- Lack of regional climatic prediction models and downscaling models, thus, Global Circulation Models (GCMs) were used with high spatial distribution. Precipitation modeling using these GCMs models gave poor results.
- Lack of well developed methodologies and tools worldwide for undertaking vulnerability and adaptation studies especially for health and socioeconomic sectors.
- Limited local and international V&A studies to perform comparisons with the studies conducted during the SNC preparation and to verify the obtained results.
- Lack of financial resources to address needs, conduct research and studies, and implement adaptation measures.

Needs to Address the Identified Problems and Constraints

- Improve meteorological and water monitoring through modernization of equipment and extension of monitoring networks.
- Raising technical capacity for monitoring and data collection, data management and updating of basic data sets, and preparation of basic maps and databases.
- Capacity building is needed in the area of methodologies, tools and guidelines to conduct V&A studies.
- Conduct studies and research to assess adverse impacts and vulnerability to climate change in different sectors specially those that were not included in SNC, such as tourism and sea level rise sectors. In addition, studies are needed to geographically cover all potentially vulnerable areas of the kingdom.
- In the field of climate and climate change scenarios there is a need to establish regional models and downscaling models.
- Secure and mobilize financial resources to conduct studies and implement adaptation measures.

- During the preparation of SNC, adaptation measures were proposed by the V&A team. These measures were formulated into programs and projects and were included in a proposed preliminary adaptation action plan.

There is a need to further develop the proposed plan into a comprehensive multi-sectoral "National Adaptation Action Plan" through the participation and engagement of the relevant institutions and stakeholders including ministries of environment, water, agriculture and health. This action plan is expected to address all needs in the area of V&A and to focus on prioritizing the proposed programs and projects based mainly on the vulnerability of the different sectors. The plan is also expected to identify barriers to implementation of the adaptation measures and put forward programs, projects and mechanisms to deal with them. Such barriers include the problems and constraints mentioned earlier, such as lack of financial resources, lack of awareness, lack of adequate tools, knowledge and methodologies, and lack of incorporation of climate change in developing policies, strategies and plans of climate sensitive sectors.

6.3 FINANCIAL RESOURCES AND TECHNICAL SUPPORT FOR THE PREPARATION OF NATIONAL COMMUNICATIONS AND FOR ACTIVITIES RELATING TO CLIMATE CHANGE

Global Environment Facility (GEF) financially supported Jordan in executing the following climate change activities:

- Preparation of the Initial National Communication (INC), executed by General Corporation for Environment Protection (GCEP) (later became Ministry of Environment (MoEnv)), 1996-1997.
- Vulnerability and adaptation to climate change, carried out by MoEnv in the year 2000 as completion to the INC.
- Establishing a pilot biogas facility at Russifa domestic landfill site, executed by Greater Amman Municipality, commissioned in the year 2000.
- Technology needs assessment (TNA) and technology transfer (TT), executed by MoEnv, (2004-2005).
- National Capacity Self Assessment for Global Environmental Management (NCSA). This project was implemented to assess the capacity constraints and potentials for implementing the three international environmental conventions on biodiversity, climate change and desertification, executed by MoEnv, 2005.
- Enabling Activities for the Preparation of Jordan's Second National Communication to the UNFCCC, executed by MoEnv, 2006-current.

The above projects have been executed with UNDP support, and technical support from other United Nations organizations including UNEP and UNFCCC. In addition, National Communication Support Programme (NCSP) -which is a UNEP/UNDP programme- has provided technical support during the preparation of Jordan's SNC through training workshops, provision of guidelines and guidance materials, review of studies and reports and provision of online support and tele-conference calls.

Jordan's contribution in these projects is in the form of in kind cost including human resources, office space and furniture, communications, and the associated cost.

6.4 TECHNOLOGY TRANSFER

Technology transfer needs, constraints and gaps have been addressed in two GEF funded projects; Technology Transfer Needs Assessment (TT/NA) and the National Capacity Self Assessment for Global Environmental Management (NCSA). Main constraints and gaps identified at the NCSA project can be summarized as follows:

- Lack of appropriate funding for technology transfer and research.
- Routine government procedures and lack of specialized staff in the public sector.
- Lack of incentives and high taxation and customs on modern technology.
- Insufficient information and training courses allocated to emphasize the effectiveness and the feasibilities of different technological options.
- Lack of legislative and institutional framework.
- Limited expertise in modern technology maintenance and spare parts availability.
- Special needs for foreign experts to transfer knowledge and experience of the new technologies.

APPENDIX

APPENDIX A

INVENTORY SECTORAL REPORTS

Table A1: Sectoral report for energy

(Sheet 1 of 3)
SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES
(Gg)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NOx	CO	NMVOC	SO_2
Total Energy	14713.8673	6.1586	0.2184	75.4715	224.8057	53.3562	185.2046
A Fuel Combustion Activities (Sectoral Approach)	14713.3473	1.6238	0.2184	75.4319	216.3709	52.4659	184.9076
1 Energy Industries	5573.0147	0.2090	0.0409	14.6846	1.1801	0.3784	121.1903
a Public Electricity and Heat Production	4897.6500	0.1800	0.0310	12.8400	1.0400	0.3300	105.1100
b Petroleum Refining	675.3700	0.0300	0.0100	1.8400	0.1400	0.0500	16.1100
c Manufacture of Solid Fuels and Other Energy Industries	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2 Manufacturing Industries and Construction	1858.3773	0.0489	0.0147	4.8928	0.2446	0.1223	39.5370
a Iron and Steel	156.7700	0.0000	0.0000	0.4100	0.0200	0.0100	3.7900
b Non-Ferrous Metals	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
c Chemicals	719.1700	0.0280	0.0000	1.9200	0.0900	0.0500	15.3800
d Pulp, Paper and Print	9.8400	0.0000	0.0000	0.0300	0.0000	0.0000	0.2400
e Food Processing, Beverages and Tobacco	44.1800	0.0000	0.0000	0.1200	0.0100	0.0000	0.6100
f Other (please specify)	927.8900	0.0200	0.0100	2.4200	0.1200	0.0600	19.1900

Table A1: Sectoral report for energy

(Sheet 2 of 3)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES	(Gg)						
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
3 Transport	3564.0181	0.9019	0.1308	40.3706	200.1221	48.9611	11.8334
a Civil Aviation	5.4525	0.0004	0.0002	0.0200	0.0147	0.0036	
b Road Transportation	3537.1507	0.9001	0.1304	40.0001	199.8153	48.8990	
c Railways	21.4149	0.0015	0.0002	0.3505	0.2921	0.0584	
d Navigation	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
4 Other Sectors	2779.8398	0.3977	0.0241	4.8895	1.5809	0.3556	8.7246
a Commercial/Institutional	540.4473	0.0754	0.0045	0.7537	0.1507	0.0377	
b Residential	1858.2959	0.2731	0.0164	2.7306	0.5461	0.1365	
c Agriculture/Forestry/Fishing	381.0966	0.0493	0.0032	1.4052	0.8841	0.1813	
5 Other (please specify)	938.2327	0.0662	0.0079	10.5945	13.2431	2.6486	3.6223
B Fugitive Emissions from Fuels	0.5200	4.5349	0.0000	0.0396	8.4348	0.8903	0.2970
1 Solid Fuels	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
a Coal Mining							
b Solid Fuel Transformation							
2 Oil and Natural Gas	0.5200	4.5349	0.0000	0.0396	8.4348	0.8903	0.2970
a Oil	0.0000	0.3188	0.0000	0.0396	8.4348	0.8903	0.2970
b Natural Gas	0.0000	2.4882	0.0000	0.0000	0.0000	0.0000	0.0000
c Venting and Flaring	0.5200	1.7278	0.0000	0.0000	0.0000	0.0000	0.0000

Table A1: Sectoral report for energy

(Sheet 3 of 3)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES							
(Gg)							
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Memo Items							
International Bunkers	541.56	0.04	0.02	2.88	1.82	0.67	0.43
Aviation	541.56	0.04	0.02	2.88	1.82	0.67	0.43
Marine	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO_2 Emissions from Biomass	0						

Table A2: Sectoral report for industrial processes

(Sheet 1 of 2)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg) GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NOx	CO	NMVOC
Total Industrial Processes	1594.31	0.00	0.00	0.08	0.30	62.86
A Mineral Products	1594.31	0.00	0.00	0.00	0.00	35.96
1 Cement Production	1588.74					
2 Lime Production	5.29					
3 Limestone and Dolomite Use	0.00					
4 Soda Ash Production and Use	0.29					
5 Asphalt Roofing					0.00	0.00
6 Road Paving with Asphalt						35.96
7 Other (please specify)	0.00	0.00	0.00	0.00	0.00	0.00
Glass Production						0.00
Concrete Pumice Stone						
B Chemical Industry	0.00	0.00	0.00	0.00	0.00	0.00
1 Ammonia Production	0.00				0.00	0.00
2 Nitric Acid Production			0.00	0.00		
3 Adipic Acid Production			0.00	0.00	0.00	0.00
4 Carbide Production	0.00	0.00				
5 Other (please specify)		0.00		0.00	0.00	0.00
C Metal Production	0.00	0.00	0.00	0.00	0.00	0.00
1 Iron and Steel Production	0.00			0.00	0.00	0.00
2 Ferroalloys Production	0.00					
3 Aluminium Production	0.00			0.00	0.00	
4 SF_6 Used in Aluminium and Magnesium Foundries						
5 Other (please specify)	0.00					

P = Potential emissions based on Tier 1 Approach. A = Actual emissions based on Tier 2 Approach. This only applies in sectors where methods exist for both tiers.

SO_2	HFCs		PFCs		SF6	
	P	A	P	A	P	A
1.20	0.0027	0.0005	0.00	0.00	0.00000000	0.00000209
0.83	0.00	0.00	0.00	0.00	0.00000000	0.00000000
0.83						
0.00	0.00	0.00	0.00	0.00	0.00000000	0.00000000
0.00						
0.00	0.00	0.00	0.00	0.00	0.00000000	0.00000000
0.00						
0.00						
0.00	0.00	0.00	0.00	0.00	0.00000000	0.00000104
0.00						
0.00				0.00		
						0.00000104

Table A2: Sectoral report for industrial processes

(Sheet 2 of 2)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES

(Gg)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NOx	CO	NMVOC	SO_2	HFCs		PFCs		SF_6	
								P	A	P	A	P	A
D Other Production	0.000	0.000	0.000	0.080	0.300	26.898	0.375	0.0000000	0.0000000	0.000	0.000	0.000	0.000
1 Pulp and Paper				0.080	0.300	0.198	0.375						
2 Food and Drink						26.700							
E Production of Halocarbons and Sulphur Hexafluoride	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000000	0.0000000	0.000	0.000	0.000	0.000
1 By-product Emissions									0.0000000		0.000		
2 Fugitive Emissions									0.0000000		0.000		
3 Other (please specify)													
F Consumption of Halocarbons and Sulphur Hexafluoride	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0027080	0.0004604	0.000	0.000	0.000	0.00000104
1 Refrigeration and Air Conditioning Equipment									0.0004604		0.000		
2 Foam Blowing									0.0000000		0.000		
3 Fire Extinguishers									0.0000000		0.000		0.000
4 Aerosols									0.0000000		0.000		
5 Solvents									0.0000000		0.000		
6 Other (please specify)									0.0000000		0.000		0.000
G Other (please specify)													

P = Potential emissions based on Tier 1 Approach. A= Actual emissions based on Tier 2 Approach. This only applies in sectors where methods exist for both tiers.

Table A3: Sectoral report for solvent and other product use

(Sheet 1 of 1)
SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES
(Gg)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	N_2O	NMVOC
Total Solvent and Other Product Use	0	0	13.34
A Paint Application	0.00	0.00	8.57
B Degreasing and Dry Cleaning	0.00	0.00	0.00
C Chemical Products, Manufacture and Processing	0.00	0.00	4.77
D Other (please specify)	0.00	0.00	0.00

Table A4: Sectoral report for agriculture

(Sheet 1 of 2)
SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES
(Gg)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CH_4	N_2O	NOx	CO	NMVOC
Total Agriculture	0.02990	0.58902	0.01057	0.22251	0.00000
A Enteric Fermentation	0.01808				
1 Cattle	0.00363				
2 Buffalo	0.00000				
3 Sheep	0.01169				
4 Goats	0.00227				
5 Camels and Llamas	0.00026				
6 Horses	0.00006				
7 Mules and Asses	0.00018				
8 Swine	0.00000				
9 Poultry	0.00000				
10 Other (please specify)					
B Manure Management	0.00122	0.00205			
1 Cattle	0.00015				
2 Buffalo	0.00000				
3 Sheep	0.00037				
4 Goats	0.00008				
5 Camels and Llamas	0.00001				
6 Horses	0.00001				
7 Mules and Asses	0.00002				
8 Swine	0.00000				
9 Poultry	0.00058				

Table A4: Sectoral report for agriculture

(Sheet 2 of 2)

(Gg)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CH_4	N_2O	NOx	CO	NMVOC
B Manure Management (cont...)					
10 Anaerobic		0.0000			
11 Liquid Systems		0.0000			
12 Solid Storage and Dry Lot		0.0020			
13 Other (please specify)		0.0000			
C Rice Cultivation	0.0000				
1 Irrigated	0.0000				
2 Rainfed	0.0000				
3 Deep Water	0.0000				
4 Other (please specify)					
D Agricultural Soils		0.5867			
E Prescribed Burning of Savannas	0.0000	0.0000	0.0000	0.0000	
F Field Burning of Agricultural Residues (1)	0.0106	0.0003	0.0106	0.2225	
1 Cereals					
2 Pulse					
3 Tuber and Root					
4 Sugar Cane					
5 Other (please specify)					
G Other (please specify)					
Note: The Revised IPCC 1996 Guidelines do not provide methodologies for the calculation of CH_4 emissions, and CH_4 and N2O removals from agricultural soils, or					
CO_2 emissions from savanna burning or agricultural residues burning. If you have reported such data, you should provide additional information (activity data and emissions factors) used to make these estimates.					
(1) Sub-items of F should be linked to Worksheet 4-4 sheets 1 and 2.					

Table A5: Sectoral report for land-use change and forestry

(Sheet 1 of 1)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)								
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions		CO_2 Removals		CH_4	N_2O	NOx	CO
Total Land-Use Change and Forestry	(1)	738.9869	(1)	0.0000	0.0000	0.0000	0.0000	0.0000
A Changes in Forest and Other Woody Biomass Stocks	(1)	0.0000	(1)	-221.5185				
1 Tropical Forests								
2 Temperate Forests								
3 Boreal Forests								
4 Grasslands/Tundra								
5 Other (please specify)								
B Forest and Grassland Conversion		0.0000			0.0000	0.0000	0.0000	0.0000
1 Tropical Forests		0.0000						
2 Temperate Forests		0.0000						
3 Boreal Forests		0.0000						
4 Grasslands/Tundra		0.0000						
5 Other (please specify)		0.0000						
C Abandonment of Managed Lands				0.0000				
1 Tropical Forests				0.0000				
2 Temperate Forests				0.0000				
3 Boreal Forests				0.0000				
4 Grasslands/Tundra				0.0000				
5 Other (please specify)				0.0000				
D CO2 Emissions and Removals from Soil	(1)	960.5053	(1)	0.0000				
E Other (please specify)								

Table A6: Sectoral report for waste

(Sheet 1 of 1)

SECTORAL REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES						
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2(1)	CH_4	N_2O	NOx	CO	NMVOC
Total Waste	0.0000	124.5319	0.3167			
A Solid Waste Disposal on Land	0.0000	119.7733	0.0000			
1 Managed Waste Disposal on Land						
2 Unmanaged Waste Disposal Sites						
3 Other (please specify)						
B Wastewater Handling	0.0000	4.7586	0.3167			
1 Industrial Wastewater		0.0248				
2 Domestic and Commercial Wastewater		4.7338	0.3167			
3 Other (please specify)						
C Waste Incineration						
D Other (please specify)						
(1) Note that CO_2 from waste disposal and incineration should only be included if it stems from non-biological or inorganic waste sources						

APPENDIX B

UNCERTAINTY IN GHG INVENTORY FOR THE YEAR 2000

1. OVERVIEW

The IPCC Good Practice Guidance (2000) characterizes determination of uncertainties as a key element of any complete inventory. The purpose of uncertainty estimate is not to dispute the validity of the inventory estimate, but to help prioritize efforts and resources allocation to improve the accuracy of inventories in the future, in addition to guiding decisions on methodological choice. Quantitative estimates of uncertainty can also be used to assess the relative importance of input parameters according to their relative contribution to the uncertainty in the associated source category.

The Tier 1 uncertainty analysis for the Jordan GHG inventory for the year 2000 gives an overall uncertainty of 6.70 percent (excluding LULUCF from CO_2 uncertainty estimates), the level of uncertainty associated with the total inventory of CO_2, CH_4 and N_2O emissions estimate are 3.52 (excluding LULUCF), 35.29, and 128.28 percent respectively. The uncertainty estimates including LULUCF are 20.63 percent (for all GHG put together) and 23.85 (for CO_2 alone).

2. METHODOLOGY

The Tier 1 method (GPG, 2000) has been used to assess uncertainty in the national GHG inventory. This method is based on the error propagation equation which combines uncertainty associated with activity data and uncertainties associated with the emission factors.

International and local experts, who were elected to determine uncertainty in the activity data of the national GHG inventory, conducted a meeting to determine uncertainty in the activity data. After discussion with the international experts, in light of the IPCC guidelines, local experts determined uncertainty in the activity data.

Uncertainty in emission factors, for each source category of the inventory, has been assigned based on default values available from the IPCC guidelines. Uncertainty in the source categories were then combined to provide uncertainty estimates for the entire inventory.

3. SOURCE CATEGORY INVENTORY UNCERTAINTY ESTIMATES

In order to carryout uncertainty analysis all the input variables have been well-characterized in terms of their probability distribution functions. Tables (B1 through B5) summarize results based on assessments of source category-level uncertainty. Uncertainty in the year 2000 emissions is the combination of uncertainty of activity data and emission factors. Source category trend uncertainty has not been conducted due to the absence of reliable base year emission estimates.

Energy sector overall emissions uncertainty estimate is relatively low, and stands at 2.29 percent. Table (B1) summarizes the emissions uncertainty estimate for all source categories of the energy sector. Emissions uncertainty estimates for each source category were found by combining activity data uncertainty level with that for emission factors for each fuel consumed at the source category. Activity data uncertainty has been characterized by local expert judgment in light of the IPCC Guidelines for each source category. In order to assign uncertainty level to the emission factors for each fuel consumed at the different source categories of the energy sector, information provided from the 2006 IPCC Guidelines for National GHG Inventories (Table (2.2), Table (2.5), Table (3.2.1) and (Table 3.2.2)) was used.

Table (B2) describes the uncertainty estimate for the industrial processes sector, and shows that the overall uncertainty level is 30 percent. Activity data uncertainty is the combined uncertainty of different parameters which was assigned by local expert judgment in light of the IPCC 2006 Guidelines. The guidelines were also used to evaluate the emission factor uncertainty.

For both the agricultural and waste sectors, uncertainty estimates based on source category analysis are shown in Tables (B3 and B4). Emission factor and activity data uncertainty was estimated from the available ranges of emission factors and default uncertainty estimate in the IPCC 2006 guidelines, while the activity data uncertainty level was determined by local expert judgment.

Table B1: Energy sector uncertainty estimate

Source Category	Gas	Year 2000* Emissions Gg CO_2 Eq.	Emissions Uncertainty %
Energy Industries	CO_2	5,573.01	3.17
Energy Industries	CH_4	4.39	223.46
Energy Industries	N_2O	12.68	228.25
Commercial / Institutional	CO_2	540.44	10.62
Commercial / Institutional	CH_4	1.58	200.43
Commercial / Institutional	N_2O	1.40	233.7
Residential	CO_2	1,858.30	7.87
Residential	CH_4	5.73	200.43
Residential	N_2O	5.08	233.7
Agriculture / Forestry / Fishing	CO_2	381.10	9.72
Agriculture / Forestry / Fishing	CH_4	1.07	184.96
Agriculture / Forestry / Fishing	N_2O	1.02	340.97
Other	CO_2	938.25	8.99
Other	CH_4	1.27	90.94
Other	N_2O	2.24	1900.04
Manufacturing Industries and Construction (Auto generation)	CO_2	415.76	3.65
Manufacturing Industries and Construction (Auto generation)	CH_4	0.21	400.02
Manufacturing Industries and Construction (Auto generation)	N_2O	0.00	233.35
Manufacturing Industries and Construction (Process Heat)	CO_2	1,442.19	3.28
Manufacturing Industries and Construction (Process Heat)	CH_4	0.84	400.01
Manufacturing Industries and Construction (Process Heat)	N_2O	3.10	233.35
Transport	CO_2	3,558.57	5.14
Transport	CH_4	18.90	238.21
Transport	N_2O	40.43	243.26
Fugitive	CH_4	95.23	35.87
Total	CO_2	14,707.62	2.15
Total	CH_4	129.23	45.45
Total	N_2O	65.95	169.82
Overall Uncertainty		14,902.80	2.29

* : Values from National GHG inventory, 2009

Table B2: Industrial processes sector uncertainty estimate

Source Category	Gas	Year 2000 * Emissions Gg CO_2 Eq.	Activity Uncertainty %	Emission† Factor Uncertainty %	Emissions Uncertainty %
Cement Production	CO_2	1,588.74	30.00	2.50	30.10
Production of Lime	CO_2	5.29	1.50	2.00	2.50
Soda Ash Production and Use	CO_2	0.29	25.00	2.00	25.08
Overall Uncertainty		1,594.32			30.00

* : Values from National GHG inventory 2009

† : Source: IPCC, 2006

Table B3: Agricultural sector uncertainty estimate

Source Category	Gas	Year 2000 * Emissions Gg CO_2 Eq.	Activity Data Uncertainty %	Emission † Factor Uncertainty %	Emissions Uncertainty %
Field Burning of Agricultural Residues	CH_4	0.22	50.00	30.00	58.31
Field Burning of Agricultural Residues	N_2O	0.09	50.00	30.00	58.31
Agricultural Soils (Direct)	N_2O	127.10	20.00	80.00	82.46
Agricultural Soils (Grazing Animals Emissions)	N_2O	0.06	20.00	50.00	53.85
Agricultural Soils (Atmospheric Deposition)	N_2O	6.20	20.00	100.00	101.98
Agricultural Soils (Leaching)	N_2O	43.40	20.00	380.00	380.53
Enteric Fermentation	CH_4	379.79	20.00	20.00	28.28
Manure Management	CH_4	25.62	20.00	20.00	28.28
Manure Management	N_2O	0.62	20.00	20.00	28.28
Total	CH_4	405.63			26.54
Total	N_2O	177.48			110.27
Overall Uncertainty		583.10			38.30

* : Values from National GHG inventory 2009

† : Source: IPCC, 2006

Table B4: Waste sector uncertainty estimate

Source Category	Gas	Year 2000 * Emissions Gg CO_2 Eq.	Activity Data Uncertainty %	Emission † Factor Uncertainty %	Emissions Uncertainty %
Solid Waste Disposal Sites	CH_4	2515.17	30.00	32.02	43.88
Domestic and Commercial Wastewater and Sludge	CH_4	99.41	30.41	42.03	51.88
Industrial Wastewater and Sludge Treatment	CH_4	0.53	103.08	104.40	146.71
Indirect Nitrous Oxide Emissions from Human Sewage	N_2O	99.20	15.46	380.00	380.31
Total	CH_4	2615.11			42.25
Total	N_2O	99.20			380.31
Overall Uncertainty		2714.31			43.01

* : Values from National GHG inventory 2009

† : Source: IPCC, 2006

The uncertainty in land-use change and forestry sector source categories is shown in Table (B5). Activity data uncertainty was determined by local expert judgment in light of the IPCC Good Practice Guidance for LULUCF, emission factor uncertainty was estimated from the reported ranges of emission factors in the 2006 IPCC Guidelines.

Table B5: The land-use change and forestry sector uncertainty estimate

Source Category	Gas	Year 2000 * Emissions Gg CO_2 Eq.	Emissions Uncertainty %
Changes in forest and other woody biomass stock	CO_2	-221.61	43.27
Change in soil carbon for mineral soils	CO_2	959.93	418.98
Total		738.32	544.89

* : Values from National GHG inventory 2009

4. UNCERTAINTY IN OVERALL NATIONAL GHG EMISSIONS ESTIMATE

Tables (B6) through (B8) provide the overall uncertainty estimate for CO_2, CH_4 and N_2O emissions; respectively. The uncertainty in CO_2 emissions is 3.52 percent when LULUFC is excluded, and becomes 23.85 percent when LULUCF is included.

Table B6: CO_2 emissions uncertainty estimate (including LULUCF)

Sector	Year 2000 Emissions Gg CO_2 Eq.	Emissions Uncertainty %
Energy	14,707.62	2.15
Industrial Processes	1594.32	30.00
Agriculture	-	-
waste	-	-
LULUCF	738.32	544.89
Total	17,040.26	23.85

Table B7: CH_4 emissions uncertainty estimate

Sector	Year 2000 Emissions Gg CO_2 Eq.	Emissions Uncertainty %
Energy	129.23	45.45
Industrial Processes	-	-
Agriculture	405.63	26.54
waste	2615.11	42.25
LULUCF	-	-
Total	3149.96	35.29

Table B8: N_2O emissions uncertainty estimates

Sector	Year 2000 Emissions Gg CO_2 Eq.	Emissions Uncertainty %
Energy	65.95	169.82
Industrial Processes	-	-
Agricultural	177.48	110.27
waste	99.20	380.31
LULUCF	-	-
Total	342.63	128.28

5. PLANNED IMPROVEMENTS

In order to improve the quality of uncertainty estimates, agencies that provided information for inventory estimation need to be sensitized to the importance of uncertainty estimate. These agencies should be motivated to conduct uncertainty assessment.

Providing some country specific emission factors will reduce uncertainty in emission estimates. In addition, using Tier 2 method for estimating uncertainty (Monte-Carlo simulation technique) in future can reduce the uncertainty since it deals with the asymmetrical uncertainty ranges.

As the year 2000 emissions and uncertainty estimate are now available, in future inventory reports, uncertainty in the trend may be conducted taking the year 2000 as the base year.

REFERENCES

IPCC, 2000. IPCC Good Practice Guidance and Uncertainty Management in National Green House gas inventories, Intergovernmental Panel on Climate Change.

IPCC, 2006. IPCC Guidelines for National Greenhouse gas inventories, Intergovernmental Panel on Climate Change.

APPENDIX C

GHG MITIGATION: TABLES AND FIGURES

Tables

Figures

Table C1: Primary and final energy demand (000 TOE) for baseline scenario, 2000-2033

Energy Type	Sector	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
LPG	Industry	5.5	5	6	7	6	7	4	4.2	4.4	4.6	4.8
	H.Hold	269	271	283	286	282	291	304	319	335.3	350.7	366.6
	Agr.	16.3	11.5	12.1	12.8	9.6	9.9	14.2	14.7	15.3	15.9	16.6
	Comm.	23	19	24	25	23	24	25.5	26.5	27.6	28.7	29.8
	Total	313.8	306.5	325.1	330.8	320.6	331.9	347.7	364.4	382.6	399.9	417.8
Kerosene	Industry	3	2.4	2	3	3	2	2.1	2.2	2.3	2.4	2.5
	H.Hold	226	174	167	205	206	150	144	150.1	158.5	165.6	173
	Agr.	3	1	1	2	2	1	1	1	1.1	1.1	1.1
	Comm.	18.1	14	9.6	10.9	10.9	8.8	8.1	8.4	8.7	9	9.4
	Total	250.1	191.4	179.6	220.9	221.9	161.8	155.2	161.7	170.6	178.1	186
Diesel	Industry	249	307	309	373.1	400	437	428	453.4	480.2	506	528.7
	H.Hold	154	160	161	180	220	300	232	244.1	257.4	270	283
	Agr.	88.3	94.6	95.1	104.2	114.6	120.7	124.4	129.4	135.1	140.7	146.4
	Comm.	138	140	141	155	180	190	196	204.1	213	222.2	231.2
	Transp.	558	560	563	570	750	857	802	849	898.5	942.1	983.2
	Elect.	35.9	36	172.1	83.9	136.1	203.7	90	10.7	10.6	15.1	0.95
	Total	1223.2	1297.6	1441.2	1466.2	1800.7	2108.4	1872.4	1889.2	1986.2	2083.8	2172.9
Fuel Oil	Industry	565.9	463.2	482.3	444.8	544.7	628.4	504	533.8	565.1	595.2	621.5
	Elect.	1439.4	1468	1575.6	1459.2	905.1	782.3	624	150	163.8	138.2	16.3
	Total	2005.3	1931.2	2057.9	1904	1449.8	1410.7	1128	678.8	625.5	658	631.4
Gasoline	Transp.	628.8	666	682	695.3	696.9	735.8	762	805.8	851.7	891.2	928
Jet Fuel	Transp.	179	181.4	184.7	222.7	236.4	175.7	245.6	259.6	274.3	287	298.2
Asphalt	Service	107.9	129.8	167.2	188.5	201.2	182.9	159	163	167	171.2	174.6
Total oil products		4708.1	4703.9	5037.7	5028.4	4927.5	5107.2	4669.9	4329	4569.9	4756.9	4815.9
Natural Gas	Elect.	213	206	188	432	1195.9	1383.9	2003.5	2604.2	3247	3279.2	3771.9
Oil Shale	Elect.	0	0	0	0	0	0	0	0	0	0	0
Renewable		41.8	42.837	44.302	43.822	45.257	46.091	46.187	47.129	48.093	49.078	119.99

Table C1: Continued.

Energy Type	Sector	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Wind		0.246	0.246	0.261	0.264	0.239	0.276	0.244	0.244	0.244	0.244	70.08
Solar PV		0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.1
Solar Thermal		37.98	38.476	38.973	39.469	39.966	40.462	40.959	41.901	42.865	43.85	44.859
Biogas		0.216	0.413	0.464	0.516	0.499	0.439	0.534	0.534	0.534	0.534	0.534
Hydro		3.328	3.672	4.574	3.543	4.523	4.884	4.42	4.42	4.42	4.42	4.42
Total Primary En		4962.9	4952.2	5269	5502.7	6166.7	6534.7	6716.6	6933.5	7817.1	8036.3	8658

Table C1: Continued.

Energy Type	Sector	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
LPG	Industry	5	5.2	5.4	5.6	5.8	6	6.2	6.4	6.6	6.8	7.0652	7.3407
	H.Hold	382.2	398.2	414.4	431.3	448.8	466.8	485.5	504.8	525	545.9	567.19	589.31
	Agr.	17.2	17.7	18.3	18.8	19.4	20.1	20.7	21.3	22	22.6	23.481	24.397
	Comm.	31	32.2	33.4	34.7	36	37.4	38.8	40.2	41.8	43.3	44.989	46.743
	Total	435.4	453.3	471.5	490.4	510	530.3	551.2	572.7	595.4	618.6	642.73	667.79
Kerosene	Industry	2.6	2.7	2.8	2.9	3.1	3.2	3.3	3.4	3.5	3.6	3.7404	3.8863
	H.Hold	180.2	187.6	195.1	202.9	211	219.3	227.8	236.8	246	255.7	265.67	276.03
	Agr.	1.2	1.2	1.2	1.3	1.3	1.4	1.4	1.4	1.5	1.5	1.5585	1.6193
	Comm.	9.7	10.1	10.4	10.8	11.2	11.6	12	12.4	12.8	13.3	13.819	14.358
	Total	193.7	201.6	209.5	217.9	226.6	235.5	244.5	254	263.8	274.1	284.79	295.9
Diesel	Industry	553.1	577	600.9	625.6	651.4	678.1	705.7	734.5	764.4	795.5	825.73	857.11
	H.Hold	295.7	308.8	322.2	336.1	350.6	365.5	381	397.1	414	431.4	447.79	464.81
	Agr.	152.1	157.2	162.4	167.8	173.5	179.2	185	191	197.3	203.6	211.34	219.37
	Comm.	240.7	250.4	260.5	271	281.7	292.9	304.51	316.5	329	342	355	368.49
	Transp.	1023.2	1065.3	1107	1150	1194	1239.4	1286	1333	1381.4	1430.8	1485.2	1541.6
	Elect.	1.4	0.82	0.92	0.85	0.59	0.31	0	0	0	0	0	0
	Total	2265.6	2359	2454.1	2551	2652	2755.3	2862.2	2972.1	3086.1	3203.3	3325	3451.4
Fuel Oil	Industry	649.8	677.2	704.7	733.1	762.7	793.2	825	857.8	892	927.6	964.7	1003.3
	Elect.	21.5	22.5	8.1	3.5	2.5	0	0	0	0	0	0	0
	Total	669.2	685.1	713	735	766	793.2	825	857.8	892	927.6	964.7	1003.3
Gasoline	Transp.	963.4	1000.6	1037	1075	1114.7	1154.7	1195.3	1236.1	1278.3	1321.1	1364.7	1409.7

Jet Fuel	Transp.	309.3	321	332.4	344.2	356.5	369	382	395.3	409.1	423.4	438.22	453.56
Asphalt	Service	178.1	181.7	184.4	187.2	190	192.8	195.7	198.6	201.6	204.7	207.77	210.89
Total oil pdct		5017.4	5217.4	5401.5	5602.7	5814.8	6030.9	6255.9	6486.6	6726.3	6972.8	7227.9	7492.5
Natural Gas	Elect.	4124.5	4445.2	4753.8	4591.5	4390	4641.6	4440.5	4227.1	4485.9	4071.6	3815.5	4042.1
Oil Shale	Elect.	0	0	0	638	1277.6	1277.6	1915.6	2550.4	2552	2550.4	3177.4	3160.1
Renewable		121.02	122.08	123.16	124.26	125.39	126.55	127.73	128.94	130.18	131.45	132.74	134.07
Wind		70.08	70.08	70.08	70.08	70.08	70.08	70.08	70.08	70.08	70.08	70.08	70.08
Solar PV		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Solar Thermal		45.891	46.946	48.026	49.131	50.261	51.417	52.599	53.809	55.047	56.313	57.608	58.933
Biogas		0.534	0.534	0.534	0.534	0.534	0.534	0.534	0.534	0.534	0.534	0.534	0.534
Hydro		4.42	4.42	4.42	4.42	4.42	4.42	4.42	4.42	4.42	4.42	4.42	4.42
Total Primary En		9212.1	9732.8	10226	10902	11553	12020	12682	13334	13834	13665	14291	14765

Table C1: Continued

Energy Type	Sector	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
LPG	Industry	7.627	7.9245	8.2335	8.5546	8.8883	9.2349	9.5951	9.9693	10.358	10.762	11.182
	H.Hold	612.29	636.17	660.98	686.76	713.55	741.37	770.29	800.33	831.54	863.97	897.67
	Agr.	25.349	26.337	27.364	28.432	29.54	30.693	31.89	33.133	34.425	35.768	37.163
	Comm.	48.566	50.46	52.428	54.473	56.597	58.805	61.098	63.481	65.957	68.529	71.202
	Total	693.84	720.9	749.01	778.22	808.57	840.11	872.87	906.91	942.28	979.03	1017.2
Kerosene	Industry	4.0378	4.1953	4.3589	4.5289	4.7056	4.8891	5.0798	5.2779	5.4837	5.6976	5.9198
	H.Hold	286.8	297.98	309.61	321.68	334.23	347.26	360.8	374.87	389.49	404.69	420.47
	Agr.	1.6824	1.748	1.8162	1.8871	1.9607	2.0371	2.1166	2.1991	2.2849	2.374	2.4666
	Comm.	14.918	15.499	16.104	16.732	17.384	18.062	18.767	19.499	20.259	21.049	21.87
	Total	307.44	319.43	331.88	344.83	358.28	372.25	386.77	401.85	417.52	433.81	450.72
Diesel	Industry	889.68	923.48	958.58	995	1032.8	1072.1	1112.8	1155.1	1199	1244.5	1291.8
	H.Hold	482.47	500.81	519.84	539.59	560.09	581.38	603.47	626.4	650.21	674.91	700.56
	Agr.	227.7	236.36	245.34	254.66	264.34	274.38	284.81	295.63	306.87	318.53	330.63
	Comm.	382.49	397.02	412.11	427.77	444.03	460.9	478.41	496.59	515.46	535.05	555.38
	Transp.	1600.2	1661	1724.1	1789.6	1857.6	1928.2	2001.5	2077.6	2156.5	2238.4	2323.5

	Elect.	0	0	0	0	0	0	0	0	0	0	0
	Total	3582.5	3718.7	3860	4006.7	4158.9	4316.9	4481	4651.3	4828	5011.5	5201.9
Fuel Oil	Industry	1043.4	1085.2	1128.6	1173.7	1220.7	1269.5	1320.3	1373.1	1428	1485.1	1544.5
	Elect.	0	0	0	0	0	0	0	0	0	0	0
	Total	1043.4	1085.2	1128.6	1173.7	1220.7	1269.5	1320.3	1373.1	1428	1485.1	1544.5
Gasoline	Transp.	1456.3	1504.3	1554	1605.2	1658.2	1712.9	1769.5	1827.8	1888.2	1950.5	2014.8
Jet Fuel	Transp.	469.43	485.86	502.87	520.47	538.68	557.54	577.05	597.25	618.15	639.79	662.18
Asphalt	Service	214.05	217.26	220.52	223.83	227.19	230.59	234.05	237.56	241.13	244.74	248.41
Total oil pdct		7767	8051.6	8346.8	8652.9	8970.5	9299.8	9641.4	9995.8	10363	10744	11140
Natural Gas	Elect.	4294.9	3933	4156.5	4343.5	4569.1	4755.8	4976.8	4601.8	4925.4	5120.5	5298.9
Oil Shale	Elect.	3168	3147.6	3155.4	3164.9	3171.1	3177.4	3180.6	3166.4	2973.1	2987.3	2965.3
Renewable		135.42	136.81	138.23	139.68	141.16	142.68	144.24	145.82	147.45	149.11	150.82
Wind		70.08	70.08	70.08	70.08	70.08	70.08	70.08	70.08	70.08	70.08	70.08
Solar PV		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Solar Thermal		60.288	61.675	63.093	64.545	66.029	67.548	69.101	70.691	72.317	73.98	75.681
Biogas		0.534	0.534	0.534	0.534	0.534	0.534	0.534	0.534	0.534	0.534	0.534
Hydro		4.42	4.42	4.42	4.42	4.42	4.42	4.42	4.42	4.42	4.42	4.42
Total Primery En		15300	15202	15729	16231	16781	17303	17869	17834	18332	18922	19474

Table C2: Electricity demand forecast, baseline scenario, 2000-2033

Year	Peak Load MW	Demand GWh	Energy Growth Rate %
2000	1180	6133	
2001	1255	6392	4.2%
2002	1410	6900	7.9%
2003	1428	7330	6.2
2004	1555	8089	10.3%
2005	1751	8712	7.7%
2006	1926	9757	12%
2007	2030	12692	30%
2008	2376	14855	17%
2009	2621	16387	10.3%
2010	2871	17950	9.5%
2011	3131	19575	9.1%
2012	3387	21176	8.2%
2013	3626	22670	7.1%
2014	3856	24108	6.3%
2015	4062	25396	5.3%
2016	4266	26672	5.0%
2017	4473	27966	4.9%
2018	4669	29191	4.4%
2019	4863	30404	4.2%
2020	5054	31598	3.9%
2021	5241	32768	3.7%
2022	5426	33924	3.5%
2023	5605	35043	3.3%
2024	5780	36138	3.0%
2025	5954	37225	2.9%
2026	6128	38313	2.8%
2027	6300	39389	2.7%
2028	6471	40458	2.6%
2029	6640	41514	2.5%
2030	6807	42559	2.1%
2031	6950	43453	2.2%
2032	7100	44391	2.2%
2033	7250	45328	2.1%

Table C3: Domestic wastewater treatment plants and their projected flow, baseline scenario, 2000-2033

Treatment plant name	Treatment type	Actual flow (m^3/day)						Estimated flow (m^3/day)				
		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
As-Samra	WSP	186081.3	178902.3	186823.1	209570	221509.3	224175	228547	238603	249102	260062	271505
Aqaba Tertiary	AS					6951.5	7296	7630.2	7996	8380	8783	9204
Aqaba Natural	WSP	9310	9329.3	10332.1	10332.1	7041	6229	5515.9	6261	6261	6261	6261
Irbid	AS & BF	5081.3	7121.3	8103.3	7776.3	6695.8	6354	6363.7	6809	7286	7796	8342
Salt	AS	3597.9	3898	4248.3	4431.3	4569.4	4322	4481.7	4665	4857	5056	5263
Jerash	AS	2743	2913	4358.6	3441.1	3593.3	3312	3391.9	3572	3679	3789	3903
Mafraq	WSP	1888.5	1805	2188.5	2003	1958	1866	1990.8	2019	2047	2076	2105
Baqa'a	BF	11515.8	11768	12052.4	10587.6	10615	10978	11713.9	12065	12427	12800	13184
Karak	BF	1274.6	1508	1573.5	1755	1679.3	1618	1550.5	1608	1667	1729	1793
Abu Nuseir	AS & RBC	1800	1977	2214.9	2593	2240.3	2309	2357.6	2497	2644	2800	2965
Tafila	BF	735.9	740	844.2	969.7	1116	1013	1181.1	1276	1378	1488	1607
Ramtha	AS	1888.5	2300	3071.1	3053	3674.7	3492	3392.6	3664	3964	4290	4641
Ma'an	WSP	1556.2	2155	2119.3	2370	2352	2644	2416.5	2537	2662	2792	2929
Madaba	AS	4611	4178	4422.1	4542	4660.5	4584	4711.3	4787	4863	2704	2748
Kufranja	BF	1863.5	2223	2787.1	2402.7	2794.6	3387	3930.5	4324	4756	5231	5755
Wadi Al Seer	WSP	1401.5	1917	2445.2	2265	2762	2718	3113	3424	3767	4143	4558
Fuhis	AS	1216.6	1523	1942	1560	1606.3	1684	1791.6	1912	2040	2176	2322
Wadi Arab	AS	5734.7	7063	6666.5	7085	8315.9	9960	10701.4	11772	12949	14244	15668
Wadi Mousa	AS	532.2	866	900.3	1391.4	1820.4	1670	1984.3	2183	2401	2641	2905
Wadi Hassan	AS	280	423	725.2	1061	1140.7	1099	964.3	1003	1043	1085	1128
Tall Al-Mantah	AS & BF					271.5	274	290.3	296	303	309	315
ALEkader	WSP					3156	2872	3698.8	3778	3858	3940	4011
Alljoon	WSP					634.8	502	518	529	540	552	562

where:
WSP: waste stabilization pounds, AS: Activated sludge, BF: Bio-filter and RBC: Rotating biological contactor.

Table C3: Continued

Treatment plant name	Treatment type	Estimated flow (m³/day) 2012	Estimated flow (m³/day) 2013	Estimated flow (m³/day) 2014	Estimated flow (m³/day) 2015	Estimated flow (m³/day) 2016	Estimated I flow (m³/day) 2017	Estimated I flow (m³/day) 2018	Estimated flow (m³/day) 2019	Estimated flow (m³/day) 2020	Estimated flow (m³/day) 2021	Estimated flow (m³/day) 2022
As-Samra	WSP	283451	295923	308943	322537	336729	351545	367013	383161	400020	417621	435997
Aqaba Tertiary	AS	9646	10109	10594	11103	11711	12273	12862	13480	14127	14805	15515
Aqaba Natural	WSP	6261	6261	6261	6261	6613	6261	6261	6261	6261	6261	6261
Irbid	AS & BF	8925	9550	10219	10934	11699	12518	13395	14332	15336	16409	17558
Salt	AS	5479	5704	5937	6181	6434	6698	6973	7259	7556	7866	8188
Jerash	AS	4020	4141	4265	4393	4524	4660	4800	4944	5092	5245	5402
Mafraq	WSP	2134	2164	2194	2225	2256	2288	2320	2352	2385	2419	2452
Baqa'a	BF	13580	13987	14407	14839	15284	15743	16215	16701	17202	17718	18250
Karak	BF	1859	1919	1980	2044	2109	2177	2246	2318	2392	2469	2548
Abu Nuseir	AS & RBC	3140	3325	3522	3729	3949	4182	4429	4691	4967	5260	5571
Tafila	BF	1735	1874	2024	2186	2361	2550	2754	2974	3212	3469	3754
Ramtha	AS	5022	5434	5879	6361	6883	7447	8058	8719	9434	9983	10801
Ma'an	WSP	3072	3223	3381	3547	3720	3903	4094	4294	4505	4726	4957
Madaba	AS	2791	2836	2882	2928	2974	3022	3070	3120	3169	3220	3272
Kufranja	BF	6330	6647	7311	8042	8847	9731	10704	11775	12952	14248	15672
Wadi Al Seer	WSP	5014	5515	6066	6673	7340	8074	8882	9770	10747	11822	13004
Fuhis	AS	2478	2644	2821	3010	3212	3427	3656	3901	4163	4442	4739
Wadi Arab	AS	17235	18958	20854	22939	25233	27757	30532	33586	36944	40639	44702
Wadi Mousa	AS	3196	3515	3867	4254	4679	5147	5661	6228	6850	7535	8289
Wadi Hassan	AS	1173	1220	1342	1396	1452	1510	1570	1633	1698	1766	1837
Tall Al-Mantah	AS & BF	320	326	332	338	343	348	354	359	364	369	375
ALEkader	WSP	4083	4157	4232	4308	4385	4451	4518	4586	4654	4720	4786
Alljoon	WSP	572	582	593	603	614	623	633	642	652	661	670

Treatment plant name	Treatment type	Estimated flow (m³/day)										
		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
As-Samra	WSP	455180	475208	496117	517947	540736	564529	589368	615300	642373	670638	700146
Aqaba Tertiary	AS	16260	17041	17859	18716	19614	20556	21542	22576	23660	24796	25986
Aqaba Natural	WSP	6261	6261	6261	6261	6261	6261	6261	6261	6261	6261	6261
Irbid	AS & BF	18787	20102	21509	23014	24626	26349	28194	30167	32279	34539	36956
Salt	AS	8524	8874	9238	9616	10011	10421	10848	11293	11756	12238	12740
Jerash	AS	5565	5731	5903	6081	6263	6282	6470	6664	6864	7070	7282
Mafraq	WSP	2487	2522	2557	2593	2629	2666	2703	2741	2779	14	14
Baqa'a	BF	18797	19361	19942	20540	21157	21791	22445	23118	23812	24526	25262
Karak	BF	2629	2713	2800	2890	2982	3078	3176	3278	3383	3491	3603
Abu Nuseir	AS & RBC	5899	6247	6616	7006	7420	7858	8321	8812	9332	9883	10466
Tafila	BF	4054	4378	4728	5107	5515	5956	6433	6948	7503	8104	8752
Ramtha	AS	11687	12645	13682	14804	16018	17332	18753	20291	21955	23755	25703
Ma'an	WSP	5200	5455	5722	6003	6297	6605	6929	7268	7625	7998	8390
Madaba	AS	3324	3377	3431	3486	3542	3599	3779	3839	3900	3963	4026
Kufranja	BF	17240	18964	20860	22946	25241	27765	30541	33595	36955	40650	44715
Wadi Al Seer	WSP	14304	15735	17308	19039	20943	23037	25341	27875	30662	33728	37101
Fuhis	AS	5057	5396	5757	6143	6554	6993	7462	7962	8495	9065	9672
Wadi Arab	AS	49173	54090	59499	65449	71994	79193	87112	95824	105406	115947	127541
Wadi Mousa	AS	9118	10030	11033	12136	13349	14684	16153	17768	19545	21499	23649
Wadi Hassan	AS	1910	1987	2066	2149	2235	2347	2440	2538	2640	2745	2855
Tall Al-Mantah	AS & BF	380	385	390	396	401	407	413	419	424	430	436
ALEkader	WSP	4853	4921	4990	5059	5130	5202	5275	5349	5424	5500	5577
Alljoon	WSP	680	689	699	709	718	729	739	749	760	770	781

Table C4: Domestic solid waste generation, baseline scenario, 2000-2033

Year	Population *	Solid Waste (000) Tonnes	Year	Population *	Solid Waste (000) Tonnes
2001	4940000	1,623	2018	6950000	2,283
2002	5070000	1,665	2019	7040000	2,313
2003	5200000	1,708	2020	7140000	2,345
2004	5350000	1,757	2021	7241420	2,379
2005	5473000	1,798	2022	7344281	2,413
2006	5600000	1,840	2023	7448603	2,447
2007	5723000	1,880	2024	7554407	2,482
2008	5840000	1,918	2025	7661714	2,517
2009	5960000	1,958	2026	7770545	2,553
2010	6080000	1,997	2027	7880922	2,589
2011	6200000	2,037	2028	7992867	2,626
2012	6310000	2,073	2029	8106402	2,663
2013	6430000	2,112	2030	8221550	2,701
2014	6540000	2,148	2031	8338334	2,739
2015	6640000	2,181	2032	8456776	2,778
2016	6750000	2,217	2033	8576900	2,818
2017	6850000	2,250			

*Department of Statistics

Table C5: Crops production (tonnes), baseline scenario, 2000-2033

Crops/ year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Fodder	264.1	315	444	356	387	264	272	276	280	284	289
Vegetables	1340.3	1482.1	1452.9	1466.3	1619	1501.8	1562	1624.5	1689.4	1757	1827.3
Fruit	1329.9	1365	1422.7	1412.7	1464.4	1482.2	1511.5	1541.8	1572.6	1604.1	1636.1

Crops/ year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Fodder	283	297	302	306	311	316	320	326	330	335	340
Vegetables	1900.4	1976.4	2055.5	2137	2222.48	2311.379	2403.834	2499.988	2599.987	2703.987	2812.146
Fruit	1702.2	1736.3	1771	1806.4	1842.6	1879.4	1917	1955.3	1994.4	2034.3	2075

Crops/ year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Fodder	345	350	356	361	367	371	378	383	389	395	401
Vegetables	2924.632	3041.617	3163.282	3289.813	3421.406	3558.262	3700.593	3848.616	4002.561	4162.663	4329.17
Fruit	2116.5	2158.8	2202	2246.1	2291	2336.8	2383.5	2431.2	2479.8	2529.4	2580

Table C6: Poultry sector production, baseline scenario, 2000-2033

Year	Capacity (thousand)			
	Farm for Eggs	Farm for Broilers	Farm for Hens	Farm for Chicks
2001	6377	24209	2666.48	264.1
2002	6730	29181	3150.97	277.1
2003	6597	29145	3241	242
2004	6620	26044	3484.06	285.3
2005	7580	27520	3369.81	341.6
2006	7600	26750	3369.81	341.6
2007	7676	27017.5	3403.5081	345.016
2008	7752.76	27287.675	3437.54318	348.46616
2009	7830.2876	27560.552	3471.91861	351.95082
2010	7908.5905	27836.157	3506.6378	355.47033
2011	7987.6764	28114.519	3541.70418	359.02503
2012	8067.5531	28395.664	3577.12122	362.61528
2013	8148.2287	28679.621	3612.89243	366.24144
2014	8229.711	28966.417	3649.02136	369.90385
2015	8312.0081	29256.081	3685.51157	373.60289
2016	8395.1282	29548.642	3722.36668	377.33892
2017	8479.0794	29844.128	3759.59035	381.11231
2018	8563.8702	30142.57	3797.18625	384.92343
2019	8649.5089	30443.995	3835.15812	388.77266
2020	8736.004	30748.435	3873.5097	392.66039
2021	8823.3641	31055.92	3912.2448	396.587
2022	8911.5977	31366.479	3951.36724	400.55287
2023	9000.7137	31680.144	3990.88092	404.55839
2024	9090.7208	31996.945	4030.78973	408.60398
2025	9181.628	32316.914	4071.09762	412.69002
2026	9273.4443	32640.084	4111.8086	416.81692
2027	9366.1787	32966.484	4152.92668	420.98509
2028	9459.8405	33296.149	4194.45595	425.19494
2029	9554.4389	33629.111	4236.40051	429.44689
2030	9649.9833	33965.402	4278.76452	433.74136
2031	9746.4832	34305.056	4321.55216	438.07877
2032	9843.948	34648.106	4364.76768	442.45956
2033	9942.3875	34994.587	4408.41536	446.88415

Table C7: Fertilizer imports (tonnes), baseline scenario, 2000-2033

Fertilizer Type	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Nitrogen	40576	39526	42246	35286	35286	32416	33388	34390.1	35421.84	36484.49	37579.03
Phosphorous	255	1999	599	352	432	25	25.75	26.5225	27.31818	28.13772	28.98185
Potassium	851	9861	706	451	451	2995	3084.8	3177.40	3272.717	3370.899	3472.026
Compound	7883		10291	11519	11519	13345	13745.4	14157.7	14582.44	15019.92	15470.51
Total	**49565**	**49305**	**54042**	**47608**	**47608**	**48781**	**50244.4**	**51751.8**	**53304.32**	**54903.45**	**56550.55**
Fertilizer Type	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Nitrogen	38706	39867	41063	42295	43564	44871	46217	47603	49032	50503	52018
Phosphorous	29.85	30.1	31	32	33	34	35	36	37	38	40
Potassium	3576	3683	3793	3907	4025	4145	4270	4398	4530	4666	4806
Compound	15934	16412	16905	17412	17934	18472	19026	19597	20185	20791	21414
Total	**58247**	**59994**	**61794**	**63648**	**65557**	**67524**	**69550**	**71636**	**73785**	**75999**	**78279**
Fertilizer Type	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Nitrogen	53579	55186	56842	58547	60303	62112	63976	65895	67872	69908	72005
Phosphorous	41	43	44	45	47	48	49	51	52	54	56
Potassium	4950	5099	5252	5409	5572	5739	5911	6088	6271	6459	6653
Compound	22057	22719	23401	24103	24826	25570	26338	27128	27941	28780	29643
Total	**80628**	**83046**	**85538**	**88104**	**90747**	**93469**	**96274**	**99162**	**102137**	**105201**	**108357**

Table C8: Animal production (thousand), baseline scenario, 2000 - 2033

Year	Cows			Sheep Total	Goats Total	Camels Total
	Friesian	Local	Total			
2001	63.6	3.2	66.8	1456.9	425.9	14
2002	67.2	2.6	69.8	1433.3	557.25	13
2003	61.78	4.49	66.27	1476.5	547.47	12
2004	64.79	4.47	69.26	1539.9	501.11	13
2005	67.59	4.21	71.8	1901.16	516.13	13
2006	68.25	3.2	71.45	1971.54	473.8	13
2007	69.27375	3.248	72.52175	2001.113	480.907	13.195
2008	70.31286	3.29672	73.60958	2031.13	488.1206	13.39293
2009	71.36755	3.346171	74.71372	2061.597	495.4424	13.59382
2010	72.43806	3.396363	75.83443	2092.521	502.8741	13.79773
2011	73.52463	3.447309	76.97194	2123.909	510.4172	14.00469

Table C8: Continued

Year	Cows			Sheep Total	Goats Total	Camels Total
	Friesian	Local	Total			
2012	74.6275	3.499018	78.12652	2155.767	518.0734	14.21476
2013	75.74692	3.551504	79.29842	2188.104	525.8445	14.42798
2014	76.88312	3.604776	80.4879	2220.925	533.7322	14.6444
2015	78.03637	3.658848	81.69521	2254.239	541.7382	14.86407
2016	79.20691	3.713731	82.92064	2288.053	549.8642	15.08703
2017	80.39501	3.769437	84.16445	2322.373	558.1122	15.31334
2018	81.60094	3.825978	85.42692	2357.209	566.4839	15.54304
2019	82.82495	3.883368	86.70832	2392.567	574.9811	15.77618
2020	84.06733	3.941618	88.00895	2428.456	583.6059	16.01282
2021	85.32834	4.000743	89.32908	2464.883	592.36	16.25302
2022	86.60826	4.060754	90.66902	2501.856	601.2454	16.49681

Table C8: Continued

Year	Cows			Sheep Total	Goats Total	Camels Total
	Friesian	Local	Total			
2023	87.90739	4.121665	92.02905	2539.384	610.264	16.74426
2024	89.226	4.18349	93.40949	2577.474	619.418	16.99543
2025	90.56439	4.246242	94.81063	2616.136	628.7093	17.25036
2026	91.92285	4.309936	96.23279	2655.379	638.1399	17.50912
2027	93.3017	4.374585	97.67628	2695.209	647.712	17.77175
2028	94.70122	4.440204	99.14143	2735.637	657.4277	18.03833
2029	96.12174	4.506807	100.6285	2776.672	667.2891	18.3089
2030	97.56357	4.574409	102.138	2818.322	677.2984	18.58354
2031	99.02702	4.643025	103.67	2860.597	687.4579	18.86229
2032	100.5124	4.712671	105.2251	2903.506	697.7698	19.14522
2033	102.0201	4.783361	106.8035	2947.058	708.2363	19.4324

Table C9: Forestry area (thousand dunums), baseline scenario, 2000-2033

Governorate	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Balqa	199	199	199	199	199	199	199	200	200	201	201
Karak	195	195	195	195	195	195	195	196	196	197	198
Madba	177	177	177	177	177	177	177	178	178	179	179
Irbid	148	148	148	148	148	148	148	148	148	149	149
Ajlun	137	137	137	137	137	137	137	138	138	138	139
Tafylah	115	115	115	115	115	115	115	115	116	116	116
Jerash	93	93	93	93	93	93	93	93	93	93	94
Amman	73	73	73	73	73	73	73	73	73	73	73
Zarqah	71	71	71	71	71	71	71	71	72	72	72
Mafraq	68	68	68	68	68	68	68	68	68	68	68
Ma'an	30	30	30	30	30	30	30	30	30	30	30
Aqaba	1	1	1	1	1	1	1	1	1	1	1
Total	1305	1305	1305	1305	1305	1305	1305	1309	1313	1317	1321

Table C9: Continued

Governorate	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Balqa	202	203	203	204	204	205	206	206	207	207	208
Karak	198	199	199	200	201	201	202	202	203	204	204
Madba	180	180	181	181	182	183	183	184	184	185	185
Irbid	150	150	151	151	152	152	153	153	153	154	154
Ajlun	139	140	140	141	141	141	142	142	143	143	144
Tafylah	117	117	117	118	118	118	119	119	119	120	120
Jerash	94	94	95	95	95	95	96	96	96	97	97
Amman	74	74	74	74	75	75	75	75	75	76	76
Zarqah	72	72	73	73	73	73	73	74	74	74	74
Mafraq	69	69	69	69	69	70	70	70	70	70	71
Ma'an	30	30	30	30	30	30	31	31	31	31	31
Aqaba	1	1	1	1	1	1	1	1	1	1	1
Total	**1325**	**1329**	**1333**	**1337**	**1341**	**1345**	**1349**	**1353**	**1357**	**1361**	**1365**

Governorate	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Balqa	209	209	210	211	211	212	212	213	214	214	215
Karak	205	205	206	207	207	208	209	209	210	210	211
Madba	186	186	187	188	188	189	189	190	190	191	192
Irbid	155	155	156	156	157	157	158	158	159	159	160
Ajlun	144	144	145	145	146	146	147	147	147	148	148
Tafylah	121	121	121	122	122	122	123	123	123	124	124
Jerash	97	97	98	98	98	99	99	99	99	100	100
Amman	76	76	77	77	77	77	78	78	78	78	78
Zarqah	75	75	75	75	76	76	76	76	76	77	77
Mafraq	71	71	71	72	72	72	72	72	73	73	73
Ma'an	31	31	31	31	31	31	32	32	32	32	32
Aqaba	1	1	1	1	1	1	1	1	1	1	1
Total	**1369**	**1373**	**1377**	**1381**	**1386**	**1390**	**1394**	**1398**	**1402**	**1406**	**1411**

Table C10: Total GHG emissions (Gg) for the years 2000-2033, baseline scenario

Categories	2001			2002			2003		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Total Energy	14926	6.051	0.066	16256	5.635	0.07	16487	12.05	0.072
Energy Industry	6026	0.228	0.042	6755	0.257	0.044	6677	0.242	0.045
Electricity prod.	5351	0.198	0.032	6079	0.227	0.034	6002	0.212	0.035
Refinery	675.4	0.03	0.01	675.4	0.03	0.01	675.4	0.03	0.01
Mnuf.&Const.	1893	0	0	2021	0	0	2087	0	0
Transport	4163	9E-04	2E-04	4444	9E-04	2E-04	4588	1E-03	2E-04
Commercial	550.6	0.077	0.005	587.9	0.082	0.005	607	0.085	0.005
Residential	1893	0.278	0.017	2021	0.297	0.018	2087	0.307	0.018
Agriculture	400.3	0.052	0.003	427.3	0.055	0.004	441.2	0.057	0.004
Fugitives	0	5.415	0	0	4.942	0	0	11.36	0
Industrial Proces	1756	0	0	1756	0	0	1756	0	0
Cement	1749	0	0	1749	0	0	1749	0	0

Others				7.26	0	0	7.26	0	0	7.26	0	0
Total Agr.				0	0.019	3E-04	0	0.02	3E-04	0	0.02	3E-04
Enteric Fermint.				0	0.018		0	0.018		0	0.019	
Manure Mgmt.				0	0.001	3E-04	0	0.001	3E-04	0	0.001	3E-04
Total LUCF				724.1	0	0	721.9	0	0	719.7	0	0
Total Waste				0	137	0.322	0	139.8	0.331	0	143.3	0.339
Dom&com WW					12.04	0.322		11.6	0.331		11.8	0.339
Industrial WW				0	0	0	0	0	0	0	0	0
Solid Waste				0	125	0	0	128.2	0	0	131.5	0
Total Jordan				17407	143.1	0.389	18734	145.5	0.402	18963	155.4	0.411
CO_2 eq				17407	3005	120.5	18734	3055	124.5	18963	3263	127.6
TotalCO_2eq					20532			21914			22353	
Categories	2004			2005			2006			2007		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Total Energy	17830	33.22	0.08	19408	37.16	0.087	21205	53.49	0.088	20021	67.13	0.087
Energy Industry	6838	0.211	0.049	7092	0.212	0.053	7682	0.204	0.05	7311	0.159	0.051
Electricity prod.	6163	0.181	0.039	6416	0.182	0.043	7006	0.174	0.04	6636	0.129	0.041
Refinery	675.4	0.03	0.01	675.4	0.03	0.01	675.4	0.03	0.01	675.4	0.03	0.01
Mnuf.&Const.	2338	0	0	2620	0	0	2876	0	0	2703	0	0
Transport	5141	0.001	2E-04	5760	0.001	2E-04	6325	0.001	2E-04	5945	0.001	2E-04
Commercial	680.1	0.095	0.006	762	0.106	0.006	836.7	0.117	0.007	786.4	0.11	0.007
Residential	2338	0.344	0.021	2620	0.385	0.023	2877	0.423	0.025	2704	0.397	0.024
Agriculture	494.4	0.064	0.004	553.9	0.072	0.005	608.2	0.079	0.005	571.6	0.074	0.005
Fugitives	0	32.51	0	0	36.38	0	0	52.67	0	0	66.39	0
Industrial Proces	1756	0	0	1756	0	0	1756	0	0	1756	0	0
Cement	1749	0	0	1749	0	0	1749	0	0	1749	0	0
Others	7.26	0	0	7.26	0	0	7.26	0	0	7.26	0	0
Total Agr.	0	0.02	3E-04	0	0.02	3E-04	0	0.02	3E-04	0	0.021	3E-04
Enteric Fermint.	0	0.019		0	0.019		0	0.019		0	0.019	
Manure Mgmt.	0	0.001	3E-04	0	0.001	3E-04	0	0.001	3E-04	0	0.001	3E-04
Total LUCF	717.6	0	0	715.4	0	0	713.3	0	0	711.1	0	0
Total Waste	0	148.3	0.349	0	151.6	0.357	0	156.8	0.365	0	160.9	0.375
Dom&com WW		13	0.349		13.24	0.357		15.24	0.365		16.16	0.375
Industrial WW	0	0	0	0	0	0	0	0	0	0	0	0
Solid Waste	0	135.3	0	0	138.4	0	0	141.6	0	0	144.7	0
Total Jordan	20304	181.5	0.429	21880	188.8	0.445	23674	210.4	0.453	22489	228	0.462
CO_2 eq	20304	3812	133	21880	3965	137.8	23674	4417	140.5	22489	4788	143.3
TotalCO_2eq		24250			25983			28232			27420	

Table C10: Continued

Categories	2008			2009			2010			2011		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Total Energy	21921	0.786	0.09	22645	0.818	0.094	24035	0.852	0.098	25448	0.894	21921
Energy Industry	8866	0.188	0.054	8872	0.187	0.056	9591	0.19	0.058	10437	0.206	8866
Electricity prod.	8190	0.158	0.044	8197	0.157	0.046	8916	0.16	0.048	9762	0.176	8190
Refinery	675.4	0.03	0.01	675.4	0.03	0.01	675.4	0.03	0.01	675.4	0.03	675.4
Mnuf.&Const.	2777	0	0	2929	0	0	3072	0	0	3193	0	2777
Transport	6106	0.001	2E-04	6442	0.001	2E-04	6756	0.001	3E-04	7021	0.001	6106
Commercial	807.8	0.113	0.007	852.2	0.119	0.007	893.7	0.125	0.007	928.7	0.13	807.8
Residential	2777	0.408	0.024	2930	0.431	0.026	3073	0.452	0.027	3193	0.469	2777
Agriculture	587.2	0.076	0.005	619.4	0.08	0.005	649.6	0.084	0.005	675.1	0.088	587.2
Fugitives	0		0	0		0	0		0	0		0
Industrial Proces	1756	0	0	1756	0	0	2632	0	0	2632	0	1756
Cement	1749	0	0	1749	0	0	2624	0	0	2624	0	1749
Others	7.26	0	0	7.26	0	0	8.712	0	0	8.712	0	7.26
Total Agr.	0	0.021	3E-04	0	0.021	3E-04	0	0.022	3E-04	0	0.022	0
Enteric Fermint.	0	0.02		0	0.02		0	0.02		0	0.021	0
Manure Mgmt.	0	0.001	3E-04	0	0.001	3E-04	0	0.001	3E-04	0	0.001	0
Total LUCF	709	0	0	706.9	0	0	704.8	0	0	702.6	0	709
Total Waste	0	147.7	0.381	0	150.7	0.389	0	153.8	0.396	0	156.8	0
Dom&com WW		0	0.381		0	0.389		0	0.396		0	
Industrial WW	0	0	0	0	0	0	0	0	0	0	0	0
Solid Waste	0	147.7	0	0	150.7	0	0	153.8	0	0	156.8	0
Total Jordan	24387	148.5	0.471	25109	151.5	0.484	27372	154.7	0.494	28783	157.7	24387
CO_2 eq	24387	3119	146.1	25109	3182	149.9	27372	3248	153.2	28783	3312	24387
TotalCO_2eq		27651			28441			30773			32252	

Categories	2012			2013			2014			2015		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Total Energy	27297	0.956	0.112	28609	0.997	0.116	31699	1.018	0.12	34738	1.04	0.124
Energy Industry	11665	0.24	0.069	12344	0.251	0.071	14797	0.244	0.073	17177	0.235	0.075
Electricity prod.	10517	0.189	0.052	11195	0.2	0.054	13649	0.193	0.056	16029	0.184	0.058
Refinery	1148	0.051	0.017	1148	0.051	0.017	1148	0.051	0.017	1148	0.051	0.017
Mnuf.&Const.	3325	0	0	3460	0	0	3595	0	0	3735	0	0
Transport	7312	0.002	3E-04	7608	0.002	3E-04	7905	0.002	3E-04	8213	0.002	3E-04
Commercial	967.2	0.135	0.008	1006	0.14	0.008	1046	0.146	0.009	1087	0.152	0.009
Residential	3326	0.489	0.029	3460	0.508	0.031	3596	0.528	0.032	3736	0.549	0.033
Agriculture	703.1	0.091	0.006	731.6	0.095	0.006	760.1	0.099	0.006	789.8	0.103	0.007
Fugitives	0		0	0		0	0		0	0		0
Industrial Proces	2632	0	0	2632	0	0	2632	0	0	2632	0	0
Cement	2624	0	0	2624	0	0	2624	0	0	2624	0	0
Others	8.712	0	0	8.712	0	0	8.712	0	0	8.712	0	0
Total Agr.	0	0.022	4E-04	0	0.023	4E-04	0	0.023	4E-04	0	0.023	4E-04
Enteric Fermint.	0	0.021		0	0.021		0	0.022		0	0.022	
Manure Mgmt.	0	0.001	4E-04	0	0.001	4E-04	0	0.001	4E-04	0	0.001	4E-04
Total LUCF	700.5	0	0	698.4	0	0	696.3	0	0	694.2	0	0
Total Waste	0	159.6	0.411	0	162.6	0.419	0	165.4	0.426	0	168	0.433
Dom&com WW		0	0.411		0	0.419		0	0.426		0	0.433

Industrial WW	0	0	0	0	0	0	0	0	0	0	0	0
Solid Waste	0	159.6	0	0	162.6	0	0	165.4	0	0	168	0
Total Jordan	30630	160.6	0.523	31940	163.6	0.535	35028	166.4	0.546	38065	169.1	0.557
CO_2 eq	30630	3372	162.3	31940	3436	165.9	35028	3495	169.3	38065	3550	172.7
TotalCO_2eq		34165			35542			38692			41788	

Table C10: Continued

Categories	2016			2017			2018			2019		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Total Energy	36003	1.081	0.128	39080	1.105	0.132	42133	1.129	0.136	43484	1.174	0.141
Energy Industry	17759	0.245	0.077	20136	0.237	0.079	22471	0.228	0.082	23086	0.239	0.084
Electricity prod.	16611	0.194	0.06	18988	0.186	0.062	21323	0.177	0.065	21938	0.188	0.067
Refinery	1148	0.051	0.017	1148	0.051	0.017	1148	0.051	0.017	1148	0.051	0.017
Mnuf.&Const.	3880	0	0	4029	0	0	4182	0	0	4339	0	0
Transport	8533	0.002	3E-04	8860	0.002	3E-04	9196	0.002	4E-04	9540	0.002	4E-04
Commercial	1129	0.157	0.009	1172	0.163	0.01	1216	0.17	0.01	1262	0.176	0.011
Residential	3881	0.57	0.034	4030	0.592	0.036	4183	0.615	0.037	4339	0.638	0.038
Agriculture	820.5	0.107	0.007	852	0.111	0.007	884.3	0.115	0.007	917.4	0.119	0.008
Fugitives	0		0	0		0	0		0	0		0
Industrial Proces	3289	0	0	3289	0	0	3289	0	0	3289	0	0
Cement	3280	0	0	3280	0	0	3280	0	0	3280	0	0
Others	9.583	0	0	9.583	0	0	9.583	0	0	9.583	0	0
Total Agr.	0	0.024	4E-04	0	0.024	4E-04	0	0.025	4E-04	0	0.025	4E-04
Enteric Fermint.	0	0.022		0	0.023		0	0.023		0	0.023	
Manure Mgmt.	0	0.002	4E-04	0	0.002	4E-04	0	0.002	4E-04	0	0.002	4E-04
Total LUCF	692.2	0	0	690.1	0	0	688	0	0	686	0	0
Total Waste	0	170.7	0.44	0	173.2	0.47	0	175.8	0.453	0	178	0.459
Dom&com WW		0	0.44		0	0.47		0	0.453		0	0.459
Industrial WW	0	0	0	0	0	0	0	0	0	0	0	0
Solid Waste	0	170.7	0	0	173.2	0	0	175.8	0	0	178	0
Total Jordan	39984	171.8	0.568	43059	174.3	0.602	46110	177	0.59	47459	179.2	0.6
CO_2 eq	39984	3608	176.2	43059	3661	186.8	46110	3716	182.8	47459	3763	186.1
TotalCO_2eq		43768			46907			50009			51408	
Categories	2020			2021			2022			2023		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Total Energy	43268	1.191	0.146	46252	1.217	0.15	47517	1.263	0.155	48987	1.312	0.16
Energy Industry	22106	0.222	0.087	24306	0.211	0.089	24761	0.22	0.092	25389	0.231	0.095
Electricity prod.	20958	0.171	0.07	23158	0.16	0.072	23613	0.169	0.075	24241	0.18	0.078
Refinery	1148	0.051	0.017	1148	0.051	0.017	1148	0.051	0.017	1148	0.051	0.017
Mnuf.&Const.	4501	0	0	4668	0	0	4840	0	0	5019	0	0
Transport	9898	0.002	4E-04	10264	0.002	4E-04	10644	0.002	4E-04	11037	0.002	4E-04
Commercial	1309	0.183	0.011	1358	0.189	0.011	1408	0.196	0.012	1460	0.204	0.012
Residential	4502	0.662	0.04	4669	0.686	0.041	4841	0.711	0.043	5020	0.738	0.044
Agriculture	951.8	0.124	0.008	987	0.128	0.008	1023	0.133	0.009	1061	0.138	0.009
Fugitives	0		0	0		0	0		0	0		0
Industrial Proces	3289	0	0	3289	0	0	3289	0	0	3289	0	0
Cement	3280	0	0	3280	0	0	3280	0	0	3280	0	0

Others	9.583	0	0	9.583	0	0	9.583	0	0	9.583	0	0
Total Agr.	0	0.025	4E-04	0	0.026	4E-04	0	0.026	4E-04	0	0.026	4E-04
Enteric Fermint.	0	0.024		0	0.024		0	0.024		0	0.025	
Manure Mgmt.	0	0.002	4E-04	0	0.002	4E-04	0	0.002	4E-04	0	0.002	4E-04
Total LUCF	683.9	0	0	681.8	0	0	679.8	0	0	677.8	0	0
Total Waste	0	180.6	0.465	0	183.1	0.472	0	185.7	0.479	0	188.4	0.486
Dom&com WW		0	0.465		0	0.472		0	0.479		0	0.486
Industrial WW	0	0	0	0	0	0	0	0	0	0	0	0
Solid Waste	0	180.6	0	0	183.1	0	0	185.7	0	0	188.4	0
Total Jordan	47241	181.8	0.611	50223	184.3	0.623	51487	187	0.635	52954	189.7	0.647
CO_2 eq	47241	3818	189.4	50223	3871	193	51487	3927	196.7	52954	3985	200.5
TotalCO_2eq		51249			54287			55610			57139	

Table C10: Continued

Categories		2024			2025			2026			2027	
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Total Energy	48918	1.337	0.166	50382	1.388	0.171	51802	1.439	0.177	53332	1.493	0.183
Energy Industry	24448	0.216	0.097	25008	0.225	0.1	25490	0.233	0.103	26048	0.242	0.107
Electricity prod.	23300	0.165	0.08	23860	0.174	0.083	24342	0.182	0.086	24899	0.191	0.09
Refinery	1148	0.051	0.017	1148	0.051	0.017	1148	0.051	0.017	1148	0.051	0.017
Mnuf.&Const.	5205	0	0	5397	0	0	5597	0	0	5803	0	0
Transport	11445	0.002	4E-04	11868	0.002	5E-04	12307	0.003	5E-04	12761	0.003	5E-04
Commercial	1514	0.211	0.013	1570	0.219	0.013	1628	0.227	0.014	1688	0.235	0.014
Residential	5206	0.765	0.046	5398	0.793	0.048	5598	0.823	0.049	5805	0.853	0.051
Agriculture	1101	0.143	0.009	1141	0.148	0.01	1183	0.154	0.01	1227	0.159	0.01
Fugitives	0		0	0		0	0		0	0		0
Industrial Proces	4110	0	0	4110	0	0	4110	0	0	4110	0	0
Cement	4100	0	0	4100	0	0	4100	0	0	4100	0	0
Others	10.54	0	0	10.54	0	0	10.54	0	0	10.54	0	0
Total Agr.	0	0.027	4E-04	0	0.027	4E-04	0	0.028	4E-04	0	0.028	4E-04
Enteric Fermint.	0	0.025		0	0.025		0	0.026		0	0.026	
Manure Mgmt.	0	0.002	4E-04	0	0.002	4E-04	0	0.002	4E-04	0	0.002	4E-04
Total LUCF	675.7	0	0	673.7	0	0	671.7	0	0	669.7	0	0
Total Waste	0	191	0.493	0	193.8	0.5	0	196.5	0.507	0	199.3	0.514
Dom&com WW		0	0.493		0	0.5		0	0.507		0	0.514
Industrial WW	0	0	0	0	0	0	0	0	0	0	0	0
Solid Waste	0	191	0	0	193.8	0	0	196.5	0	0	199.3	0
Total Jordan	53704	192.4	0.659	55166	195.2	0.672	56584	198	0.684	58112	200.8	0.697
CO_2 eq	53704	4040	204.3	55166	4100	208.2	56584	4157	212.1	58112	4217	216.1
TotalCO_2eq		57948			59474			60953			62546	
Categories		2028			2029			2030			2031	
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Total Energy	54808	1.547	0.189	56388	1.604	0.195	56529	1.638	0.202	57551	1.703	54808
Energy Industry	26514	0.25	0.11	27047	0.259	0.113	26103	0.244	0.117	26000	0.257	26514
Electricity prod.	25366	0.199	0.093	25899	0.208	0.096	24955	0.193	0.1	24852	0.206	25366
Refinery	1148	0.051	0.017	1148	0.051	0.017	1148	0.051	0.017	1148	0.051	1148
Mnuf.&Const.	6018	0	0	6241	0	0	6471	0	0	6711	0	6018
Transport	13233	0.003	5E-04	13723	0.003	5E-04	14230	0.003	6E-04	14757	0.003	13233

Commercial	1751	0.244	0.015	1815	0.253	0.015	1882	0.263	0.016	1952	0.272	1751
Residential	6019	0.884	0.053	6242	0.917	0.055	6473	0.951	0.057	6712	0.986	6019
Agriculture	1273	0.165	0.011	1320	0.171	0.011	1368	0.178	0.011	1419	0.184	1273
Fugitives	0		0	0		0	0		0	0		0
Industrial Proces	4110	0	0	4110	0	0	4110	0	0	4110	0	4110
Cement	4100	0	0	4100	0	0	4100	0	0	4100	0	4100
Others	10.54	0	0	10.54	0	0	10.54	0	0	10.54	0	10.54
Total Agr.	0	0.028	4E-04	0	0.029	4E-04	0	0.029	4E-04	0	0.03	0
Enteric Fermint.	0	0.027		0	0.027		0	0.027		0	0.028	0
Manure Mgmt.	0	0.002	4E-04	0	0.002	4E-04	0	0.002	4E-04	0	0.002	0
Total LUCF	667.7	0	0	665.7	0	0	663.7	0	0	661.7	0	667.7
Total Waste	0	202	0.521	0	205	0.529	0	208	0.536	0	211	0
Dom&com WW		0	0.521		0	0.529		0	0.536		0	
Industrial WW	0	0	0	0	0	0	0	0	0	0	0	0
Solid Waste	0	202	0	0	205	0	0	208	0	0	211	0
Total Jordan	59586	203.6	0.71	61163	206.6	0.725	61302	209.7	0.738	62322	212.7	59586
CO_2 eq	59586	4275	220.2	61163	4339	224.6	61302	4403	228.8	62322	4467	59586
TotalCO_2eq		64081			65727			65934			67023	

Table C10: Continued

Categories	2032			2033		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Total Energy	59239	1.765	0.216	60771	1.828	0.222
Energy Industry	26521	0.265	0.124	26842	0.273	0.127
Electricity prod.	25373	0.214	0.107	25694	0.222	0.11
Refinery	1148	0.051	0.017	1148	0.051	0.017
Mnuf.&Const.	6959	0	0	7216	0	0
Transport	15303	0.003	6E-04	15869	0.003	6E-04
Commercial	2024	0.282	0.017	2099	0.293	0.018
Residential	6960	1.023	0.061	7218	1.061	0.064
Agriculture	1471	0.191	0.012	1526	0.198	0.013
Fugitives	0		0	0		0
Industrial Proces	4110	0	0	4110	0	0
Cement	4100	0	0	4100	0	0
Others	10.54	0	0	10.54	0	0
Total Agr.	0	0.03	4E-04	0	0.031	4E-04
Enteric Fermint.	0	0.028		0	0.029	
Manure Mgmt.	0	0.002	4E-04	0	0.002	4E-04
Total LUCF	659.7	0	0	657.7	0	0
Total Waste	0	214	0.551	0	217	0.559
Dom&com WW		0	0.551		0	0.559
Industrial WW	0	0	0	0	0	0
Solid Waste	0	214	0	0	217	0
Total Jordan	64009	215.8	0.767	65538	218.9	0.781
CO_2 eq	64009	4532	237.8	65538	4596	242.2
TotalCO_2eq		68779			70377	

Table C11: Composition of total GHG emissions in baseline scenario, 2000-2033

GHG emissions by Gas	2000	2011	2022	2033
CO_2 %	84.6	89.24	92.51	93.13
CH_4 %	13.6	10.269	7.131	6.531
N_2O %	1.7	0.486	0.356	0.344

Table C12: List of mitigation projects

No.	Project name	No.	Project name
1	Awareness program for applying best management practices in Irrigated farming fertilization appl	21	Al-Karak DSWLF
2	Winter pool/hotel	22	Maddaba DSWLF
3	Waste heat rec./hotel	23	Aldulail DSWLF
4	Insulation/food factory	24	Al-Salt DSWLF
5	Ceramic factories Condensate recovery/	25	As-Samra DWWTP
6	Solar heating/hotel	26	Wadi Arab DWWTP
7	solar water heaters	27	Baqa>a tertiary DWWTP
8	Electronic ballasts/medical factory	28	Ramtha DWWTP
9	Food factory	29	Mining industry/heat exchanger
10	Regenerative burners/ steel factory	30	Salt DWWTP30
11	VSD in pumps/paper fac	31	Aqaba tertiary DWWTP
12	comp. air control system/ canning factory	32	Al-Hareer wind farm
13	Condensing heat exch./ mining industry	33	Kamsha wind farm
14	CF lamps/residential	34	Aqaba wind farm
15	Demand side management	35	Ma>an wind farm
16	Samra power conversion to CC	36	Fujaij wind farm
17	Natural gas network/Amman	37	Ibrahimya wind farm
18	Natural gas network/Aqaba	38	Growing perennial forages in the Badia region
19	Natural gas network/Zarqa		
20	AL-Ekaider DSWLF		

Table C13: Yearly emissions reductions from all proposed mitigation projects (000 t CO_2eq.), 2009- 2033

	Project number										
Year	1	2	3	4	5	6	7	8	9	10	11
2009											
2010	0	0	0	0	0	0	0	0	0	0	0
2011	7	367	22.8	10.4	6.47	8.25	21.6	77.2	154	193	64.4
2012	8	383	23.5	10.5	7	8.58	23.7	78.6	157	196	65.5
2013	8	400	24.2	10.7	7.58	8.94	26.1	80	160	200	66.7
2014	8	418	25	10.9	8.2	9.3	28.7	81.4	163	204	67.9
2015	9	436	25.7	11.1	8.87	9.68	31.6	82.7	165	207	68.9

2016	9	455	26.5	11.2	9.6	10.1	34.8	83.9	168	210	69.9
2017	10	475	27.3	11.4	10.4	10.5	38.2	85.2	170	213	71
2018	10	496	28.1	11.6	11.2	10.9	42.1	86.4	173	216	72.1
2019	11	518	28.9	11.8	12.2	11.4	46.3	87.7	175	219	73.1
2020	11	541	29.8	12	13.2	11.8	50.9	89	178	222	74.2
2021	12	565	30.7	12.2	13.9	12.3	56	90.2	180	226	75.2
2022	12	589	31.6	12.4	15.1	12.8	61.6	91.5	183	229	76.3
2023	13	615	32.6	12.6	16.3	13.4	67.7	92.8	186	232	77.3
2024	14	642	33.5	12.8	17.6	13.9	74.5	94.1	188	235	78.4
2025	14	671	34.5	13	19.1	14.5	82	95.4	191	239	79.5
2026	15	700	35.6	13.2	20.6	15.1	90.2	96.8	194	242	80.7
2027	16	731	36.6	13.4	22.3	15.7	99.2	98.1	196	245	81.8
2028	16	763	37.7	13.6	24.2	16.3	109	99.5	199	249	83
2029	17	797	38.9	14.3	26.2	17	120	101	202	252	84.1
2030	18	832	40	14.5	28.3	17.7	132	102	205	256	85.3
2031	19	868	41.2	14.7	30.6	18.4	145	104	208	259	86.5
2032	20	907	42.5	15	33.1	19.2	160	105	210	263	87.7
2033	21	946	43.8	15.2	35.8	20	176	107	213	267	89

Table C13 : Continued

	Project number										
Year	12	13	14	15	16	17	18	19	20	21	22
2009			178	125	53.4		0.2	0.73	0.78	0.03	0.05
2010	0	0	221	155	66.4	0	0.2	0.73	0.78	0.03	0.05
2011	122	426	248	174	74.4	287	0.2	0.73	0.78	0.03	0.05
2012	124	426	272	191	81.7	287	0.2	0.73	0.78	0.03	0.05
2013	127	426	310	217	93	287	0.2	0.73	0.78	0.03	0.05
2014	129	426	335	235	101	287	0.2	0.73	0.78	0.03	0.05
2015	131	426	349	244	105	287	0.2	0.73	0.78	0.03	0.05
2016	133	426	378	265	113	287	0.2	0.73	0.78	0.03	0.05
2017	135	426	393	275	118	287	0.2	0.73	0.78	0.03	0.05
2018	137	426	395	277	119	287	0.2	0.73	0.78	0.03	0.05
2019	139	426	411	288	123	287	0.2	0.73	0.78	0.03	0.05
2020	141	426	423	296	127	287	0.2	0.73	0.78	0.03	0.05
2021	143	426	435	305	131	287	0.2	0.73	0.78	0.03	0.05
2022	145	426	448	314	134	287	0.2	0.73	0.78	0.03	0.05
2023	147	426	461	323	138	287	0.2	0.73	0.78	0.03	0.05
2024	149	426	474	332	142	287	0.2	0.73	0.78	0.03	0.05
2025	151	426	488	342	146	287	0.2	0.73	0.78	0.03	0.05
2026	153	426	502	352	151	287	0.2	0.73	0.78	0.03	0.05
2027	155	426	517	362	155	287	0.2	0.73	0.78	0.03	0.05
2028	158	426	532	372	160	287	0.2	0.73	0.78	0.03	0.05
2029	160	426	547	383	164	287	0.2	0.73	0.78	0.03	0.05
2030	162	426	563	394	169	287	0.2	0.73	0.78	0.03	0.05
2031	164	426	579	406	174	287	0.2	0.73	0.78	0.03	0.05
2032	167	426	596	417	179	287	0.2	0.73	0.78	0.03	0.05
2033	169	426	613	429	184	287	0.2	0.73	0.78	0.03	0.05

Year	Project number											
	23	24	25	26	27	28	29	30	31	32	33	34
2009	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2010	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2011	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2012	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2013	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2014	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2015	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2016	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2017	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2018	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2019	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2020	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2021	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2022	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2023	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2024	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2025	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2026	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2027	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2028	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2029	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2030	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2031	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2032	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60
2033	0.3	0.14	0.16	396	0.15	1.5	0.74	82.50	85.00	519.50	77.60	116.60

Table C13: Continued

Year	Project number				
	35	36	37	38	Total
2009	328	388	0.7333	6.09	2761.569
2010	328	649	0.7333	6.09	3109.093
2011	328	958	0.7333	6.09	5239.855
2012	328	1,317	1.4667	6.09	5680.079
2013	328	1,729	1.4667	6.09	6199.568
2014	328	2,197	1.4667	6.09	6751.552
2015	328	2,720	1.4667	6.09	7335.949
2016	328	3,304	1.4667	6.09	8012.676
2017	328	3,950	1.4667	6.09	8724.887
2018	328	4,661	1.4667	6.09	9476.889
2019	328	5,438	1.4667	6.09	10325.05
2020	328	6,285	1.4667	6.09	11236.11
2021	328	6284.76	1.4667	6.09	11302.33
2022	328	6284.76	1.4667	6.09	11371.41
2023	328	6284.76	1.4667	6.09	11443.19
2024	328	6284.76	1.4667	6.09	11517.81
2025	328	6284.76	1.4667	6.09	11595.41
2026	328	6284.76	1.4667	6.09	11676.15
2027	328	6284.76	1.4667	6.09	11760.2
2028	328	6284.76	1.4667	6.09	11847.74
2029	328	6284.76	1.4667	6.09	11939.42
2030	328	6284.76	1.4667	6.09	12034.53
2031	328	6284.76	1.4667	6.09	12133.74
2032	328	6284.76	1.4667	6.09	12237.29
2033	328	6284.76	1.4667	6.09	12345.43

Figure C1: Composition of GHG emissions in the baseline scenarios for the years 2011, 2022 and 2033 in comparison to the base year 2000

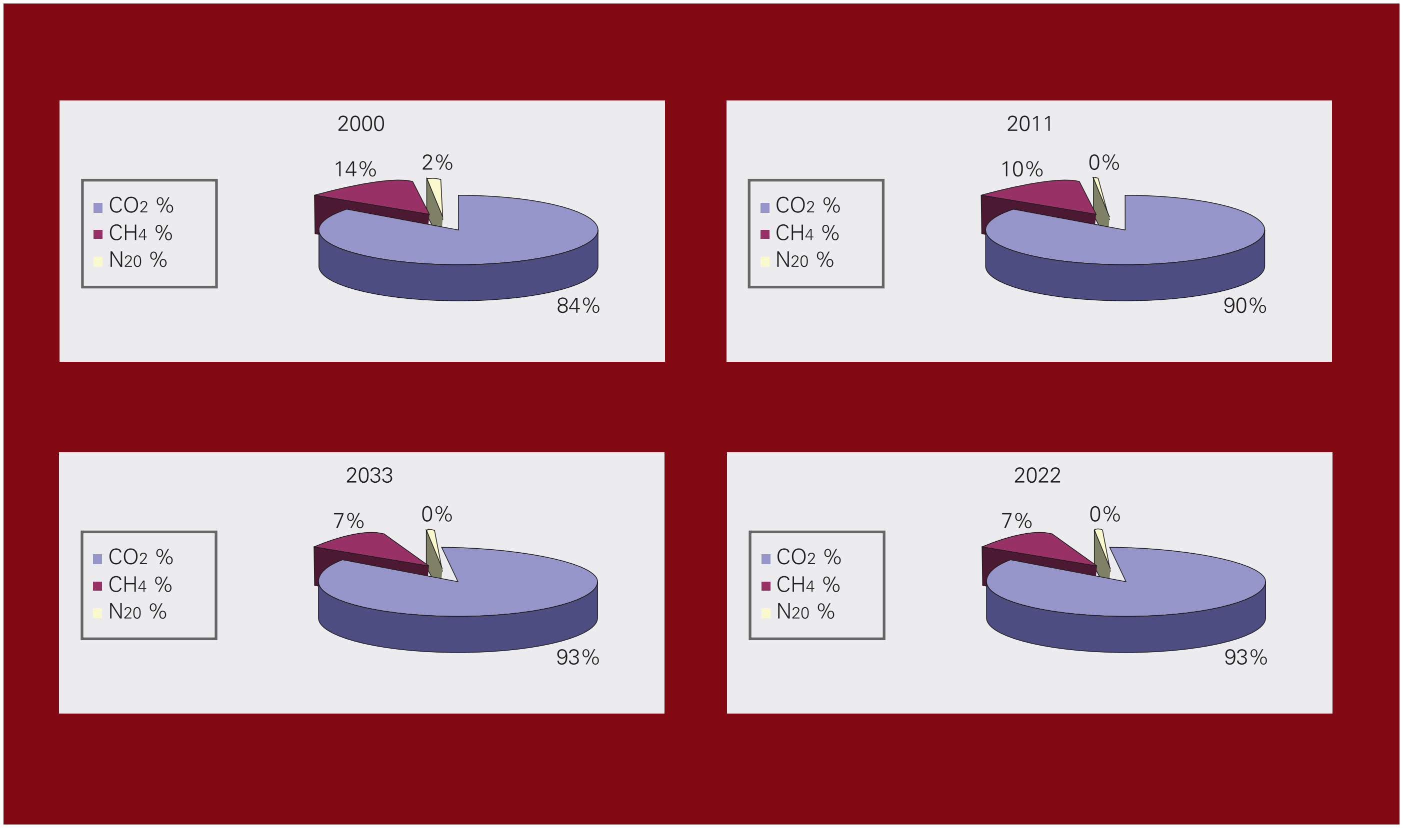

Figure C2: Total GHG emissions and emissions by gas, baseline scenario, 2000-2033

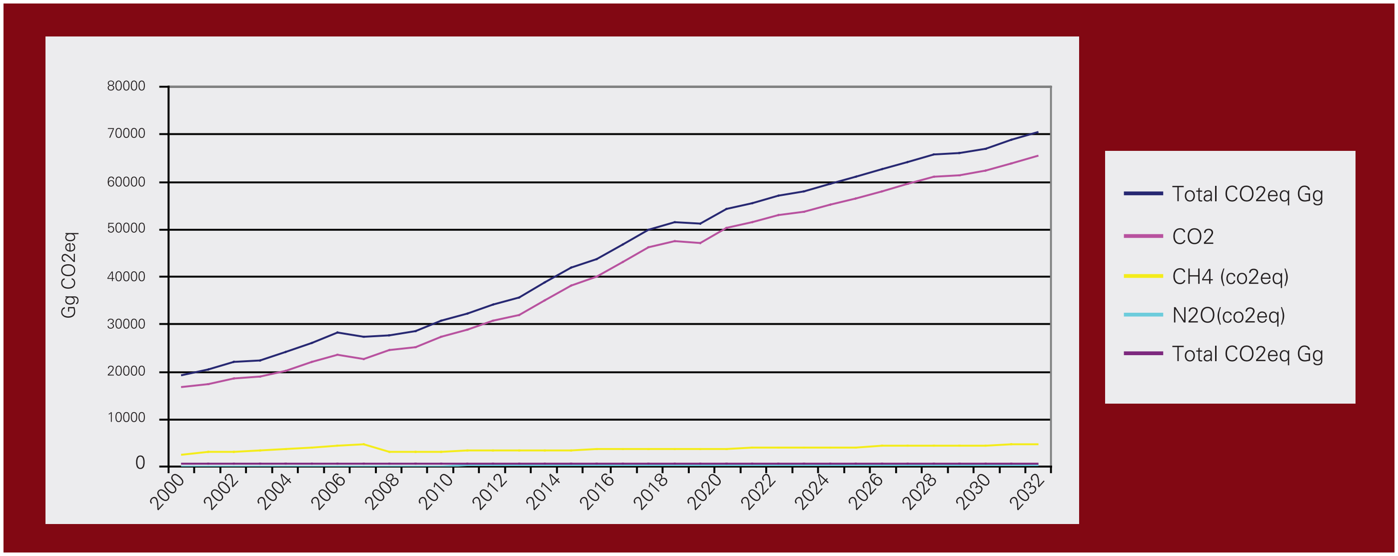

Figure C3: Sectoral emissions (emissions by source) in the baseline scenario, 2000-2033

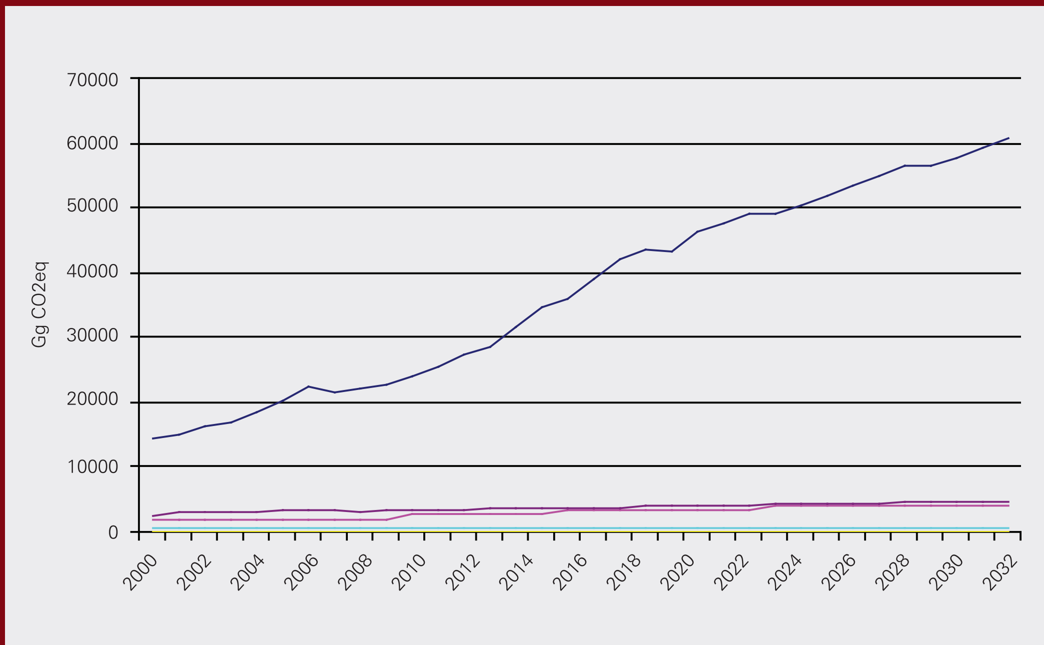

Figure C4: Sectoral emissions (emissions by source) in the baseline scenarios for the years 2011, 2022 and 2033 in comparison to the base year 2000

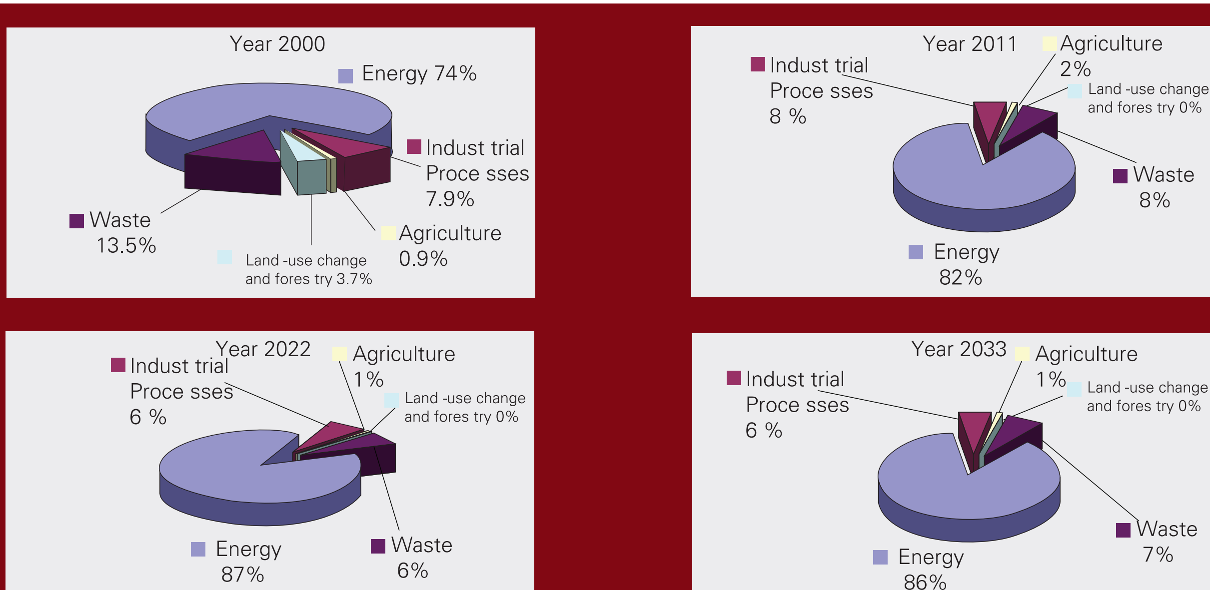

Figure C5: Energy sector emissions by sub-sector for the years 2011, 2022 and 2033 in comparison to the base year 2000

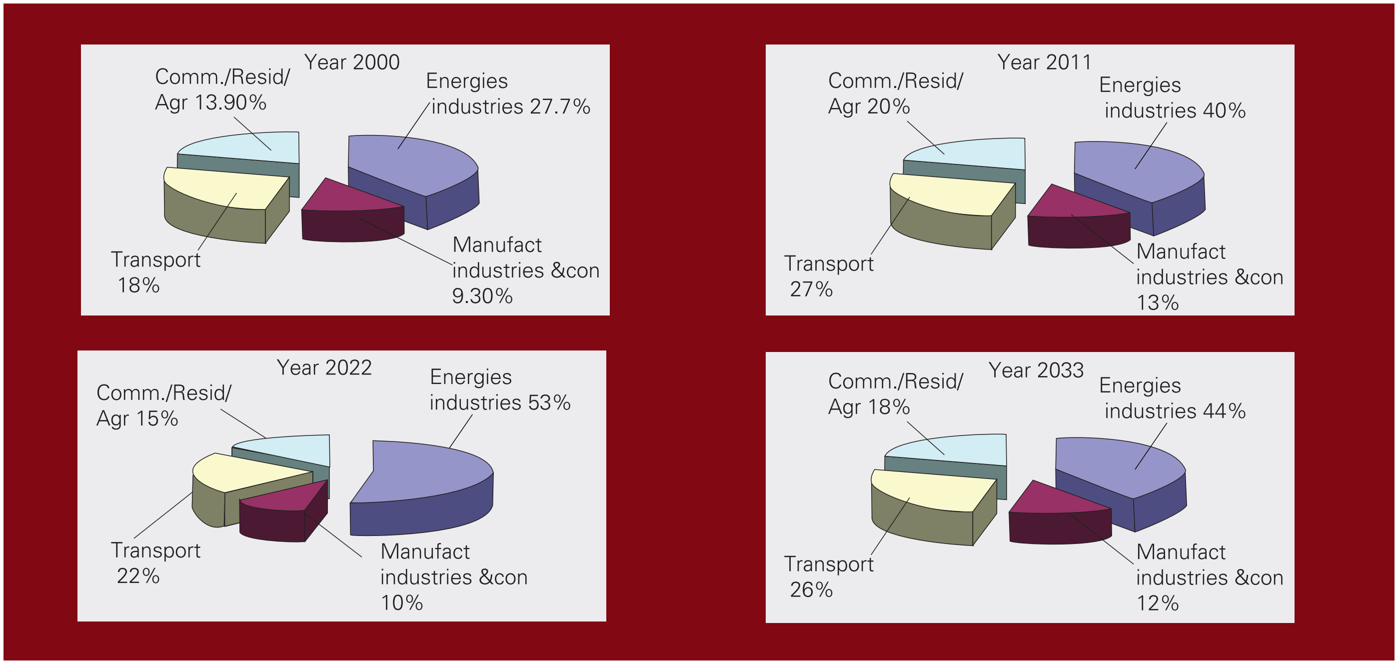

Figure C6: Carbon Dioxide emissions from electricity generation sector, baseline scenario, 2000-2033